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MALAYSIA

INTERIM REPORT
OF
FEASIBILITY STUDY
FOR
THE TEKAI HYDROELECTRIC POWER DEVELOPMENT PROJECT

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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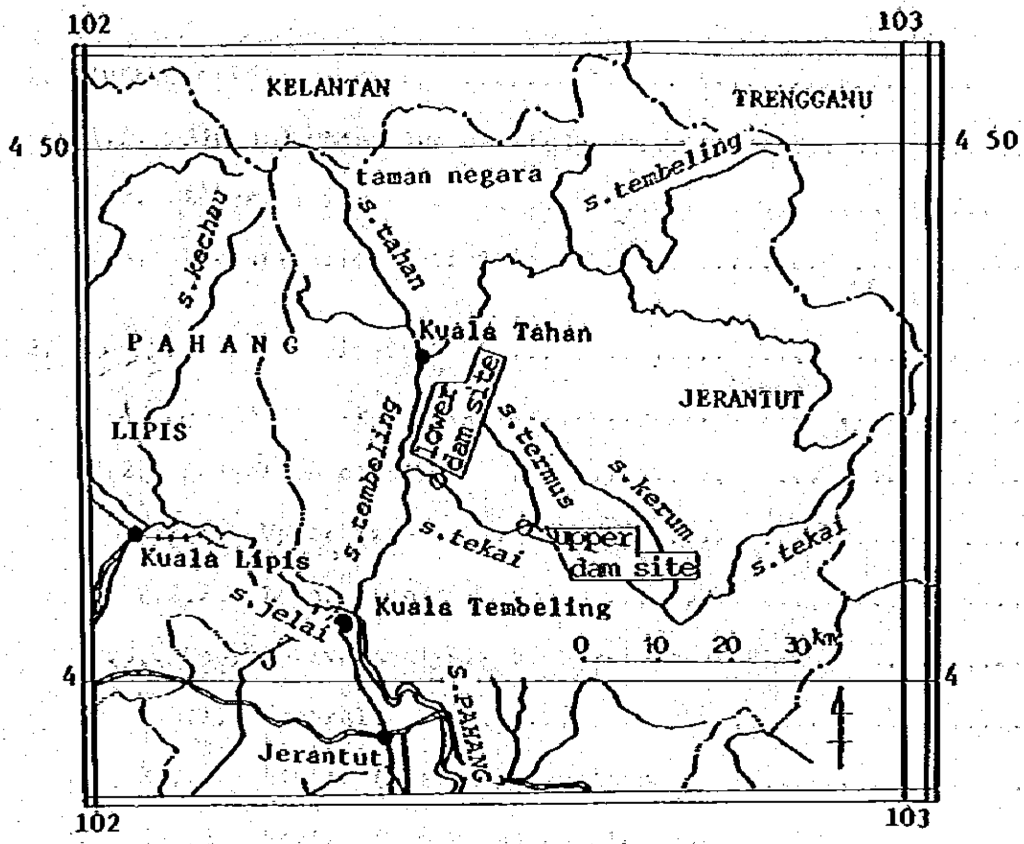
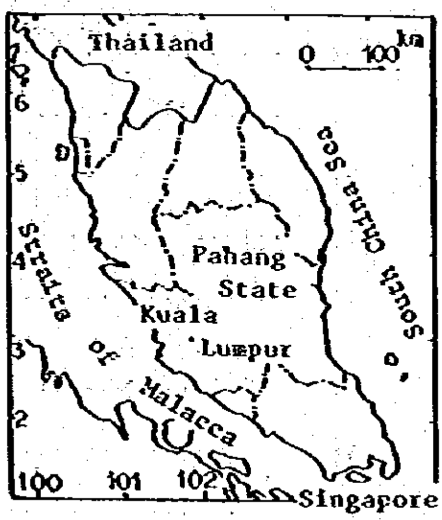
LOCATION MAP





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CHAPTER 1

INTRODUCTION

Chapter 1 Introduction

1.1. Aim and Objective of Study

The objective of this study undertaken by the JICA survey team in response to a request made by the Government of Malaysia is to examine a feasibility of the Tekai Hydro-electric Development Project to be developed on the Tekai River, a tributary of the Tembeling River of the Pahang River Basin in Pahang State of West Malaysia.

As for the Pahang River, an Australian team conducted a study of the entire basin of the said river from 1972 to 1974 on a Government-to-Government basis. The team forwarded a report dealing with the results of their study of which emphasis was placed on the aspects of flood mitigation and control in development of the river.

The mission of the JICA survey team was to review the results of the previous study performed by the Australian team from an angle of hydro-electric power development.

Because of the above historical background, this report presented herewith has been prepared, based upon the first-hand information obtained during the course of the site investigations and also on the results of analysis of data and information made available to the team in Malaysia after their return home to Tokyo.

1.2. Scope of Work

The feasibility study of the Tekai Hydro-electric Development Project will be undertaken at the following three stages:

(1) Stage 1: A preliminary investigations

(2) Stage 2: A detailed site investigations

(3) Stage 3: Planning based on feasibility

In order to achieve the objectives given in the previous section, studies were carried out on the following items at the stage of preliminary investigations.

i) <u>Collection and analysis of existing data and information</u>

a. Electric power situation in Malaysia

b. Meteorology and hydrology

c. Present situation and future plans for water control and utilization of the River Basin

d. Socio-economic and environmental impact of the development project upon the community

ii) <u>Reconnaissance of the upper and the lower sites</u>

Through reconnaissance of the ground surface, possible sites for constructing main structures including dams, power stations, switchyards, etc. were investigated, and topographical and geological characteristics of possible earth, sand and rock supply sites was surveyed.

As for filling areas for the two sites, geological surveys of the ground surface and aerial survey using a helicopter was carried out to spot collapses, limestone outcrops and possible quarry sites and borrow areas as well as to investigate geological formations of the areas. Appropriate sites for hydrological observation facilities were proposed by identifying and comparing the conditions of various alternative sites from the standpoints of required locational conditions.

iii) <u>Site investigations</u>

Based upon the results of the site reconnaissance, the following site investigations were conducted:

a. Topographical surveys of areas to be inundated at the upper and the lower sites,

b. Gological surveys of the upper and the lower sites by seismic prospecting.

c. Geological surveys of the two sites by bore-hole drillings.

d. Guidance to be given for the establishment of hydrological observation facilities.

e. Observations of floods in the rainy season.

iv) Preliminary design

a. Examination of a development scheme,

b. Examination of a scale of development,

c. Examination of a pumped-storage, and diversion scheme

d. Preparation of plans for future studies.

1.3. Investigation Activities

A request was made by the Government of Malaysia in connection with the performance of a feasibility study on the Tekai Hydro-electric Development Project in 1980. In response to this request, the Government of Japan decided to cooperate with this work and delegated the Japan International Cooperation Agency (JICA) to proceed with this study on the Project. A survey team composed of the specialists in the fields of dams, geology, hydrology, civil engineering for power generation, electric demand forecast, geological surveying and so forth was organized by JICA.

Upon settlement of the scope of work and related terms and conditions related to the performance of the said study, the advance survey team visited Malaysia for a period of 25 days from the 1st of March through 25th, 1981 in order to conduct reconnaissance in the field for preparation of a preliminary site investigation plan and for purposes of collecting data and information required for the site investigation.

Then the survey team visited Malaysia for a period of approximate five (5) months from the middle of June to the end of October for the purpose of undertaking the preliminary site investigations.

During its stay in Malaysia, the survey team was engaged in supervision of bore-hole drillings, seismic prospectings and aerial photography of the upper and lower sites, all conducted by local contractors. The team members also undertook surface surveying for preparation of aerial charts, and longitudinal profile and cross section surveyings of the upper and lower sites as well as hydrological observation. In addition to the various work, the survey team conducted data and information collection in the respective fields.

It is noteworthy that a specialist of hydrological observation visited the country from the middle of November to the end of December, 1981 for observation of floods during the rainy season in Malaysia.

Comparisons between the two proposed sites - Upper Tekai and Lower Tekai Sites have been made in the report. For each proposed site, several development alternatives were studied according to criteria of locational conditions for construction of hydro-electric project, taking various merits and demerits contained in each alternative.

It is believed that the findings incorporated in the report will be of great help to working out a plan for performance of further studies on the Project.

CHAPTER 2

SUMMARY AND CONCLUSIONS

Chapter 2 Summary and Conclusions

2.1. Summary

The proposed site for the Tekai Hydro-electric Power Development Project is located about 40 km to the north of Jerantut, the administrative center of the area, and is at the lower reaches of the Teaki River which is one of the tributaries of the Pahang River situated in the northern part of the Pahang State, the largest state of West Malaysia.

The Project is a part of the electric power development plan to cope with the rapidly increasing power demand in West Malaysia.

At the same time, it is expected that the Project may incidentally contribute to the development of Area.

The fundamental facts which became known as a result of the study undertaken in the framework of the present preliminary site investigation can be resumed as follows:

(1) The Tekai River Basin is composed of continental sediments, metasediments and granites. Continental sediments are called Tembeling Group (Mesozoic Era), and are made up of Kerum formation, Laris conglomerate, Mangking sandstone and Termus redbed. In both vicinities of the upper site and the lower site, Mangking sandstone and Termus redbed are outcropping.

Mangking sandstone mainly consists of hard quartzose sandstone and includes grayish, reddish shale. As for Termus redbed, it is made up of reddish shale, and interbedded by sandstone.

At both the upper and lower sites, where the slope is gentle, the ground is covered with completely weathered zone and highly weathered zone which are completely laterized.

As one of approaches the river bed, the weathered zone gets thinner. The base rock which lies underneath is either very little weathered or fresh, and is composed extremely hard quartzose snadstone and shale. Its seismic velocity is approximately 2.0 - 3.5 km/sec, and its bearing capacity is large.

Mountain ranges in the Tekai River Basin mainly stretch from north-north-west to south-south-east.

Such a linearment has much to do with geological structure of the area. The fold axis of strata is prevailing from north-north-west to south-south-east.

As for Tembeling Group, in general, strata dips from north-north-west to south-south-east and also various scales of anticline and syncline structures can be identified.

Over the whole Tekai River Basin, many minor faults were observed, but so far no major fault was found.

(2) The discharge measurement has been taken since 1972 by the NEB (National Electricity Board) at Penut point (catchment area; 1,390 km^2) near the lower site.

Also in the vicinity of the Tekai river basin, at Kuala Tahan point (catchment area; 3,220 km^2) on the Tembeling River which is 15 km upstream for the Tembeling-Tekai confluence, the same measurement has been taken since 1972.

However, the discharge data at Penut point is not complete due to the lacking many measurements.

Consequently, discharge of upper and lower sites to be used for the study of Tekai Hydro-electric Power Development Project was obtained through catchment ratio conersion of discharge data at Kuala Tahan point (1973-1980).

By means of such calculations, the following figures were obtained:

The annual mean discharge is 40 m^3/sec at the upper site and 46 m^3/sec at the lower site, and annual mean runoff at the lower site is 1,470 x 10^6 m^3 and annual depth of runoff is 1,060 mm at the lower site.

As to the rainfall measurement in the Tekai river basin, available data was only since 1974 at two points (Station No. 4227001 and No. 4127001).

Both these data being incomplete, so annual average rainfall of the Tekai river basin was established, by using data from the nearby observation points, approximately at 2,300 - 2,400 mm.

In the Pahang River Basin, flood takes place during the season of monsoon between late December and early January. Well-known floods are these occurred in 1926, January 1971 and December 1972.

Probable flood of 1/100 year at the lower site was computed as the 3,000 m^3/sec in connection with the probable discharges and catchment area at the six locations of the Pahang river basin observation stations.

Furthermore, estimated maximum probable flood of 1/1,000 year was 4,500 m^3/sec at the upper site and 5,000 m^3/sec at the lower site based upon the unit hydrograph and tank model method calculation.

(3) As far as the Takai River Basin is concerned, there exist no concrete development project at present for either potable water, industrial water or water for agriculture.

In the Pahang River Basin, irrespective of the Tekai Hydro-Electric Power Development Project, implementation of an irrigation project is undertaken actually under the name of "National Small Scale Irrigation Project" by the Ministry of Agriculture.

However, as the hydro-electric power development will make possible stable water supply to the Pahang River, this indicates the potential water utility effect of the project which will make it possible to cope with the future water demand for irrigation.

Presently industrial activities in the area designated for the Tekai Hydro-electric Power Development Project are limited to forestry.

Fishery and agriculture are practised on a small scale for meeting local consumption only along the Tembeling River.

The project area and its vicinity are located within the National Tekai-Tembeling Forest Reserve under the forestry agency. In future its exploitation is to be undertaken by the JENGKA.

In the area expected to be submerged as a result of the Tekai Hydro-electric Power Development as well as in its neighboring area, couples of a minority mountain group households are there, but no fixed community of long duration and its facilities exist therein.

2.2. Selection of Sites

Candidate sites were selected at the upper and lower sites because of the topography, geology and the viewpoint of construction work.

2.2.1. Upper Site

U-2 candidate site was selected as a optimum site among U-1 and U-3 sites based upon the cost estimates of the main dam construction.

Further studies were made on the dam types at the selected U-2 sites. (Topographical dam limit was 90.00 m). Rockfill type was adopted in comparison with the concrete gravity type due to the cost estimates of the main civil work including the spillway and diversion facilities.

The height of dam was compared based upon the maximum output and annual energy generation under the following conditions.

Case	Height of Dam	Conditions
1	50 m	1) Effective Reservoir Storage (540×10^6 m^3)
2	75 m	2) Firm Discharge (40 m^3/sec x 4 = 160 m^3/sec)
3	90 m	3) Peak Operation Time (6 hrs)

Case 3 dam height 90 m was adopted.

Power generation was examined in connection with the peak operation time, cases 6 hrs, 8 hrs, and 12 hrs. And peak operation time 6 hrs were judged to be most advantageous in view of the surplus benefit in terms of B-C.

2.2.2. Lower Site

L-1 candidate site was selected as the optimum site compared with L-2 site in the same manner aforementioned.

Studies were also made on the dam type. (Topographical and geological dam limit was 60.00 m). Concrete gravity type was adopted under the same method at 2.2.1.

The height of dam was compared based upon the maximum output and annual energy generation under the following conditions.

Case	Height of Dam	Conditions
1	52 m	1) Effective Reservoir Storage ($630 \times 10^6 m^3$)
2	60 m	2) Firm Discharge ($46 m^3/sec \times 4 = 184 m^3/sec$)
		3) Peak Operation Time (6 hrs)

Case 2 dam height 60 m was adopted.

Power generation was examined in connection with the peak operation time; cases 6 hrs, 8 hrs, and 12 hrs.

And 12 hrs peak operation time was judged to be most advantageous in view of the surplus benefit in terms of B-C.

2.3. Comparative Analysis of Development Plans

2.3.1. General

A single (one dam) development scheme at the respective upper and lower sites, and a series (two dams) development scheme should be considered.

In determination of the optimum scale of the single (one dam) development scheme, studies were made on the height of dam, operation time of a power plant, maximum turbine discharge, drawdown of a reservoir (effective depth), annual energy generation, installed capacity and economic analysis in terms of a benefit/cost ratio and according to a formula of benefit-cost.

The optimum scale involved in the series (two dams) development scheme has been determined on the assumption that the normal water level of lower dam is to be in the same as the tailrace water level of upper dam upon settlement of the optimum scale of the upper single (one dam) plan which will produce a larger quantity of energy, making studies on the operation time of a power plant, drawdown of a reservoir (effective depth) and annual energy generation, installed capacity and analysis of benefit/cost and benefit-cost.

As the Tekai river basin represents very few catchment, when compared with the whole Pahang River Basin, flood control effect of the Project cannot be substantial. As a result, flood mitigation was not included in the calculation of benefit.

In the same way, though its potential effect on water utility may be great, it was not included in the calculation of benefit.

Consequently, the benefit (B) represents only that derived from power generation.

Loss of forest area resulting from its submersion was excluded from the cost calculation.

These comparative studies are shown in Tables 9-1 and 9-2.

2.3.2. Single (One Dam) Development

(1) Upper Site

Calculation for power generation was carried out with the 90.00 m dam height, 6 hrs peak operation time and 160 m^3/sec maximum turbine discharge for an effective water depth of 2.50 m, 4.50 m and 10.00 m. As a result of the comparison, 10 m was judged to be most advantageous.

In this case, the maximum output will be 104 MW.

(2) Lower Site

Calculation for power generation was carried out with the 60.00 m dam height, 12 hrs peak operation time and 92 m^3/sec maximum turbine discharge for an effective water depth of 10.00 m, 18.00 m and 25.00 m. As a result of the comaprison, 10 m was judged to be most advantageous.

In this case, the maximum output will be 38.7 MW.

2.3.3. Series (Two Dams) Development

(1) Upper Site

Optimum scale of upper single (one dam) development; maximum output 104 MW.

(2) Lower Site

The normal water level of lower dam will be in the same level as the tailrace water level (EL. 82.00 m) of the upper power station, and the effective storage capacity for power generation will be $630 \times 10^6 - 540 \times 10^6 = 90 \times 10^6$ m^3.

In this case the height of dam becomes 38 m. The optimum scale of series (two dams) development has been determined according to B/C and B-C obtained from the effective depth of the lower dam, plant operation time (hrs) for peak duration, maximum turbine discharge, annual energy generation and maximum output.

Maximum output under series (two dams) development becomes 12 MW for the lower site.

Total maximum output under series (two dams) development becomes 116 MW.

2.4. Conclusions

The following are our conclusions derived from the investigation and examination at the preliminary study stage.

(1) The series (two dams) development is most advantageous compared with the respective single (one dam) developments.

(2) In this case, rockfill type dam with a height of 90.00 m is most appropriate for the upper site, and for the lower site concrete gravity type dam with a height of 38.00 m is.

(3) Full supply level of EL. 165.00 m for the upper dam (Effective depth 10 m) and that of EL. 83.00 m for the lower dam (Effective depth 4 m) are most suitable.

(4) Daily 6 hours peak operation employing a maximum turbine discharge of 160 m^3/sec for the upper site and 24 hours flat operation employing a maximum turbine discharge of 46.3 m^3/sec for the lower site will be preferable.

(5) For the upper dam the maximum output will be 104 MW and L-5 output will be 102 MW and for the lower dam, the maximum output and L-5 output are both 12 MW.

Consequently, the combined maximum output will be 116 MW and combined L-5 output will be 114 MW.

As for the annual energy generation, it is 225 GWh for the upper and 102 GWh for the lower and 327 GWh in total.

(6) For the series (two dams) development, cost benefit ratio (B/C) is 1.27 and surplus benefit (B-C) is 12.37 x 10^6 M$.

The internal rate of return will approach about 10 percent.

Conclusions in relation to the diversion scheme and pumped-storage scheme as for the relative development.

(7) Selection of three candidate sites was made by means of a topographical map on a scale of 1/63,360. Then calculation of electric energy generation and estimates of costs of intake facilities were prepared by reference to the length of diversion tunnels and the catchment area. Based upon the calculation, this scheme would not be profitable.

(8) The pumped-storage scheme should be studied with due attention given to a long-term power demand, especially configuration of a daily load curve, composition of power sources and availability of sites suitable for pumped-storage generation.

Then the pumped-storage scale should be determined in consideration of harmonies combination of other categories of power sources in the system, which will be most economical for the whole system.

MAIN FEATURE

ITEMS \ TYPE	SINGLE (ONE DAM) DEVELOPMENT		SERIES (TWO DAMS) DEVELOPMENT	
	UPPER DAM	LOWER DAM	UPPER DAM	LOWER DAM
1. DAM				
Crest Level (m)	EL.170	EL.110	EL.170	EL.88
Height of Dam (m)	90	60	90	38
Volume of Dam Embankment (m^3)	$2.6x10^6$	$2.09x10^5$	$2.6x10^6$	$7.4x10^4$
Maximum Spillway Discharge (m^3/sec.)	5,000	4,500	5,000	1,000
2. RESERVOIR				
Catchment Area (Km^2)	1,200	1,390	1,200	1,390
Full Supply Level (m)	EL.165	EL.105	EL.165	EL.83
Minimum Operating Level (m)	EL.155	EL.95	EL.155	EL.79
Gross Storage Volume (m^3)	$3,400x10^6$	$1,000x10^6$	$3,400x10^6$	$265x10^6$
Live Storage Volume (m^3)	$1,100x10^6$	$410x10^6$	$1,100x10^6$	$90x10^6$
Surface Area at FSL (ha)	10,600	6,000	10,600	2,400
3. POWER STATION				
No. and Size of Unit (MW)	2 x 52	2 x 19.4	2 x 52 and 2 x 6	
Average Annual Generating Energy (GWH)	225	155	225 and 102 (327)	
Maximum Water Discharge (m^3/sec)	160	92	160 and 46	
4. CONSTRUCTION COST (M$$10^6$)	300	160	300 and 96 (396)	

CHAPTER 3

GATHERED DATA

Chapter 3 Gathered Data

Basic data and information used fot the studies given in this report cover hydrology, meteorology, geology, etc. Most of these data and information were collected by the Survey Team during their stay in Malaysia from June to October 1981 with the cooperation of the authorities concerned of the said country.

In addition to the above-mentioned data and information, data on electric power system, transmission line, financial situation, socio-economic condition, agriculture, environment, etc. have been made available to the Investigation Team in making studies on the Project.

CHAPTER 4

BACKGROUND OF PROJECT

Chapter 4 Background of Project

4.1. Outline

The annual increase in power demand in the Peninsula Malaysia in recent years is as high as 14.7 percent (assumed average annual increase from 1980 to 1985), and the National Electricity Board (NEB) is promoting power development actively so as to cope with the demand.

The Tekai Hydro-electric Power Development Project is one of the development plans, and "Tekai" is positioned as a vital hydro-electric power development project to play its role as a driving force for the industrial development in the State of Pahang in the Peninsula Malaysia. In addition, it is expected to contribute to the development of the Area.

4.2. Project Site

The project site for the Tekai Hydro-electric Power Development Project is located at the lower reaches of the Tekai River which is one of the tributaries of the Pahang River (catchment area of 28,500 km^2) which flows through the State of Pahang which is the largest state in West Malaysia.

These are two possible project sites, among which the lower site (catchment area of 1,390 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 18.5 km further upstream from the lower site.

The project area is adjacent to the southern side of the National Park called Tamang Negara located in the northern tip of the State of Pahang, and is, in a beeline, about 150 km northeast from the capital city of Kuala Lumpur.

Administratively, it belongs to the Jerantut District, and it takes about one and a half hours by jeep and boat from the administrative center of Jerantut to the lower project site. One reaches the upper site from the lower site by boat.

4.3. Regional Topography

The Pahang River, the largest river on the Malay Peninsula, 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 Tembeling River is one of the main upper reaches of the Pahang River and joins the Jelai River at Kuala Tembeling.

The Tekai River is the largest tributary of the Tembeling River. 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 at about 20 km upstream of Kuala Tembeling. The Tekai River Basin is a forested, hilly area surrounded by mountains. The highest mountain in the area is the G. Taris (4,960 ft.) which belongs to the Trengganu coastal range.

The upper reaches of the Tekai River have a considerably steep gradient of riverbed, while the gradient of the lower reaches is very gentle (1 : 1,000). The riversides of the Tekai River are generally formed with a gentle slope, but there are some steep valleys where hard rock is exposed on the banks of the river.

In general, the mountains in the area carry investigation on their summits, because the rocks are heavily weathered and are often concealed by thick covers of Laterite.

4.4. General Description of Pahang

The State of Pahang is the third largest state in Malaysia. The 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. The climate is tropical, though it differs between regions. Approximately 65 percent of the total area is covered with forest. Cultivated land is mainly in the basin of the Pahang River where approximately 566,600 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 eight 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 (1980 estimate) of which approximately 25 percent of the people 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.

Natural population growth between 1971 and 1980 was a mean annual rate of 2.6 percent which is less than 2.8 percent average for the country as a whole during this period. According to the Fourth Malaysia Plan (1981 - 1985), it is estimated that the population growth will average 2.4 percent annually.

This lower growth rate is due to low infant mortality and fertility brought about by improvements in culture, education, and medical cares. During the 1970's, there was an influx of population from the rural districts to the urban districts and migration from other states by the implementation of industrial projects under the First, Second and Third Malaysia Plans, but this migration of population from within and outside the state is assumed to have taken off after the Fourth Malaysia Plan. Population growth rate in the 10 year period was 4.5 percent, but the growth rate is estimated to have decreased to 4.1 percent. The composition of the population is 58 percent Malay, 35 percent Chinese and 7 percent other races.

The national railway serves 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 from the state. The road network consists 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 constructed and existing roads are being upgraded and improved. There is a daily air service by Malaysian Airlines between Kuala Lumpur and Kuantan. Approximately 1,300,000 m^2 of land has been set aside to construct an airport at Jerantut. Improvement and expansion of a nationwide telecommunication system is underway. Subscriber trunk dialing by microwave and cable is in service and under expansion to cover the entire nation, including the states of Sabah and Sarawak. A deep sea port has been undertaken by the Federal Government, located about 26 km to the north of the city of Kuantan. This port is at present partially operational for both the mineoil berth and the palm oil berth. This port is expected to become the major outlet for expect of products of the eastern states.

Historically, economic activities in the eastern states lagged behind the western states. The major cause of this situation was the undeveloped states of infrastructures to provide impetus for economic growth. 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 the First, Second, Third and Fourth Malaysia Plan.

In line with the government policy, the state of Pahang has enacted and is actively implementing various economic policies. In order to emerge from an economy based on agriculture and forestry, the state is aiming towards industrialization by utilizing agricultural and forestry resources as raw materials. To achieve this objective, the state has established industrial estates at Jebeng and Semanbu in Kuantan District, Pekan in Pekan District, Temerloh in Temerloh District and Bentong in Bentong District. In these industrial estates there are wood product manufacturing industries, rubber refining and manufacturing industries, palm oil refining and manufacturing industries, and also export oriented electronic and electrical equipment manufacturing industries, but these are all of small scale. The government is also actively inviting foreign manufacturers to invest in the country by enacting laws granting various privileges and tax relief. Anticipating development and growth of export oriented industries in the future, the government has decided to set up a free trade zone in Gebeng Industrial Estate.

The State of Pahang is blessed with recreational and resort regions along its some 200 km long coastline and highlands in the interior. The state has built recreational and resort facilities at these places and is actively attracting tourists, both domestic and from overseas.

The recent discovery of oil and natural gas off the state's coast in the South China Sea is expected to bring about a spring-board in the rapid and expanding growth of the economy.

Training and education of a labour force to support the industrialization program is essential. In the state there is a polytechnic school, six vocational schools and skills training institute which can supply the skilled man-power needs of the industries in the state.

With the implementation of economic policies under the Malaysia Plans, the gross domestic product (GDP) and per capita GDP of the state has grown progressively. In the last year of the First Malaysia Plan, which was 1971, the GDP was 647 million M$ and per capita GDP was 1,170 M$ at 1970 prices. This per capita GDP was 1.0 in ratio to the national average. In the Third Malaysia Plan ending in 1980, the state's target GDP was 1,218 million M$ and per capita GDP 1,486 M$ at 1970 prices. And in the Fourth Malaysia Plan ending in 1985, the predicted GDP will be 2,491 million M$ and per capita GDP 2,558.8 M$ at 1970 prices. This per capita GDP ratio is 1.09 to the national average. During the period (1971 - 1980) inflation as indicated by consumer price index averaged a rate of 5.8 percent annually.

The GDP composition by industries at the end of the First Malaysia Plan was agriculture and forestry 48.5 percent, manufacturing 6.5 percent and services 30.1 percent. However, according to the Third Malaysia Plan the composition is agriculture and forestry 38.2 percnet, manufacturing 26.2 percent and services 25.9 percent. And in the Fourth Malaysia Plan ending in 1985, the GDP composition is agriculture and forestry 27.75 percent, manufacturing 29.1 percent and services 28.5 percent. It will be noted from the above given values that the economy of the state will be tranformed from basically agriculture and forestry to the manufacturing sector. In this context, it will be hoped that the socio-economic infrastructures of the country can be implemented as quickly as possible.

The electricity demand of the state is partly served by the NEB's transmission network, but the greater part of the state is served by local diesel plants of small capacity. As an integral part of the Malaysia Plans to strengthen the infrastructure, the NEB has planned and is implementing a program to serve all of the eastern states, including Pahang, from its national grid.

CHAPTER 5

ELECTRIC POWER SITUATION IN MALAYSIA

Chapter 5 Electric Power Situation in Malaysia

5.1. Power Generating Plant

5.1.1. Power Generating Plant of NEB

The installed capacity of NEB's generating plants with the following compostion amounts to approximately 2,235 MW as of October, 1981;

(1) Hydro Power Stations

Temengor	4 units	x 87 MW	348 MW
Sultan Idris II	3	x 50	150
Sultan Yusuf	4	x 25	100
Chenderoh	3	x 10	30 (PRHEC)
Others			15.4
	(Sub-total)		643.4 MW

(2) Thermal Power Stations

Connaught Bridge	4 units	x 20 MW	80 MW
Gelugor	4	x 10	40
Malaka	4	x 10	40
Sultan Ismail	3	x 10	30
	3	x 30	90
Perai	3	x 30	90
	3	x 120	360
Tuanku Jaafar (Port Dickson)	4	x 60	240
	3	x 120	360
Malim Nawar	2	x 20	40 (PRHEC)
	(Sub-total)		1,370 MW

(3) Gas Turbines

Gelugor	1 unit	x 20 MW	20 MW
Connaught Bridge	1	x 20	20

Tuanku Jaafar	1	x 20 MW	20 MW
Tanjong Gelang	1 unit	x 20	20
Sultan Ismail	1	x 20	20
	(Sub-total)		100 MW

(4) <u>Diesel-engine Generators</u>

Lundang		43.95 MW
K. Trengganu		24.15
Kemaman		4.16
Dungun		3.565
Kuantan		11.37
Lemal		5.20
K. Rompin		2.85
Others		20.031
Diesel engine generator for rural electrification		6.972
	(Sub-total)	122.248 MW
	Total	2,235.648 MW

The percentage of generating plants connected with the NEB integrated system is 65 percent for thermal power stations, 30 percent for hydro power stations and 5 percent for gas turbines. (Note, however, that diesel engine generators serving the rural area are not included in the above figure, although such diesel are operated at night for 12 hours daily.)

5.2. Power Demand and Supply

5.2.1. Power Demand in the Past

Electrical energy sold over the past decade (1970 to 1979) of the electric power system of NEB has been as follows: (The fiscal year in Malaysia starts on September 1st and ends on August 31st.)

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

(Source; NEB Annual Reports, 1969/70 - 1978/79)

Table 5-2 Energy Setout (GWH) Breakdown according to Generating Source

Fiscal Year	Thermal	NEB Diesel	Hydro	Gas Turbine	** PRHEC	Rural Area	PUB*	Others
1970	1298.4	96.7	918.8	-	92.3	-	-	0.1
1971	1498.4	114.0	933.3	-	100.0	-	-	0.1
1972	1901.0	133.5	909.0	-	109.5	4.3	-	0.1
1973	2303.8	131.0	928.1	-	124.3	4.5	-	0.1
1974	2745.8	146.0	898.8	-	134.0	4.8	-	0.1
1975	3343.0	164.0	780.9	-	148.9	5.0	-	0.1
1976	4042.6	180.3	710.5	-	163.6	5.9	-	0.3
1977	4913.3	176.8	673.8	-	182.3	6.9	-	n.a.
1978	5512.7	210.5	744.8	-	162.5	7.5	12.5	0.8
1979	5590.2	275.4	891.9	251.4	179.0	10.5	100.9	3.1

Note: * Singapore, **PRHEC; Perak River Hydro Electric Co.,
(Source; NEB Annual Reports, 1969/70 - 1978/79)

Table 5-3 Energy Generated in the Peninsula Malaysia (GWH)

Fiscal Year	Thermal	Diesel	Hydro	Gas Turbine	Total
1970	1922.0	328.2	1137.8	-	3387.9
1971	2152.0	332.8	1147.8	-	3632.7
1972	2593.1	320.5	1094.3	-	4008.0
1973	3008.5	475.4	1140.7	-	4524.5
1974	3484.1	412.9	1130.1	-	5027.1
1975	4052.1	403.2	989.0	-	5444.3
1976	4646.6	441.4	902.2	-	5990.3
1977	5441.8	460.2	797.6	-	6699.6
1978	6061.8	538.5	831.8	-	7432.1
1979	6255.4	615.6	1004.0	244.4	8119.4

(Source; NEB Annual Reports, 1969/70 - 1978/79)

Table 5-4 Energy Used in the Peninsula Malaysia Classified by Consumer (GWH)

Fiscal Year	Mining		Cement	Commerce & Industry	Households /Lighting	Total
	Tin Mining	Other				
1970	1017.1	47.2	117.6	1211.3	560.0	2953.2
1971	1054.5	20.9	125.2	1385.5	592.1	3178.1
1972	1075.0	7.4	127.3	1631.3	639.6	3480.5
1973	1029.1	7.0	130.4	2018.5	741.9	3927.0
1974	1010.0	5.4	135.3	2410.7	800.5	4361.9
1975	1000.2	5.1	134.5	2736.7	876.3	4753.3
1976	906.0	5.6	159.7	3128.6	945.5	5145.5
1977	920.0	4.8	181.2	3528.6	1073.6	5708.2
1978	927.5	4.4	193.7	3981.7	1276.9	6384.0
1979	933.9	4.8	196.2	4507.3	1456.7	7098.9

(Source; NEB Annual Reports, 1969/70 - 1978/79)

5.2.2. Present Demand and Load Curves

Typical weekly load curves in May, 1981 in the NEB system were as shown separately in Fig. 5-1 and 5-2. According to the above, the maximum demand, weekly energy and average load factor were 1,320 MW, 167 GWH and 75.3 percent, respectively, for which thermal power stations accounted for 139 GWH (83.2 percent) and hydro power stations 28 GWH (16.8 percent).

On the other hand, typical daily load curves by the end of August, 1981, were represented by the daily load curves observed on August 26, Wednesday (Fig. 5-3) showing a peak value of approx. 1,530 MW, August 29, Saturday (Fig. 5-4) with a peak value of 1,460 MW and August 30, Sunday (Fig. 5-5) with a peak value of 1,070 MW or so.

As indicated by the load curves, thermal power stations are used to cope with base loads, while hydro and gas turbine power stations are utilized to cope with peak loads so as to ensure adequate power generation. The duration of operations of hydro and gas turbine power stations is approximately 19 hours/day to cope with peak loads during weekdays.

5.2.3. Demand Forecast

NEB established the following long-term demand forecast (1981 to 2000) in April, 1981 (see Fig. 5-6). The forecasting method was based on time-series analysis and econometric models (GDP, population, etc.) System load factor will not change greatly over the forecast period, on this basis. Maximum demand will be 4,154 MW and annual energy will be 25,254 GWH in 1990, while maximum demand in the year 2000 will be 9,135 MW and the annual energy will be 55,550 GWH. These figures are 6 to 7 times greater than present figures, with an average annual increase rate of around 9.8 percent.

Table 5-5 Long-Term Demand Forecast by NEB (1981 to 2000)

Fiscal Year	Annual Electrical Energy (GWH)	Maximum Demand (MW)	Load Factor (%)
1980	8,610	1,397	70.38
1981	9,641	1,621	67.89
1982	11,034	1,614	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)

5.3. Power Development Program

5.3.1. Power Expansion Program

(1) Power Stations Committed

Power stations of which commitment has already been decided on and by the NEB, are to be constructed by 1985 are as follows:

					completion scheduled
Pasir Gudang (O)	2 units	x	120 MW	240 MW	1982
Connaught Bridge (G/T)	2	x	80	160	1983
Bersia (H)	3	x	24	72	1983
Kenering (H)	3	x	40	120	1983/4
Paka (C/C)	6	x	75	450	1984/5
Port Klang (O)	2	x	300	600	1985
Kenyir (H)	4	x	100	400	1985
			Total	2,042 MW	

where, (O): Heavy oil burning

(G/T): Gas turbine heavy oil burning

(H): Hydro power station

(C/C): Combined cycle, natural gas burning

(2) Power Stations Planned (as of 1981)

Paka (C/C)	6 units	x	75 MW	450 MW	1986
Port Klang (C)	2	x	300	600	1987/8
Ulu Trengganu (H)				200	1989/90
Pergau (H)				100	1989
Tembeling(H)				110	1990
			Total	1,460 MW	

As described in the foregoing, the NEB has established a specific plan for 1990 and subsequent years. According to the plan, power stations with a total installed capacity of 3,500 MW will be constructed by 1990, which may be plotted in the above mentioned long-term demand forecast, as shown in Fig. 5-7.

5.3.2. Transmission Line Expansion Program

In parallel with the above power generation development program, expansion and reinforcement program for the existing 132 kV/ 275 kV transmission lines network are being implemented. This will cover the whole of the western coast of the Peninsula Malaysia, from north to south, and will be the the interconnection of a 275 kV ring spanning the east coast states, the north and central regions of the peninsula.

The 275 kV loop transmission lines consist of two lines of ACSR 300 mm^2 x 2, having a maximum transmission capacity of 1,174 MVA (587 MVA x double circuits). These are scheduled to be completed by 1985.

The power system of the Public Utilities Board of Singapore (PUB), on the other hand, is currently connected by a 22 kV line, but it is planning to construct a 230 kV cable line having a maximum capacity of 200 MW to cope with emergency conditions.

For ECAT (Electricity Generating Authority of Thailand), connection is currently made at the Bukit Ketri Substation in the northern parts of Malaysia by a 132 kV 150 mm^2 line (completed in February, 1981), hence electricity may be technically interchangable to a maximum capacity of 75 MVA. This is limited to 30 MVA to 50 MVA in practice, but the interchange of electricity is made only for emergency conditions.

5.3.3. Transmission Line Plan for Tekai Hydro Power Station

NEB's basic plan for the construction of transmission lines for the Tekai hydro power station is as follows: Construction of two new 132 kV lines of approximately 60 km (route length) starting from the upper power station to an existing substation close to Tekai via the lower power station. The existing Jerantut Substation is connected to Kg. Awah Substation by a 150 mm^2 transmission line having a transmission capacity of 77 MVA; therefore, if the output of the Tekai Hydro

Power Station exceeds the capacity of the existing 132 kV transmission a new 132 kV transmission line of about 71 km length will be constructed from the Jerantut Substation along the existing transmission line extended to Kg. Awah.

CHAPTER 6

GEOLOGY

Chapter 6 Geology

6.1. Topography and Geology of the Tekai River Basin

6.1.1. Topography of the Tekai River Basin

The Tekai River Basin is bounded by latitude 4°00'N;4°22'N and longitude 102°24'E;102°42'E. It is surrounded by the mountains of the Trengganu coastal range. There are many peaks along the range. Among them, G. Dulang (3,488 ft.), G. Ulu Bakar (4,561 ft.), G. Tapis (4,960 ft.) and G. Angus (2,571 ft.), shown in Fig. 6-1, are the notable peaks. The range is oriented mainly in the north-northwest south-southeast direction, which is called the "main direction." The Tekai River and its tributaries are mainly flowing down from north-northwest to south-southeast, or from south-southeast to north-northwest (main direction). Such an alignment of the ranges and rivers has a close relation to the geological structure of this area. The axes of the folding system have predominantly north-northwest south-southeast orientation (main direction).

Since rock in the mountain area is heavily weathered and covered with thick laterized material, the slopes of the mountains are generally gentle. However, G. Laris and its range, consisting of very hard conglomerate cores, have been so violently eroded that the rocks are much exposed on the heights and the cliffs.

There are some small landslides in the upper reaches of the Tekai River where granitic rocks are distributed. The granitic rocks are completely weathered and form some sandy zones at the surface layer. Flowing ground water exerts pressure on the sandy particles, which leads to liquefaction of sandy soils and impairs the stability of slopes.

Around the Termus River and the Jemar River, the rock consists of reddish shale which is soft and cleaved, therefore the slopes of both riversides are gentle and some wide terraces are distributed along the river banks. Also the riversides of the Tekai River are mainly formed with gentle slopes, but there are some steep valleys which are composed of hard sandstone. The damsites would be selected at the valleys as a matter of course.

6.1.2. Geology of the Tekai River Basin

The Tekai River Basin is underlain predominantly by continental sediments, metasediments and granitic rock as shown in Fig. 6-1.

1) Continental sediments

Since continental sediments are distributed in the Tembeling District, they are named the "Tembeling Group" after derivation of the rock. From fossil evidence, the environment of their deposition is basically continental and the age of deposition is Mesozoic. They are mainly composed of conglomerate, sandstone, shale and volcanic rock. These can be divided into 4 units from the viewpoint of litho-stratigraphy. Fig. 6-2 shows the rock formation in the Tekai River Basin. This is defined from the oldest to the youngest as follows:

i) Kerum formation
ii) Laris conglomerate
iii) Hangking sandstone
iv) Termus redbeds

i) Kerum formation

This is named after the derivative rocks which are typically developed along the Kerum River. It is mainly composed of volcanics, shale and quartzose sandstone. The volcanic rocks are of both taff and lava, with composition ranging from acid to intermediate.

ii) Laris conglomerate

This is named after the derivative rocks which are typically developed around G. Laris. It is a unit made up of reddish conglomerate, sandstone and shale. Since these rocks are very hard, they form outstanding strike ridges with steep cliffs.

iii) Mangking sandstone

This is named after the derivative rocks which are typically developed along the Mangking River. The unit consists mainly of quartzose sandstone interbedded with grey and red shale. It is widely distributed in the midstream and downstream areas of the Tekai River.

iv) Termus redbeds

This unit forms two belts along the Termus River and the Jemar River. The rocks forming this unit are predominantly composed of reddish shale, interbedded with minor amounts of quartzose sandstone. The reddish shale is soft and cleaved, therefore it forms flatish ground surfaces on the riversides. It is overlying the Mangking sandstone, but the boundary between the Termus redbeds and the Mangking sandstone is undistinguished because of the conformity of both formations.

2) The metasediments

The metasediments form a belt between the continental sediments and the granitic rocks in the upstream area of the Tekai River, as shown in Fig. 6-1. They are named "Bangak metasediments" after derivation of the rocks which are typically distributed along the Bangak River. They are considered to be of the Palaeozoic Era from fossil evidence. The grade of metamorphism is low, but the rocks are generally foliated and those near the granite have been affected by contact metamorphism. They are composed of slate, phyllite, metaquartzite, metasandstone, semischist and hornfels.

3) Granitic rocks

The granitic rocks are confined to the eastern part of the Tekai River, as shown in Fig. 6-1 and consist mainly of adamellite. The granitic rocks are deeply weathered in the mountain area and the surface layers are composed of loose coarse sands. The river sediments consisting of quartz sands are supplied from these granitic zones.

Geological Structure

1) Folding

Sediments of the Tembeling group have been folded into large or small anticlinorium and synclinorium structures which generally tend NNW-SSE (main direction). There are some large folding axes in the Tekai River Basin, as shown in Fig. 6-2.

i) Termus syncline

This is a large fold axis which extends along the Termus River Valley and tends NNW-SSE passing through Kuala Tahan.

ii) Tekai syncline

This is another large fold axis which tends parallel to the lower reaches of the Tekai River. The axis tending NNW-SSE, extends to the Jemar River.

iii) Penut anticline

This is a major anticline between the Tekai syncline and the Termus syncline. It plunges to the southeast.

2) Faulting

There are many small faults throughout the Tekai River Basin, but large faults affecting the geological structure have not been seen so far.

6.2. Geology of the Project Site

6.2.1. Geology of the Upper Site

Geological investigation on foot was executed around the upper site containing the proposed damsites, quarry sites, borrow area, etc. Geological mapping was done on a scale of 1 : 10,000 around the upper site, as shown in Fig. 6-5.

The rock at the upper site is composed of Mangking sandstone and Termus redbeds. The stratigraphy of this site is shown in Table 6-1. The Termus redbeds consists mainly of soft, cleaved shale (TSh) interbedded with sandstone (TSs). In the eastern part of this area, the Termus redbeds is developed along the Termus River. It forms gentle relief landforms in the mountainous area and wide terraces in the riversides, because the rocks are deeply weathered and eroded evenly.

The Mangking sandstone is developed in the central and western part of the area. It consists mainly of quartzose sandstone interbedded with grey and red shale. It forms a mountainous terrain, because it consists of very hard quartzose sandstone and the rocks are eroded differently at the ground surface. The Termus redbeds overly the Mangking sandstone, with the nature of contact unknown. It is apparent that the boundary between the Mangking sandstone and the Termus redbeds makes a line which extends in the NNW-SSE direction through the Termus conjunction as shown in Fig. 6-5.

The Mangking sandstone is divided into 6 types from the viewpoint of litho-stratigraphy in the upper site. They are:

i) red-purplish shale (HSh_2)

ii) predominantly quartzose sandstone (HSs_2)

iii) alternation of sandstone and shale (Mal_2)

iv) alternation of shaly sandstone and quartzose sandstone (Mal_1)

v) dark grey and light grey shale (MSh_1)

vi) quartzose sandstone and lithic sandstone (HSs_1)

Table 6-1 Stratigraphy of Tekai Upper Site

Geological Age		Symbol	Formation	Lithology
Cenozoic	Quaternary	r	River Bed Deposits	Mainly quartz sand containing silt and gravel
		Qtr	Terrace Deposits	Mainly clay containing gravel and organic material
Mesozoic	Lower Cretaceous	TSh	Termus Redbeds	Reddish purplish-red shale interbedded with mudstone and sandstone
		TSs		Quartzose sandstone and sandstone
	Upper Jurassic	MSh_2	Mangking Sandstone	Purplish-red shale interbedded with mudstone and sandstone
		MSs_2		Predominantly quartzose sandstone interbedded with greyish shale
		Mal_2		Alternation of sandstone and shale
		Mal_1		Alternation of sandstone and shale interbedded with shaly sandstone and quartzose sandstone
		MSh_1		Dark-grey and greyish shale interbedded with fine sandstone
		MSs_1		Mainly quartzose sandstone interbedded with shale, siltstone and shaly sandstone

Around the Termus conjunction, there are some wide terraces which are formed by loose sandy clay including organic material (Qtr). There are some narrow terraces along the banks of the Tekai River. They are distributed on the left bank of 250 m upstream from the upper damsite and on the right bank 200 m downstream from the upper damsite. They consist of gravel and sand which are tightly consolidated.

Within the river channel, there are gravel, sand and clay deposits (r) which are periodically flushed out by floods. On the river banks, there are deposits of fine grained sand forming relatively flat terraces.

The rock in the upper site has been folded into anticlinorium and synclinorium structures which generally tend NNW-SSE, plunging in either of the two directions. The major fold axis in the upper site is the Termus syncline which extends along the Termus River. There are another several fold axes in this site, as shown in Fig. 6-5 and Fig. 6-6. Wave lengths of the folds vary from 200 m to 1,000 m.

No remarkable faults have been found throughout the site.

Fig. 6-6 shows a geological profile of the upper dam center. The rock consists of quartzose sandstone, lithic sandstone, shaly sandstone, shale and some conglomerate. There are three fold axes which are respectively located at the right flank, the right riverside and the left flank.

6.2.2. Geology of the Lower Site

Geological investigation on foot was executed around the Tekai lower site containing the proposed damsite, quarry site borrow area, etc. A geological map drawn from observations in the field is shown in Fig. 6-7, and the stratigraphy of the lower site is shown in Table 6-2.

The rock in the lower site is composed of Mangking sandstone and Termus redbeds similar to the upper site. The Termus redbeds is distributed in the eastern part of the area. The Mangking sandstone is developed in the central and western part of the area, as shown in Fig. 6-7.

Table 6-2 Stratigraphy of Tekai Lower Site

Geological Age		Symbol	Formation	Lithology
Cenozoic	Quaternary	r	River Bed Deposits	Mainly quartz sand containing silt and gravel
		Qt	Terrace Deposits	Mainly clay containing organic material and gravel
Mesozoic	Lower Cretaceous	TSh	Termus Redbeds	Reddish purplish-red shale interbedded with yellow ocher mudstone
		TSs		Predominantly quartzose sandstone and sandstone
	Upper Jurassic	MSh_2	Mangking Sandstone	Purplish-red shale interbedded with purplish sandstone
		MSs_2		Predominantly quartzose sandstone and sandstone
		Mal		Alternation of quartzose sandstone and shale
		MSh_1		Dark-grey and greyish shale interbedded with fine sandstone
		MSs_1		Mainly quartzose sandstone interbedded with shale and shaly sandstone
		MCg		Conglomerate interbedded with shale

The Termus redbeds consist of two types of rock. One is a reddish purplish shale (TSh), and the other is a quartzose sandstone and lithic sandstone (TSs).

The Mangking sandstone is divided into 6 types from the viewpoint of litho-stratigraphy in the lower site. They are:

i) red-purplish shale (MSh_2)

ii) predominantly quartzose sandstone (MSs_2)

iii) alternation of quartzose sandstone and shale (Mal)

iv) dark grey shale (Msh_1)

v) mainly quartzose sandstone (MSs_1)

vi) conglomerate (MCg)

Terrace deposits are locally distributed along the banks of the Tekai River. They consist mainly of clay including organic material and contain gravel and sand in some places.

Within the river channel there are gravel, sand and clay deposits which are periodically flushed out by floods.

There are two large folds around the lower site. One of them is the Penut anticline and the other the Tekai syncline, as shown in Fig. 6-2. The Penut anticline is a major fold axis between the Tekai syncline and the Termus syncline. The fold axis, tending NW-SE, passes through the northern part of the lower site. The Tekai syncline is a major fold axis which extends along the Tekai River in the lower site and tends in a NW-SE direction.

No remarkable faults have been found throughout the lower site, but small localized faults have been confirmed as shown in Fig. 6-7. Brecciated zones of these faults are several meters in width.

Fig. 6-8 shows a geological profile of the lower dam center. The rock consists of quartzose sandstone, lithic sandstone, shaly sandstone and shale. The strata are dipping to the SE, i.e., in the upstream direction and on the left side of the river, as shown Fig. 6-7.

6.3 Drilling and Permeability Testing

6.3.1. Drilling

The locations of drill-holes are as illustrated respectively in Fig. 6-3 and Fig. 6-4. The quantity of drilling work and permeability testing is shown in Table 6-3.

Table 6-3 Quantity of Drilling Work and Permeability Test

Site	Drill-hole	Depth (m)	Permeability Test
Upper Damsite	U-1	46.0	5
	U-2	44.0	8
	U-3	40.0	7
	U-4	50.0	8
	U-5	50.0	6
Lower Damsite	L-1	50.0	7
	L-2	40.0	6
	L-3	39.0	7
	L-4	51.0	7
Total		410.0	61

The findings of the drilling work are summarized in Fig. 6-10 and Fig. 6-11, with the geological log of each bore hole shown. With regard to geological log, weathering, quality classifications of rock and RQD are defined as follows:

1) Weathering

Table 6-4 shows grades of weathering for sandstone and shale in the project site.

Table 6-4 Grade of Weathering

Grade	Weathering	Description
I	Fresh	No visible deterioration.
II	Slightly weathered	Brown limonite staining along cracks, but pieces of NX core are fresh.
III	Moderately weathered	Considerably altered, but pieces of NX core cannot be broken off by hand.
IV	Highly weathered	Pieces of NX core are almost completely altered and can sometimes be broken off by hand.
V	Completely weathered	Sample disintegrates when placed in water.

2) Quality Classification of Rock

Quality classification of foundation rock is shown in Table 6-5.

Table 6-5 Quality Classification of Foundation Rock

Classification	Characteristics
A	Rock-forming minerals are fresh and not weathered or altered. Joints and cracks are very closely adhered with no weathering along their planes. A clear sound is emitted when hammered.
B	Rock-forming minerals are weathered slightly or partially altered, the rock being hard. Joints and cracks are closely adhered. A clear sound is emitted when hammered.
C_H	Rock-forming minerals are weathered but the rock is fairly hard. The bond between rock blocks is slightly reduced and each block is apt to be exfoliated along joints and cracks by strong hammering. Joints and cracks sometimes contain clay and other material which may be coloured by limonite. A slightly dull sound is emitted when hammered.

(To be Cont'd)

Table 6-5 (Cont'd)

Classification	Characteristics
C_H	Rock-forming minerals are weathered and the rock is slightly soft. Exfoliation of the rock occurs along joints and cracks by normal hammering. Joints and cracks sometimes contain clay and other material. A somewhat dull sound is emitted when hammered.
C_L	Rock-forming minerals are weathered and the rock is soft. Exfoliation of the rock occurs along joints and cracks by light hammering. Joints and cracks contain clay. A dull sound is emitted when hammered.
D	Rock-forming minerals are weathered, and rock is very soft. There is virtually no bond between rock blocks, and collapse occurs at the slightest hammering. Joints and cracks contain clay. A very dull sound is emitted when hammered.

(Source; Standards for Geological Investigation of Dam Foundations, J.N.C.I.C. on Large Dams)

3) RQD

Rock Quality Designation (RQD) was defined by *Deere D.V. as the sum of core length being 10 cm or over to unit depth of the boring. It is given by the equation

$$RQD = \frac{\Sigma li}{L},$$

where L: unit depth of the boring

li: core length being 10 cm or over

RQD gives information on engineering geological conditions much more than recovery of core, because it represents the frequency of fissures.

The relationship between RQD and quality classification of rock at the project site is shown in Fig. 6-9(a), and also the relationship between RQD and the grade of weathering is shown in Fig. 6-9(b). RQD, quality classification and weathering are closely related to each other.

* Deere, D.V; Design of surface and near surface construction in rock, 8th Symp. rock mechanics. 1966 Proc. AIME, 1967

Upper Damsite

The locations of drill holes at the upper damsite are shown in Fig. 6-3 and Fig. 6-5, and the geological log of each hole is summarized in Fig. 6-10. The geological features found through the drilling work are as follows:

i) River deposits consisting of boulders and sands are very shallow (0.9 m in thickness) at point U-3.

ii) At points U-2 and U-4, located on both flanks of the damsite, completely and highly weathered zones are rather thin (5 - 10 m).

iii) At points U-1 and U-5, located on both heights of the damsite, completely and highly weathered zones are quite thick (about 20 m).

iv) In general, fresh or slightly weathered rocks are composed of very hard quartzose sandstone and shale. However, some of them are very cracky, therefore RQD values are very small or zero in several places.

Lower Damsite

The locations of drill holes at the lower damsite are shown in Fig. 6-4 and Fig. 6-7, and the geological log of each hole is summarized in Fig. 6-11. The geological features found through the drilling work are as follows:

i) River deposits consisting of boulders and sands are shallow (3.3 m in thickness) at point L-2.

ii) At point L-3, located on the right flank of the damsite, completely to moderately weathered zones are rather thin (about 3 m), and slightly weathered or fresh rocks are distributed close underneath the ground surface.

iii) At points L-1 and L-4, located on both heights of the damsite, completely to highly weathered zones are not so thick (about 8 m), as compared with those of both heights of the upper damsite.

iv) In general, fresh or slightly weathered rocks are composed of very hard quartzose sandstone and shale. However, some are very cracky and, therefore, RQD values are very small or zero at places. These geological conditions are very similar to those of the upper damsite.

6.3.2. Permeability Tests

Permeability tests were executed at each bore hole at the upper and lower damsites. The coefficient of permeability obtained in the permeability tests are summarized in Fig. 6-12 and Fig. 6-13. The permeability of solid rock is mainly due to water percolation along bedding planes and joints. At both damsites, the surface layers of the rocks possess high permeability ($K > 2 \times 10^{-4}$ cm/sec.), since the bedding planes and joints are widened by weathering. In general, the fresh rocks possess low permeability ($K < 6 \times 10^{-5}$ cm/sec.), because the bedding planes and/or joints of them are closed. However, in case of cracky zones the permeabilities of them are high ($K = 2\sim7 \times 10^{-4}$ cm/sec.) though the rocks are fresh.

6.4. Seismic Prospecting

6.4.1. Relationship of Seismic Velocities to the Geology

The rocks of the project site consist of interbedded areneous and argillaceous sediments which are mainly composed of quartzose sandstone and shale respectively. The seismic waves are mostly refracted along zones of abrupt change in degree of weathering which cut across lithological boundaries, although there is some lithological control on the development of these weathering zones.

Weathering of the shales is mainly affected by chemical decomposition with gradual change in seismic velocity from about 3,500 m/sec. for fresh shale to about 900 m/sec. for highly weathered shale. The sandstone are far more chemically resistant and weathering is mostly affected by dissolution of the cement along a prominent blocky joint system. The velocities vary from about 5,000 m/sec. for fresh and particularly wall cemented units to as low as 1,000 m/sec. for highly weathered sandstone. The considerable velocity variation of overburden (top soil and completely weathered zone) is found along the individual seismic lines. The velocities of the overburden vary from about 350 m/sec. to 500 m/sec. in the prospecting area.

Table 6-6 shows the relationship between the seismic velocity and the weathering grade of rocks in the upper and lower damsites.

Table 6-6 Relationship between Seismic Velocity and Weathering

Weathering	Seismic Velocity
1. Fresh	5,000 m/sec. (Sandstone)
2. Slightly ∿ fresh	2,000 ∿ 3,500 m/sec.
3. Moderately ∿ slightly	1,400 ∿ 2,000 m/sec.
4. Completely ∿ highly	900 ∿ 1,300 m/sec.
5. Top soil ∿ completely	350 ∿ 500 m/sec.

6.4.2. Interpretation of Seismic Prospecting

1) Upper Damsite

As shown in Fig. 6-3, the seismic lines at the upper damsite were chosen as a network covering the entire damsite. Among them the main alignment U-A was set up along the proposed dam center. The amount of seismic prospecting work done is shown in Table 6-7.

Table 6-7 Amount of Seismic Prospecting Work Done at Upper Damsite

Name of Line	Length (m)	Spread
U-A	670	7
U-B	290	3
$U-C_1$	110	1
$U-C_2$	110	1
U-D	310	3
U-E	280	3
U-F	290	3
U-G	200	2
U-H	200	2
$U-J_1$	110	1
$U-J_2$	180	2
Total	2,750	28

The seismic profile of the main alignment U-A is shown in Fig. 6-14. Three refractors were detected under the overburden of 400 to 500 m/sec. The velocity of the shallower ranges from 900 to 1,300 m/sec., and it may be interpreted as completely to highly weathered zones. The velocity of the intermediate layer is about 1,800 m/sec., and it may be considered as a moderately weathered zone. The deepest ranges from 2,000 to 3,500 m/sec. which corresponds to the fresh to slightly weathered formation. At both heights of the damsite, the overburden and shallower refractor are quite thick (18 m to 20 m).

The values of seismic velocity provide useful information on the rippability of a rock material. Fig. 6-16 shows a seismic rippability chart as regarded to sandstone and shale, published by Caterpillar Tractor Company for various types of caterpillar tractors. According to the figures, the layers of 2,000 m/sec or less velocity can be excavated by a ripper dozer.

2) Lower Damsite

As shown in Fig. 6-4, the seismic lines at the lower damsite were chosen to form a network covering the whole damsite. Among them, the main alignment L-A was set up along the proposed dam center. The amount of seismic prospecting work done is shown in Table 6-8.

Table 6-8 Amount of Seismic Prospecting Work Done at the Lower Damsite

Name of Line	Length (m)	Spread
L-A	570	5
L-B	310	3
L-C_1	110	1
L-C_2	220	2
L-D_1	210	2
L-D_2	210	2
L-E	250	3
L-F_1	110	1
L-F_2	100	1
L-G_1	200	2
L-G_2	230	2
Total	2,520	24

The seismic profile of the main alignment L-A is shown in Fig. 6-15. Three refractors were detected under the overburden of 350 to 450 m/sec. The velocity of the shallower is about 1,000 m/sec. The velocities of the intermediate and deepest are respectively 1,400 - 2,000 m/sec. and 2,000 - 3,500 m/sec. These conditions are very similar to those of the upper damsite, however, the thickness of the overburden and shallower layers of the lower damsite are much thinner than those of the upper damsite. Accordingly, the weathering condition of the lower damsite is evaluated to be better than that of the upper.