GOVERNMENT OF MALAYSIA
ECONOMIC PLANNING UNIT OF THE PRIME MINISTER'S DEPARTMENT

MALAYSIA

FEASIBILITY STUDY REPORT ON THE TEKAI HYDROELECTRIC POWER DEVELOPMENT PROJECT

Executive Summary

SEPTEMBER 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of Malaysia, the Government of Japan decided to conduct a feasibility study on the Tekai Hydro-electric Power Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Malaysia a survey team headed by Mr. Keiichi Takahira from March 1, 1981 to December 15, 1982.

The team exchanged views with the officials concerned of the Government of Malaysia and conducted a field survey in the Tekai Project area, in Pahang State. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

Tokyo, August 1983

Keisuke Arita
President
Japan International Cooperation Agency

FORWORD

In 1980 the Government of Malaysia made a request to the Government of Japan asking for cooperation in carrying out a feasibility study for a hydroelectric power development project in the basin of the Tekai River, a tributary of the Tembeling River of the Pahang River Basin in Pahang State, West Malaysia. In response to this request, the Government of Japan entrusted the execution of the study to the Japan International Cooperation Agency (JICA).

Prior to carrying out this development project, JICA held consultations with authorities of the Malaysian Government regarding the contents of the project. JICA then dispatched a survey team who spent 10 days from October 27 to November 5, 1980 in Malaysia confirming particulars such as the contents, background, etc. of the request made by the Malaysian Government and drawing up the scope of work to conduct the feasibility study. Further consultations on the details of the scope of work were carried out February 18 and 19, 1981 between the Economic Planning Unit (EPU) and National Electricity Board (NEB) representing the Malaysian Government and JICA and the parties concerned to establish final details.

Based on the conclusions reached, it was decided to conduct a feasibility study consisting of the three stages mentioned below. A survey team composed of ten specialists was organized and immediately dispatched to Malaysia for a period of 25 days from March 1 through 25, 1981 in order to conduct field reconnaissance in preparation for preliminary site investigation and for the purpose of collecting data and information required for site investigation. The investigation results are described in the Inception Report.

(1) Preliminary Investigation Stage

The preliminary investigation stage is aimed at determining the optimum site.

(2) Detailed Field Investigation Stage

The detailed field investigation stage is aimed at carrying out field investigations at the optimum site determined in the previous stage.

(3) Feasibility Design Stage

The feasibility design stage is aimed at carrying out design of the hydroelectric power development project at the optimum site and carrying out an economical feasibility study of the project.

In the preliminary investigation stage a survey team composed of specialists in the fields of dams, geology, hydrology, civil engineering for power generation, power demand forecasting, geological surveying, etc., was organized by JICA. The survey team visited Malaysia for a period of approximately five (5) months from mid June to late October, 1981 to undertake preliminary site investigations. During its stay in Malaysia, the survey team was engaged principally in supervision of drilling, seismic prospecting and aerial photography of the upper and lower sites. The team members also undertook a ground control survey in order to draw up aerial maps and longitudinal profiles and cross section surveys of the upper and lower sites as well as hydrological observations. In addition to this work, the survey team members collected data and information in their respective fields. Next, comparative analysis of the merits and demerits of the two proposed development sites, i.e., Upper Tekai Site and Lower Tekai Site, was carried out based on the results of the aforesaid investigations with the purpose of determining the most advantageous development method and the approximate scale of the development project. In addition, a preliminary analysis of the project was carried out with the purpose of providing basic data and information for subsequent stages of investigation and analysis. The results of the aforementioned investigations, analysis and discussions are described in the Interim Report. (March.1982)

In the detailed field investigation stage, the survey team organized for the preliminary field investigation stage was reinforced with specialists in the fields of forestry, zoology and economics, taking into consideration the findings incorporated in the Interim Report. This reinforced survey team visited Malaysia for approximately 6 months from the mid May to late October, 1982 to carry out detailed field investigation.

In the feasibility design stage the development system and scale of the development project proposed in the Interim Report were reviewed taking into consideration the results of the aforementioned detailed field investigations. Further, detailed design corresponding to the optimum development scale was also carried out in the feasibility design stage. In addition, a works progress chart for implementation of this project, detailed estimation of construction costs, economic analysis, social and environmental impact study for the project were also discussed and conclusions presented in the final report of the following composition.

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Volume I	**Main Report**
Volume II	**Survey**
Volume III	**Hydrology**
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Volume IV	**Geology Appendix**
Volume V	**Design and Construction Planning**
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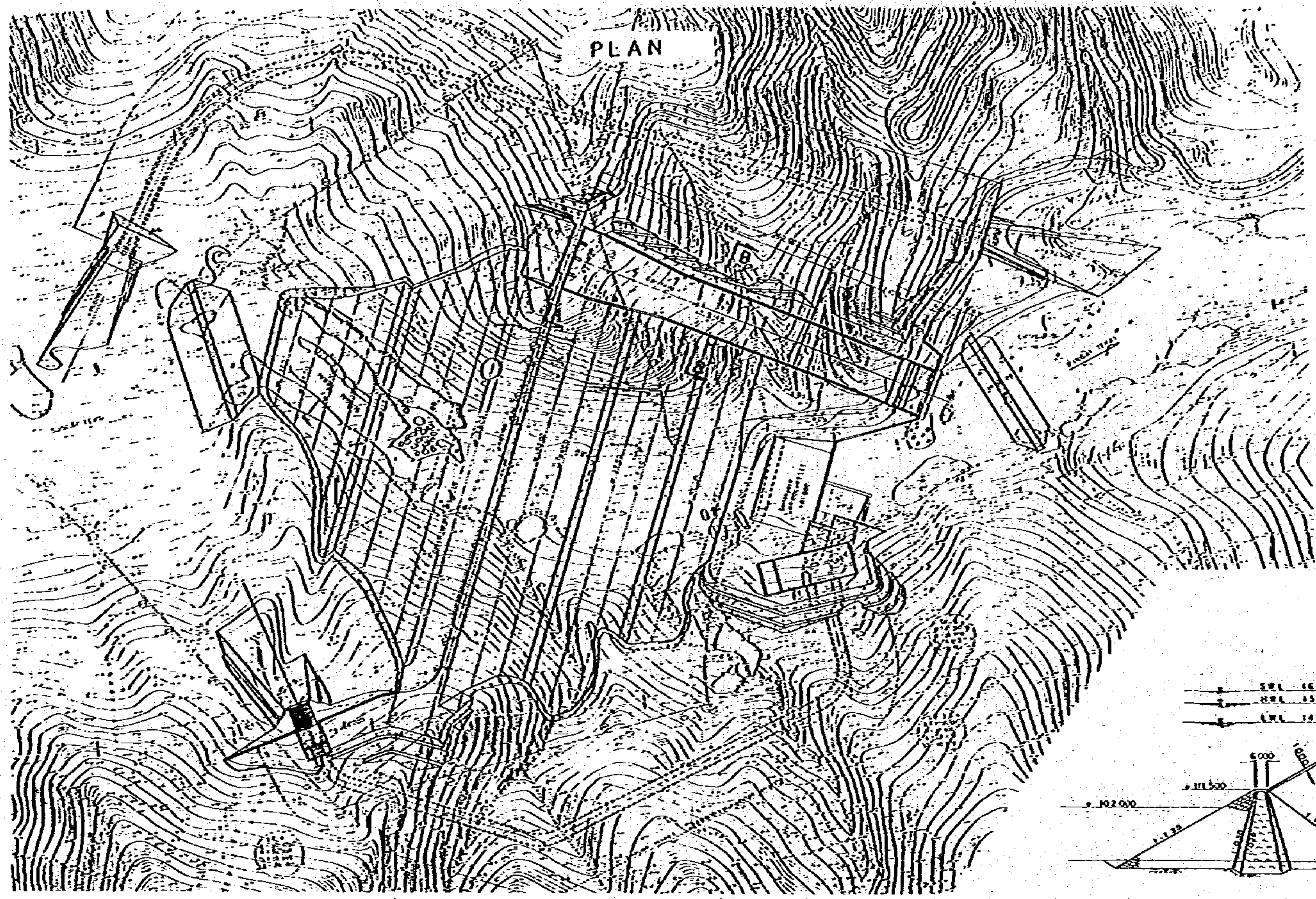
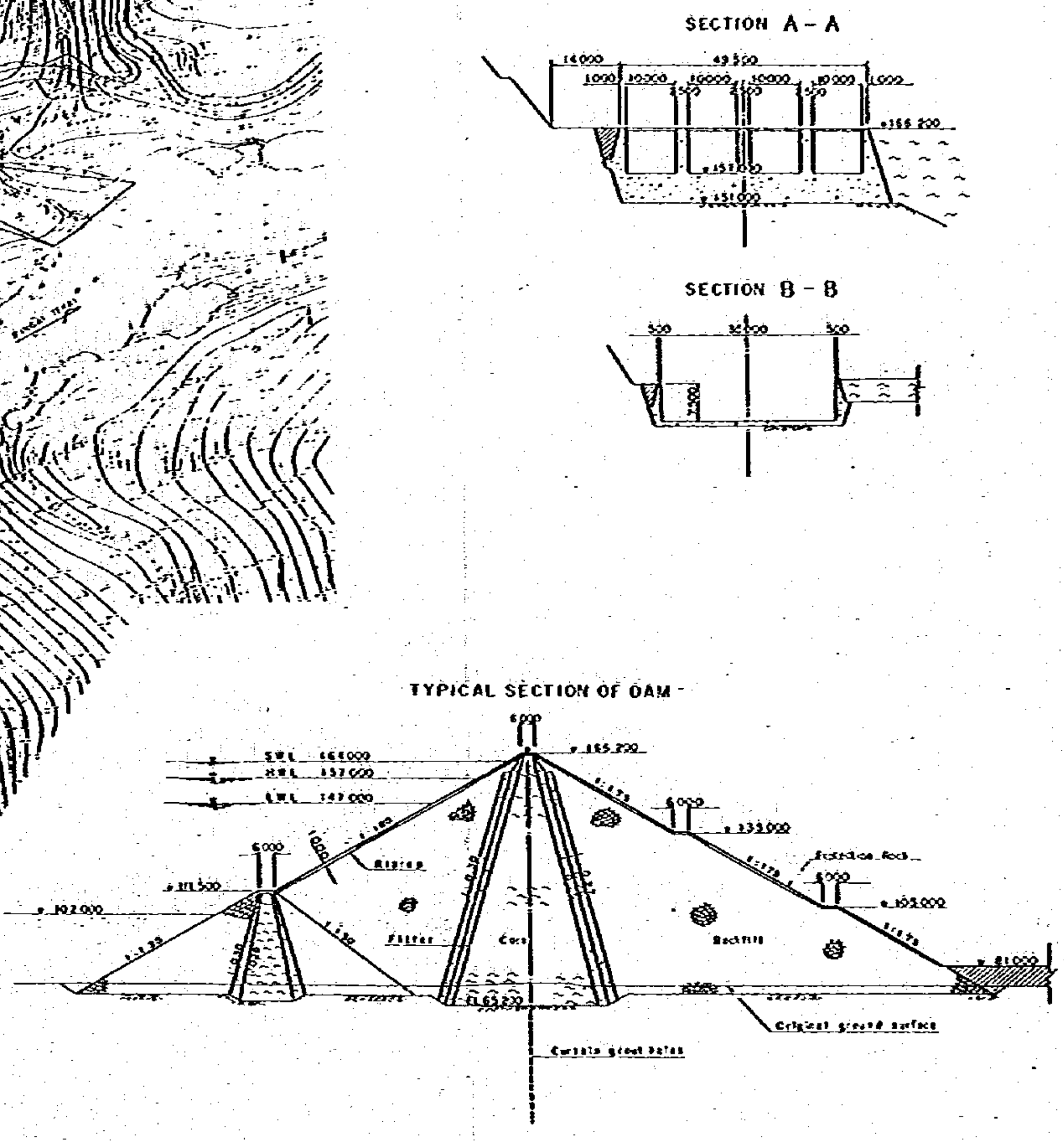
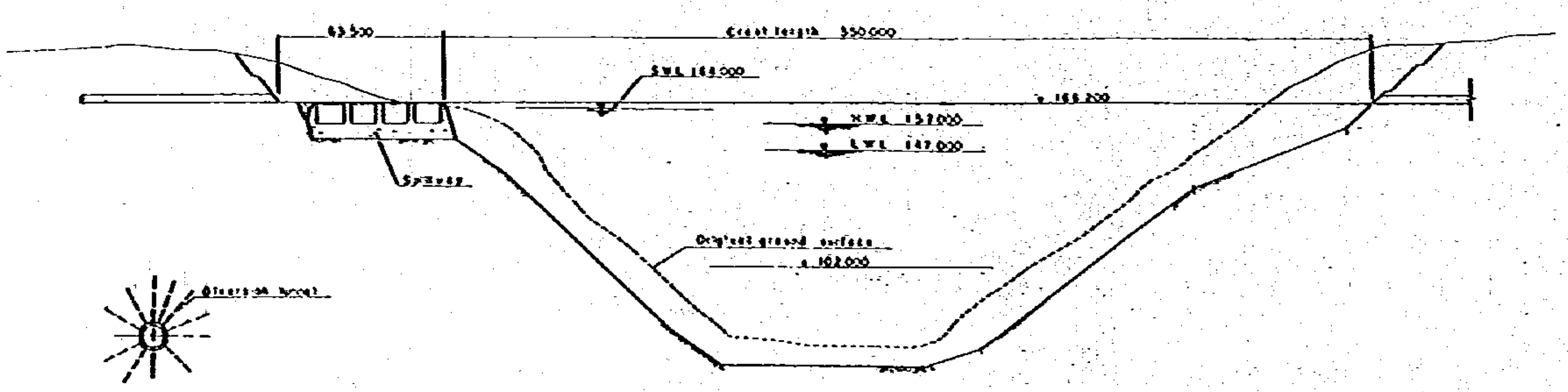






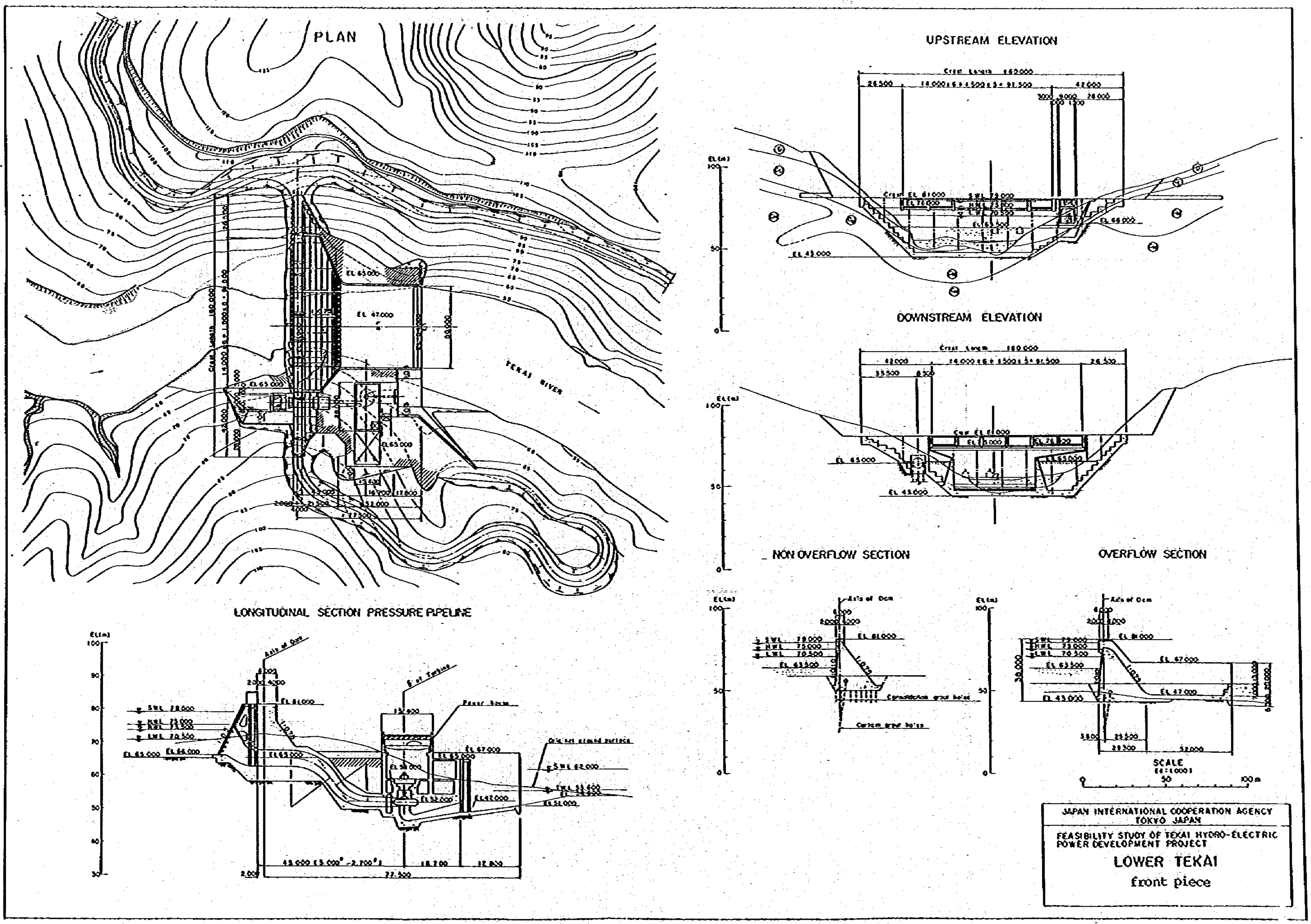
SCALE

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO JAPAN

FEASIBILITY STUDY OF TEKAI HYDRO-ELECTRIC POWER DEVELOPMENT PROJECT

UPPER TEKAI

front piece


PLAN
TEKAI RIVER
UPSTREAM ELEVATION
DOWNSTREAM ELEVATION
LONGITUDINAL SECTION PRESSURE PIPELINE
NON OVERFLOW SECTION
OVERFLOW SECTION
Axis of Dam
Power house
Original ground surface
Consolidation grout holes
Curtain grout holes
SCALE
0
50
100 m
JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO JAPAN
FEASIBILITY STUDY OF TEKAI HYDRO-ELECTRIC POWER DEVELOPMENT PROJECT
LOWER TEKAI
front piece

1. SUMMARY AND CONCLUSION

1. Summary and Conclusion

The purpose of this investigation is to study the feasibility of the Tekai River Basin Water-power Development Project for the Pahang Drainage System running through the Pahang. The study was performed to ascertain the most economical development method, development scale, structural design and work schedule for the two proposed sites (Upper and Lower Tekai). These sites, located on the downstream basin of the Takai River, were selected to ensure the highest possible effective utilization of hydraulic resources.

Study of the development method and scale was made on two cases: a single development plan (Independent Upper and Lower Tekai) and a series development plan (integrating Upper and Lower Tekai). In this study, water power, that is, the ability to respond quickly to load fluctuation and the superior availability of power supply to meet peak load demand, were taken into consideration.

The optimum scale of single development was determined from the benefit/cost (B/C) ratio and extra benefit (B-C), while calculating annual power generation on the basis of comparison of dam height, equipment output and available water depth.

The optimum scale of series development was determined from B/C and B-C, while calculating annual power generation on the basis of comparison of equipment output (the optimum scale of the independent development plan for the Upper Tekai fixed and the H.W.L. of the Lower Tekai set to tailrace water level of the Upper Tekai). In calculating the benefit, the gas turbine was considered as a substitute thermal power source.

For the design of sturctures, a study was made of the arrangement and technical data to ensure the highest level of economical feasibility within a precision range applicable at the feasibility study stage. Results of various investigations of topography, geology, weather, river conditions, etc. were used as bases for conclusions.

As for the development method, it is concluded that the series development (integrating the Upper and Lower dam) is feasible, as a result of the examination of the aforementioned facts. It is recommended that the Detail Design of this project be started immediately, including the construction of the access road and the logging of the area to be innundated by the Upper dam.

The following are the most optimum development scale and the principal dimensions of Tekai Project.

(1) The most appropriate form and scale for the proposed Upper Tekai dam is the center core rockfill type with a height of 101 m (crest level EL. 166.2 m). For the Lower Tekai, a concrete gravity dam with a height of 38 m (crest level EL. 81 m) would be recommended.

(2) The installed capacity of the Upper Tekai dam is 150 MW, while the Lower Tekai works' capacity is 5.8 MW. Consequently, the total of the two dams is 155.8 MW.

(3) The average annual energy generation is 194.8 GWH at Upper Tekai and 40.3 GWH at Lower Tekai, totaling 235.1 GWH for the two dams.

(4) The estimated construction cost is 289 x 10^6 M$ for Upper Tekai and 62 x 10^6 M$ for Lower Tekai, totaling therefore 351 x 10^6 M$.

(5) The benefit/cost ratio (B/C) of the series development of Upper and Lower Tekai is 1.53, the extra benefit (B-C) is 23.10 x 10^6 M$ and the internal rate of return (I.R.R.) is 14.78% (Assuming that fuel oil remains at a constant price, including construction cost of power transmission line).

(6) The approximate stage of execution of works is expected to be as follows, when the start of operation of Upper and Lower Tekai is planned in July 1991.

(1) Tekai Development Scheme

	Upper Dam	Lower Dam	Series
• Installed Capacity	150,000 kW	5,800 kW	155,800 kW
• Dam Body Volume	3.125×10^6 m^3	5.69×10^4 m^3	
• Dam Height	101 m	38 m	
• Maximum Operating Level	157 m	75 m	
• Minimum Operating Level	147 m	70.5 m	
• Effective Depth	10 m	4.5 m	
• Effective Storage Capacity	680×10^6 m^3	21.5×10^6 m^3	
• Normal Water Level	153.7 m	73.5 m	
• Tailrace Water Level	75 m	55.6 m	
• Maximum Turbine Discharge	235 m^3/s	40 m^3/s	
• Construction Cost	289×10^6 M$	62×10^6 M$	351×10^6 M$
• Annual Cost	35.83×10^6 M$	7.98×10^6 M$	43.81×10^6 M$
• Annual Energy Generation	194.8×10^6 kWh	40.3×10^6 kWh	235.1×10^6 kWh
• Annual Benefit	58.42×10^6 M$	8.49×10^6 M$	66.91×10^6 M$
• B-C	22.59×10^6 M$	0.51×10^6 M$	23.10×10^6 M$
• B/C	1.63	1.06	1.53

(2) Estimated Construction Cost

For Optimum Development Scheme

	Upper Tekai	Lower Tekai
. Preparatory Works	32.26×10^6 M$	3.93×10^6 M$
Access Road	16.51×10^6 "	0.10×10^6 "
Temporary Facilities	15.74×10^6 "	3.83×10^6 "
. Civil Works	156.19×10^6 "	34.77×10^6 "
Diversion and Care of River	20.57×10^6 "	5.08×10^6 "
Dam	59.97×10^6 "	$16.00\ 10^6$ "
Spillway	21.20×10^6 "	4.95×10^6 "
Intake Structure	3.51×10^6 "	0.92×10^6 "
Penstock	25.65×10^6 "	0.81×10^6 "
Powerhouse	20.45×10^6 "	6.44×10^6 "
Switchyard	1.33×10^6 "	---
Mechanical Equipment	3.50×10^6 "	0.58×10^6 "
. Generating Equipment	53.00×10^6 "	13.00×10^6 "
. Engineering Service	19.31×10^6 "	4.14×10^6 "
. Government Administration	7.25×10^6 "	1.55×10^6 "
. Contingency	21.44×10^6 "	4.59×10^6 "
. Grand Total	289.45×10^6 M$	61.98×10^6 M$

(3) Economic Analysis

Series Development for Upper and Lower Tekai

	IRR %	NPV (M$x10^6) for Discount Rate			
		10%	12%	14%	16%
Case 1	14.78	104.8	46.8	10.2	-13.3
Case 2	17.13	181.8	98.7	46.8	13.4
Case 3	19.60	292.0	170.2	95.7	48.3
Case 4	11.62	33.2	6.6	-30.6	-45.3
Case 5	13.67	87.1	29.8	-5.0	-26.6
Case 6	15.86	164.2	79.8	29.2	-2.2

Case 1 : Fuel oil at constant price

Case 2 : Fuel oil with relative price escalation of 1.5 percent per annum

Case 3 : Fuel oil with relative price escalation of 3 percent per annum

Case 4 : Natural gas at constant OEP

Case 5 : Natural gas with relative price escalation of 1.5 percent per annum

Case 6 : Natural gas with relative price escalation of 3 percent per annum

(4) Construction Schedule

Upper Tekai

a) Completion of access road and temporary road (road from the aggregate plant to spoil site) - February 1986
b) Start of excavation of diversion tunnel - June 1986
c) Start of excavation of diversion and dam - October 1987
d) Dam embankment start - July 1988
e) Grouting of dam body - October 1989 (complete)
f) Spillway - July 1987
g) Penstock - May 1987
h) Power plant - March 1988
i) Start of reservoir filling - November 1989
j) Start of operations - July 1991

Lower Tekai

a) Start of temporary facilities erection - January 1989
b) First coffering - April 1989
c) Dam excavation - August 1989
d) Start of concrete pouring on the right bank - January 1990
e) Secondary coffering - June 1990
f) Start of concrete placement on the left bank - October 1990
g) Excavation of spillway and water intake - August 1989
h) Penstock - November 1989
i) Power plant - August 1989
j) Start of operations - July 1991

2. INTRODUCTION

2. Introduction

The mountain regions of the Peninsular Malaysia, in an area of heavily rainfall, have immense hydroelectric power development potential, thanks to the abundant availability of water. Furthermore, there are many sites suitable for construction of dams for hydroelectric power development in view of their global potentialities comprising factors such as topography, geology, and suitable reservoir area, etc.

The Tekai site is located on the Tekai River, a tributary of the Tembeling River in the basin of the Pahang River, and consists of the Upper Tekai Site and Lower Tekai Site.

A rockfill dam with a catchment area of 1,200 km^2, maximum power generation of 150 MW and dam height of 101 m is planned for the Upper Tekai Site. On the other hand, a concrete gravity dam with a catchment area of 1,380 km^2, maximum power generation of 5.8 MW and dam height of 38 m is planned for the Lower Tekai Site. The latter is a peak load power source that will function as a re-regulating dam for the Upper Tekai Site as well as provide regulation of the residual area.

Electricity demand in Malaysia is expected to grow by a high annual average of 14.7% during the 1980-1985 period and the National Electricity Board (NEB) of Malaysia is pushing forward in development of power sources in order to cope with this demand. The present project is part of the development programme and is regarded as a particularly important hydroelectric power development required to promote economical development of Pahang State. In addition, the Tekai Hydroelectric Power Development Project is expected to make considerable contributions for regional development of Pahang State.

3. PROJECT AREA

3. Project Area

3.1 Location

The project site for the Tekai Hydro-electric Power Development Project is located on the lower reaches of the Tekai River, one of the tributaries of the Pahang River (catchment area of 28,500 km^2) which flows through the state of Pahang, the largest state in West Malaysia. The project area is located about 150 km northeast of the capital city of Kuala Lumpur and is adjacent to the southern border of the Tamang Negara National Park on the northern tip of the state of Pahang.

The Pahang River, the largest on the Peninsular Malaysia, rises in the mountainous interior of Pahang State, is joined by many tributaries, and flows south through the Jerantut District. It then turns east in the neighbourhood of Temerloh and finally reaches the South China Sea in the south of Kuantan.

The Tekai River is the largest tributary of the Tembeling River which is one of the main upper reaches of the Pahang River and joins the Jelai River at Kuala Tembeling. It rises mainly in the Trengganu coastal range which lies on a north-northwest, south-southeast axis with extensions from Ulu Trengganu District to Kuantan District. The Tekai River flows mainly west-northwest and joins the Tembeling River about 20 km upstream of Kuala Tembeling.

There are two possible project sites, of which the lower site (catchment area of 1,380 km^2) is situated at 8.0 km upstream along the Tekai River from the Tembeling - Tekai junction, and the upper site (catchment area of 1,200 km^2) is situated about 20 km further upstream from the lower site.

3.2 Topography and Geology

The mountains area of the Tekai River Basin exhibits a gentle dip caused by marked weathering activity. The gradient of the Tekai River is relatively steep in the mountain area of its upper reaches, but the gradient becomes marked gentle in the lower reaches. The geology of the Tekai River basin area can be roughly grouped into sedimentary rocks, metasediments, and granitic rocks.

3.3 Climate and Hydrology

The climate of Peninsular Malaysia is generally influenced by the north-east monsoon and the south-west monsoon.

The north-east monsoon brings moisture from the South China Sea, usually from November to January, striking the north-eastern parts of the country first and then covering almost all of Peninsular Malaysia. All areas exposed to the north-east monsoon receive heavy rainfall, especially the northern part of the east coast. More than 1,000 mm of monthly rainfall has been experienced in the Kuala Trengganu region in the north-east. On the other hand, the northern part of the west coast, which is sheltered by the mountains of Central Malay, receives little rain during this season. Hours of sunshine during the monsoon season are the shortest of the year in December and January throughout Peninsular Malaysia.

February and March are the driest months of the year. Relative humidity is at its lowest and hours of sunshine are the longest during these months.

Generally in April or May, the south-west monsoon reaches the west coast from across the Indian Ocean. The monsoon prevailing over Peninsular Malaysia in May-June causes fairly heavy rainfall on the west coast, but is not significant on the east coast. Due to the sheltering effect of Sumatra, rainfall during this season is less than that during the north-east monsoon season, with the exception of the northern part of the west coast. Maximum temperatures usually occur in April on the west coast and in May on the south and east coasts.

During the period between the two monsoons, from August to October, the northern part of the west coast has a peak in rainfall brought by western winds.

Rainfall

Due to the lack of rainfall data for the upper catchment, rainfall estimates were mainly derived from gauges in the surroundings of S. Tekai.

The average annual rainfall at Ulu. Tekai, derived with the result of correlation analysis with the Kamgsar Station, was estimated at about 2,210 mm.

The probability calculation on the basis of data from 10 stations along the Tekai River Basin showed the five-day rainfall for a period of 10,000 years at about 840 mm.

Runoff

The estimation of damsite discharge in this project was based on observation data obtained at Penut downstream of the lower damsite.

But, due to the lack of measurements in the data, the estimation was finalized by supplement and correction through correlation analysis with surrounding stations and conversion from the rainfall of runoff model.

As a result, the annual mean discharge per day was estimated at 34.84 m^3/s for the upper damsite and 40.07 m^3/s for the lower damsite.

3.4 Outline of Pahang State

The State of Pahang is the third largest in Malaysia. Total area of the State is about 36,260 km^2 and it has a coastline extending over 200 km facing the South China Sea. Approximately 65 percent of the total area is covered with forest. Cultivated land is mainly in the basin of the Pahang River where approximately 566,000 ha. - only 16 percent of the total area - is under cultivation. Of this area, 257,000 ha. is devoted to rubber, 267,000 ha. to palm oil, 7,200 ha. is paddy and the remainder, other crops.

The State of Pahang is divided into ten administrative districts, and the state capital is situated in the city of Kuantan in the Kuantan district facing the South China Sea. The population of the state is 820,000 persons (1980 estimate), of which approximately 25 percent of live in the district of Kuantan. Other districts where the population density is relatively high are Pekan, Temerloh and Bentong, where industrial estates are located.

The national railway connects the towns of Kuala Lipis, Jerantut and Mentekab in the interior of Pahang with other major cities and towns in the Federation. Before the port of Kuantan was built, the railroad was the major means of shipping products out of the state. The road network includes of a freeway about 270 km long connecting the city of Kuantan with Kuala Lumpur. To the south, there is a road along the coastline leading to Singapore and to the north, a road along the coastline to Kota Baru. Within the state major roads are being newly constructed and existing roads upgraded and improved. There is a daily air service by Malaysian Airlines between Kuala Lumpur and Kuantan.

The economy of the state is basically agriculture and forestry, and all efforts are being made to promote improvements in productivity, plant breeding and use of fertilizer. The government is placing emphasis on the development of underdeveloped states having great potential and in order to promote industrialization and modernization to a level comparable to the advanced states. Since the 1960's the government has established and implemented First, Second, Third and Fourth Malaysia Plans.

In line with government policy, the state of Pahang has enacted and is actively implementing various economic policies.

4. HYDROELECTRIC DEVELOPMENT

[illegible]

4. Hydroelectric Development

4.1 Introduction

The JICA survey team visited Malaysia for approximately 5 months from June to October 1981 with the purpose of drawing up the hydroelectric power development project in the Tekai River and studying the feasibility of the project. During this period of stay in Malaysia the survey team carried out preliminary field investigations as well as examination of the project. Examination consisted of comparative study of the merits and demerits of the two development sites (Upper Tekai Site and Lower Tekai Site) proposed in the project area, in order to determine the most advantageous development system and the approximate scale of the development project. The contents of the study carried out of in the preliminary investigation stage are presented in the Interim Report of March 1982. According to this report integrated development consisting of an Upper Dam and a Lower Dam is considered most advantageous. The JICA survey team carried out a further additional detailed field investigation and collection of relevant data and information over a period of approximately 7 months from May to December, 1982, based on the development alternative proposed in the Interim Report. Review of the development project based on the newly obtained data and information from the detailed field investigation concludes that the series development is feasible.

4.2 Dam Site Geology

4.2.1 Geology of Upper Dam Site

The geology of the Upper Site is composed of Termus redbeds and Mangking sandstone. The Termus redbeds are distributed along the Termus River, in the area upstream of the dam site and are thought to belong to the Cretaceous period of Mesozoic in age.

Around the Upper Site, the Termus redbeds are composed mainly of shale (Tsh) and sandstone.

4.2.2 Geological Engineering Assessment of Upper Dam Site

The upper dam site is considered to be a good site for a dam since it is composed of sandstone and shale, with its valley relatively narrow and endowed with a shallow layer of rock suited for the foundation of a fill dam. Although the strata have undergone folding, in the area upstream of the dam site they dip toward the upper reach. The center core type rock fill dam is considered suitable for this site since construction materials (core, rock, etc.) are available in its vicinity.

On the right bank of the dam site, there is inferred to exist a fractured zone of relatively large scale (estimated at 20 to 40 meters), which intersects with the dam axis at a low angle. Careful attention is therefore required in foundation treatment and the design structures.

4.2.3 Geology of Lower Dam Site

The geology of the lower site resembles that of the upper site in that it is composed of Hangking sandstone thought to date from Jurassic period of Mesozoic in age.

The Hangking sandstone found at the Lower Site consists mainly of sandstone and shale, with sandstone having the wider distribution.

4.2.4 Geological Engineering Assessment of Lower Dam Site

The lower dam site is composed of sandstone and shale. This site is geologically inclined upstream. Weathered zones in both right and left banks are a little deeper than those in the upper dam site.

A fill dam and concrete gravity dam are among the dam types possible here. But the latter brings greater advantages because of lower construction costs. As for the former no promising place has been found as yet for securing construction materials, especially core material.

4.3 Construction Materials

The JICA survey team investigated four quarry and borrow sites in the vicinity of the Upper and Lower Tekai Dam Sites to determine the availability of core material, rock material and aggregate for construction of the center-core type rock fill dam at the Upper Site, and the availability of aggregate for construction of the concrete gravity dam at the Lower Site. The 4 sites investigated are located in the vicinity of the Upper and Lower Tekai Dam Sites and are identified as sites A, B, C and D, respectively, from the upper reaches of the Tekai River. (Refer to the Fig.II)

Sites A and B are located upstream and downstream of the Upper Dam, and were examined for supply of core materials, rock materials and aggregate. The core material available at both sites consists of highly weathered sandstone and shale. Soil tests of samples collected from the pits excavated at both sites indicate that they have sufficient impermeability to be used as core material. The coefficient of permeability of these samples is of the order of $1x10^{-7}$ cm/sec. The difference between the natural moisture content and the optimum moisture content is minor. Accordingly, the core material can be transported directly from the borrow site to the upper dam site. The maximum dry density of the material is approximately 1.8 g/cm^3.

At site A the topography is rather steep and the highly weathered rock layer is thin, but at site B, which has plateau topography, the layer of highly weathered rock is thicker compared with site A. Site B appears more advantageous from the point of view of available deposit of core-material and ease of excavation work, therefore.

Fresh rock and slightly weathered rock located beneath the highly weathered rock for core material at sites A and B were examined for use as rock material and aggregate. Rock tests were carried out using boring cores obtained at these sites.

The results of these rock tests indicate that the sandstone has a specific gravity of approximately 2.55 and the percentage of water absorption does not exceed 3% at either site A or site B. The shale has a specific gravity of approximately 2.35 and a rather large percentage of water absorption. Normally, aggregate of good quality is required to have specific gravity larger than 2.5 and a percentage of water absorption rate below 3%. Accordingly, sandstone seems better than shale for use as aggregate and rock material.

On the other hand, the results of the geological investigations indicates that site B is the more advantageous because it contains more sandstone.

Site C is located on the right bank of downstream of the Lower Dam. Rock tests of boring cores were carried out to examine the potential of this site for sandstone and shale aggregate supply. The results of these rock tests are the same as those for sites A and B. Geological investigation indicates that the weathered rock layer at site C a relatively thick.

Site D is located on the upper reaches of the Tembling River downstream of the Lower Dam. Site D was examined for limestone aggregate. Geological investigations were not carried out at the site but the results of rock tests with boring cores obtained at the site are quite satisfactory, showing specific gravity of 2.7 and a percentage of water absorption not exceeding 0.3%.

Excavated material of the foundations, spillways, power stations, etc., of the upper and lower dam sites consists of sandstone and shale. Accordingly, this excavated material can be used good as rock material and for other purposes.

Quarry site B is selected to supply the core, rock and aggregate materials for the upper dam. Quarry site D is selected to supply the aggregate material for the access road and the lower dam.

It is recommended that core material, rock material and aggregate should be excavated principally from site B, taking into consideration the results of the geological investigation and the ease of work, because it is located in the vicinity of the Upper Dam, which requires movement of a considerable volume of earth and needs a large deposit of core material.

4.4 Selection of Dam Site

The lower reaches of the Tekai River show a very gentle river gradient of the order of 1:1,000, and high potential for a large storage capacity through construction of dams. The area of the present development project is restricted exclusively to the lower reaches of the river with a view towards utilizing as effectively as possible the hydroelectric potential there. Two development sites (Upper site and Lower site) for construction of dams were selected based on the following premises.

- Outcropping of bedrock
- Satisfactory geological conditions
- Proximity of the river banks
- Topography suited for construction of a large storage reservoir in the upper river reaches

The upper site is located downstream of the confluence of the Tekai River and the Termus River. The river bed has rather steep topography and outcroppings of bedrock are observed from the river bed halfway up the slopes on both banks.

The lower site is located approximately 20 km downstream of the upper site and shows similar conditions.

In the present feasibility study the mission carried out field explorations from March 1 to 25, 1981 to confirm the appropriateness of these development sites.

Three dam axes, i.e., U-1, U-2 and U-3, were selected at the upper site and U-2 was proposed in the inception report as the top priority dam axis in view of the favourable topographical and geological conditions. Two dam axes, i.e., L-1 and L-2 were selected at the lower site and L-1 was proposed in the inception report as the top priority dam axis because of the favourable topographical and geological conditions.

4.5 Type of Dam

4.5.1 (Upper Dam)

Examination of hydrological data and hydroelectric output of the Tekai River basin points to construction of a dam with a height of 100 m and a 165 m dam crest elevation at the upper dam site. Each type of dam is examined in this section through comparative study of respective construction costs.

The merits and demerits of the following types of dam are comparatively examined.

Rockfill Dam	∘ Earth impermeable core type ∘ Concrete facing type ∘ Asphalt facing type
Concrete Dam	∘ Concrete gravity dam

The results of comparison indicate that in the case of concrete dam the cost is larger compared with the rockfill dam because the dam body volume is very large. On the other hand, in the case of a rockfill dam the costs of facing type dams show larger than earth core type, and the asphalt facing type with 100 m dam height presents considerable demerit as to the ease of execution of the construction work and other relevant conditions compared with the earth core rockfill dam.

It is concluded that construction of an earth core impermeable wall rockfill dam is recommendable for this dam site. This alternative has the following merits.

i) Geological and topographical conditions of this dam site are best suited to construction of a rockfill dam.

ii) Rockfill and core material of good quality are available in abundance in the vicinity of the dam site.

iii) Most of the construction materials are locally available and therefore the project does not require external (foreign) sources for supply of construction materials. Furthermore, construction would not be influenced by the foreign exchange situation.

4.5.2 Lower Dam

The Lower Tekai Dam is to function as a regulating pondage for the upper site in the form of power source for peak hours and to regulate residual area. The optimum scale for the lower site seems to be 38 m dam height and approximately 81 m dam crest elevation. Comparative examination of construction costs of dam types was carried out in the same types as for the upper dam.

Concrete Dam	Concrete Gravity Dam
Rockfill dam	• Earth impermeable core type dam • Concrete facing dam • Asphalt facing dam

The results of cost comparison points to construction of a gravity concrete dam at the lower site.

4.6 Optimum Project Size

To determine the optimum size, including dam height, installed capacity and spillway crest length, a study was made to determine construction costs for a range of project sizes and the comparable power benefits in terms of kW and kW·H values. These costs and benefits were converted into annual equivalents and size comparisons made using B/C and B-C values. For these purposes, other benefits and costs of the Project were ignored.

The annual power benefits as expressed in M$ were evaluated using the following formula:

$$B\ (M\$) = 142.7\ (M\$/KW) \times P + 0.19\ (M\$/KWH) \times E$$

where P represents output (kW) and E annual energy generation (kW·H) of the project. The annual power benefits of kW and kWh are as follows.

1 kW = 142.7 M$

1 kWh = 0.19 M$

These values were based on the alternative (gas turbine) power generation costs.

4.6.1 Upper Tekai

(1) Study of Dam Height

In the study of dam heights, 4 cases - 80 m, 90 m, 100 m and 110 m - were compared.

The results of comparison shows that a 100m high dam is most favourable.

(2) Study of Drawdown (Effective Storage Capacity)

In the foregoing study, it was determined that the optimum height of the dam is 100 m. Following this study, four cases - 20 m, 15 m, 10 m and 5 m - of drawdown were examined.

The results of the study indicate that a drawdown of 5 m is slightly more advantageous than a drawdown of 10 m. However, a larger effective storage capacity is beneficial with the 10 m drawdown from the standpoint of flood control (this benefit is not considered in the above table) and also from the standpoint of effective utilization of water resources. Therefore, a drawdown of 10 m is selected.

(3) Study of Installed Power Capacity

In this study, four cases of installed capacity - 50 MW, 100 MW, 150 MW and 200 MW - were examined on the basis of a dam height of 100 m and a drawdown of 10 m as determined in aforementioned studies. In each of the above case, a unit capacity of 50 MW was adopted.

The results of the study indicates that an installed capacity of 150 MW is the most optimam

(4) Study of Spillway Overflow Crest Length

After comparing the non-gate spillway and gate spillway, the overflow crest length for non-gate spillway was compared in the case of 40 m, 60 m and 80 m.

On a result of the study, a spillway overflow crest length of 40 m is adopted.

4.6.2 Lower Tekai

(1) Most Suitable Development Plan

The installed capacity was determined taking accounts of the re-regulating function of Lower Tekai Dam which can discharge to the downstream for 24 hours by re-regulating the peak discharge of the Upper Tekai Dam. By this 24-hour discharge, it will be ensured the navigation and future water use for irrigation and other purposes in the downstream.

The annual run-off at the Lower Dam Site is approximately 40 m^3/s, therefore the maximum discharge, 40 m^3/s, of the power station was designed. This can generate maximum output of 5,800 kW.

Regarding the number of units, capacity of 5,800 kW is small and the losses during maintenance is also small, therefore one unit was adopted.

4.7 Power Stations

4.7.1 Upper Tekai

The proposed power station is a conventional mass and reinforced concrete surface structure. The two units have a centreline spacing of about 18.6 m which allows adequate space for construction of the turbine spirals in position.

Inlet valve will be provided with consideration of keeping the width at a minimum.

The length and width of the powerhouse will be about 54.8 m and 31.0 m, respectively.

One overhead travelling crane will be provided, traversing the fuel length of the building.

It is proposed that the turbine spiral casing be fully embedded with a turbine floor level of about EL. 68.5 m. Structural crosswall between the machines are not required. There is adequate space for auxiliary turbine plant on this floor.

The main transformers and 132 KV switchyard will be located external to the station at ground-level at downstream of dam.

4.7.2 Lower Tekai

The proposed power station is a conventional mass and reinforced concrete surface structure.

The length and width of the powerhouse will be about 28 m and 21.2 m, respectively.

One overhead travelling cranes will be provided, traversing the full length of the building.

It is proposed that the turbine spiral casing be fully embedded with a turbine floor level of about EL. 52.00 m.

The main transformers and 132 KV switchyard will be located external to the station at ground-level at downstream of dam.

4.8 Access Facilities

4.8.1 General

Jerantut, approximately 150 km NE of Kuala Lumpur, is nearby the project site and is expected to function as a base for project construction. Over-land access from Kuala Lumpur to Jerantut is provided by a highway of approximately 180 km via Betong, Karak and Mentekab. This highway is fully paved and will be used as the main route for transportation after the start of construction work.

The base for sea transportation will be Gelang, a port located approximately 26 km north of Kuantan, the capital city of Pahang State. The port of Gelang is equipped with the facilities required to land large-scale plant equipment and construction materials.

The highway from Gelang to Jerantut via Maran and Temeloh is approximately 220 km long and is fully paved.

The road from Jerantut to the Project Area existing at present will be paved for use as a construction road and for maintenance purposes after completion of the Project.

As for the access road located in the Project Area (road providing access from the existing road to the upper dam site via the lower dam site) will be constructed on the left bank of the storage reservoir, taking into consideration cost, distance and work schedule.

4.8.2 Access to the Project Area

(1) Existing Road

There is a road of approximately 40 km from Jerantut to a point 2 km downstream of the lower dam site. It will be sufficient to pave this road without excavation for access road not only for construction but also for maintenance purposes after completion.

(2) Newly Constructed Access Road

Construction of a new road is required in order to provide access from approximately 2 km downstream of the lower dam site to the lower dam site and on to the upper dam site.

The construction of a paved 6 m wide road with a 20 m minimum radius of curvature and 8% maximum slope gradient is considered in this case, in order to make possible use not only during construction of the project, but also for maintenance purposes after completion.

4.9 Quantity and Cost Estimates

4.9.1 General

The estimated costs are broadly divided into the following categories. These are preparatory works, civil works, generating equipment, engineering services, government administration and contingencies.

Engineering services and government administration were estimated at 8% and 3%, respectively, of the sum of preparatory works, civil works and generating equipment costs. Contingency funding represents 8% of the total cost.

The above costs are prices prevailing during the first half of 1982.

4.9.2 Unit Construction Costs

In estimating the unit costs, construction planning and the construction schedule were considered and the types, number and operating hours of construction equipment for each category of works were estimated. The unit costs were calculated by adding labour costs, material costs, equipment costs and miscellaneous costs.

4.10 Construction Planning and Implementation Schedule

To expedite the completion of work, an access road will be completed prior to starting the primary work. Consequently, this work will be started immediately after conclusion of the work contract. Construction of the Upper Tekai power station is scheduled to be started in March 1986, followed by the start of filling in November (when the rainy reason begins) 1989 with operations scheduled to start in July 1991. To reduce construction costs by utilizing the flood control function of the Upper Tekai, the power plant work of the Lower Tekai will be started with sluice diversion in April (during the dry season) 1989. Dam concrete will be placed two months after the start of filling of the Upper Tekai. The start of operations of the Lower Tekai power station will be in July 1991, the same as for the Upper Tekai power station.

The total construction period for the primary work is about five years.

The construction schedule is shown in Fig. XII. and the principal construction schedule is as follows.

(1) Upper Tekai

a) Completion of access road and temporary road
(road from the aggregate plant to spoil site) - February 1986
b) Start of excavation of diversion tunnel - June 1986
c) Start of excavation of diversion and dam - October 1987
d) Dam embankment start - July 1988
e) Completion of grouting - October 1989
f) Start of excavation of spillway - July 1987
g) Start of excavation of penstock - May 1987
h) Start of excavation of power station -March 1988
i) Start of reservoir filling - November 1989
j) Start of operations - July 1991

(2) Lower Tekai

a) Start of temporary facilities erection - January 1989
b) First coffering - April 1989
c) Dam excavation - August 1989
d) Start of concrete placing on the right bank - January 1990
e) Secondary coffering - June 1990
f) Start of concrete placement on the left bank - October 1990
g) Start of excavation of spillway and water intake - August 1989
h) Start of excavation of penstock - December 1989
i) Start of excavation of power station - August 1989
j) Start of operations - July 1991

5. ECONOMIC EVALUATION FOR POWER BENEFIT AND OTHER ASSOCIATED ASPECTS

5. Economic Evaluation for Power Benefit and Other Associated Aspects

5.1 Introduction

The purpose of this chapter is to identify and quantify the costs and benefits concerning the proposed Project in order to evaluate its economic viability. The criterion used in this appraisal is the Internal Rate of Return for the power benefit which is derived from the viewpoint of comparison of costs between the Project and an assumed alternative power generation scheme. The cash flow table of the Project is in accordance with the construction schedule presented in Figure M. Included in the analysis are several cases with varying assumptions for the yearly fuel costs of the alternative scheme; and IRRs and Net Present Values (NPV) are estimated for each of these cases.

Although the present Project is conceived as a single-purposed one, the subsequent sections deal not only with the main benefit but also other major aspects such as forestry, flood mitigation, irrigation and agriculture, tourism and others. For the main benefit, following a description on power generation and transmission in Peninsular Malaysia, the evaluation framework and the major parameters used in the present analysis are explained.

With respect to the other aspects, however, only forestry losses are estimated in terms of NPV. The effects of the Project on the otehr aspects - e.g. flood mitigation, irrigation and agriculture, tourism and others - are assessed qualitatively, since they are either expected to be small or subject to uncertainties and therefore not easily measurable. The results of the economic evaluation are presented in Section 5.8.

5.2 Power Benefits

5.2.1 Power Generation in the Peninsular Malaysia

During the fiscal years 1970 to 1980, total electricity sales in the Peninsular Malaysia increased at an average annual rate of about 13 percent, reflecting the economy's need for additional power (see Table 5.1). In April 1981, the NEB forecast the long-term power demand for the years up to 2000 using econometric models, with the assumption that the system load factor will not greatly change over the forecast period. As shown in Table 5.2, maximum demand and annual energy demand were forecast to be 4,154 MW and 25,254 GWH in 1990, and 9,135 MW and 55,550 GWH respectively in the year 2000. These figures are six to seven times greater than the corresponding present figures, and show an average annual increase rate of 9.8 percent (1971~2000, Table 5.2).

The present installed capacity of NEB's generating plants amounts to approximately 2,480 MW with the composition. The percentage of generating plants connected with the NEB integrated system (except diesel-engine generators for rural electrification) is 65 percent for thermal power stations, 26 percent for hydro power stations, 4 percent for gas turbines, and 5 percent for diesel generators. According to the plan established by the NEB based on the long-term power demand forecast, power stations with a total installed capacity of 3,262 MW are scheduled to be constructed by 1990 with hydro power stations accounting for 28 percent, gas turbines for 5 percent, and oil-fired thermal and combined cycle stations for 67 percent. Fig. 5.1 shows the generation development schedule with the nominal installed capacity and the forecast peak demand up to the fiscal year 1990.

5.2.2 Power Transmission

In parallel with the NEB's power generation development program established in April 1981, the expansion and reinforcement program for the existing 132 KV/275 KV transmission network is now under implementation. This program covers the whole west coast of the Peninsular Malaysia and a 275 KV loop transmission line which interconnects the west coast with the east coast, and the north and the central regions of the Peninsula. (See Fig. 5.2). The 275 KV loop transmission line consists of double circuits, each with ACSR 300 mm^2, carrying a maximum transmission capacity of 1,174 MVA (587 MVA x 2). The program is scheduled to be completed by 1985.

The NEB system is currently linked with the systems of Singapore (PUB) and Thailand (EGAT). The connection with the PUB system, currently using a 22 KV line, is planned to be upgraded to a new 230 KV cable line with a maximum capacity of 200 MVA to cope with emergency conditions. In the case of the EGAT, the connection was completed in February 1981 at the Bukit Ketri Substation using a 132 KV, 150 mm^2 line with a maximum capacity of 75 MVA. Here again, however, the interchange of electricity is made only under emergency conditions and is limited to 30 MVA to 50 MVA in practice.

The NEB's basic plan for the construction of transmission lines for the Tekai hydro power station is as follows. Construction of 132 KV x 2 double circuits is to be made over a distance of approximately 60 Km from the Upper Tekai station to the existing Jerantut Substation via the Lower Tekai station. The Jerantut Substation is connected to the Kg. Awah Substation by a 150 mm^2 transmission line with a capacity of 77 MVA. Therefore, because the output of the Tekai hydro power stations will exceed the capacity of the existing 132 KV transmission line, a new 132 KV transmission line of about 71 km in length should be constructed from the Jerantut Substation along the existing transmission line extended to Kg. Awah.

5.2.3 Evaluation Framework

The economic value of public funds invested in these power projects which aim at alleviating future shortages in the system's peak-load capacity or improving system reliability cannot be fully quantified and thus an estimate of return on investment cannot be expressed. In the absence of an established methodology for properly quantifying the benefits of power supply, an economic evaluation (especially for hydro projects) is usually carried out by comparing the costs attributable to the concerned project (net of duties and taxes) - including the cost of transmission - to the least costly alternative (thermal) program able to meet the same system demand.

It must be mentioned, however, that any evaluation made in this way implicity assumes that the demand for future peak-load power generation must be met either by the proposed project or by some alternative means, because the social loss of not meeting the power demand would be far larger than the net benefits accruing to any marginal non-power projects. Thus, the IRR (or more exactly, the discount rate, which equalize the present values of the costs of the two alternatives) calculated on this assumption is not relevant when making a choice between the proposed project and any marginal projects in other sectors of the economy, although it is relevant for evaluating projects within the power sector.

In general, a new project is evaluated not as an individual project but as a part of a comprehensive program in order to take account of the capabilities and load-follow operation characteristics of all existing as well as planned facilities. However, because of the relatively small size of the proposed project's capacity (15.58 MW compared with the system's forecast peak demand of more than 4,000 MW in 1990), it was suggested by NEB that the evaluation would be restricted to comparing the proposed project with an assumed single alternative project using gas turbine units, considering the load-follow operation for peak demand which is to be met by the proposed project.

Table 5.1 Energy Generated and Sold by NEB (GWH)

Fiscal Year	Energy generated & purchased (GWH)	Sending end energy (GWH)	Energy sold (GWH)	Rate of increase (%)
1970	2498.1	2406.3	2175.0	-
1971	2755.8	2645.8	2398.9	10.3
1972	3189.4	3057.4	2766.4	15.3
1973	3647.0	3491.8	3145.4	13.7
1974	4106.3	3929.5	3502.1	11.3
1975	4650.7	4441.9	3982.3	13.7
1976	5356.9	5103.2	4543.5	14.1
1977	6257.8	5953.6	5297.1	16.6
1978	6991.5	6651.4	5934.2	12.0
1979	7651.3	7302.4	6541.0	10.2
1980	8466	8071	7266	11.1

(Source ; NEB Annual Reports, 1969/70 - 1979/80)

Table 5.2 Long-Term Demand Forecast by NEB (1981 to 2000)

Fiscal Year	Annual Energy (GWH)	Peak Demand (MW)	Load Factor (%)
1980	8,610	1,397	70.38
1981	9,641	1,621	67.89
1982	11,034	1,814	69.44
1983	12,730	2,127	68.32
1984	14,595	2,388	69.77
1985	16,449	2,778	67.59
1986	18,906	3,110	69.40
1990	25,254	4,154	69.40
1995	36,976	6,082	69.40
2000	55,550	9,138	69.40

(Annual Growth Rate (%))

Fiscal Year	Energy	Peak Demand
1980 - 1985	13.8	14.7
1980 - 1990	11.4	11.5
1980 - 1995	10.2	10.3
1980 - 2000	9.8	9.8

(Source ; NEB System Development, 1981 - 2000 Part I : Load Forecasts)

Fig. 5.1 Generation Development 1981-1990

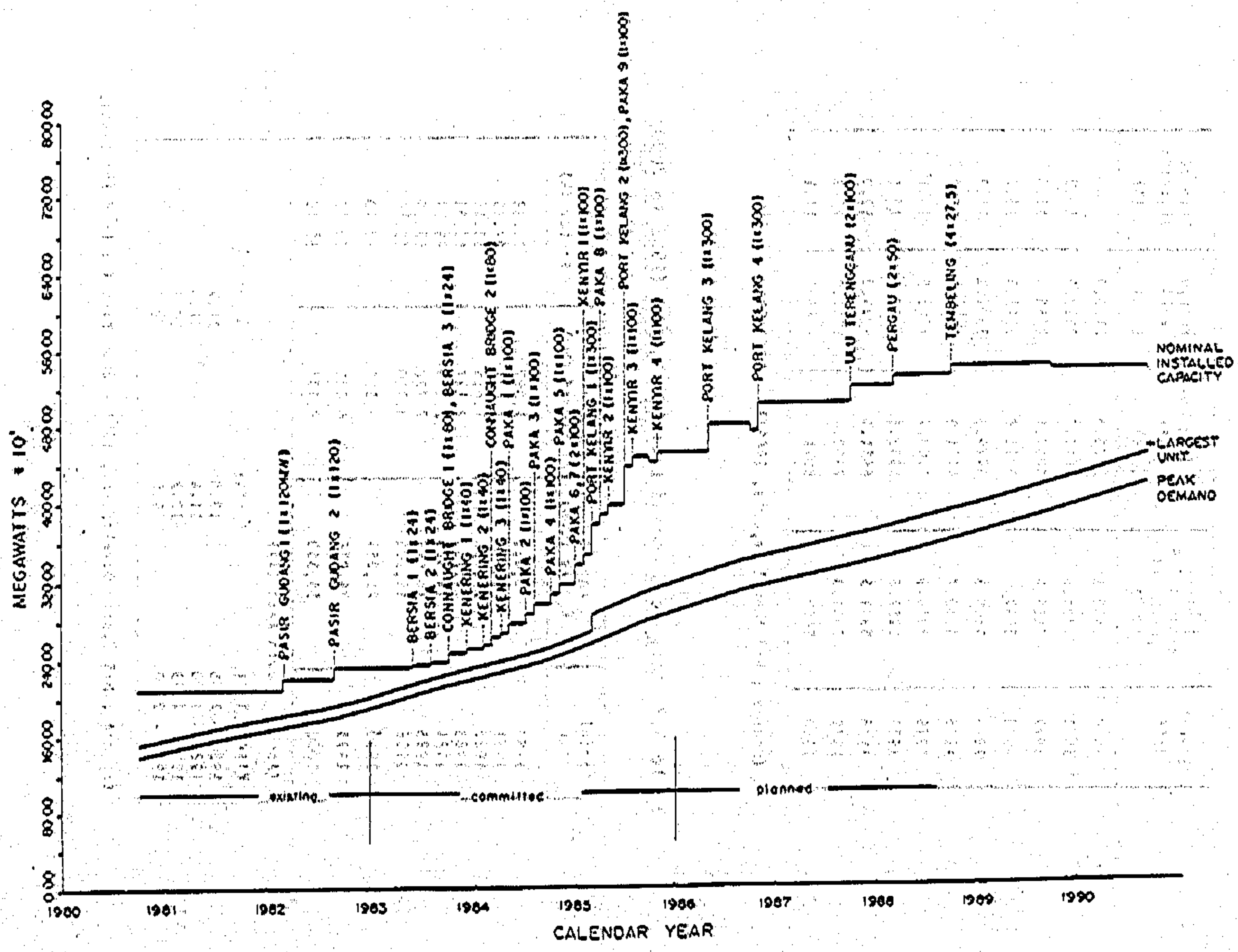
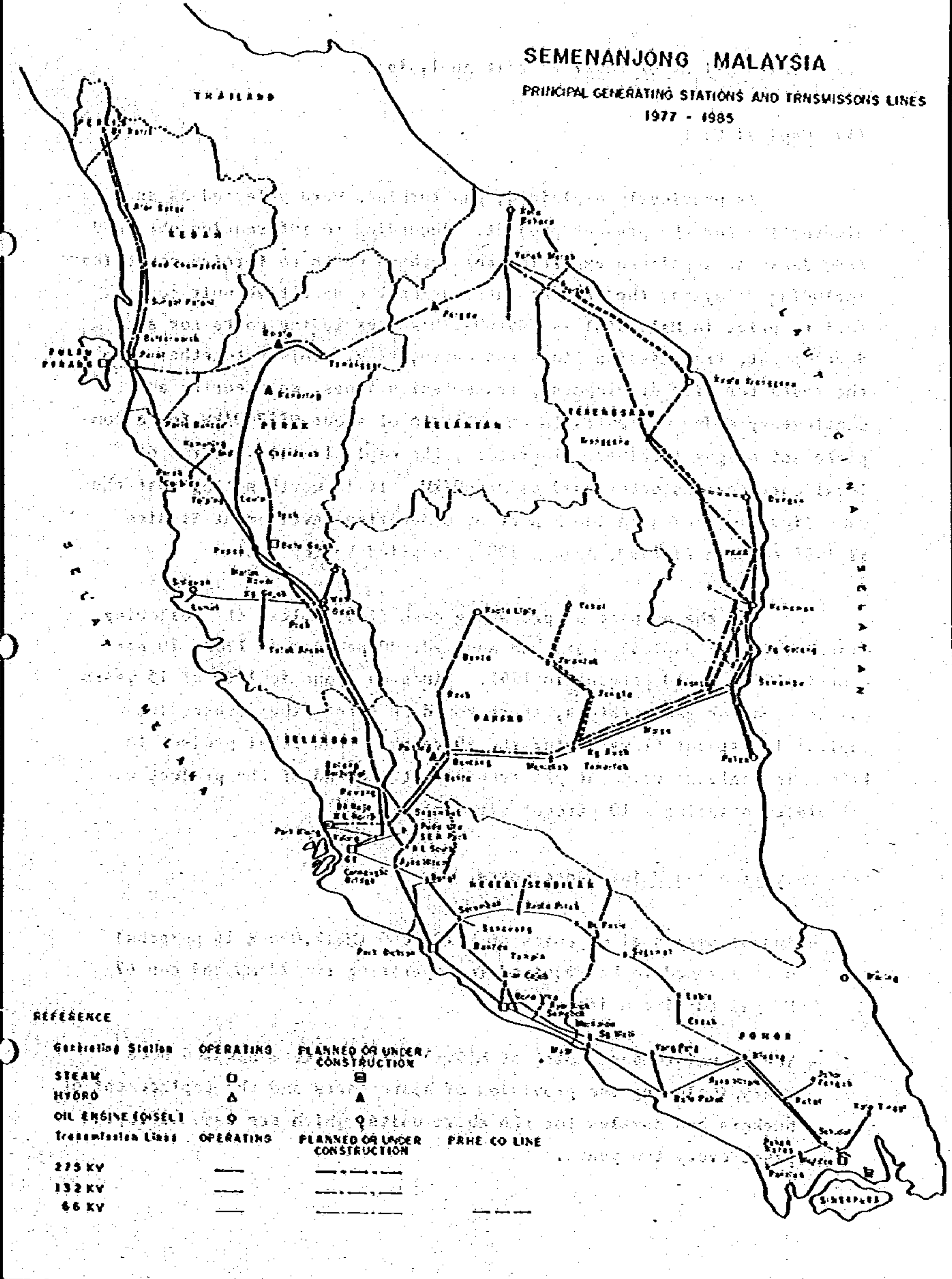


Fig. 5.2 Main Transmission System



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5.2.4 Assumptions of Power Benefit Analysis

(1) Capital Cost

As previously explained, gas turbines were selected as an alternative for the present project. According to information obtained from Japanese suppliers exporting gas turbine units to foreign countries including Malaysia, the present international competitive unit cost (c.i.f. price in Malaysia) is US$160-170/kW, excluding costs for site development, transmission lines and engineering. This - together with the costs for site development, transmission lines, engineering and contingency added - results in an estimate of about US$300/kW for a complete set of gas turbines. Therefore, the capital cost in terms of local currency was determined as M$660/kW. It is worth noting that the same figure was used in the Report of Generation Development Studies FY 1986 through FY 1990, August 1981, supplied by the NEB.

For the purpose of preparing cash flow tables, the following distribution of capital costs was assumed: 20 percent in 1989, 70 percent in 1990 and 10 percent in 1991. Since an economic life of 15 years was assumed for gas turbines, there would be three other subsequent capital investment flows during the 50 years of the Tekai project is life. The salvage value of gas trubines at the end of the project was calculated assuming a 10 percent discount rate.

(2) Operation and Maintenance Costs

- Annual personnel expenses of M$192,000 (M$12,000 x 16 persons) were assumed to be required for operating two 22 MW and one 67 MW gas turbine units.

- Yearly maintenance costs of M$6.152 million were assumed necessary, including the provision of spare parts and the replacement of buckets and nozzles for the above units, which are assumed to take place every two years.

(3) Fuel Costs

The NEB purchases its fuel oil at a domestic price. For the calculation of economic return, however, the world market price of M$617/ton (US$30/bbl) was used, based on the Singapore f.o.b. price of medium fuel oil in early 1982.

An amount of 313.62 ton/G.W.H of fuel consumption was obtained by assuming the daily load curve and using technical data supplied by a plant manufacturer were used. A decrease of 10 percent in thermal efficiency due to temperatures in Malaysia and a heat value of 11,000 kcal/kg were assumed in this calculation.

(4) Adjustment Factors

Adjustment factors of 1.119 for kW value and 0.982 for kW.H value were applied for the above costs in preparing cash flow tables.

5.3 Forestry

5.3.1 Forest Resources in the Reservoir Area

It is anticipated that the proposed Upper Tekai Dam will begin to store water in November 1989 and that by the middle of 1991 both the Upper and Lower Tekai Dams will reach operating levels. The reservoirs of the two dams will flood an area of about 8,210 ha including approximately 7,960 ha of primary forest area. These areas include a number of small islands in the proposed reservoirs.

Logging is practiced at present in Malaysia, for marketable species of trees with a Diameter at Reference Point (usually at breast height) of 18 inches (45.7 cm) and over. Thus, for the present purpose of economic evaluation, the forest resources in the reservoir area are based, in order to obtain the total net volume of marketable trees of 18 inches and over, on the following two data sources:

(1) Data gathered at PLOT-1 (0.25 ha) and PLOT-2 (0.15 ha) of the field biotic environment survey carried out by the present study team (for details, see Appendix 2, Fig. 2); and

(2) A National Inventory of West Malaysia, 1970-1972

For the 14 species of marketable trees of 18 inches and over recorded in the PLOT-1 and PLOT-2, a bole volume (or a gross volume) of each tree was calculated by using the following formula:

$$V = \frac{d^2 \cdot hb}{12h^2} (3h^2 - 3h \cdot hb + hb^2)$$

where, h stands for height of a tree, hb for height of the first large branch and d for diameter at breast height.

From the calculated figures, bole volumes and weights of marketable trees per hectare by species are estimated for the PLOT-1 and PLOT-2 Specific gravities of 0.8 for medium hard wood and 0.7 for light hard wood are assumed in this estimation. Then, by applying the estimated loss rates of 15 percent during harvesting and transport and 30 to 35 percent of defective trees for sales net volumes and weights are estimated at 106.55 m^3/ha and 71.71 ton/ha for the PLOT-1 and 54.11 m^3/ha and 36.25 ton/ha for the PLOT-2. As PLOT-1 and PLOT-2 can be regarded as representing 4,580 ha and 3,380 ha of the total flooded forest area of 7,960 ha, the total net volume and weight of forest resources are estimated at about 0.67 million m^3 and 0.45 million tons, based on the field survey data.

The second data source (A National Forest Inventory of West Malaysia) shows the national weighted average figures of gross volume of forest resources by forest type. Since the net volume of marketable species expressed as a percentage of gross volume was estimated at 47, the estimated net volumes and weights per hectare for the forest types S and G, which are mapped in the reservoir area, are 87.28 m^3/ha and 57.48 ton/ha for the forest type S and 78.26 m^3/ha and 52.43 ton/ha for the forest type G, respectively. Thus, by multiplying the estimated forest areas of 1,100 ha for the type S and 6,860 ha for the type G, we arrived at a total net volume of about 0.63 million m^3 and a total net weight of about 0.42 million tons.

The small differences between the two estimations seem to be due mainly to (1) the smallness of both PLOT-1 (representing areas of low undulation) and PLOT-2 (representing relatively steep slopes along the river channel); (2) the fact that the national inventory data cover a wide area with different characteristics by random samplings in which 10 to 30 percent of standard error is reportedly involved; and (3) possible inaccuracy of the small-scale inventory map indicating the border line of forest types. Thus, in the following valuation of forestry losses, the average figures of the two estimates of 0.65 million m^3 and 0.435 million tons are used.