5.3. Geology of Alternative Dam Sites

The geological features of alternative dam sites are shown in the geological plane map, cross-sectional map and Table 5-4. The rocks underlying the dam sites consist of many kinds of Mesozoic to Palaeozoic clastic rocks alternated with pyroclastic sedimentary rocks.

All kinds of the rocks are hard and compact. But there is a considerable difference in the weathering condition of baserocks, the thickness of alluvium in the river balley, the topography and the effect by the Lebir Fault among the dam sites. (see Fig.5-7 - Fig.5-11).

5.4. Considerations from a Viewpoint of Engineering Geology

5.4.1. Dam Type Recommendable for Each Site

(1) Tualang Dam Site

The rock weathered zones on the mountainside slopes which will serve as the abutments of the dam are 15 to 20m thick. But the crest length of the dam will be shortest among the three sites and the dam site has less defects in the geological structure, including faults. Accordingly, the dam site will support the construction of a concrete gravity dam.

The properties and tectonic structure of rocks underlying the saddle dam at Tualang are good, but the weathered zones at the abutments of both banks of the saddle dam site are as too thick being 20 m wide. The valley on the saddle dam site is wide. A rockfill dam would be suitable for construction on the site of such topographic and geologic features.

(2) Jeram Panjang Dam Site

The baserocks underlying the Jeram Panjang Dam Site are good in properties and geological structure. But the weathered zones at the abutments of the dam on both banks are 15 to 20 m thick. The valley on the dam site will make the crest length of the dam longer. Accordingly, the dam site is more suitable for the construction of a rockfill dam, although a concrete gravity dam would be able to be constructed on the dam site.

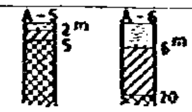
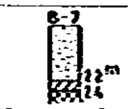
The weathered zone on the platform on the right bank of the Jeram Panjang No.1 Saddle Dam Site is about 20 m thick and is water-tight. Accordingly, the No.1 Saddle Dam site is suitable for the construction of a rockfill type dam.

The Jeram Panjang No.2 Saddle Dam Site has more geological problems than the other dam sites, because the dam site is located at the saddle part of mountain and the weathered zones on the dam site are thick. Although the proposed dam is rather low, a rockfill dam would be able to be constructed on the site but with an increased construction cost.

(3) Kiak Dam Site

The dam site has a topographic feature in that the crest length should be made longer, if a dam is constructed. In addition, deliberate studies should be made on the suitability of geology of the flat sections on both banks as suitable baserock for the dam site. The flat sections on both banks are platforms over which the weathered layers are 25 m thick. The weathered zones should inevitably be used as baserocks for the dam. The construction of a fill type dam will be barely possible on this site.

Table 5-4 Summary of Geology of Each Proposed Dam Site

Site	Dam	Topography	Baserock geology: Kind of rock	Baserock geology: Lithologies	Baserock geology: Structure	Weathering of baserock	Alluvium	Geological characteristics	Type of Dam (Highest water level El. 90m)	Remarks
Tualang Site	Dam	Riverbed elevation : 18m. Both banks present a steep slope of 35° from the riverbed up to EL.55m. The mountain at or near the crest end on the right bank is rather thin, and the left bank is a small hilly mountain.	Tuff breccia, lapilli tuff, tuff, shale, & chert.	All kinds of rocks are hard and compact. Pyroclastic rocks have lithology similar to decites. Cherts are red colour.	Alternative layers of clastic rocks and pyroclastic rocks. Strike : N20-45W Dip: 30-60E	 The weakly weathered zones for A-1 to A-3 are hard and cracky. But those for A-4 become soft.	Alluvial sand 3 to 4 m thick spread over the dam site. The riverbed rocks have no overburden.	Fresh part of bed rocks is hard and compact due to silicification. Weathered zones on mountainsides on both banks are rather thick.	Suitable for a fill dam and concrete dam. However in case of concrete dam, excavation depth of bedrocks becomes deeper than 15m.	
Tualang Site	Saddle dam	Dam bottom elevation : 45 m. Dam bottom portion is a flat 230m wide. On both banks gentle slopes of 20° continue monotonously.	Lapilli tuff & shale.	Hard & compact. Lapilli tuffs are bluish green colour.	Bedding:N30W which is the same direction as the Peninsular Malaysia.	 The rock weathered zones are thin on the plain area at the bottom of valley and thick on the mountainside slopes.	This talus or soil and sands lie on the flat sections at the bottom of valley.	Flat zone at the valley bottom is formed by erosion and has a very thin Alluvium of 2 to 3 m.	Suitable for fill dam because bedrocks on mountainside lie deeply beneath the ground.	
Jeram Panjang Site	Dam	Riverbed elevation:26m. Riverbed width:130m. Both banks have river terraces at EL. 45m. There is a flat portion on the left bank at EL. 100m. The abutment on the right bank looks like a cape. The riverbed forms a rapid.	Tuff breccia, lappili tuff, tuff, shale and hornfels.	All kinds of rocks are very hard and compact due to silicification,but some of them have cracks. Tuffious rocks are bluish green.	Bedding structure is conspicuous. Strike:N40E Dip: 34S Monoclinic Structure. Some small faults can be seen.	 Heavily rock weathered zones spread over the mountainsides. Thickness of weakly rock weathered zones is almost same. Fresh rocks are exposed widely on the river bed.	Base rocks are exposed over the almost whole area of the riverbed. Alluvial sands and gravel 3 to 4 m which are distributed partially.	Bedrocks are extensively outcropped. Weathered zones on mountainsides of both banks show a constant thickness of approx. 15m.	Suitable for a fill dam.It is not impossible to construct a concrete dam, however disadvantageous due to too deep bedrock lines under sleeve parts of both banks.	There is a river-terrace downstream of the dam site, but only small ones at the dam site.
Jeram Panjang Site	Saddle Dam No. 1	Dam bottom elevation: 45m. Mountainside on left bank presents a rather steep slope of 30°. There is a semi-flat portion 120m wide at EL.75m on the right bank The dam axis is located at the watershed of a tributary.	Tuff breccia, tuff & tuffaceous sandstone.	Similar to lithology of dacites. The stratum is pinky white colour.	Flow and bedding structures are remarkable and parallel to each other toward N10W and 55W. There are a few faults.	 The rock weathered zones are not cracky but compact and hard.	Alluvial sands 3m thick are distributed partly at the bottom of valley.	There are no large faults nor fracture zones. The weathered zones of tuff and tuff breccia are rather thick without any crack. Therefore, watertightness is excellent.	Suitable for a fill dam.The weathered zones on a semi-flat land on the right bank are thick, so unsuitable for concrete dam.	A truck-road is provided at the valley bottom of the dam site.
Jeram Panjang Site	Saddle Dam No. 2	Dam bottom elevation: 85m. The dam site is located at a concave portion of the ridge formed by erosion. The ridge at the dam axis is very thin.	-ditto-	-ditto-	-ditto- The weathered layers are rather thick.	 The rock weathered zones are rich in clay and thicker.	The weathered zones of baserocks are exposed without any overburden.	Dam site located on the ridge of the mountain. Weathered zones are very thick and loose.	Possible to construct fill dam. Unsuitable for concrete dam.	Dam site is 1 km distant from the Lebir Fault.
Kiak Site	Kiak Dam	Riverbed elevation:27m. Both banks present river terraces formed by erosion. Some bedrocks can be seen.	Shale, tuff breccia and schist.	Some tuffaceous rocks are grayish green colour if they are fresh. Tuff breccias are hard and compact.	Bedding strike in the middle of river: N70W. There can be seen no alluvium or, a small number, if any on the flat on the right bank.	 The heavily rock weathered zones are formed into clay in a thick bed.	The alluvial soil and sands on the main stream are estimated to be about 10m thick. There is no alluvium or,a small number, if any on the river terrace hilly zone.	Semi-flat areas on both banks are erosion plains of baserocks, and bedrocks are deeply under the ground surface. Weathered zones are argillizated and have a high compactness as compared with the Alluvium.	Possible to construct a fill dam. Unsuitable for a concrete dam.	Dam axis overlaps with the Kiak bridge.

5.4.2. Quarry Sites

(1) Geological Outline of Quarry Sites

The candidate locations of quarry sites and volume of materials to be made available at each of the sites are shown in Table 5-5.

Table 5-5 Quarry Sites

Location		Kind of materials	Available quantity	Remarks
Dome mountain		Stones, soil mixed stones	much	Stones will be quarried only from the dome mountain. Soil mixed stones from weathered zones.
Platform	Higher elevation	Soil mixed stones, clay	medium	Much available at Jeram Panjang
Platform	Lower elevation	Clay and sands	medium	Much available at Kiak
Riverbed		Sands and gravel	small	The sediments on the riverbed are estimated to be 5 to 8 m thick

(2) Quality and Quantity of Materials

The rocks of the material quarry sites consist of clastic rocks and pyroclastic sedimentary rocks and do not include igneous rocks. Fresh rock parts of clastic rocks and pyroclastic sedimentary rocks are hard and compact and have a nature similar to semi-massive rocks. Those rocks do not show a large difference in quality as embanking materials. It is worth noting that those rocks in the weathered zone show a considerable difference in quality.

If the members are alternating, the yield rate of material quarry from such usually is low. But, although the members on the proposed quarry sites are alternating, each of the beds is almost equal in properties. So the yield rate of material quarry will not be so lowered.

The rock weathered zones show a sharp change in the rock faces from clay to rock pieces. This will make it easier to obtain diverse materials suitable for various purpose from the rock weathered zones. However, the quantity to be made available from a specific point will be limited.

Sands and gravel on the riverbed are great in quantity, particularly gravel is very much limited in quantity.

Materials of quality suitable for use as a rockfill dam would be available from the boundary parts of dome mountains and platforms, in view of the geological conditions of this area.

(3) Outline of Quarry Sites

a) Tualang Quarry Site

Tualang is a suitable site for a quarry site on the dome mountain. The kinds of available rocks are lapilli tuffs and shales. Shale pieces are consolidated by silification. But, the shales have shisty folication. Accordingly, a large-size rock mass will not be able to be quarried from shales. A considerable amount of concrete aggregates and fill dam materials would be supplied from this site.

b) Jeram Panjang Quarry Site
(on the left bank of the Lebir River)

This site is also suitable as quarry site on the dome mountain. The kinds of available rocks are mainly cherts and sandstones. Massive lapilli tuffs are sometimes mixed into these rocks. A platform 50 m by 200 m is developed adjacent to the quarry site which provides an enough space for quarrying of core materials from this site.

c) Jeram Panjang Saddle Dam Quarry Site

Materials available on this site are mainly tuffs. The weathered zones on this site consist of soft rocks. This site will be able to supply a sufficient quantity of embanking materials for a rockfill dam similar to an earthfill dam.

d) Kiak Quarry Site

Materials will be quarried mostly from the platforms which contain a little stones. But this site can supply a good quality and sufficient quantity of materials for the construction of an earthfill dam.

5.4.3. Influence of the Lebir Fault on Dam Construction

The Jeram Panjang No.1 Saddle Dam and No. 2 Saddle Dam are directly influenced by the Lebir Fault. Other dam sites are not influenced by the Lebir Fault.

The weathered zone in the Lebir Fault becomes thick. The scale of the Lebir Fault is not so large and it is not active at present. Accordingly, rockfill dams will be able to be constructed on both saddle dam sites, if we do not mind an increase in excavations of the foundations. The dam structures will not be required to be designed as earthquake-proof structures. It will be sufficient for the dam foundation treatments, if the fault parts or fractured parts are excavated rather deeply.

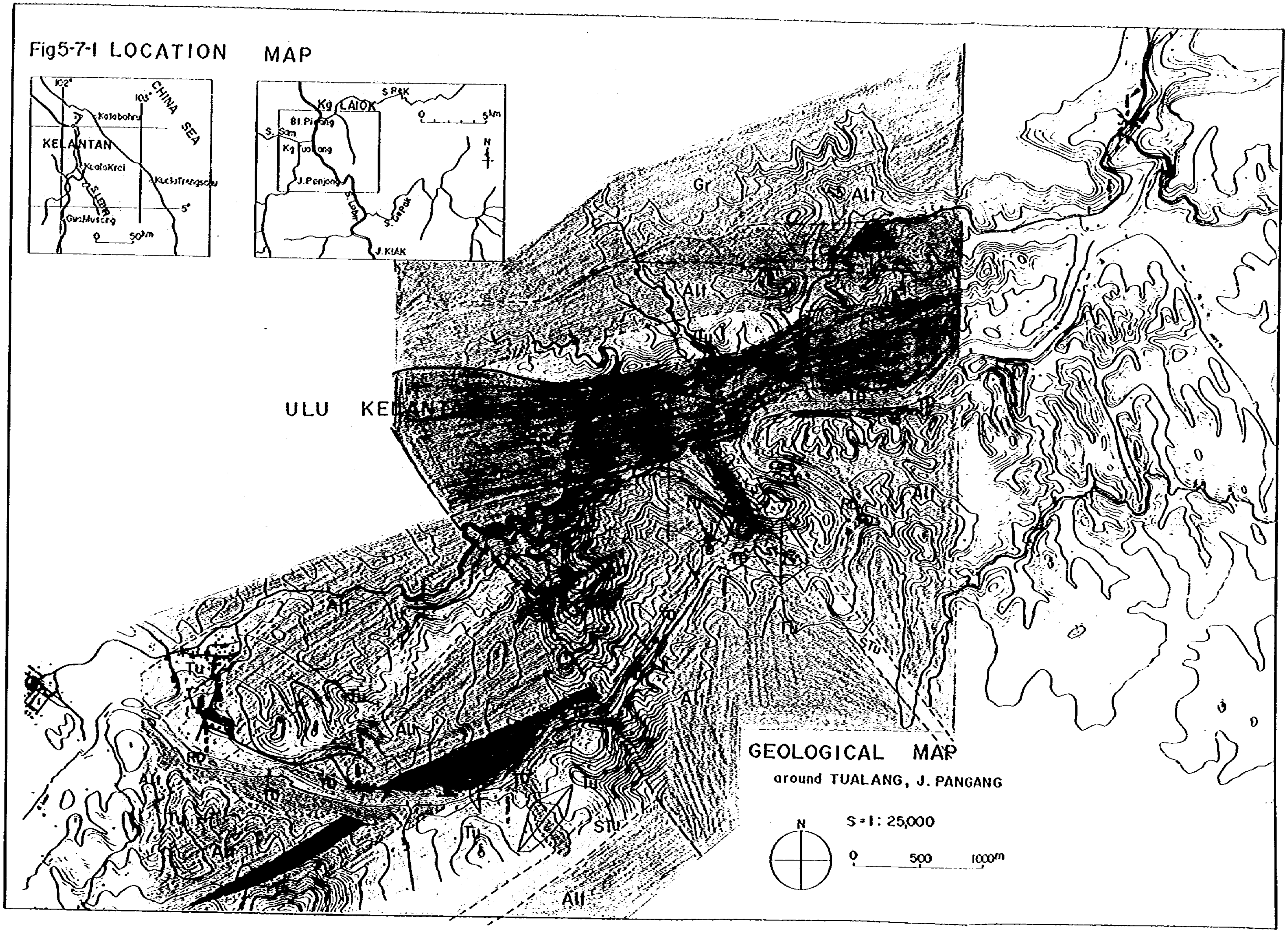


Fig5-7-1 LOCATION MAP
CHINA SEA
KELANTAN
Kotabahru
KualaKrai
KualaTrengganu
S. Lebir
Gn.Musang
0 50km
Kg. LAIOK
S. Rek
Bt. Pisang
S. Sam
Kg. Tualang
J. Panjang
S. Lobir
S. Gepak
J. KIAK
0 5km
N
ULU KELANTAN
Gr
All
Tu
STu
GEOLOGICAL MAP
around TUALANG, J. PANGANG
S = 1 : 25,000
N
0 500 1000m

Fig. 5-7-2

LEGEND : Geological map around TUALANG, J. PANJANG. 1/25,000

Symbol	Formation	Lithofacies	Geol. age
RD	Present river deposits	mainly loosed medium sand. Gravels are few	Alluvium
TD	River terrace deposits	Loosed sand and clayey sand	Older Alluvium
Gr	Granites	Granodiorite, Granite, Mylonite (dotted massive)	After sediment R. intrusion
Tu	Tuff, Lapilly tuff	Dacitic, somewhere retrograde meta-morphic,weathered clay are pinkish.	Mesozoic ~ Triassic Conformity
STu	Sandy tuff	Dacitic, pyroclastic ~ Clastic, Somewhere Quartzite	
	Slate, Shale	mainly tuffaceous	
	Conglomerate, Tuff breccia	Both are nearly same. weathered zone are pinkish	
ALt	Pyroclasti, clastic rocks alternation	Bedding slightly beeing	

58 45 Bedding strikes and dips

Boundary of formations

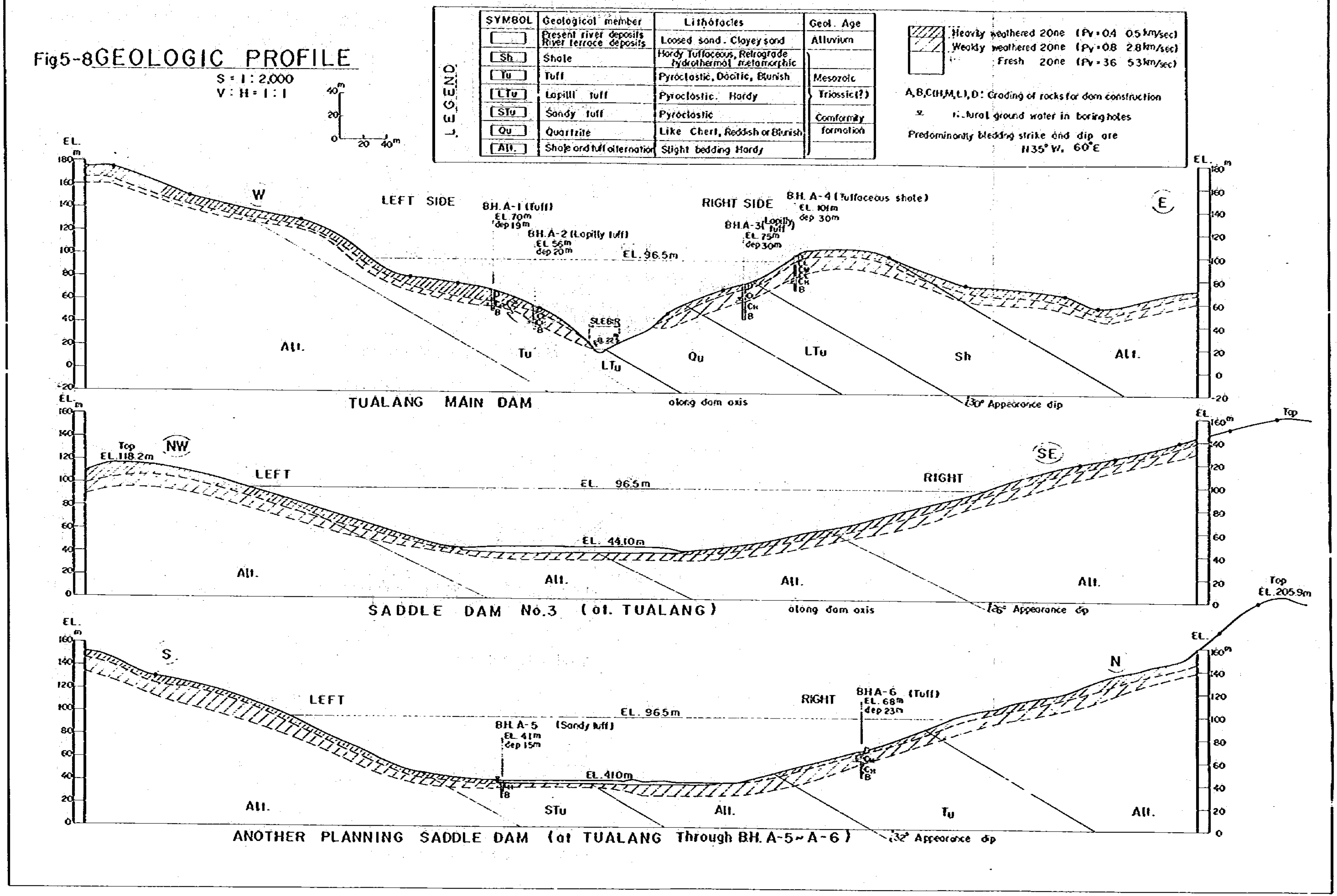
Estimated faults (By stratigraphy)

Fault (By observed and photo lineament)

Planning dam sites

Fig5-8 GEOLOGIC PROFILE

S = 1 : 2,000
V : H = 1 : 1



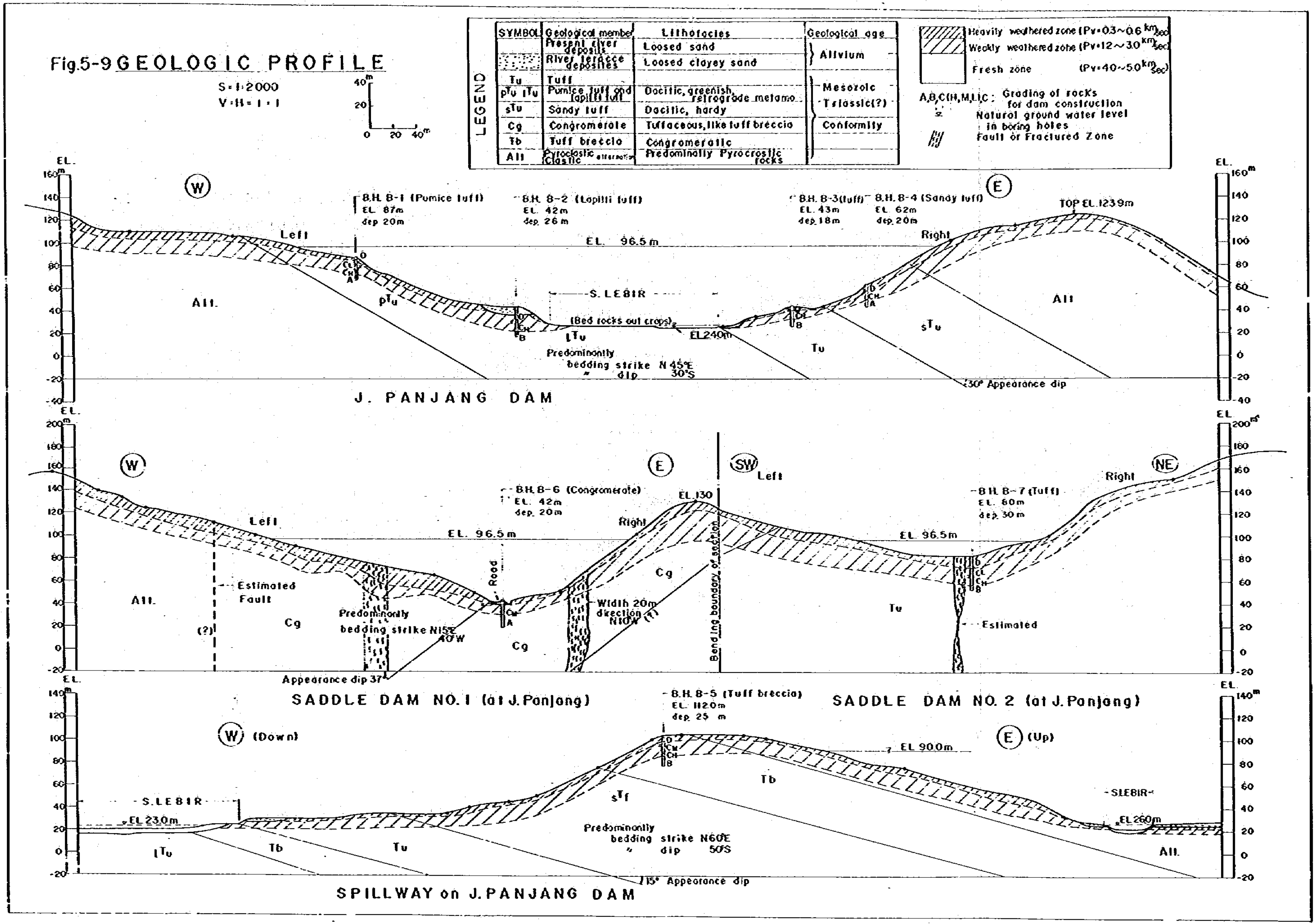


Fig.5-9 GEOLOGIC PROFILE

Fig5-10 Geologic profile along KIAK DAM AXIS

S = 1 : 5.000
V : H = 1 : 1

1979

LEGEND

SYMBOL	Geological member	Lithofacies	Geologicalage
	Present river deposits	Loosed Sand	Alluvium
	River terrace deposits	Soft clayey sand not seeing gravels	Alluvium
Tu	Tuff and Lapilli Tuff alternation	Hardy like Schärsteine greenish blocky	Mesozoic (Triassic)
Alt	Slate and shale alternation	Hardy like schist green~black schistosity	- ditto -

Heavily weathered zone (Pv = 0.35~1.0 km/sec) } weathered zone
Weakly weathered zone (Pv = 1.0~2.0 km/sec)
Fresh zone (Pv = 3.2~4.5 km/sec)

Fractured zone

Bedding strike and dip (Predominantly) N 70°W 50°N

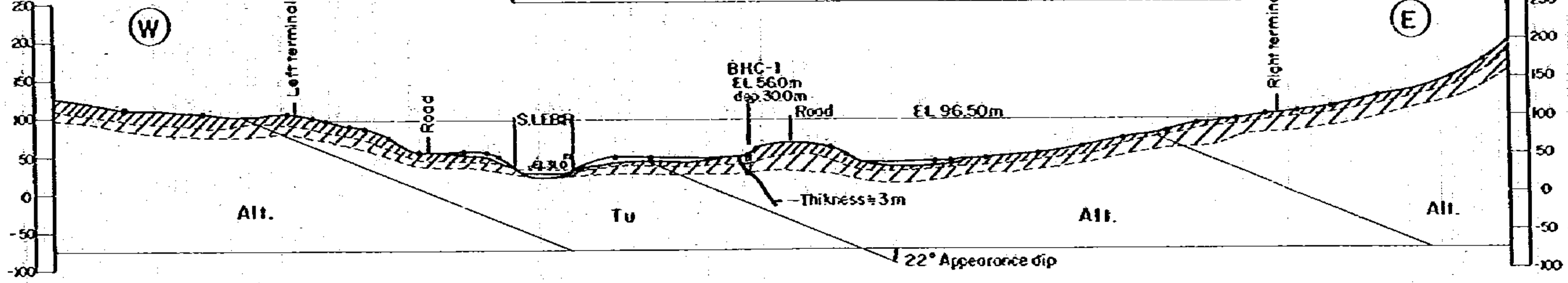
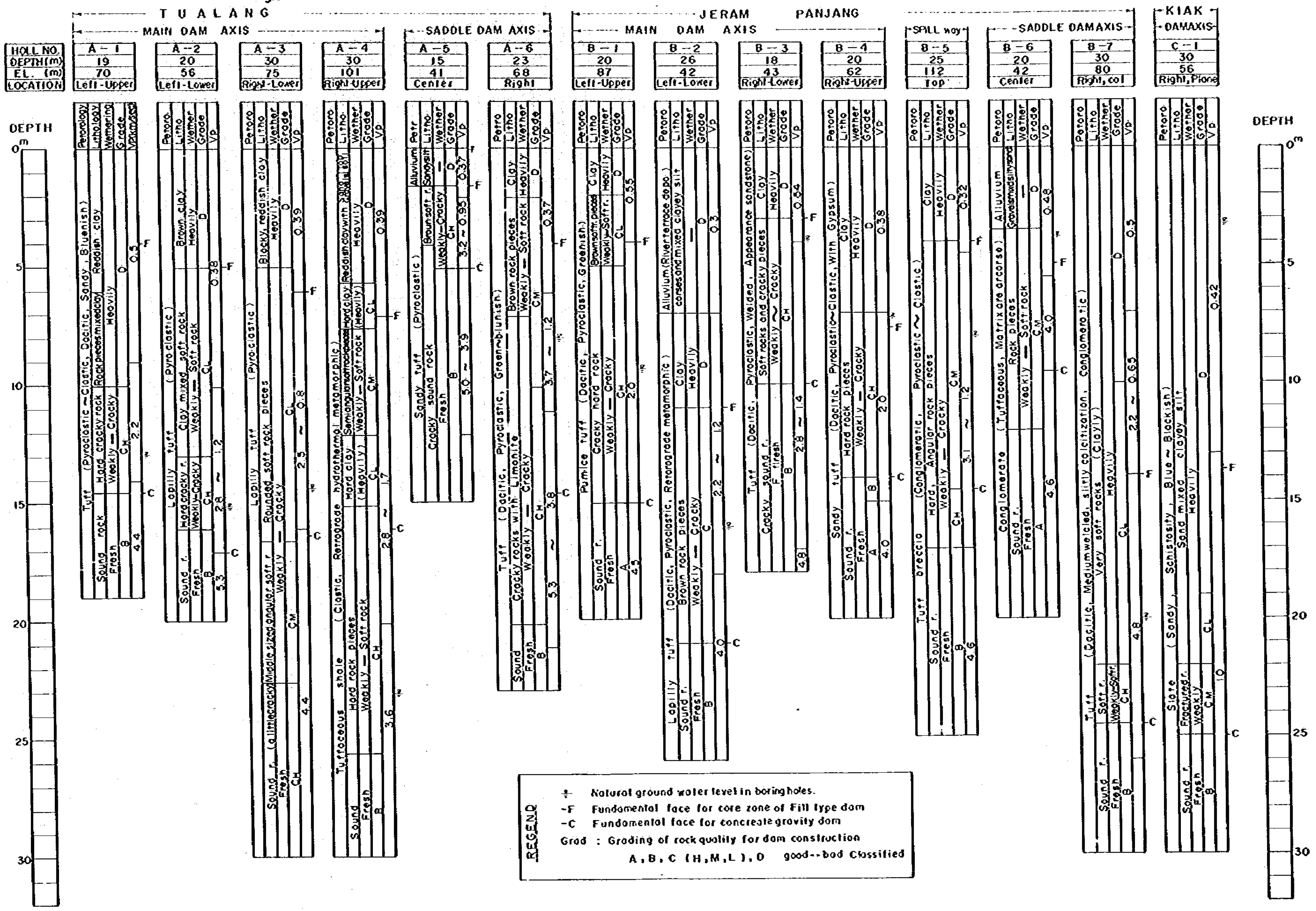


Fig5-11 RESULTS of BORING CORE EXAMINATION on LEBIR PROJECT (1979)



6. Meteorology and Hydrology

6.1. Meteorology

The climatic conditions in the State of Kelantan are influenced largely by northeast or southwest monsoons.

A year in the Peninsular Malaysia can be divided into four seasons; two seasons of the two types of monsoons and other two intermediate seasons between the two monsoon seasons. Climatic phenomena including temperature, humidity, sunshine and rainfall vary with the change of season.

Generally the southwest monsoon starts blowing from late May or early June and ends in September. After two month suspension of winds, the northeast monsoon starts blowing from late October or early November and ends in March. Then, after another two months, the southwest monsoon blows again.

On the east coast including the State of Kelantan from October to March when the northeast monsoon blows, the temperature is relatively low and the sunshine is less with much rainfall, but a change in the temperature is not so distinct. In contrast, the climatic conditions in a period of the southwest monsoon show a reverse trend.

According to the observation record from 1968 to 1972, the mean temperature at Kota Bharu is 26.9°C, the maximum temperature 28.1°C in May and the minimum temperature 25.9°C in January. A difference between the maximum temperature and the minimum temperature is only 2.2°C. There is not so much variation in the temperature throughout a year. But a change in the temperature in a day is relatively large; the temperature becomes lowest (about 24°C) at 6 o'clock in the morning and reaches a maximum temperature of about

30°C at 1 o'clock in the afternoon. The mean difference between the maximum temperature and the minimum temperature exceeds 6°C. In a period of 5 years from 1968 to 1972, the recorded maximum temperature is 36.7°C and the minimum temperature 18.3°C. (see Table 6-1)

The mean relative humidity during the same 5 years shows a high value of 80.7 %. In a year, the minimum relative humidity was 79.1 % in March and the maximum relative humidity 82.2 % in November. A difference between the maximum relative humidity and the minimum one was only 3 %. The relative humidity varies largely in a day according to the change of temperature; the maximum relative humidity is about 94 % at 6 o'clock in the morning and the minimum one about 68% from the noon time to 1 o'clock in the afternoon. (see Table 6-2)

The mean sunshine in a day is 7.03 hours; the shortest time is 5 hours in November and December and the longest time 8.7 hours from March to April, the intermonsoon season. In this regard, statistics indicate that days of rainfall in a year are 182 days, which means a rainfall day every 2 days. There seems no correlation between the season and the days of rainfall. (see Table 6-3 and 6-4)

6.2. Precipitation

The east coast including the State of Kelantan belongs to regions of plentiful rainfall. Generally, an annual mean rainfall of 3,050 mm occurs on the coastal area and an area several km inland of the sea coast, and the annual mean rainfall decreases as we go further inland, reaching about 2,540 mm at the eastern foot of the Central Mountain Range.

The observation record from 1950 to 1975 indicates that the Lebir River Basin belongs to a zone of less rainfall in the Kelantan River

Basin. The annual precipitation is in the range of 2,000 mm to 2,250 mm. This is due to blocking of the northeast monsoon by the coastal mountain range east of the Lebir River Basin. The precipitation on the coastal plain east of the mountain range, from November to March is about 2,000 mm, but the precipitation in the Lebir River Basin in the same period is only 1,000 mm.

Table 6-5 and Fig.6-1 show mean monthly rainfalls recorded at typical rainfall gauging stations in the tributaries of the Kelantan River. Rainfall patterns can be classified into three types; a rainfall pattern recorded at Gua Musang and Bertang on the upper reaches, the 2nd rainfall pattern at Dabong, Bongor and Lalok on the middle reaches and the other one at Kota Bharu on the coast.

In Kota Bharu, the precipitation is extreme in a period of the northeast monsoon from October to January, and it is very little in other seasons. The precipitation comes down to the lowest figure in February and then increases gradually until the next season of the northeast monsoon. In contrast, the precipitation at Lalok in December which is in a period of the northeast monsoon is much more than in other months, and it comes down to the minimum in February. This rainfall pattern is similar to that on the coastal area. But the precipitation at Lalok shows the same characteristics as at Gua Musang, in a point, that it shows one peak in May and another one again in September.

Table 6-6 shows correlative coefficients of monthly rainfalls recorded at the rainfall gauging stations in the State of Kelantan. According to this table, correlations of the monthly rainfall at Lalok with those at the other gauging stations are generally high; the monthly rainfall at Lalok shows correlative coefficients of 0.6 to 0.85 with those at the other gauging stations. The monthly rainfall at Lalok corresponds to 0.73 of the observed figure at Kota Bharu and 0.77 of that at Bertang on the upper reaches. Even if we assume a coefficient of confidence to be 99 %, existence of a correlation among the observed records is testified by this table.

Table 6-7 shows probable rainfalls at Lalok once in 24 hours, 48 hours, 72 hours and 120 hours analyzed by the Gumbel Method on the basis of daily rainfall records and hourly rainfall records at Lalok.

Table 6-8 shows various constants obtained on the basis of the above probable rainfalls, for use into the Talbot type precipitation intensity formula which is deemed most suitable in the intended calculation. This table indicates that the 100 year return daily rainfall at Lalok is estimated at 457 mm. This probable daily rainfall is larger than a maximum daily rainfall of 348 mm recorded at Lapang Kabu which is near to Lalok, but it is smaller than 585 mm/day in Kota Bharu. For reference, the 10 year return daily rainfall at Kota Bharu was estimated to be 262 mm/day, based on the actual record from 1960 to 1970.

6.3. River Discharge

An automatic water level gauge is installed by the Drainage and Irrigation Department at Tualang. The water level has been observed at Tualang since 1973. The water level record which we collected this time covers only one year and seven months from December, 1975 to June, 1977.

The discharge at Tualang was commenced for observation from September, 1974 and has been observed 69 times until now. The maximum discharge recorded is 844 m^3/sec. and discharges exceeding 1,000 m^3/sec. have not almost been observed there. A discharge of 3,900 m^3/sec. which was observed with a float is the only record that exceeds 1,000 m^3/sec.

The record of observation at Tualang indicates that a relation between the water level and the discharge cannot be shown by a relative curve and repeats the fluctuations year by year and a width of the fluctuation in discharge at the same water level sometimes reaches 100 m^3/sec. Accordingly, in case we try to obtain a discharge at the time of low discharge, conversion from a water level to a discharge by means of one relative curve may probably cause a large error. The water levels recorded in 1976 and 1977 were converted into the discharges, referring to the results of discharge observations made in 1976 and 1977. The discharges converted in the above method are drawn by curves in Fig. 6-2 We entered the high water discharges observed with a float in the figures for reference, and we could obtain satisfactory results.

The discharge at Tualang which was estimated by the water level record and the water level-discharge curve is shown in Table 6-9. In Fig. 6-3, the values obtained by multiplying the daily discharge at the Guillemard Bridge by the catchment ratio of Tualang to Guillemard are plotted in order to examine a correlation between the discharge at Tualang in 1976 and the discharge at the Guillemard Bridge. The actual line shows values converted from the water level and the dotted line, values converted by the catchment ratio. As shown in the figure, both values coincide with each other. But if we look at the figure carefully, we can recognize that the discharge obtained by the catchment ratio conversion is higher from late October to late April and the discharge converted from the water level is higher in other months.

a) Long-term Discharge

As mentioned above, actual observation record of discharge on the Lebir River is available only for a period of 18 months. Accordingly, the long-term discharge must be estimated by correlative analysis of actual observation records of discharges observed at other gauging stations near the river.

The mean monthly discharge from 1949 to June, 1978 and the daily and hourly discharges from July, 1965 to June, 1978 were recorded at the Guillemard Bridge.

Using a correlation between the discharge at Tualang converted from the water level and the discharge estimated by the catchment area ratio, the long-term discharge at Tualang was synthesized. In Fig.6-4, a cumulative value of the discharge at Tualang converted from the water level in the horizontal axis and a balance of a cumulative value of the discharge at the Guillemard Bridge minus a cumulative value of the mean discharge in the vertical axis are plotted as a double mass curve. The observation of water level at Tualang was interrupted in April and December. Those omitted water levels are excluded in the figure. This figure shows clearly the feature of precipitation in a period of the northeast monsoon as mentioned in the preceding Subsection and makes it clear that the discharge at Tualang is smaller in a period of the northeast monsoon and larger in other seasons than the discharge at the Guillemard Bridge. This phenomenon is due to less precipitation in the Lebir River Basin blocked by the coastal mountain range in a period of the northeast monsoon than those in the other river basins, a difference in humidity holding capacity of forests in the Lebir River Basin and other river basins and effects by the southwest monsoon.

Table 6-5 shows a correlation between the monthly discharge at Tualang and the monthly discharge at the Guillemard Bridge. The black balls indicate correlative coefficients of both monthly discharges from October to March in a period of the northeast monsoon and the white balls show those in other seasons. The correlative coefficient of both discharges in the dry season is 0.995 and that in the rainy season is 0.982. Accordingly, the long-term discharge was estimated separately for the dry season and the rainy season.

Table 6-10 shows the monthly discharge at Tualang estimated for the respective rainy season and dry season from the monthly discharge at the Guillemard Bridge by the first regression formula. The record of monthly discharge at the Guillemard Bridge is lacking for some months. The monthly discharges at Tualang for the lacking months were filled up by the first regression formula, using the discharge record observed at the Iskandar Bridge in the Perak River which has a similar river characteristic to the Kelantan River. The monthly discharges at Tualang for the months when the monthly discharge record at the Iskandar Bridge also lacks, were synthesized by the tank model method based on the daily discharge record at Lalok. Fig. 6-6 shows a correlation of the monthly discharge synthesized by the tank model and the monthly discharge estimated from the actually recorded discharge and the Guillemard Bridge discharge.

b) Flood Discharge

The number of floods which were observed at Tualang during a period of the actual observation was limited. It is not sufficient for an analysis of flooding at Tualang. Accordingly, the respective flood discharges of various return periods were obtained by analysis of discharge by the storage function method and by correlative analysis of the discharge records at the Guillemard Bridge and Tualang. Adequacy of the thus estimated flood discharges was examined by the catchment area ratio of flood discharges already analyzed for the other river basins.

Table 6-11 shows the discharge at Tualang which was estimated by applying the actual rainfall record at Lalok for three periods of 12 Dec.,1975 to 15 Jan. 1975, 18 Dec. 1975 to 21 Dec. 1975, and 25 Nov., 1979 to 28 Nov. 1979 to the storage function method and a comparison of the peak value of the thus estimated discharge at Tualang with the actually measured discharge. The peak value of the estimated discharge at Tualang and the actually recorded discharge at Tualang show a good coincidence, although the rainfall patterns and discharges at Lalok and Tualang are different, and the flood discharge at Tualang could be simulated in the above method.

A hyetograph of central concentration type which is expected to occur most frequently, was prepared, using rainfall intensities for various return periods which were estimated in Sub-section 6.2. Applying the rainfall shown in the hyetograph to the discharge model which was developed as above, the peak discharges for various return periods were estimated. Table 6-12 shows the peak discharges thus estimated for various return periods.

As of the second method, the peak discharge at Tualang at the time when the peak discharge at the Guillemard Bridge exceeds 500 m^3/sec., was obtained from the actual records of discharges observed at Tualang and the Guillemard Bridge from November, 1975 to June, 1977. As the results, we have obtained 30 sets of such peak discharges. Fig. 6-7 shows a correlation of the peak discharges at Tualang and the Guillemard Bridge. As shown in the Fig. a correlative coefficient is 0.928. Using this figure as a correlative coefficient between the peak discharge at the Guillemard Bridge and the peak discharge at Tualang, the annual maximum discharges at the Guillemard Bridge for a period of 28 years were revolved to those at Tualang and the probable flood discharges were estimated by the Iwai Method. The results of estimate are shown in Table 6-12. The flood discharge estimated by the 2nd method coincides considerably with that estimated from the probable rainfall.

The maximum possible, 1/20 return period, 1/50 return period, and 1/10 return period peak floods which were estimated for Jeram Panjang in the Kelantan River Basin Study made by ENEX, New Zealand consultants, were converted to the flood discharges at Tualang by the catchment area ratio. Fig. 6-8 shows the flood discharges thus converted, which are not far apart from the flood discharges estimated in the two above methods.

6.4. Flood Analysis

In order to analyze effects of flood regulation at the Lebir River dam, and of hydraulic bores resulting from the peak operation of the powerhouse, are to be transmitted at the Guillemard Bridge downstream of the dam site, a river course model was formulated by the storage function method and hydraulic characteristics of the river course were analyzed.

Table 6-13 shows a comparison of the actual records of discharges at Tualang, Dabong and the Guillemard Bridge with the peak discharges estimated for these three sites by applying three different patterns of rainfall to the above river course model. As shown therein, an error between the estimated flood discharges and the actually recorded flood discharges is only 5 %. This means that the river course model reproduces faithfully the flow characteristics in the actual river course.

In order to examine the effect of flood control with the dam, the necessary capacity of the reservoir for regulation of the maximum flood which took place in Dec., 1973 and the resulting decrement in the peak flood at the Guillemard Bridge were computed. The results of computation are shown in Table 6-14. The necessary capacity of the reservoir to lower a discharge of 700 m^3/sec. equivalent to 4.6 % of the discharge at the Guillemard Bridge is estimated to be 190 million m^3.

In the meantime, how the discharge at the Guillemard Bridge fluctuates in a repeated cycle of 6 hour discharge of 400 m^3/sec. for peak operation of the power station and 18 hour out-of-operation during a drought period of the river basin was analyzed. As shown in Fig. 6-9, the maximum discharge and minimum discharge at the bridge under such conditions would be 210 m^3/sec. and 190 m^3/sec. respectively.

A fluctuation in the discharge at the bridge is only less than $\pm$10 %

and a hydraulic bore almost declines at the Guillemard Bridge. If the discharge comes down farther to the mouth of the river, an effect in the river flow by the peak operation of the power station becomes almost negligible. The discharge released for the peak operation under such a drought condition will have a sufficient effect to maintain the river stream.

6.5. Sediments in the River

At the Preliminary Investigation Stage, the density of suspended load in the river was measured and bed load materials in the river were also collected. But we have not yet completed analyses of these materials.

The sediment load in the Kelantan River was studied in Section 5 of Enex Report Volume 1, 1977 entitled "the Kelantan River Basin Study". The annual sediment in the river was estimated to be around 110 m^3/km^2/year in the report.

Using a sediment rate of 110 m^3/km^2/year estimated by ENEX, we have estimated sediments at Tualang for a period of 100 years. As the results, we have obtained about 30 million m^3. This sediment is about 0.7 % of a gross storage capacity of 4,400 million m^3 of the reservoir with the reservoir high water level designed at EL. 90.

6.6. Surface Evaporation

There are no measurement records of the surface evaporation in the Lebir River basin. NEB has been observing the surface evaporation with an evaporating pan as well as the temperature, humidity and wind velocity since July, 1979.

Shown in Section 5 of the ENEX Report Volume 1 is the monthly surface evaporation which was quoted from "Water Resource Publication No.5". Table 6-15 reproduces the same monthly surface evaporation.

The report indicates that the maximum surface evaporation in Kota Bharu is 6 mm/day in April, the minimum 4 mm/day in December and the mean value 5 mm/day; the annual surface evaporation is about 1,800 mm on the average. The report also describes that the daily evaporation in the Lebir River basin is about 4.5 mm/day which is smaller by 10 % than that in Kota Bharu.

7. Environment

7.1. General

Various environmental effects may occur with the construction and operation of dams and reservoirs. These effects may be either large or small, beneficial or adverse, depending upon the pre-project environmental conditions. This chapter deals with the possible adverse effects.

7.2. Changes in Water Quality and Acquatic Environment

A reservoir with an area of 247 km^2 and a storage capacity of 4,397 x 10^6 m^3 will be created by the construction of a dam at the Jeram Panjang Site.

The coastal length of this man-made lake is more than 1,000km and its maximum depth is 66.0 m. The foreshore of the reservoir goes up to the Baduna River about 75 km upstream of Jeram Panjang.

The project will bring social and economic benefits of flood mitigation in a period of floods and an increment in the discharge during a drought period to the downstream area, particularly a section between the powerhouse and the confluence with the Galas River. Normally, the flood mitigation will result in the preservation of human life and property and the increment in the discharge will enable a stable supply of irrigation water. But there are only a few villages in the section. The demand for irrigation water is small. Accordingly, the benefits are not expected to be large.

An adequate warning system should be provided against a sharp release of discharge from the spillway. Some effect could occur to navigation. But it will not pose a serious problem, once the Kuala Keral - Gua Musang Highway is completed.

The water quality in the reservoir will undergo a sudden change for several years after the commencement of the reservoir water filling but it will become stable gradually after that. Referring to what happened in reservoirs in a tropical zone, the following consequences are anticipated to take place with the construction of the reservoir. (see Table 7-1 to 7-3 for water quality record and Figs. 7-1 to 7-2 for location of water quality stations).

a) Dissolved oxygen

Plants at the bottom part of the reservoir will decompose with the reservoir filling. In the course of decomposition, much oxygen will be consumed and dissolved oxygen will be decreased remarkably. But after several years, dissolved oxygen in the upper layer of the reservoir water will be restored to saturation, and dissolved oxygen in the lower layer will be restored more slowly.

b) Hydrogen sulfide

Hydrogen sulfide will be generated by decrement of dissolved oxygen due to decomposition of plants. It will increase sharply for several years after the reservoir filling but it will be decreased slowly. The deterioration of the water quality will give adverse effects to the area downstream of the dam. But, as mentioned before, the river section from the dam to the Galas River which will be placed under the effects is not populated by many villages. Therefore, the problem will not be serious.

c) Nourishment

The water quality in the reservoir will be nourished for a long term. The river water of the Lebir River and the Kelantan River contains little nitrate and ammonia. But the river water downstream of the Chenderoh Reservoir contains nitrate, ammonia and phosphoric acid. In view of the vegetation in the proposed reservoir area, the water quality in this reservoir is expected to become of similar quality to the Chenderoh reservoir. The progress of nourishment will be influenced by the future land use around the reservoir area. It will become dull, if the development of villages around the reservoir is limited except in the resident area of Orang Asli. The Aring land development project has the possibility of aggravating the water quality in the reservoir. Accordingly, some adequate means should be taken to preserve the water quality.

d) Transport of Soil and Sands

The reservoir coastal area has the possibility of undergoing small-scale landslides due to fluctuation in the ground water level. Logging of forests, land reclamation by fires and development of logging roads will accelerate soil erosion and the transport of soil and sands. Care should be taken for the development of forests around the reservoir so that erosions of the coast line and the transport of soil and sands may be minimized. The riverbed downstream of the dam may be eroded because of the stopping of sediment transport by the dam. However, its effect will not reach the area downstream of the confluence with the Galas River.

7.3. Biologic Consequences

7.3.1. Plants

The reservoir and its surrounding area are covered by tropical plants. There are variety of species and any predominant kind cannot be specified. The typical trees are high trees of dipterocarpaceane which include meranti, chengal, keruing, hapur and balau for logging. The only effect of the project on the present plants is the submergence of forests in the reservoir.

In the past any detailed survey of existence of valuable sorts of plants has not been carried out yet. It is, therefore, desirable that the existence of valuable sorts of plants should be surveyed. Just like other reservoirs in a tropical zone, floating water plants including water hyacinths-eichornia crassipes may probably grow rapidly in the reservoir. Growth of water plants will be proportional to the nourishment of the water quality. Careful attention will be required in this respect in planning the development of land near the reservoir.

7.3.2. Animals

a) Mammal

In the southern mountains of the State of Kelantan, protected animals shown in Table 7-4 are noted. A considerable number of protected animals are supposed to live in the reservoir area.

But in the area salt licks are not found. From this fact, it seems that this area is not an important place of living for big wild animals. The National Park is located upstream of the reservoir but it is outside the proposed reservoir area.

After the commencement of the reservoir water filling, most of the big animals will move to the mountainous area. Natural feed for them will decrease with the construction of the reservoir. But the area of the reservoir is only 247km^2 out of a total catchment area of 2,474 km^2. Accordingly, a sufficient space for their living will remain even after the completion of the reservoir. Mr. Mohd Khan bin Nomin Khan reports a density of primates in forest as per Table 7-5. Based on his estimate, about 850 monkeys will be affected by the inundation of about 247 km^2. (see Fig. 7-3 for location of habitants of wild animals).

b) Fish

Any detailed investigation of fish living in the Lebir River has not been made. Mr. D. S. Johnson reports that the northern part of the Peninsular Malaysia including the State of Perak, the State of Kelantan and the area north of the Trengganu River belongs to a common ecosystem. The fish living in the northern part of the Peninsular Malaysia are rasbora borapatensis and labiobarbus lineatus. Besides these, aplocheilus panchax (kepala timah) and trichopsisvittatus (karim) are supposed to live in the Lebir River.

As migratory fish, anguilla (eel) and giant-freshwater prawn are supposed to live in the Lebir River.

The dam will cut the river flow. Eels will disappear from the reservoir. No adverse influence is expected to be given to fish living downstream of the dam. But in the reservoir fish which are fond of nourished water in static conditions will grow large.

7.4. Socio-Cultural Consequences

7.4.1. Villages

The population in the proposed reservoir area is about 700 persons (about 120 households), half of whom are native people called "Orang Asli".

The majority of residents other than Orang Asli are farmers. Their villages are scattered along the riverside, and one village is composed of several households. Most of them come from the downstream plains to seek new agricultural land. In the beginning, they burn the riverbanks and cultivate corn, beans and bananas. After several years, they try to plant rice and rubber. But few of them succeed and they move to other areas.

As mentioned above, their living is not rooted to one place. Naturally, their houses are of temporary nature. And there are no schools nor churches. The properties affected by the inundation are only agricultural fields. If they follow their way of living, they can maintain their living by themselves by cultivating new land along the reservoir shore line.

However, the reclamation of land along the shore line of the reservoir should be strictly limited from viewpoints of prevention of soil and sand transport, prevention of nourishment of the water quality and public hygiene.

A main motive for their resettlement is a shortage in the agricultural land on the plains.

The Orang Asli living in the area, belong to the Batez Tribe of the Negrito. They live in villages in the forests. Near the Kiak Site, a regional center for the Orang Asli was provided by the Bureau of Orang Asli, where a school, a dormitory and a clinic are built. For their assimilation, a vegetable garden of 13 acres and a rubber estate of 60 acres are cultivated under the Bureau's assistance and young rubber trees are given to them for their plantations.

The residential area of the Orang Asli spreads widely in the forests. And they always move from one place to another. Accordingly, it is very difficult to predict how far their life will be affected by the dam construction.

Inspite of the government's policy for their assimilation, it will take a long time before they will be assimilated to the degree of the Orang Malay. In a transient period, their living area should be reserved independently. From viewpoints of conservancy of the forests and reservoir water quality, the land use around the reservoir area should desirably be under the government's control. And a certain boundary should be established in their living area, to conserve the forests and reservoir water quality. The means of their assimilation including rubber plantation should be continued after the completion of the reservoir. For these reasons, a resettlement plan for the Orang Asli is recommended to be drawn out.

The resettlement land is estimated to be 3,000 ha, if we give one of them 10 ha; and it should be located on the left bank area of the Lebir River which has a gentle slope. In the resettlement land a regional center for the Orang Asli will be reconstructed, and a vegetable garden and a rubber plantation will also be reclaimed. Access to the regional center will be made from the reservoir and the Gua Musang-Kuala Kerai Highway.

7.4.2. Public Hygiene

Infectious diseases which sometimes break out in the State of Kelantan are malaria, typhoid fever and small pox. (see Table 7-6)

It is difficult to predict whether the reservoir will provide a hotbed for breeding of mosquitoes. But the area around the reservoir is less populated. Accordingly, there is a small possibility that malaria will break out explosively.

The most sensitive period from a viewpoint of public hygience is the period of construction when many people work at the site at one time. Adequate measures should be devised to maintain public hygiene during the construction.

It seems that no schistosomes live in the State of Kelantan.

7.4.3. Archaeological Ruins

The villages in the reservoir area are not of a permanent nature. Accordingly, there are no cultural facilities in the area.

In the residential area of the Orang Asli, there remains the possibility that some facilities owned by them are ethnologically valuable. At the time of their resettlement, those facilities will also be required for resettlement.

An archaeological survey has not been made in the area. But some archaeologists think that the Lebir River was used as a route of resettlement of the people through Thailand toward the south. Therefore, there is the high possibility that archaeological ruins remain in the area. An archaeological survey is recommended to be carried out in the reservoir area.

7.5. Industrial Consequences

The main industrial activity in the reservoir area is forestry. (see Table 7-7). The other activities are merely small-scale self-supply agriculture and fisheries. The main industrial consequence of the dam is a decrease in the area of forests.

(1) Forestry

The product of logging is different depending on the topography of forests, kinds of trees and method of cutting. If we adopt 20 m^3/gross ha/year as the product of forestry, a loss derived from the reservoir water filling will amount to M$25/ha/year. Before the commencement of the reservoir filling, all trees to be submerged in the reservoir should be cut to minimize the loss caused by the inundation and conserve the water quality.

(2) Fishery

Most of edible fish in Malaysia are sea fish. But recently limmetic fishes have drawn people's attention. Attempts have been taken to plant lampan Java (puntius gonionotus), lee koh (cyprius carpio) and tongsan kepala besar (aristichthys nobilis) mainly in ponds and swamps on the plain area. There is the possibility that those fishes will be planted in the reservoir. The development of fisheries in the reservoir will be possible after the marketability of them is studied and developed, the market route is arranged well, methods of catching and breeding fishes are studied, and a corporation responsible for the development of fisheries is organized. But the possibility of developing fisheries in the reservoir should be pursued to develop a supply source of albumen.

(3) Tourism

The reservoir will be able to be utilized for recreation and tourism including water sports and fishing. But the development of tourism with the use of the reservoir will not be so prospective. The construction of a warden house is planned at the south edge of the Lebir forest reserve in the National Park under the management of the Games Dept.. On completion of the reservoir, approach to the National Park by boat/ship will become much easier.

7.6. Countermeasures for Environmental Consequences

The environmental impact caused by the construction project will be settled properly, if adequate measures are taken.

(1) Recommended Investigations

a) Biologic investigations are proposed in the reservoir area, particularly with respect to the existence of valuable plants in the reservoir area, the study of water plants and prediction of growth of water plants in the reservoir, and the study of kinds of fishes suitable for plantation in the reservoir.

b) Archaeologic investigations are proposed in the reservoir area.

(2) Countermeasures recommended for solution of environmental problems

a) Establishment of warning system to the downstream area at the time of release of discharge.

b) Establishment and implementation of public hygiene during the period of the construction.

c) Establishment and implementation of land development plans around the reservoir.

Especially, Item c) is the most important problem. The water quality in the reservoir and volume of soil and sand transport into the reservoir will be influenced by land use around the reservoir. The Aring Land Development Scheme planned by FELDA will have a direct effect on the reservoir. It is recommended that adequate countermeasures should be taken in planning the scheme to control the water quality in the reservoir and minimize transport of soil and sands into the reservoir.

8. Alternative Development Plans

8.1. Method of Comparative Analysis of Alternative Plans

In the Peninsular Malaysia, many steam power projects are planned or under construction to supply the sharply increasing power load. Reflecting a recent hike in the oil price, main efforts have shifted to develop as many hydroelectric potentials as possible, particularly, hydroelectric potentials in the States of Kelantan and Pahang combined with non-power benefits including flood control, irrigation and tourism.

The Preliminary Stage Investigation is intended to optimize the size of development in each of the three dam sites taking account of irrigation and flood control benefits and to clarify the technical and economic viabilities of the optimum plan from among various alternatives to justify detailed investigation of the optimum plan following this Preliminary Investigation Stage.

Alternative development plans were worked out so as to produce the highest combined benefits of power generation, irrigation and flood control.

The topographic feature of the Lebir River will make it possible to develop only a dam type hydroelectric power station. As the benefits of irrigation and flood control will be measured only by the discharge at the Guillemard Bridge, the location of the site has inevitably been limited to the lower reaches of the Lebir River.

For the purpose of comparative analysis, two typical dam types of a concrete gravity dam and a fill type dam were adopted. And a combined fill-concrete type dam was also adopted so as to suit a specific topography at some dam site. Foundation excavation lines and methods of foundation treatments for construction of dams at the alternative dam sites and heights of the dams were determined on the basis of the topographic surveys, seismic prospecting and drilling works carried out at this stage.

For each of the dam sites, the annual generated energies, maximum outputs, firm capacities, irrigation water supplies in a drought period and the effects of flood control were computed for various reservoir high water levels and maximum discharges, based on the 30-year monthly discharge. A plan for each of the dam sites which will produce the maximum benefits of power generation, irrigation and flood control among the alternative plans was selected as the optimum development plan for the dam site. After comparison of the optimum plans for the three alternative sites, the optimum dam site and height of dam were selected.

In the comparative analysis, an adopted rule of the reservoir operation is that the power station would be operated for peak generation and time of its peak continuous operation is assumed to be 6 hours except when the reservoir water level reaches the maximum. Thus the water level of the reservoir is maintained at a maximum normal operating water level. The flood mitigation benefit was obtained by fixing the scale of free overflow dam and the evaluation of its location, so as to maximize the sum of power benefit and flood control benefit. The irrigation benefit was estimated on the basis of contribution of the discharge for power generation to supply of part of the irrigation water requirements to feed the ultimate crop pattern, but any reserve of water for irrigation was not provided in the operation rules of the reservoir.

For the analysis, a storage capacity curve was drawn by means of the topographic maps of the reservoir area newly produced at this stage. And a water level-discharge curve at Tualang which was based on the actual measurements was used to determine the water level at the tailrace. Furthermore, water level-discharge curves at Jeram Panjang and Kiak which were obtained by the step by step method for non-uniform flow by means of the ground survey maps were also used for the analysis.

8.2. Identification of Dam Sites

On the lower reaches of the Lebir River, the Tualang Site was identified as a promising dam site characterized by the narrow width of the river, steep slopes of both banks and exposure of hard bed rocks. This site is just on the same location as a cable for the discharge observation which was installed by the Drainage and Irrigation Department, and it also overlaps the site for a bridge on the route of the Gua Musang-Kuala Keral Highway. The elevation of the riverbed at Tualang is only 16 m above the sea level. Downstream of Tualang, the river width becomes large, with gentle slopes of the mountainsides on both banks, and villages including Lalok are scattered along the river. Accordingly, the Tualang Site is considered the most downstream site for the construction of a dam.

The Jeram Panjang Site which has been proposed for the dam site in previous studies is located at the S-shaped curve of the river course 3.2 km upstream of the Tualang Site. This site presents a narrower valley next to the Tualang Site and the slopes of mountainside on its both banks are as gentle as 15°.

The two sites are near to each other, and there is not so large a difference in catchment area between both sites. Two common saddle dam will be required for the development of both dams.

Another saddle dam will be required for the development of the Tualang Dam Site.

The Jeram Kiak Site is located at the zigzag curve of the river stream 11 km upstream of the Jeram Panjang Site. It is just on the place where a road bridge for transport of cut wood crosses the river. But there is no other bridge except the Manek Urai Railroad Bridge in a distance of about 20 km downstream of this site. Of course, there is no other bridge upstream of the site. The site presents a wide valley and the slopes of mountainside on its both banks are extremely gentle. This topographic feature is worse of this dam site compared to the other two sites. But the site does not necessitate the construction of any saddle dam.

Upstream of the Jeram Klak Site, there are found no other suitable dam sites, because the catchment area becomes smaller and the valley of the river becomes too wide.

8.3. Tualang Site

The catchment area of the Lebir River at the Tualang Site is 2,480 km^2 which corresponds to about 73 % of the total catchment area at the confluence at Kuala Kerai.

The Site is just at the place where a cable for discharge observation was installed by the Drainage and Irrigation Department and just upstream of the confluence with the Sam River, a tributary of the Lebir River. On the left bank there is a dome-shaped small mountain mass (elevation 206 m). A small ridge, about 110 m high, extends from a NNE tending small mountain, on the right bank. This is also a boundary of the watershed with the Rek River. The mountain mass and ridge forms a V-shaped valley.

The small mountain on the right bank extends in a distance of 4 km toward the southsoutheast until it encounters with the Pedah River, a tributary of the Lebir River, upstream of the S-shaped curve of the river course at the Jeram Panjang Site. The Pedah River traverses the south foot of this small mountain and reaches a branch of the Coastal Mountain Range. There is a saddle part with the lowest elevation of 40 m on the boundary between the catchment areas of the Pedah River and the Rek River.

The left bank confronts a mountain which is connected to the Central Hill Zone, forming a watershed between the Lebir River and the Sam River, setting apart a dale-shaped topography with a low elevation upstream of the dome-shaped small mountain mass. The Sam River flows towards the east at its confluence with the Lebir River and joins the Lebir River at a right angle. The main stream of the Lebir River changes its direction after passing the north edge of the dome-shaped mountain mass and flows in the southnorth direction. The dale-shaped low land upstream of the dam site forms a saddle part with the lowest elevation 40 m at the boundary between the catchment areas of the Lebir River and the Sam River.

The elevation of riverbed at the Tualang Site is 16 m above the sea level. The distance from the site to the mouth of the river is 110 km or more. Accordingly, there is no other dam site downstream of it.

Restricted by the topography of the ridge on the right bank and the exposure of baserocks, the maximum water level of the reservoir is limited to about elevation 90 m.

If a high water level of the reservoir is fixed at 90 m above the sea level, the reservoir area will be 250 km^2. The gross storage capacity is estimated to be $4,495 \times 10^6$ m^3. The reservoir will extend about 75 km upstream of the dam site, and inundate 36 % of the area for the Aring and Lebir land development schemes. The elevation of the tailrace, which will vary a little according to the discharge, will be around 24.7 m above sea level. A maximum gross head of about 61 m will be made available by this plan. For reference, the respective reservoir areas and storage capacities in case the high water level of the reservoir is fixed at 80 m and 70 m are shown in Table 8-1.

The dam site is situated in the location enabling adjustment of flood discharge from 73 % of the Lebir River Basin. The reservoir, if operated adequately, will be capable of increasing a 10 year return drought discharge of 17 m^3/sec. to 80 m^3/sec. at the maximum.

On the site, either dam types concrete gravity dam or a fill dam are able to be constructed. If a fill dam is selected, we could not find a suitable site for the spillway. If we construct the spillway on the right bank or the left bank, the volume of excavations will be a extremely large.

Fresh bedrocks are exposed from the riverbed to Elevation 30 m on both banks. At a higher elevation, the weathered zones become thick, and around Elevation 50 m the heavily weathered zones are 5 to 10 m thick and the weakly weathered zones also 5 to 10 m thick; the mean thickness of weathered zones reaches about 15 m. There is found a small area with a low seismic wave velocity on the left bank, for which an adequate treatment will be required in the construction.

An adequate space for the powerhouse and switchyard is available on the right bank 100 m downstream of the dam site.

8.4. Jeram Panjang Site

This site is located on the S-shaped river course. Along the S-shaped river course, Jeram Kushon, Jeram Chendawru, Jeram Panjang and Jeram Tembeling continue for a length of 2,500 m. The elevation of riverbed is lowered by 4 m in this length.

The width of river on the dam site is 150 m. Bedrocks are exposed on the riverbed of the dam site. The normal river flow is limited to a 60 m wide river channel on the right bank side. The lowest riverbed is Elevation 24 m. The slopes of the mountainsides on both banks are 30° to 40° up to Elevation 45 m and 15° on the average at a higher elevation.

A ridge of the mountain range which lies on the boundary between the Lebir River and the Sam River extends towards the eastwest on the left bank side and has a 110 m high flat terrace-shaped topography near the Lebir River. After the ridge extends 500 m toward the east, it slopes down to the Lebir River. The mountainside of a 1,500 m long independent ridge extending toward the southsouthwest from a point 1,000 m north of the curve upstream of the S-shaped river course forms the slope of the right bank. The ridge is about 110 m high near the Lebir River and the riverbed is about 500 m wide.

Fresh bedrocks are exposed on the riverbed. But the dam site except on the riverbed is covered by heavily weathered laterite zones; on the terrace parts at elevation 45 m the heavily weathered zones are 5 m to 7 m thick and the weakly weathered zones 8 m to 16 m.

The catchment area of the Lebir River at the Jeram Panjang Site is 2,474 km^2 which is not different from that at the Tualang Site.

Considering the topographic and geologic conditions on the site, both types of a fill dam and a concrete gravity dam are able to be constructed on the dam site. A spillway is able to be constructed at the ridge on the right bank, if the dam height is designed adequately.

The water level at the tailrace is 1.3 m higher than that for the Tualang Site, because the tailrace for the Jeram Panjang Site exists 3 km upstream from that for the Tualang Site.

An adequate space for the switchyard and powerhouse is available on the left bank. If the powerhouse is designed as a semi-underground powerhouse, the baserocks of the proposed powerhouse site will not pose any problem.

The high water level of the reservoir is limited up to elevation 90 m by the topographic feature on top of the ridge on the right bank because part of the fresh bedrocks on the top of ridge drops down to elevation 84 m.

If the high water level of the reservoir is fixed at elevation 90 m, the reservoir area will be 247 km^2 which will create a gross storage capacity of 4,397 x $10^6 m^3$. The reservoir area is 98.8 % of that for the Tualang Site and the storage capacity 97.8 % of that for the Tualang Site. If the high water level of the reservoir is fixed at elevation 90 m, 80 m or 70 m, the reservoir area and gross storage capacity are vary as shown in Table 8-1 and Fig. 8-1.

8.5. Jeram Kiak Site

This site is 11 km upstream of the Jeram Pangang Site. The catchment area of the Lebir River at this site is 2,292 km^2 which is smaller by 190 km^2 than the catchment areas of the two other sites or corresponds to 92 % of the other catchment areas.

The valley on the dam site is wide, and the slopes of the mountainsides on both banks are gentle. But the other two sites downstream of this site will require the construction of two common saddle dams whose bedrocks have some geologic problem. Accordingly, this site has been proposed as an alternative dam site.

The width of the river stream is about 80 m. Fresh bedrocks are exposed on the riverbed. The right bank presents a platform from elevation 50 m with repetition of 10 m high undulations in a length of 700 m. After that, the right bank presents a gentle slope of about 40°. The peaks of both banks are 200 m high or more. But the bedrocks of both banks lie deeply under the ground; especially on the right bank the heavily weathered zone is 5 m to 12 m thick, and the weakly weathered zone is 10 m to 26 m thick. There are many parts where the total weathered zones, both weakly and heavily weathered, are 30 m thick.

A concrete gravity dam on this site is not adequate, because the volume of excavation of the foundation will be large.

The dam site could support the construction of a fill dam, if grout injections are given to the baserocks of the dam core part. An adequate site for the spillway is not available on both sides. An overflow concrete gravity dam would be constructed on the right bank side of the baserocks.

If the high water level of the reservoir is fixed at elevation 90 m, the reservoir area will be 217 km^2 which is equal to 86.8 % of the reservoir area at Tualang and the gross storage capacity would be 3,570 x $10^6 m^3$ which corresponds to 79.3 % of the gross storage capacity for Tualang. Located 14 km or more upstream of the Tualang Site, the water level at the tailrace would be higher by 6.2 m than the tailrace water level for the Tualang Site.

8.6. Alternative Plans for the Respective Site

Various alternative plans for the respective site were formulated in the method as stated below to find the best solution for each of the sites.

Keeping the high water level of the reservoir at elevation 90 m which was described before as a maximum limit of the high water level and elevation 70 m which was proposed as the economic minimum high water level in previous studies, the layouts of dams for the respective site were designed for the two high water levels governed by the geologic, topographic and hydrologic conditions of the site. The construction costs of two cases of the dam heights for the site were estimated on the basis of the developed layouts. In the layout studies, a fill dam or a concrete gravity dam was adopted for the designs of the dams.

Two layout plans for the respective site, totally six layout plans, were formulated, and the construction costs of the six plans were estimated on the basis of the layout designs. Then, the thus

developed construction costs were compared with each other. As for
the results, the construction costs of the dams at the Jeram Klak Site have proven highest, while the accrued benefits are lowest. Accordingly, this site was dismissed for further study at the very initial stage of comparative analysis.

For comparison of the remaining two sites, 12 cases of alternative plans were developed, for three reservoir high water levels of elevations 90 m, 80 m and 70 m and various discharges for power generation. The preliminary costs of those 12 cases were estimated.

8.7. Reservoir Operation Calculation

Using the monthly discharge from 1948 to 1977, the monthly generated energy, maximum output, minimum output and mean reservoir water level of each of the 30 cases were computed to obtain the annual mean generated energy and firm output in a 30-year return drought period.

Assessment of the power benefit, irrigation benefit and flood control benefit is described in the subsequent Sections. Any additional water other than the discharge for power generation would not be required for supply of irrigation requirements. Accordingly, any reserve of water for irrigation was not made in the reservoir operation curve.

9. Layout Designs of Alternative Sites

9.1. Outline of Layout Designs

The concept applied to the layout designs of the Project's main components for the alternative sites is outlined below.

Design Flood Discharge

For the estimation of design flood discharge, the probable flood discharge of 1,000 year return period was adopted. Flood wave pattern used are the compound one with the hyetograph at Kg. Lalok described in Sub-section 6.3. b) and the river channel run-off model.

The dam freeboard is fixed at 3.5 m, taking into account the conventional figure for the flood discharge at 1/1,000 return period. The design flood discharge applied to the diversion tunnel during construction is 50 year probable flood discharge in case of fill type dam, and 20 year probable flood discharge in case of concrete dam. The diversion tunnels (Diameter: 8m) are considered to have concrete lining to lessen to loss of waterway. In case of fill type dam, it is designed that the floods which may occur during construction can be dealt with only by the diversion tunnels (Diameter: 12m). On the other hand in case of concrete dam, the floods will be treated by the diversion tunnels plus other diversion tunnels to be installed in the dam body during construction. Such additional tunnels in the dam body are used to mitigate the load of the original diversion tunnels.

Type of Dam

The layout designs of the alternative dams for each of the sites were made considering both topography and geology of the site.

At this preliminary design stage, standard designs of both types of dams were adopted after examination of their stabilities of their applications to each site. In the following stage, detailed comparisons of dam types and shapes for each of the sites will be carried out to select the optimum type and shape with a lower construction cost and a smaller dam volume.

Regardless of the dam types, curtain grouting is planned to be injected into the base rocks so that it may reach two-thirds of the water pressure. For extremely thin portions of the ridges, both curtain grouting and consolidation grouting are planned to be undertaken to stabilize the fresh bedrocks.

Spillway

A chute-type open spillway is selected by reason of its reliability and surplus discharge capacity.

Two control ways are considered as the discharge control of the spillway. One is natural control by free overflow weir and the other is control by regulating gate. In the Lebir dam, natural control by free overflow weir was regarded as the main control way. However, control by regulating gate has the merit of selecting the discharge regardless of the water level in the reservoir. In this report, the study was made only to how much the power benefit can increase when peak discharge to downstream is set equal to the natural overflowing discharge.

In case of concrete dam, the spillway is installed on the dam body, while in case of fill type dam, it is installed on the appropriate ground far from the dam body. But, at Kiak site, no appropriate ground can be found for the spillway of fill type dam. In this case, a part of fill type dam is converted to concrete dam on which the spillway is to be installed as a compound dam.

The energy dissipator to be installed at the end of the spillway is of horizontal apron type, flip bucket type, ski-jump type, etc. considered. Taking into account the topographic conditions around the proposed spillway sites and the hydraulic characteristics of the river, ski-jump type spillway is applied only to the fill dam at Jeram Panjang site, and horizontal apron type is adopted to all other proposed sites.

Intake and Penstock

The depth of deposited silt in the reservoir was calculated based on the total transport of sediment for a period of 100 years. The intakes for the concrete dams were designed to be attached to the dam bodies. The intakes for the fill-type dams were designed so as to suit to the surrounding topography and their elevations were decided so that some marginal water depth may still remain even at the lowest low water level. The shapes and structures of the intakes were designed so that an inlet loss may be kept smaller and an outflow vortex would be difficult to form, even at the lowest water level.

The diameters of the penstocks were determined most economically from the net generating benefit. As the power stations are to be constructed directly downstream of the dams and the tailraces are also constructed directly downstream of the power stations, so surgetanks are not necessary for construction.

Power Station

As all alternative sites for the power station are located on good bedrocks and favorable topography, each power station was designed to be of the less expensive semi-underground type, and the barrel-type foundation was adopted.

All alternative sites for a power station have suitable sites for a switchyard nearby, therefore, such a system was adopted that step-up transformers are placed on the premises of the power station and 275 kV power cables are strung to connect the step-up transformers with the switchyard.

Gates and Valves

Radial gates were selected to be installed on the spillways so as to make the hoist size minimum. All gates were designed to be provided with stoplogs for repair.

The intakes were designed to be equipped with trash rake screens and discharge regulating gates. On the downstream side of the gates, a man-hole for inspection of the penstock will be provided and on the front side of the gates, stoplogs will be provided for repair of the gates.

At this stage, two (2) lines of the penstock to supply water to respective hydraulic turbines were designed. One (1) line of penstock with branch-off halfway along is also possible, but detailed comparisons are left for the following stage of this study.

The inlets of hydraulic turbines would be equipped with butterfly valves. The draft outlets of the turbines would be equipped with a roller-gate which can be used in common for two draft-outlets so as to enable inspection and repair of the hydraulic turbines and drafts.

Hydraulic Turbine

Vertical shaft Francies turbines were selected from the view-points of recent production records of manufacturers in the world, economical costs, and ease of operation and maintenance.

Generator and Power Factor

Umbrella-type generators were selected to lower the height of generators for stability and to save the height of the power station.

As the power station is of a dam type with short penstocks there is little possibility of sudden change in the water pressure. It is not necessary to provide any special measure for heightening the fly-wheel effect. Therefore, the natural value was adopted as GD^2 of the generators.

It is usual to adopt a conservative figure for the power factor against normal operation of a hydro power station. For this Project, the figure 0.9 was used.

It is estimated that a runaway speed of a generator of this capacity will be 180 % approximately.

Overhead Crane

The heaviest of the equipment of the power station is the rotor of the generator. Its assembled weight is estimated about 370 tons. Accordingly, an overhead crane of this capacity will be required for the power station, but details will be studied in the following stage. The heaviest unit weight in transport is estimated at about 60 tons, which is closely related to the selection of the number of units.

Step-up Transformer

Special three-phase transformers which can be divided into three sections for transportation were adopted.

The transformation ratio is 13.2 kV/275 kV, the capacity is 70,000 kVA and the power factor is 90 %. No load tap will be used on the high voltage side. The maximum weight in transit would not exceed 400 tons.

Switchyard

The outdoor switchyard would be of the ICB system and the bus-bar would be of the aluminum pipe bus type. Gas circuit breakers would be used because of their high reliability. The transmission line from the switchyard would be two circuits. Problems in relation to future extension will be examined in the following stage.

9.2. Layout Design for the Tualang Site

The general plan of the Tualang site development is shown in Fig. 9.1. - Fig. 9-5.

The Tualang plan requires the construction of three main construction roads. The Tualang plan is made on the assumption that the highway route from Gua Musang to Kuala Kerai will be changed to the route which crosses the Lebir River from the right bank to the left bank midway between the Kampung (Village) Sungai Rek and the Kampung (Village) Lebtu, goes south to cross the Sam River and then goes west around dome-shaped mountain. The required construction roads for this plan are; a permanent road 900 m long to branch off from the highway at the point of the bridge over the Lebir River to the power station site along the right bank of the Lebir River, a new road 1500 m long from the south of the cross point of the Sam River to the quarry site through the dam site and the No.3 saddle dam, and the existing logging road to be improved from Kampung Lalok to the No.1 and No.2 saddle dam. Of course, roads to the aggregate quarry site, borrow-pit site, spoil banks and construction plant sites are also required to branch off from the main construction roads.

The main dam is of the concrete gravity type, and its spillway is installed on the center of the dam, and equipped with a horizontal apron as a stilling pond. The dam height is 77.5 m, the crown height is 93.5 m above mean sea level, and the crown width is 370 m. The upstream side slope is 1 to 0.1 and the downstream one is 1 to 0.75.

The spillway has at its center, an overflow section shapes with a crest height of 74 m. The overflow section is equipped with five radial gates of 10 m by 16 m to regulate the discharge. With the gates fully open at the highest design water level of EL. 90 m, the spillway has a capacity of 7,000 m^3/sec.

The intake with two inlets is constructed on the dam to the right bank. The bottom elevation of the intake at EL. 64 m makes it possible to intake water at Elevation 76.4 m which is the lowest design water level. Operation of the trash screens and the regulating gates is done from the dam crest, so that an easy approach to the intake screens and safety in the screen operations is mainly considered.

The penstocks (2 lines, each 5.8 m diameter) starting from the intake go through the dam body, appearing in the downstream slope of the dam and then passing underground to reach the power station 150 m downstream of the dam.

The power station is constructed near the downstream end of the dam apron and against its side wall. No tailrace is constructed, and the discharge water is to be released directly to the river.

The switchyard would be constructed on the small stream downstream of the power station. The step-up transformers would be installed nearby the power station, and the power station and the switchyard would be connected with the power cables after step-up.

The Tualang plan requires, besides the main dam, three saddle dams altogether, i.e., two saddle dams on the boundary between the Pedah River and the Rek River, and one saddle dam on the boundary between the Lebir River and the Sam River. These saddle dams are fill-type dams. The dimensions of each dam would be as follows:

	Site	Dam Height (m)	Crown Height (m)	Crown Length (m)
Saddle Dam No.1	West side of the saddle between the Pedah and the Rek Rivers	67.5	93.5	370
Saddle Dam No.2	East side of the saddle between the Pedah and the Rek Rivers	33.5	93.5	220
Saddle Dam No.3	Saddle between the Sam and the Lebir Rivers	58.5	93.5	700

9.3. Layout Design for Jeram Panjang Site

The general plan of the Jeram Panjang site development is shown in Fig.9-6 - Fig.9-11.

Two main construction road routes are considered for this site. One is the permanent road with total distance of about 3 km branched from Gua Musang - Kuala Kerai Highway at the vicinity of Tualang and reached along the left bank of the Lebir river to the Jeram Panjang site. The other permanent road is going from the Jeram Panjang site to saddle dam No.1 and No.2 with total distance of about 2.5 km via levee crown of the main dam, the ridge of the left bank and the small mountain mass zone. In addition to these roads, repairing of the temporary logging road is required for the construction of the project, together with new road construction for quarry, core site, spillway, plants and other temporary facilities.

Main dam is center core shaped, fill type dam. Taking into account some safety allowance, it is designed to have 12 m crown width, 1 : 2.2 upstream slope gradient, 1 : 1.85 downstream slope gradient, 69.5 m dam height, EL.93.5 m dam crest elevation and 645 m crest length. Main dam include the second cofferdams with 35 m dam height at the upstream and 16.5 m dam height of the downstream, in order to reduce the volume of main dam.

Spillway is to be installed on the excavated ground at the right bank of the ridge. At the overflow portion is installed the arc-shaped free overflow weir with EL.83.8 m overflow crest elevation, 5 m dam height and 160 m crest length. The channel width being narrowed to 60 m at the downstream of the weir, the stream flows down on the steep inclines after passing through the ridge. Ski-jump type energy dissipator is provided at the edge of the spillway (EL.50 m). The capacity of the spillway was determined in consideration of maximum discharge of 5,200 m^3/sec. obtained from the flood control study of the reservoir in case of 1/1,000 probability flood.

Two intakes are installed at the left bank of the dam. The bed elevation of the intakes is fixed at EL.60 m, so that taking water can be made without difficulty even in the low water level of EL.73.1 m in the reservoir. The intakes are provided with two sluice gates and two man-holes for repairing of waterway tunnels and penstocks, as well as the screen and trash rack.

Headrace tunnels are composed of two penstocks each having an internal diameter of 6.2 m and tunnel length of 350 m. The penstocks have two parts: steel lining part at the upper portion of the tunnels and underground portion at the vicinity of power-house site, and exposure part at the middle portion.

Powerhouse is installed on the ground of the mountain foot at the downstream of dam left bank abutment. Adjacent to the powerhouse, switchyard is to be constructed. Powerhouse is of semi-underground type, the ground surface elevation of the powerhouse being fixed at EL.43.5 m with a freeboard of more than 1.5 m above the design flood water level. The powerhouse below the floor level of the generator room is constructed underground.

Tailrace tunnel route utilizes the eroded valley extended from the proposed powerhouse site to the river. The tunnel is an open channel made of concrete with trapezoidal cross-section. The rapid stream portion at Jeram Panjang was avoided as the proposed outlet of the tailrace. In order to get the effective water head as practicable as possible, the outlet of the tailrace is located at the end of the horizontal S-shaped stream, where the riverbed gradient is becoming gentle.

Moreover, the construction of No.1 and No.2 saddle dams is also required at Jeram Panjang site, same as required at Tualang site.