6.5. Engineering Geological Assessment

6.5.1. Damsite

1) Upper Damsite

Tekai upper damsite is geologically suitable for the construction of an earthfill, rockfill or concrete dam, but the height of the dam is limited by the topographic and geological conditions. Foundation preparation for the dam will involve removal of top soil and highly weathered rock down to generally moderately or slightly weathered rocks.

Fig. 6-6 shows the geological profile of the dam center. Over most of the damsite, the bedrock is obscured by a mantle of residual soil and a weathered zone on the slope. This mantle tends to increase in thickness with increasing elevation. It will be proper to strip the highly and moderately weathered zones for a concrete dam. For a rockfill dam, it will be best to strip completely and highly weathered zones. The stripping depths for concrete and rockfill dams are estimated for each of the drill holes as shown in Table 6-9.

Table 6-9 Estimated Foundation Stripping Depth at the Upper Damsite

Drill Hole No.	Concrete	Rockfill	
		Impervious section	Other section
	(m)	(m)	(m)
U-1	18.2	18.2	16.2
U-2	0.7	0.7	0.7
U-3	1.6	1.6	0.9
U-4	5.1	5.1	2.7
U-5	18.7	18.7	3.7

The stripping depths should be estimated at the detailed design stage, based on grade of weathering, quality classification of rock, RQD and permeability data determined by much more drilling work anyway, it is recommendable from the viewpoint of geological condition to adopt a fill-type dam at the site because the stripping volume for a concrete dam is enormous, as shown in Table 6-9, and a great deal of concrete material will be substantially required for the dam construction.

As shown in Fig. 6-5 and Fig. 6-6, the rock at the damsite is mainly composed of quartzose sandstone inter interbedded with shale. The fresh rock possesses great bearing capacity except for fractured zones. The dip of the strata tends upstream, although the strata have been folded. These conditions are favourable for a dam foundation.

Data from water pressure tests at the damsite are shown in Fig. 6-12. All sections with high leakage rates can be correlated with places of severe weathering or of open joints. Since the zones of high permeability occur essentially in the upper sections of the foundations, blanket grouting would be required over the full width of the impervious section of a fill-type dam.

The height of the dam will be limited to about 90 m in the case of the proposed dam center line U-A, based on topographic and geological conditions. In any case, it will be limited to 120 m under topographic restrictions.

2) Lower Damsite

Fig. 6-8 shows a geological profile of the lower dam center. Outcroppings of hard quartzose sandstone are found on the right bank of the river, but over most of the damsite the foundation rock is covered with a mantle consisting of residual soil and heavily weathered rock. The mantle tends to increase in thickness with increasing elevation, but the thickness is not so great as compared that of the upper damsite. The stripping depths for concrete and rockfill dams are estimated for each of the drill holes as shown in Table 6-10.

Table 6-10 Estimated Foundation Stripping Depth at the Lower Damsite

Drill Hole No.	Concrete	Rockfill	
		Impervious section	Other section
	(m)	(m)	(m)
L-1	9.3	9.3	7.0
L-2	3.3	3.3	3.3
L-3	1.0	1.0	0.5
L-4	7.7	7.7	5.1

The lower damsite is suitable for the construction of an earthfill, rockfill or concrete dam only from topographic and geological viewpoints, but the height of dam will be limited to about 60 m because the left ridge of the damsite is 70 m above the river bed and the weathered zones to be cut off are about 10 m in thickness.

As shown in Fig. 6-7 and Fig. 6-8, the damsite is composed of quartzose sandstone and shale, and the dip of strata tends simply upstream. This geological condition is favourable for a dam foundation, but there are high permeability zones in the upper sections of the foundation, as shown in Fig. 6-13, therefore, plenty of curtain grouting will be necessary to prevent water leakage.

6.5.2. Diversion Tunnel

From the topographic and geological conditions, the diversion tunnel at the upper site would be best located on the left bank. Since the tunnel will be excavated below the ground-water level, some water inflow can be expected during excavation. It is unlikely, however, that large inflow will be common, because the ground-water level is very low, as shown in Fig. 6-6, and the rock is generally tight, as indicated by permeability test of U-5.

There is some concern about stability above the tunnel portal, because the weathered zone at this point may be rather thick. This problem should be further investigated during the detailed design stage.

6.5.3. Power Station

The power stations at the upper and lower site would be located respectively on the right bank in view of topographical and geological conditions. Both proposed power station sites are covered with top soil and highly weathered rock, however fresh to slightly weathered rock may be distributed at the level of the river bed, and this is expected to have adequate strength as a formation. Further explorations will be required during the next stage.

6.5.4. Spillway

With an earth or rockfill dam at the upper site, the spillway can be located cutting through the left bank. Much of the spillway will be virtually founded on the moderately weathered rock. The sections of excavation above the spillway chute foundation will be composed of completely and highly weathered rocks. These materials are inferred from the results of the seismic prospecting and drilling work to be about 20 m in thickness. Batter slopes of 1 : 1 should be stable except for a portion of the overburden. Further explorations will be required.

6.5.5. Quarry Site

Rock around the upper and lower damsites is mainly composed of sandstone and shale. Fresh sandstone is suitable for construction material except rock in the sheared or fractured zones, while shale is generally unsuitable because of its cleavage.

Fig. 6-3 and Fig. 6-4 show respectively the proposed upper and lower quarry sites, where a large volume of hard sandstone is distributed.

At both sites, sound rock is covered with weathered rock, which may range from 15 m to 30 m in depth. The amount of stone dug out is given by the thickness and extent of the sound rock. A good topographical plan is necessary for detail investigation. At both sites, topographic maps on a scale of 1 : 10,000 were prepared by surveying in site, respectively, and then the geological conditions were expressed in cross-sections, from which the total volume of stone was computed. The total volumes of fresh rock in the upper and lower sites were roughly estimated to be 9.8×10^6 m^3 and 1.24×10^6 m^3, respectively. Exploration should, however, be carried out by drilling, seismic prospecting, technological tests, etc.

6.5.6. Borrow Site

Residual and highly weathered in site deposits are considered to be a source of borrow material, because they are composed of widely graded clay-sand-fine rock fragments which are good as impervious fill materials. In the project area, weathered zones are generally quite thick. A proposed borrow area at the upper site is shown in Fig. 6-3. It is located on the left bank of the Tekai River near the Termus River crossing, taking into consideration a short distance from the damsite and a possibility of a vast supply of material. Explorations should be executed prior to the definite study of the Project.

The flood plain and river bed deposits consisting of quartz sands, may be rather variable within short distance. Fig. 6-17 shows particle size distribution curves obtained by sieve analysis testing. The river deposits may form a satisfactorily fine aggregate because they consist mainly of medium-coarse-grained sand and fine gravel, as shown in Fig. 6-17.

6.6. Seismicity

Some recent works have revealed characteristics of seismicity which are of great interest with reference to major techtonic mechanisms and patterns. It is pointed out that virtually all the epicenters are located within a degree or so of the topographic rift.

Fig. 6-18 shows the seismicity of the earth in southeast Asia over the 1961 - 1967 period. The distribution of the epicenters makes a belt along the Indonesian arch. On the other hand, there has been no earthquake over magnitude 4 on the Malay Peninsula. In fact there is a remarkable rift along the western front of the Indonesian arch on which the epicenters are scattered. The Malay Peninsula forms one part of the Sunda Shelf, which is very stable against crustal movement of the earth, and, therefore, there have been no remarkable earthquakes within it.

Fig. 6-19 shows earthquake accelerations which are inferred from earthquakes with known magnitude, depth and location of epicenters. It is assumed that earthquake acceleration on the Malay Peninsula is less than 0.01 g (≒ 10 gal).

CHAPTER 7

HYDROLOGY AND METEOROLOGY

7.1. General

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

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

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

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

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

7.1.1. Atmospheric Temperatures

The atmospheric temperature recording from 1972 to 1979 shows that the average annual atmospheric temperature at Kuala Tahan near the Tekai River is 26.0 degrees centigrade (°C). In terms of the monthly average air temperatures, May registered the highest of 27.1°C, while January registered the lowest of 24.1°C. The difference between the highest average temperature and the lowest is only 3.0°C, indicating that there is apparently very little variation in temperature throughout the year.

On the other hand, there is comparatively a greater variation in temperature during the day. Usually temperatures are lowest at 6:00 a.m., and hottest at around 1:00 p.m. The difference between the highest and lowest temperatures during the day exceeds 6°C even at mean values.

7.1.2. Relative Humidity

At Temerloh, a city located at the center of the Pahang river basin, the average humidity throughout the year registers as high as 86 percent. There is little variation in humidity throughout the year, with a minimum of 85 percent occurring in March and April, and the maximum of 89 percent in November. The difference between the maximum and the minimum humidities is only around 4 percent. The variation during the day is larger than the seasonal variation.

7.1.3. Sunshine Duration

The average sunshine duration throughout the year is 5.79 hours at Kuantan on the east coast; 4.67 hours at Cameron Highlands, situated at the high altitude part of the Pahang River Basin. Here it is six to seven hours during the dry season from February to April, and four hours in the rainy season from November to December.

7.1.4. Evaporation

The annual amount of evaporation along the Pahang River Basin is about 1,800 mm, measured by the Class A (black) pan. It is evenly distributed throughout the year except during the north-east monsoon season. The annual evaporation is registered at 1,200 mm at the high-altitude Cameron Highlands, at 1,270 mm at Kuala Tahan, situated on the middle course of the Pahang River, and at 1,660 mm in the coastal areas of Kuantan.

The value of the actual evapotranspiration is almost equal to that of evaporation, due to high humidity.

7.1.5. Wind

The wind blowing over the Pahang River Basin is gentle throughout the year. The average wind velocity is 1.7 m/sec. in the coastal areas, and less than 0.37 m/sec. at Kuala Tahan. The directions of the winds in the coastal areas are mainly north to north-east from December to March, and west to south-west from June to October, with the highest velocity for the north-east wind.

The north-east wind is also the fastest in velocity in the areas of 5 degrees North Latitude or farther south since these areas lie outside the typhoon belt.

7.2. Rainfall

7.2.1. General Rainfall Characteristics

The rainfall in Peninsular Malaysia was firstly studied by Dale. He divided Peninsular Malaysia into five rainfall regions as shown in Fig. 7-2 and distinguished the characteristics of rainfall in each region as follows:

(i) North West Region, which has peaks in rainfall during both the post-equinoctial transition periods between monsoons, low rainfall during the north-east monsoon, and moderate precipitation during the south-west monsoon. The plain of Kedah and Perlis receives less rain than the Kedan Peak, as well as the mountainous parts of Penang and south Kedah.

(ii) West Region, which has peaks in rainfall during the transitional periods; often the first (April) is more intense but of shorter duration than second (October and November) during which there is more rain in total. Fair amounts of rain are received during the north-east monsoon. The period of the south-west monsoon has least rain, especially in July.

(iii) Port Dickson-Muar Coast Region, which sometimes has rain during the first transitional period. Usually there is a steady buildup during the north-east monsoon to a maximum during the second transitional period, followed by little rain during the south-west monsoon.

(iv) South West Region, which has a rather equitable distribution of rain throughout the year. Rainfall is low inland, and increases towards the coast.

(v) East Region, which has heavy rainfall during the north-east monsoon and a very little rain during the rest of the year.

Fig. 7-2 shows the typical seasonal rainfall pattern of each region.

7.2.2. Annual Rainfalls

The isohyetal map shown in Fig. 7-3 was made by the MMS, using annual precipitation records kept by 97 climatological stations for the ten years period from 1961 to 1970.

The average annual rainfalls range from 2,060 mm at Mentekab (at the basin center) to 3,630 mm at S. Lembing Hospital, (at a typical location representing the East Coast Range).

The rainfall in Trengganu and the border areas to Kelantan is little known, as there are only 21 stations to observe rainfalls at higher places with 300 m or more above sea level.

The annual average rainfall along the Pahang River Basin is estimated at 2,300 mm to 2,400 mm.

There are two rain gauges, station No. 4227001 and 4127001, installed in the Tekai River Basin. The recordings at the gauges started as recently as in 1974, and there have been many occasions when no measurements were taken. The readings at the gauges, therefore, cannot be taken as the representative average rainfalls in the Tekai Basin. However, supplemented by the recordings done at the nearby stations, the average rainfall in the region is estimated to be about 2,300 - 2,400 mm.

7.2.3. Monthly Rainfalls

1) Monthly Rainfalls in the Pahang River Basin

Fig. 7-3 shows month-to-month distribution patterns of rainfalls recorded at the stations with significant monthly variations (Kuantan, Mentekab, Cameron Highlands) within the Pahang River Basin.

Table 7-2 shows monthly average rainfalls at the three typical stations selected from the stations shown in the Fig. 7-3, together with their standard deviations, maximum values and minimum values per month.

From the above figure and the table, the followings have been determined:

(i) In the east coast region represented by Kuantan, there is large seasonal variation in rainfall. (Coefficient of variation, 0.60)
Nearly the half of the annual rainfall occurs during the north-east monsoon season that lasts from November to January.

(ii) At higher places represented by the Cameron Highlands, the annual rainfalls are most evenly distributed throughout the year. The maximum rainfall occurs in April and October, when the monsoons change their course.

(iii) The middle course areas represented by Mentekab is the driest region, having little variation in annual rainfall.

(iv) In general, the driest time in the basin is from June to July. The rainfall, however, falls at a minimum in February during some years.

Table 7-2 shows data observed at Kuala Tahan. The values show characteristics very similar to those recorded in the middle course region.

2) Monthly Rainfall in the Tekai River Basin

The recording of rainfall in the Tekai River Basin started, when three digital rainfall recorders were installed, with the technical assistance of the Australian Study Team under the Colombo Plan.

According to a map of climatological stations obtained in July 1981, these recorders were installed at station No. 4227001 and 4127001. However, data are from the recordings of the period of only several months.

Correlation regression analysis was conducted, using these data and data obtained from the nearby stations.

Judging from the regression equation of data obtained from the station No. 4227001, the monthly rainfall around station No. 4227001 in the Tekai River Basin is estimated to be larger than the rainfalls recorded by other stations. In contrast, station No. 4127001 registered smaller observation values.

Table 7-3 Monthly Rainfall Data Used in Correlation Analysis

Station No.	Station Name	70	71	72	73	74	75	76	77	78	79
4324113	Kuala Tahan Taman Negara										
4227001											
4127001											
4023001	Sg.Yap										
4223115	Kg. Merting										
4023117	Sek. Keb. Kg.Tembeling										
3933003	Balok Kuantan										
3924072	Paya Kangsar Pumphouse										
3828091	Ulu lepar Estate										

(Source; N.W.R.S.)

7.2.4. Rainfall Depth-duration-frequency Relationships

Fig. 7-5 shows regional distribution of maximum daily Rinfall and maximum continuous five days rainfall in the two years return period and 100 years return period for each rainfall. The distribution map was prepared based upon the records of 34 years kept at 30 stations in the basin.

As can be seen from the map, the north-eastern part of the basin has the largest rainfall, while the western part of the Basin has the smallest.

Fig. 7-6 shows the intensity curves of short rainfalls based upon the observations conducted at Kuantan and Cameron Highlands. Some curves in the figure are obtained by the logarithmic normal distribution method, and another curves are based on the Gumbel method. The figure shows that the Gumbel method usually yields higher estimate values than the logarithmic normal distribution method.

Table 7-7 shows maximum rainfalls of 15 minutes to 10 days durations observed at four climatological stations. Three stations on the east coast came up with similar results, while the station at Cameron Highlands yielded far smaller observation values, an apparent characteristic of the western part of the Basin.

7.3. River Runoff

7.3.1. Examination on the Discharge Data of the Tekai River

Since 1972 the National Electricity Board (NEB) has been conducting observations of the water level of the Tekai River at Penut, 5 km upstream from the confluence of the Tekai River and the mainstream Tembeling River. The NEB is also conducting the same types of observations at Kuala Tahan on the Tembeling River, which is 15 km upstream from the confluence of the two rivers.

1) Examination of Water Level-Discharge Curves

Observations of discharges against water levels have been done since April, 1972, and about 90 different measured values have been obtained. So far, the maximum water level observed is 3.31 m, and the maximum discharge observed is 150 m^3/sec. The observation of discharge at high levels are not obtained.

The relationship between water levels and discharges cannot be shown in one rating curve according to the results of these observations. As the ratings fluctuate year to year, the following equation was obtained by comparing the observation results of each year. (Please refer to Fig. 7-9 - 15) Our results show close correlations with the rating table made by the NEB. Likewise, an excellent rating curve was obtained at Kuala Tahan.

7.3.2. Comparison of Discharges

The data analysed by the catchment area-discharge ratio conversion at Kuala Tahan practically corresponds to the discharge data at Penut.

7.3.3. Discharges at the Dam Sites

The discharge to be used for the Tekai Hydro-electric Development Project was obtained by converting discharge at Kuala Tahan into a value over the entire basin, since some observations were not done for discharge at Penut, and a runoff at the Tekai River Basin is small in spite of the fact that the Basin is situated in the rain belt.

The lack of the data mentioned above was supplemented by the following procedures:

(i) Where discharge data at Penut are available, discharge at Kuala Tahan was obtained by regression equations based upon discharge correlation analysis for each month.

(ii) Where discharge data at Penut are not available, but the lack of observation is only for a short period, reduction of discharge was taken into consideration upon supplementation. When data are not available for a longer period of time (June and July, 1976), they were supplemented by taking account of monthly discharge for the same month of some other years.

- Discharge at the Lower Damsite:

$$Q_{LD} = Q_k \times \frac{A_{LD}}{A_k}$$

- Discharge at the Upper Damsite:

$$Q_{UD} = Q_k \times \frac{A_{UD}}{A_k}$$

Where Q_{LD} : Discharge at the Lower Damsite
Q_{UD} : Discharge at the Upper Damsite
Q_k : Discharge at Kuala Tahan
A_{LD} : Catchment area at the Lower Damsite
= 1,390 km^2

A_{UD} : Catchment area at the Upper Damsite
= 1,200 km^2

A_k : Catchment area at Kuala Tahan
= 3,220 km^2

The annual average discharge at the Upper and the Lower Damsites, obtained by converting the discharge at Kuala Tahan into the rate over the entire basin, are 40 m^3/sec. and 46 m^3/sec., respectively.

Table 7-9 shows the flow regime of each damsite. This table shows that the year 1977 was a dry year. The annual average runoff at the Lower Damsite was 1,470 x 10^6 m^3, and the annual depth of runoff was 1,060 mm. The average rainfall along the Tekai River Basin, estimated by the results of correlation analysis of monthly rainfall and the rainfall at Kuala Tahan (Aug = 2,100 mm), is 2,300 to 2,400 mm. Assuming that the actual evapotranspiration is 1,300 mm, the annual depth of runoff estimated at 1,060 mm may be appropriate.

7.4. Floods

7.4.1. Historic Floods

Floods in the Pahang River Basin occur during the north-east monsoon season from the latter half of December to the beginning of January. Historic floods include those in 1926, January 1971, and December 1972. Fig. 7-19 is an isohyetal map provided by the Malaysian Meteorological Service (MMS). The map shows that the upstream area of the Tembeling River, that is, the bordering area to Trengganu, is a high-rainfall area.

(i) 1926 Flood

The scale of the flood was the largest in the present century. Since the Basin was not adequately developed at that time, the region narrowly avoided devasting damage.

(ii) January 1971 Flood

Heavy rains began to fall on December 26th, 1970. The rainfall for that day registered 314 mm on the East Coast, 104 mm in the Tembeling Basin, and 109 mm in Jelai Basin. The downpour weakened on the 29th over nearly all areas, but it began again on 30th, and continued to rain until January 5th, 1971. The maximum rainfall for the day registered at 341 mm on the East Coast, 142 mm in the Tembeling River Basin, 124 mm in the Jelai Basin, 154 mm in the Semantan Basin, and 221 mm in the Teriang Basin. The peak of the flood along the main tributaries was on January 4th and 5th.

For the 40-year period from 1931 to 1971, there had been no major floods, and hence urban and agricultural developments had been carried out in low-lying areas, which were inevitably more vulnerable to floods. As a result, most of the commercial and residential areas at Mentekab, for example, were submerged. At Sungai and Semantan, the water levels were raised almost up to the rails on railway bridges. The total amount of damage reached as high as 380 billion Malaysian dollars. The number of the persons killed was 24, and 153,000 persons were evacuated. The scale of the flood damage was, therefore, the largest in Malaysia's history.

(iii) December 1972 Flood

The rain began on December 11, and continued up to December 23. The maximum rainfall recorded for the entire period of 13 days was 1,150 mm on the East Coast, 440 mm in the Tembeling Basin, and 298 mm in the Jelai Basin. This torrential rain was characterized by the fact that it poured most heavily on the eastern half of the basin. The damage was especially heavy in the cities of Pekan, Temerloh and Mentekab. The total amount of damage reached 60 billion Malaysian dollars.

7.4.2. Probable Flood Discharges

Fig. 7-21 shows regional flood frequency curves for the Pahang River Basin. To obtain the curves, water levels - discharge recorded at six climatological stations in the Pahang River Basin were first subject to probability process in frequency by Gumbel's moment method, then the relationship between probable discharge and the catchment area was plotted graphically on logarithmic paper.

The validity of assumption of this figure was verified by the water levels and discharge obtained at five stations (Table 7-10).

Accordingly, the Pahang River Basin was divided into the following two regions:

- S. Tembeling and East of S. Pahang (Region 1)
- S. Jelai and West of S. Pahang (Region 2)

Thus the Tekai River Basin belongs to Region 1, and the probable flood discharge of the 100 year return period is about 3,000 m^3/sec. at the Lower Damsite.

(Source; 3.7 and Ex. 11, Vol. 3 Pahang River Basin Study)

7.4.3. Design Floods at the Damsite

Dams are artificial structures which are built to bar the natural flow of rivers, and to store or take in river water semi-permanently. In designing dams, measures should be taken to safeguard the dams against floods at the damsites.

The flood discharge to be considered in designing dams is the probable flood discharge of the 1,000 years return period of the maximum probable flood predicted to occur at the damsites.

The design floods at the Damsite planned in the Pahang River Basin were calculated by the unit hydrograph method.

Fig. 7-22 shows envelope curves based upon design floods employed by another project. In the figure, four distinct zones are identified.

Table 7-11 Design Flood Characteristics

Damsite	Tekai Lower	Tembeling Upper	Tembeling Lower	Telom/Jelai Kechil
Area (km^2)	1,390	2,850	5,150	2,090
5-day Rainfall (mm)	1,680	1,680	1,680	640
Mean Point Rainfall	1,230	1,260	1,180	640
Unit Hydrograph Log Time (hr)	24	30	40	20
Initial Base-flow (m^3/sec.)	110	230	420	200
Effective Rainfall (mm)	740	700	480	290
Inflow Peak (m^3/sec. × 10^3)	5.01	8.67	10.17	5.71

(Source; 3.5.13, Vol.3 Pahang River Basin Study)

7.5. Sediment

7.5.1. Observations of Running Sand

Periodical observations of sediment have not been done on the Tekai River. Such observations on the Pahang River started only as recently as in 1972.

The Drainage and Irrigation Department (DID) is now conducting sediment observations on the Pahang River at five points shown on Table 7-12.

Table 7-12 Steam Flow Stations with Sediment Data

Station No.	Station Name	Catchment Area (km3)	Data Period	Average Sediment Concentration (ppm)
3423421	Semantan	2,920	72-78	110
3424411	Pahang	19,000	72-74	140
4019462	Lipis	1,670	72-76	130
4023412	Pahang	13,200	72-74	150
4223450	Tembeling	5,050	74-77	130

(Source; N.W.R.S.)

7.5.2. Sediment Concentration

According to available data; the sediment concentration on the Pahang River is approximately 110 to 150 ppm. On the Tekai River, a project team took three samplings at each of the five designated points from July 1981 to September of the same year. Analyses of the samplings indicate that the sediment concentration on the Tekai River is 10 ppm or so. This means that the Tekai was clearer than the main course of the Pahang. This may be partly due to the fact that the sampling on the Tekai River were taken in the dry season.

7.5.3. Siltation of Reservoir

The siltation of a reservoir depends mainly on the amount of precipitation, the gradient of the stream, the geology of the area and the character (if they are bare or overgrown).

A precise determination of the amount of coarse, material such as sand and gravel is possible only by measuring the volume of the deposit after damming the river for several years.

According to reports of measurements for some reservoirs, the amounts of sediments silted up in reservoirs of forested land are generally less than 100 m^3/km^2 per year.

*Namba proposed an experiential equation (1) for the amount of sediment silted up in a reservoir, depending upon the results of measurement for a number of dam reservoirs in Japan.

$$E = 0.02743 \times \frac{PR}{F} - 240.9, \quad \ldots\ldots \quad (1)$$

Where
E : amount of sediment per year (m^3/km^2)
P : mean annual precipitation (mm)
R : relief energy (mm)
F : percentage of forest area (%)

For this project area, the values of P, R and F are respectively supposed as follows:

$P = 2,400$ mm, $R = 500$ mm, $F = 100\%$.

Using equation (1), the amount of sediment can be calculated, i.e., $E = 88.3\ m^3/km^2$.

Making allowances for the possibility much more sedimentation, it may be appropriate to apply a volume of 100 m^3/km^2/year as the amount of sediment for the project area.

Since the catchment area of this project is approximately 1,200 km^2, the total amount of sediment is inferred to be 120,000 m^3 per year ($1,200\ km^2 \times 100\ m^3/km^2$).

* Source; Senji Nanba, Laboratory Report No. 173 (1965), Forestry Test Laboratory, Japan

7.6. Evaporation

7.6.1. Evaporation

The Drainage and Irrigation Department (DID) and the National Electric Board (NEB) are currently conducting the observations of evaporation on the Pahang River Basin.

Fig. 7-24 shows the relationship between elevation and evaporation obtained from the Class A Pan Evaporation values at DID stations, mainly in low-lying areas, and at NEB stations.

Judging from the Class A Pan Evaporation in the Pahang River Basin, seasonal variations are relatively small, and the data for the same month of the year do not fluctuate for many years.

Table 7-13 shows monthly average evaporations and standard deviations at three representative stations in the Pahang River Basin and at Kuala Tahan near the Tekai River Basin. The maximum evaporation was recorded around May, and the minimum evaporation, around December. The range of variations is 20 to 25 percent of the monthly mean value.

7.6.2. Actual Evapotranspiration

Where records of rainfall and runoff are available, actual evapotranspiration can be obtained by calculating the difference between rainfall and runoff.

Table 7-14 shows the results of such calculations using the data obtained from the stations in six basins in Peninsular Malaysia and in the Tekai River Basin.

Fig. 7-24 shows the relationship between elevation and actual evapotranspiration. The actual evapotranspiration in the Tekai River Basin is estimated to be approximately 1,280 mm, assuming from the annual rainfall at Kuala Tahan.

CHAPTER 8

ENVIRONMENTAL ISSUES

Chapter 8 Environmental Issues

8.1. Outline

In development of the Project, it is necessary to predict effects of the development activities on environments, and to examine the plans beforehand. To grasp the present status of natural environments existing at the proposed sites, therefore, forms a vital initial requisite in order to foresee the effects of development upon environments and possible changes in future. The survey for the Project was thus conducted so as to grasp general environmental conditions, prior to the field survey required to grasp effects of the Project upon environments.

In relation to the development project, however, detailed scientific studies on natural and social environments have not been made up to the present. In preparation of the Report, the field investigation, visits to related organizations and hearings were made to collect data. Hearings were held for following organizations, and related data were provided by them.

Item	Name of Visited Office
Environmental Aspects	Ministry of Science, Technology and Environment, Environmental Division
Fishery	Agriculture Ministry, Training Division
Archaeology	National Museum
Animal	Dept. of Wildlife
Forestry	Forestry Reserach Institute
Forestry	Dept. of Forestry
Zoology	Zoological Dept. University of Malaya
Public Health	Medical Research Institute
Wildlife	Wildlife Dept. of National Park
Regional Plan	Economic Planning Unit of Pahang State

(To be cont'd.)

Item	Name of Visited Office
Forestry	Forestry Dept. of Pahang State
Fishery	Fishery Dept. of Pahang State
Public Health	Medical Dept. of Pahang State
Agriculture	Agriculture Dept. of Pahang State
Hydrology, Meteology	National Water Resources Study Team

The site under this Project (annual rainfall 2,200 mm) is classified as tropical rain belt, according to the meteorological classification by Troll, C.* The rainfalls in the West Malaysia show characteristics in annual and monthly rainfalls for different areas due to the effects of hilly mountains located both at the east and west of the Malay Peninsula, as shown in Fig. 8-1. Characteristics of the site, as seen from the figure, indicate that the rainfalls of this site are greater than those of the place located at the south of the Malay Peninsula. Nevertheless, the rainfalls are not markedly heavy as in the case of typical mountain area. Fig. 8-2, on the other hand, shows monthly rainfalls of Kuala Tahan located approximately 30 km north to the project site. The distribution of monthly rainfalls does not exhibit significant monsoon-type seasonal changes between the rainy season and dry season, as observed in the coastal areas such as Kuantan, Pekan, etc., measuring locations intended for this project, shown in Fig. 8-1, but the same tendency as in the cases of K.Lipis, Ipoh, etc. is observed. In this sense, it may be said that weather conditions around the project site will show relatively even monthly rainfalls for tropical rain weather.

The florae at the project site falls under the category of tropical rain forest. The characteristic features of the forest are said to have the most complex structure among the plant communities in the world, with an extreme variety in composition of botanic species, having very high productivity. Animals living in this rich forest are, therefore, also various, and the protection of wild animals in the tropical rain forest began to draw attention of people concerned.

* Troll, C.: Seasonal Climate of the Earth (1966)
World Map of Climatology, Springer

Of finny tribes living in the Pahang State, many kinds of fishes are edible, and hence fish markets exist in vital locations. Since the Tembeling River is said to be one of routes for racial migrations from the Continent of China, some archaelogical remains have been also confirmed.

The present land utilization shows that a certain degree of agriculture is established along the Tembeling River, and the forest is a national forest akin to primeval forests, with many of the areas designated as forestry conservations. As for the forestry, useful lumbers are being utilized with emphasis placed on cutting lumbers.

As a whole, it may be said that the region is superior in natural resources to economic activities.

Under the hydro-electric development project, dams, power plants, waterways, roads, etc. will be constructed. Through the construction of dam banks, a dam lake will appear at the upperstream, while variation in river discharge will occur at the downstream. Additionally, due to the construction of power plants, waterways or roads, substantial changes will occur as the surface plants will be cut off and the ground will be digged, banked, etc.

Under this Project, both upper and lower dams will have large-scaled dam lakes (upper dam: approx. 105 km^2, the max. water depth 83 m or so; lower dam: approx. 24 km^2, max. water depth 33 m or so), as mentioned in Chapter 9. Water level fluctuations for the upper reservoir are very mild with the maximum fluctuation velocity of 60 cm/month, due to its large scale.

In this chapter, it was decided to make rough predictions and studies on effects of the construction plans mentioned in the foregoing upon hydrological conditions, biota and socio-economic conditions. When making predictions, the present status was grasped based on available data obtained so far concerning the environments in the proposed site. It should be noted, however, that more direct surveys on environments in the proposed site will be necessary, due to the fact that available data cover only hydrological aspects such as water properties, etc. This Chapter, therefore, may be said to be of study nature on possible general effects that may occur by the construction of dams.

8.2. Effects on Water Regions

8.2.1. Effects on Flowing Conditions

1) Present status

Terrestrial waters at the proposed site and its surrounding areas are all rivers, and no lakes, swamps, mining pools, paddy fields or other sealing-up-type water areas have been found so far as the field surveys and topographical explorations are concerned.

As for discharges, the mean discharge is about 4 x 10^6 m^3/day at S. Penut (Basin area 1,390 km^2) located at the downstream of the lower dam in the Tekai River, as mentioned in Chapter 7 of the Report. Water level fluctuation between the flood conditions and the minimum flow (low water) is 7 m or so at the same location during the observation period.

2) Predicted effects

It is predicted that certain changes will occur in the downstream flowing conditions according to durations of construction and operation. The present plan is as follows: the total storage will be 3,400 x $10^6 m^3$ for the upper reservoir, and 265 x 10^6 m^3 for the lower reservoir; since the annual discharge at the lower dam site is expected to be 1,440 x 10^6 m^3, the river discharge equivalent to the total discharge for 2.5 years will be reserved upon completion of both dams. It is thus probable that aquatic animals and water plants will be subject to certain effects by the above. Namely, due to the lowering of water level, finny tribes and amphibia making use of the waterside for spawing, etc., and vegitations at the waterside will go through certain changes in their births and breedings. Further, because of dams, the running sand and earth will be held, resulting in changes in gravel silting. In practice, therefore, it will be necessary to take adequate measures so as to minimize such effects on the downstream areas, by starting partial water filling during the process of the works, initiation of the operation of power plants as soon as the fillings reach the water levels to allow power generation, etc. It is thus desirable to carry out more detailed surveys on effects of dam construction to be placed on the downstream basin, including the above mentioned questions, and to examine the appropriateness of filling velocity.

As regards effects of dam lakes after the storage of water, such effects may be roughly classified into those related with the emergence of dam lakes and those related with changes in downstream river discharge. Due to the emergence of dam lakes, the area will change from river(s) to a water area of lakes and swamps. Because of this transfer into lake and swamp area, hydrological changes will occur. Other effects on inorganic environments will include effects on soil, geological characteristics or underground hydrological properties. In addition, changes will occur in the soil and water content in the earth caused by fluctuations in underground water levels, and landslides, etc. may take place as a result. It is also predicted that sand and earth may flow into dam lakes, and sufficient safeguards will be necessary so as to prevent soil flow losts and landslides when developing riparian areas.

As for changes in river discharge at the downstream due to the emergence of dam lakes, the downstream flowing conditions may be stabilized through the discharge adjustment by the reservoirs, while the water control efficiency and stable supply of agricultural irrigation may be ensured at the same time. On the other hand, adequate preliminary surveys will be necessary concerning environmental effects caused by influences in the downstream areas, since the effect of rapid discharge from the dam flood discharge outlets at the time of floods may also arise.

8.2.2. Effects on Water Properties

1) Present status

In order to predict changes in water properties that may be affected by the dam construction, the present status of water qualities was investigated at both damesites and 5 points at the downstream (see Fig. 8-3 and Table 8-1). According to the results of water quality tests, no significant characteristics are observed. It may be said that the content of nitrogen compounds is somewhat high, but this does not exhibit a notable characteristic. As compared with observation results obtained at a further downstream location of the Pahang Basin, however, it should be noted that mild alkaline tendency was found at the downstream through all recent tests repeated 4 times (July, September-twice and October), in comparison to the mild acidity that had been found in June (see Fig. 8-4 and Table 8-2).

2) Predicted effects

Occurrence of turbid water is predicted for the dam construction period and the period between the completion of dam construction and the stabilization of the surface. Turbid water will affect on aquatic or water utilizing animals and aquatic plants. It will also exhibit an adverse factor for the utilization of the water system and scenery. It will be, therefore, vital to take measures to control the occurrence of turbid water except for inevitable cases.

Due to the emergence of dam lakes, the areas will transfer from river system to lake and swamp system, and it is predicted that the water properties in the water areas will go through drastic changes from the initiation of filling to subsequent few years. Although the areas will be stabilized gradually, several points should be noted in relation to environmental effects, as the areas of dam lakes under the Project are large and water depths are also great.

As for changes in water properties during the stabilization period, plants located at areas to be sunk at the bottoms of the dams will be rotten in the water and generate hydrogen sulfide, etc. by the consumption of oxygen. In addition, water properties in the dam lakes may change considerably as compared with those at the time the water is flowing, due to the effluent from the earth and sand flowed in there from the surface soil. While such changes in water properties will affect on the biota in dam lakes and at the downstream areas, it will be stabilized gradually in years to come.

A long-term prediction reveals that water properties in dam lakes will go through enrichment and nutrition processes. Namely, nitrogen compounds already existing in the present water properties to a certain degree will increase due to the flow-in of organic matters to the dam lakes, and the separation of plankton, etc. will be facilitated owing to the rise in water temperature at the upper layer of each dam lake, resulting in medium-scale enrichment and nutrition.

8.3. Effects on Biota

Since it has been difficult so far to obtain practical data for effects on biota that may be caused by the dam construction, this Section only deals with data on plants (trees in particular) and animals (mammalia and edible fishes in particular).

8.3.1. Effects on Plants (trees)

1) Present status

The proposed site and the surrounding areas are included in the Tekai-Tembeli-NG Forest Reserve. Furthermore, the forest belt is also a national forest under the jurisdiction of the Ministry of Forestry Department at present, and a future forestry policy is also planned by JENGKA (Forest Public Corporation).

As mentioned earlier, the type of the natural forestry vegitation of the site is of tropical rain forest. This tropical rain forest generally has a rich composition of various kinds of plants. A clear classification of forest layers is difficult, with many of which having complex structures. It is said that *"the heights of trees on the topmost layer are quite high, and the slimness and straightness are observed as a distinctive feature throughout upper and lower layer trees. The heights of trees range from 25 to 35 m, and the crown covers the entire forest continuously in abundance. Huge layers of tall trees protrude above the crown non-continuously."

No ecological study results in which the proposed site is discussed have been found so far. In this respect, Table 8-3 is cited in the Report to show the record of lumbers cut off from the forest lumbering area adjacent to the proposed site, as a similar environmental indication. Kinds of trees listed on the table are limited to those to produce useful lumbers with high economical values due to the purpose of the recording. Therefore, the record does not cover the entire forest tree composition in the areas.

*Source; Fusato Ogawa, Tropical Ecology I (1974)

The kind of trees consisting the majority of the forest composition is deptrocarpaceae family, and the rest of trees are those which grow in the forests of deptrocarpaceae family.

According to *J. Wyatt Smith who made the classification of depterocarp forests, depterocarp forests may be roughly classified into "Lowland depterocarp-forests (approx. 300 m above sea level), "Hill depterocarp-forests (approx. 300 to 750 m above sea level) and "Upper depterocarp-forests (approx. 750 to 1,200 m above sea level)."

All of the above is of forest phase containing various kinds of depterocarp tall trees, many of which commonly found in these forests. The height of the submerged area by this project is most likely around EL. 80.00 - 500.00 m. It may be thus assumed that the proposed site consists of lowland depterocarp forests and hill depterocarp forests.

Due to the absence of scientific surveys on the forests at the proposed site, trees of rare species, etc. have not been determined. According to the impression obtained by partial explorations, however, it may be said that agriculture by a slash-and-burn land method was conducted but with a limited areal scale. Existance of rubber or coconut palm plantations has not been reported. The forest classification of the planned site is, therefore, mainly of primeval forest or secondary forest nearly resumed to the conditions of the primeval forest.

* J. Wyatt Smith: Malayan Forest Records, No. 23

2) Predicted effects

Effects on plants will be to some extent, resulting in extinction or serious damages of plants caused directly or indirectly by the installation of various structures, various construction activities, emergence of dam lakes, etc.

The emergence of dam lakes in particular will have direct effects on plants at damsites due to the fluctuation in underground water level. In longer-terms, waterside moist botanic communities, water-surface floating type botanic communities and aquatic botanic communities may develop. At the waterside, changes in botanic life due to the changes in soil content caused by water level fluctuations may occur.

For plants perished or damaged by the construction works, it is recommendable to ensure initial recovery of the present conditions as much as possible, through upmost afforestation efforts, so as to recover the ground coverage and to prevent soil flow-outs.

For botanic species that may intrude anew to the site due to the emergence of sealing-up areas, steps should be taken to restrict the propagation of species that may impair functions of the dams. The propagation of floating water plants such as hyacinth, etc. should be also restricted in terms of proper control of enrichment and nutrization.

Lumbering of the present forests will be made accompanying the filling of dam lakes, and it is desirable to remove standing timbers and branches of trees as much as possible beforehand, since they will give adverse effects on water quality.

8.3.2. Effects on Animals

1) Present status of large mammalia

The proposed site is tropical rain forest zone with extremely few artificial surroundings. In view of the high production power of the forest zone, the contribution to the animals is assumed to be very high. A clear understanding of animal living conditions is, however, not grasped due to the absence of scientific surveys at the proposed site. The northern region of the State of Pahang, on the other hand, has national park(s), with relatively many remaining forests of highly primitive nature, as compared with the rest of regions in the Malay Peninsula. The State of Pahang is vast in area but at the same time it is blessed with a great number of large mammalia, partially due to the environmental background.

Fig. 8-5 shows the distribution of numbers of such animals such as elephants, seladangs and rhinoceroses throughout the nation. It can be seen from the figure that the State of Pahang has more animals than other states. Table 8-4 shows a comparison of numbers of animals between the year 1965 and 1968, indicating a substantial decrease of animals in number. This reduction in area of tropical rain forest zone is said to be one of major causes for the reduction of animals in number. When the tropical rain forest zone is developed into rubber or coconut plantations, animals will be apt to move into further deep areas, together with the reduction of animals in number. The phenomena are said to be applicable to the forest zone located at the northern region of the State of Pahang.

As mentioned earlier, living conditions of large mammalia are not clear due to the absence of scientific surveys.

Table 8-4 Comparison of Numbers of Rhino and Elephants, Seladang in Malaysia

	Rhino	Elephant	Seladang
1965	47	692	706
1968	20	482	346

(Source; Malaysia Environment and Development, A World Bank Environmental Mission, 1975)

2) Present status of small and medium mammalia

As in the case of large mammalia, no field surveys were made on small and medium mammalia at the proposed site. Considering the high productivity of the tropical rain forest zone, it may be assumed that various small and medium mammalia still exist at the proposed site.

Major species of such animals are as follows, according to the distribution chart(s) for small and medium mammalia in tropical rain forests given by the survey report on Trengganu (Trengganu Hydroelectric Project Environmental Appraisal Report - 1978) and the medical-ecological survey report prepared by I.M.R. in September, 1978.

Namely, civets, musangs, weasels, squirrels, monkeys, rats, bats, etc. still exist. It is also indicated that various primates in particular, which hold a key to the mystery of the human evolution, still live in the Malay Peninsula, as shown on Table 8-5.

Table 8-5 Density of Primates in Forest

Species		Density of Species (Animal/km^2)	
		Secondary Forest	Primary Forest
Macaca fascicularis (Long-tailed Macaque)	*	1.54	0.37
Macaca nemestrina (Pig-tailed Macaque)	*	0.13	-
Presbytis cristana (Silvered-leaf Monkey)	*	0.26	-
Presbytis melalophos (Banded-leaf Monkey)	*	2.95	2.22
Presbytis obscura (Spectacled or Duskey-leaf Monkey)	**	0.64	0.74
Hylobates lar (White-handed Gibbon)	*	0.89	1.11
Hylobates syndactylus (Siamang)	*	0.51	1.11

Notes: * protected animals
** totally protected animals

(Source; Man's Impact on the Primates of Peninsula Malaysia)

3) Effects on mammalia

Effects of dam construction during working process include blasting impact noises and human activities. After the completion of construction works, such effects include changes in environments at watersides and sandy places caused by the emergence of dam lakes and changes in river discharge. Perished or damaged forests caused by the emergence of dams and other construction works will not only threat the food sources for animals but also change living environments for animals, such as their hiding places, resting places, breeding places, etc. It will be thus necessary to grasp the present status of mammalia in the planned site and to pay adequate attention to their vital issues.

4) Present status of finny tribes (fishes)

Sealing-up areas such as lakes and swamps do not exist around the proposed site. Existing fishes are all of flowing water type, but no surveys have been made on the living distribution of fishes.

Available data at present cover only fishes caught at the Tembeling River and sold on the market. Table 8-6 shows the data, but fishes listed on the table are naturally limited to edible fishes, mainly consisting of carps and like. The kind of fish that should be particularly noted is jelawat. Jelawat is also called "King's fish," and its length becomes as long as 50 cm when it grows up. The habitats are limited, and it is an expensive fish particularly fond of cold water areas such as rapids.

Table 8-6 Principal Categories on Fish on Sale at the Market in Jerantut

No.	Type of fish
1	Jelawat
2	Kelah
3	K. Kunyit
4	P. Mocong
5	Tenggalan
6	Kerai biasa
7	Belida
8	Tapah
9	Baung
10	Sebarau

5) Effects on fishes

Effects on fishes are usually caused by extreme reductions in river discharge and deterioration of water quality. In other words, occurrence of muddy water during the construction works and reductions in discharge at the downstream side. Other water quality deterioration factors such as reduced enrichment and nutrition, presence of hydrogen sulfides, variation in water temperature, etc. at the operating stage also pose crucial adverse factors. In addition, there is a problem of interruption of the water system caused by dam construction. The effect of the interruption is particularly serious for finny tribes having egg-laying locations in the upperstream.

It will be, therefore, necessary to conduct a survey on living conditions of finny tribes in the Tekai River, and to adequately grasp effects of environmental changes caused by above mentioned factors for each finny tribe.

6) Other animals

It is desirable to carry out as extensive as possible surveys on faunae for studies on animals. That is, studies on terrestrial (land) animals should include birds, reptiles, amphibia, insects and terrestrial shellfishes in addition to mammalia. Aquatic animals include aquatic insects, etc. in addition to fishes.

In particular, emphasis should be placed on surveys on valuable animals which are vital to the conservation of scientific or regional ecologic system, and animals which play the vital role of intermediate hosts in terms of public health. For example, turtles (batagur baska and callagur borneoensis) have drawn special attention at Trengganu, as a valuable animal species in terms of science. Likewise, snails have drawn special attention as a valuable animal species in terms of public health.

8.4. Effects on Society and Economy

8.4.1. Effects on Community

1) Present status

Several settlements are found at end around the proposed dam lake area, however some settlements are presumed to be shifting cultivators. A detail survey will be done during the next phase of the study.

8.4.2. Effects on Public Health

1) Present status

At the proposed site and the Tekai River Basin surrounding the site, there are probabilities of the incidences of tropical diseases such as malaria, typhoid, tuberculosis, dengue fever, filariasis, scttistosoniasis, etc. Accurate studies on specific probabilities are not included in this Report due to the absence of scientific surveys at the proposed site. Nevertheless, it may be said that vectors of such diseases are living in the areas and the possibility of incidences of such diseases cannot be denied; assuming from available data obtained from similar environmental studies.

Factors for infections of such diseases are generally classified into causes of infection, and existance of animals carrying such diseases, and humans infected from them. In order, therefore, to control such infections, preventive medicine type measures will be vital, including proper steps and control methods against carrier animals (intermediate hosts/vectors) of such diseases and their living environments, and betterment of human living environments against the concentration of population accompanying the construction works.

2) Predicted effects

Possible causes for occurrences or increases of diseases by the implementation of this Project will be the concentration of workers during the construction period, and environmental effects on changes in water quality and waterside plants, etc. which will affect on the living environments of vectors.

Mararia is carried by various animals, anopheles maculatus in particular (a kind of mosquito). The mosquito likes to live in moist soil vegetation areas. Since dam construction tends to create such environments through wood cutting, dam filling, etc., adequate precautions will be necessary. Prevention of mararia incidences and medical treatments after infection are adequately done by the Government. Nevertheless, particularly thorough preventive measures should be taken to cope with the concentration of workers during the construction period, and to establish a proper public health control system so as to prepare for incidences and infection of diseases and to take prompt steps.

Monkeys, cats, mosquitoes, etc. are intermediate hosts of semiperiodical brugia malayi which causes filariasis of humans. Such mosquitoes include the mansonia group (mansonioides), etc. which favor eichhornia crassipes and water fern (Salvinia SPP.) as their habitats. Due to the fluctuation of water level and increase in waterside line, increases in habitats for the mansonia group are expected.

Snails are intermediate hosts for schistosomiasis. Waterside lines will again extend by the implementation of the Project, and sunshine conditions will change by the lumbering, which will be favorable to snails. Increases in incidences of schistosomiasis were reported at the times of constructing the Aswan Dam in Egypt and the Volta Dam in Ghana. As shown on Table 8-7, similar incidences in Malaysia have been also confirmed. Namely, schistosamasis was found among 1.5% of the minority mountain group examinees, according to the survey made at a location (Kg Kuala Koyan: although it is not at the upperstream of the Tekai River, it is located on the same Pahang Water System) 90 km west of the proposed site. Probability of incidences of infection of schistosamasis by the implementation of the Project, therefore, cannot be denied.

As mentioned in the foregoing, incidences of malaria, filariasis, schistosamasis, etc. are likely to be increased. Hence, measures including adequate epidemiological preliminary surveys will be necessiated.

Table 8-7 Infection Rates of Schistosamiasis

	Percentage affected by schistosamiasis	Sample	Scientific Name
1	1%	Snails	Robertsiella coporensis
2	20%	Jungle Rats	Rattus Muelleri
3	1.5%	Human population of minority mountain group	

(Source; Results of data collected by Institute of Medical Research at Kg Kuala Koyan River Jelai)

8.4.3. Effects on Cultural Assets

1) Present status

Around the proposed development areas along the Tembeling River, several important archaeological remains are known. Those located along the Tembeling River are important and verified ones located at, from north to south, Jeram Kawi, Kuala Nyong, Telok, Lubok Puai, Bukit Jong, etc. These famous remains have been the objects of archaeological surveys since the 1900's, among which various vestiges such as neolithic stone implements, bronze implements, iron implements, etc. have been found the verified.

The reason why the Tembeling River Basin holds archaeological interests is because it is said to be a southern route from China in ancient yeras. That is, it is nearly an established theory that the southern surface route from the Continent of China to the Malay Peninsula runs along Pattani in Thailand, Kota Baru in Malaysia, the Kelantan River Basin and the Tembeling River Basin. A bronze bell, assumed to be made around BC 200 was also found along the Tembeling River Basin, for example. Many of such vestiges thus indicate the existance of the said southern route.

For the Tekai River, on the other hand, no archaeological surveys have been made, and hence a question whether remains or vestiges exist or not in the area has not been clarified.

2) Predicted effects

Effects of the Development Project on cultural assets may be divided into a positive effect of the discovery of remains, etc. and a negative effect of possible destruction. Some vestiges are discovered as they are scattered around the ground surface, and some other as buried underground.

Possible destructions of remains, etc. by the construction works may be sorted into cases where the works continue without knowing that remains exist, and cases where discoveries were made but not reported to the authority concerned. There may be additional cases where the discovery is made but the excavation is impossible which results in failure of confirmation on the presence of such a remain, or other related remains cannot be studies, etc.

In order to avoid the destruction or damage of cultural assets by the construction works, efforts should be made to conduct preliminary investigations as much as possible, and to establish a system to take appropriate steps upon discovery of cultural assets even after the initiation of the construction works.

8.5. Effects on Industrial Activities

8.5.1. Outline

Forestry is the major industry among other industrial activities at the proposed construction site. Fishery and agriculture are of small scale along the Tembeling River Basin, aimed at the local consumption.

8.5.2. Forestry

The most crucial damage of forest resources will be the sinking of such resources at the bottoms of dam lakes. The sinking area is 106 km^2 or so for the upper dam and about 24 km^2 for the lower dam. The amount of damages cannot be determined until the cumulative amount of each type of tree and its economic value are obtained to a certain degree. Thus further surveys will be necessary in future to find a clear answer to this question.

Generally speaking, forests in sank areas generate organic matters in dam lakes and consume oxygen in the water. In order, therefore, not to deteriorate the water quality, and also in terms of effective use of forests, it is recommendable to incorporate lumbering work in the framework of forestry policy plans, and to cut off some lumbers before filling the dams.

After the filling, waterside forest soil will lose organic contents, or in some extreme cases, may be subject to severe soil erosion, by the vertical fluctuations of water levels of dam lakes. It will be thus necessary to carry out well-planned lumbering, while paying adequate attention to the conservation of surface soil.

It is expected that the forest control becomes easy at the downstream areas of dams, through the roads constructed therewith, and the value of the existance of dams will be increased.

Examples of Prices of Plywood Lumbers

(Lumbers along the Tekai River Basin)
(Pricel price per ton delivered to factory at 4th Milestone, Jalan Mersing, Kluang, Johor.)
(As of April, 1980)

	Class	20" up	16"/19"	14"/15"
Mersawa	A	M$285	M$270	M$150
M. Pa'ang, M. Pipit	A	285	270	150
Mengkulang	A	285	270	150
Nytoh (Saft), M. Pasir	B	180	165	100
Kedondong, Kasai	B	170	155	100

(Source; Forestry Department of Pahang State)

8.5.3. Agriculture

People engaged in agriculture do not exist at and around the proposed site. It is also unlikely that agricultural development can be made around the Tekai River Basin even after the completion of the Project, due to geographical reasons. It may be said, however, that agricultural development can be promoted around the roads built for lumber transportation, as a secondary effect of the construction, if and when such roads are constructed between Jerantut and the Tekai River. At present there are some rubber or oil palm plantations in those areas, and the agricultural development in the primeval forests near the Tekai River is promising.

8.5.4. Fishery

According to available data obtained so far, there are no environmental factors to suppress the living of fishes, as far as water quality if concerned. Those marked with o in the following table are kinds of fishes sold on the market in Jerantut town area. Some secular changes are observed in the sales amounts.

In recent years, the Government of Malaysia, recognizing the importance of freshwater fishes, has been making efforts to make wider use of such fishes by establishing fisheries experiment station, office, etc.

In relation to the dam construction, it may be said that changes in water quality and discharge will affect the fishery at the downstream areas. Thus, it is at least necessary to maintain proper discharge. It is also possible to study the feasibility of fish planting and raising plans as an industrial merit in future.

Hauls of Fishes Classified by Kinds of Fishes in State of Pahang

Species	Quantity of fish sold (piculs)					
	PAHANG RIVER					
	'71	'72	'73	'74	'75	'76
o Jelawat	2	10	14	11	4	5
o Kelah	2	9	7	9	6	2
o Kerai	6	2	3	2	5	14
o Tenggalan	3	8	112	11	3	3
Temelian	+	-	-	1	+	+
o Baung	3	4	5	7	3	4
Lawang	3	3	8	9	3	9
Pantin	5	14	21	21	7	4
o Tapah	+	9	12	20	5	15

* 1 picul = 60.6 kg

+ less than 1 picul

o Major kinds of fishes sold on Jerantut market

Note: Sales of some species of riverine fishes in PAHANG state from 1971-1976

(Source; Annual Fisheries Statistics 1971 - 1976, Fisheries Division, Ministry of Agriculture)

8.6. Concluding Remarks

Effects of the implementation of the Project upon existing environments are extensive. Due to the fact that concrete features of the Project have not been finalized, it is difficult to clearly indicate causes of environmental effects. Accurate understanding of the present status of existing environments, that may be subject to such effects, is also limited due to the absence of biological surveys. It is thus difficult to predict environmental effects, in the strict sense.

Nevertheless, taking account of the fact that the Project is still at its initial stage, the following matters may be pointed out as the gist of the appropriateness of the Project, based on the knowledge obtained so far.

① Scientific surveys are necessary to bioecological aspects.

It is of a particular importance to carry out phytosociological surveys of forests so as to grasp how forests will be subject to structural effects.

For animals, it will be also necessary to examine the academic significance, industrial viewpoints and epidemiological aspects.

As regards aquatic plants and animals, it is vital to conduct scientific surveys in order to clarify the effects of changes in water quality and discharge.

② For a minority mountain group and archaeology, surveys including explorations will be necessary.

③ It is necessary to conduct status-quo surveys in the viewpoints of public health, and to establish firm measures to cope with the concentration of residences of workers, etc.

④ Although there are several issues to be considered as mentioned in ① through ③ above, it cannot be said that these issues will hinder the implementation of the Project, as far as knowledge and experience on environments accumulated so far are concerned.

CHAPTER 9

SELECTION OF POSSIBLE SITES
AND
FORMULATION OF DEVELOPMENT PLANS

Chapter 9 Selection of Possible Sites and Formulation of Development Plans

9.1. General

The survey team visited Malaysia for a period of approximately five months from the middle of June through the end of October, 1981 in order to undertake the preliminary field studies for ascertaining a possibility of the Tekai Hydro-electric Power Development Project.

During their stay in Malaysia, they carried out a series of work such as exploratory drillings, seismic prospectings, topographical surveys, geological surveys and so forth.

Upon analysis of data and information collected and gathered through the performance of the said work, the survey team has proposed candidate sites for construction of the upper dam and lower dam.

Likewise a single (one dam) development scheme and a series (two dams) development scheme have been proposed.

The pumped-storage scheme is as described in Chapter 10. This Chapter mainly deals with the optimum development scales of a single (one dam) development scheme and a series (two dams) development scheme.

The selection of candidate sites for the upper dam and lower dam has been made, based upon comparison of the construction cost of the main dams. As a result of this study, it has been proposed that dams be located in the same sites as those selected before and a dam at the upper site be of rockfill type and that at the lower site be of concrete gravity type.

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. (Refer to Tables 9-1,2,3,4,5 and Fig. 9-1)

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 the upper dam upon settlement of the optimum scale of the upper dam plan which will produce a larger quantity of energy, making studies on the running hours of a power plant, drawdown of a reservoir (effective depth) and annual energry generation, installed capacity and analysis of benefit/cost and benefit-cost.

Fig. 9-2 indicates a flow chart of procedures for determination of the optimum scales of single (one dam) development scheme. In addition, the results of cost calculation and economic analysis of the said scheme are as outlined below.

i) The mean discharge covering eight years from January 1973 through December 1980 is adopted as the firm discharge at the respective dam sites.

Upper Dam Sites: $Q_f = 40\ m^3/sec.$

Lower Dam Sites: $Q_f = 46\ m^3/sec.$

ii) Annual benefits accrued from power generation was calculated upon computation of annual costs per kW and kWH of thermal power plants, making an equivalent thermal development scheme as the alternatives.

M$ 0.15/kWH

M$ 75.09/kW

iii) The effective head was obtained by reduction of head losses equivalent to approximately four percent of the gross head. Then annual benefit and cost attributable to the alternatives included in single (one dam) development scheme corresponding to the size of dam, thereby obtaining benefit/cost and benefit-cost.

iv) Two units of electro-mechanical equipments have been proposed in due consideration of operation and maintenance of such equipment.

v) The normal water level of lower dam will be the same as the tailrace level of the upper dam in connection with a series (two dams) development scheme.

Table 9-1 Optimum Scale of Developments

Item		Single (One Dam) Development		Series (Two Dams) Development	
Powersite		Upper Dam	Lower Dam	Upper Dam	Lower Dam
Dam Type		Rockfill	Gravity	Rockfill	Gravity
Dam Height	(m)	90	60	90	38
Full Supply Level	(m)	EL 165.00	EL 105.00	EL 165.00	EL 83.00
Minimum Operating Level	(m)	EL 155.00	EI 95.00	EL 155.00	EL 79.00
Effective Depth	(m)	10.0	10.0	10.0	4.0
Plant Operation Time	(hr)	6	12	6	24
Maximum Turbine Discharge	(m^3/s)	160.0	92.0	160.0	46.3
Installed Capacity	(kW)	104,000	38,700	116,000	
Annual Energy Generation	(MWH)	225,000	155,000	327,000	
L-5	(kW)	102,000	33,000	114,000	
Construction Cost	$(10^6$M\$)	300	160	396	
Annual Benefit	$(10^6$M\$)	41.37	25.72	57.49	
Annual Cost	$(10^6$M\$)	34.15	18.35	45.12	
B/C		1.21	1.40	1.27	
B-C	$(10^6$MS)	7.22	7.37	12.37	

Remarks:
1) Upper dam for Series (Two Dams) Development Scheme will be the same as that involved in Single (One Dam) Development
2) Calculation of the maximum output and annual energy production are as shown Tables 9-3, 9-6 and 9-8.
3) L-5 means an annual guaranteed output.

Table 9-2 Optimum Scale of Respective Single (One Dam) Development (1)

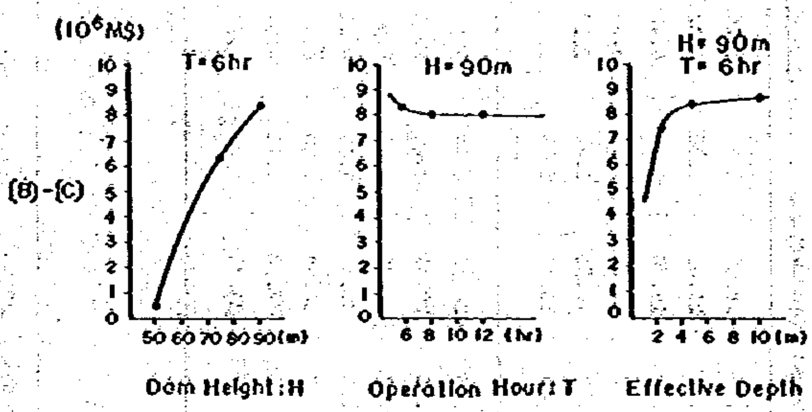
Item / Water Power Site	Dam Height (m)	Running Hour (hr)	Maximum Turbine Discharge (m^3/s)	Full Supply Level (m)	Minimum Operating Level (m)	Installed Capacity (KW)	Annual Energy-Generation (GWH)	L-5 Energy (MW)	Annual Benefit (10^6 M$)	Annual Cost (10^6 M$)	[B]/[C]	[B]-[C] (10^6 M$)	Remarks
	52	6	184.0	EL.97.0	EL.69.5	59,900	116	52	21.29	18.00	1.18	3.29	Dam Height
Lower Dam	60	6	184.0	" 105.0	" 87.0	74,000	149	66	27.35	21.03	1.30	6.32	
	60	8	138.0	" 105.0	" 87.0	55,500	149	50	26.11	19.70	1.33	6.41	Power Generation
Qmean	60	12	92.0	" 105.0	" 87.0	37,000	149	33	24.87	18.28	1.36	6.59	
$= 46m^3/s$	60	12	92.0	" 105.0	" 95.0	38,700	155	33	25.72	18.35	1.40	7.37	Effective Depth
	60	12	92.0	" 105.0	" 80.0	35,000	144	33	24.05	18.10	1.33	5.94	
	50	6	160.0	" 125.0	" 98.5	45,000	90	41	16.60	26.12	0.64	-9.52	
Upper Dam	75	6	160.0	" 150.0	" 141.5	85,000	175	78	32.15	29.52	1.09	2.63	Dam Height
	90	6	160.0	" 165.0	" 160.5	106,000	223	99	40.87	34.20	1.19	6.67	Effective Depth
Qmean	90	8	120.0	" 165.0	" 160.5	79,500	223	74	39.03	32.81	1.19	6.21	Power
$= 40m^3/s$	90	12	80.0	" 165.0	" 160.5	53,000	223	49	37.17	30.99	1.20	6.18	Generation
	90	6	160.0	" 165.0	" 162.5	107,200	216	89	39.05	34.18	1.14	4.87	Effective Depth
	90	6	160.0	" 165.0	" 155.0	104,000	225	102	41.37	34.15	1.21	7.22	

Optimum Scale of Series (Two Dams) Development (2)

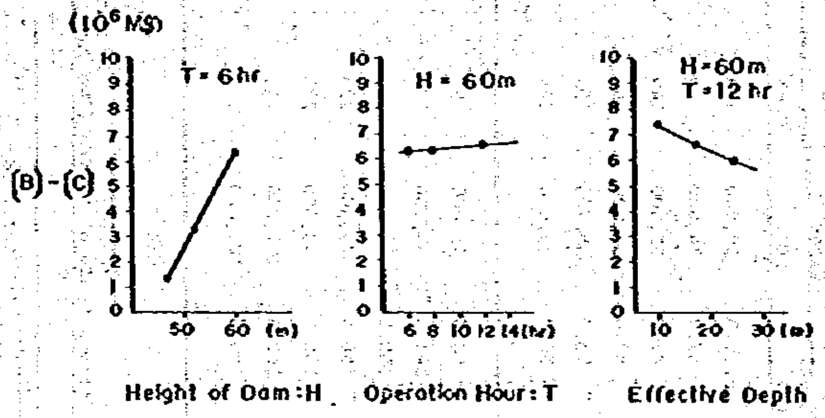
Item / Water Power Site	Dam Height (m)	Running Hour (hr)	Maximum Turbine Discharge (m^3/s)	Full Supply Level (m)	Minimum Operating Level (m)	Installed Capacity (KW)	Annual Energy-Generation (GWH)	L-5 Energy (MW)	Annual Benefit (10^6 M$)	Annual Cost (10^6 M$)	[B]/[C]	[B]-[C] (10^6 M$)	Remarks
	38	6	185.2	EL.83.0	EL.79.0	48,300	102	46	18.71	14.13	1.32	4.58	Power Generation
Lower Dam	38	12	92.6	" 83.0	" 79.0	24,100	102	23	17.0	12.41	1.37	4.57	
Qmean $= 46m^3/s$	38	24	46.3	" 83.0	" 79.0	12,000	102	12	16.12	10.95	1.47	5.17	

Fig.9-1

Upper Dam (Firm-Q≑40m³/s) Single (One Dam) Development



Lower Dam (Firm-Q≑46m³/s) Single (One Dam) Development



Lower Dam (H=38m) Series (Two Dams) Development

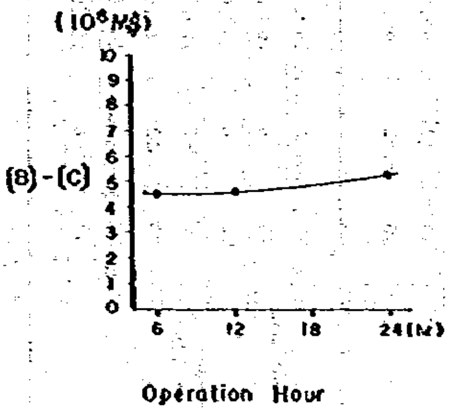
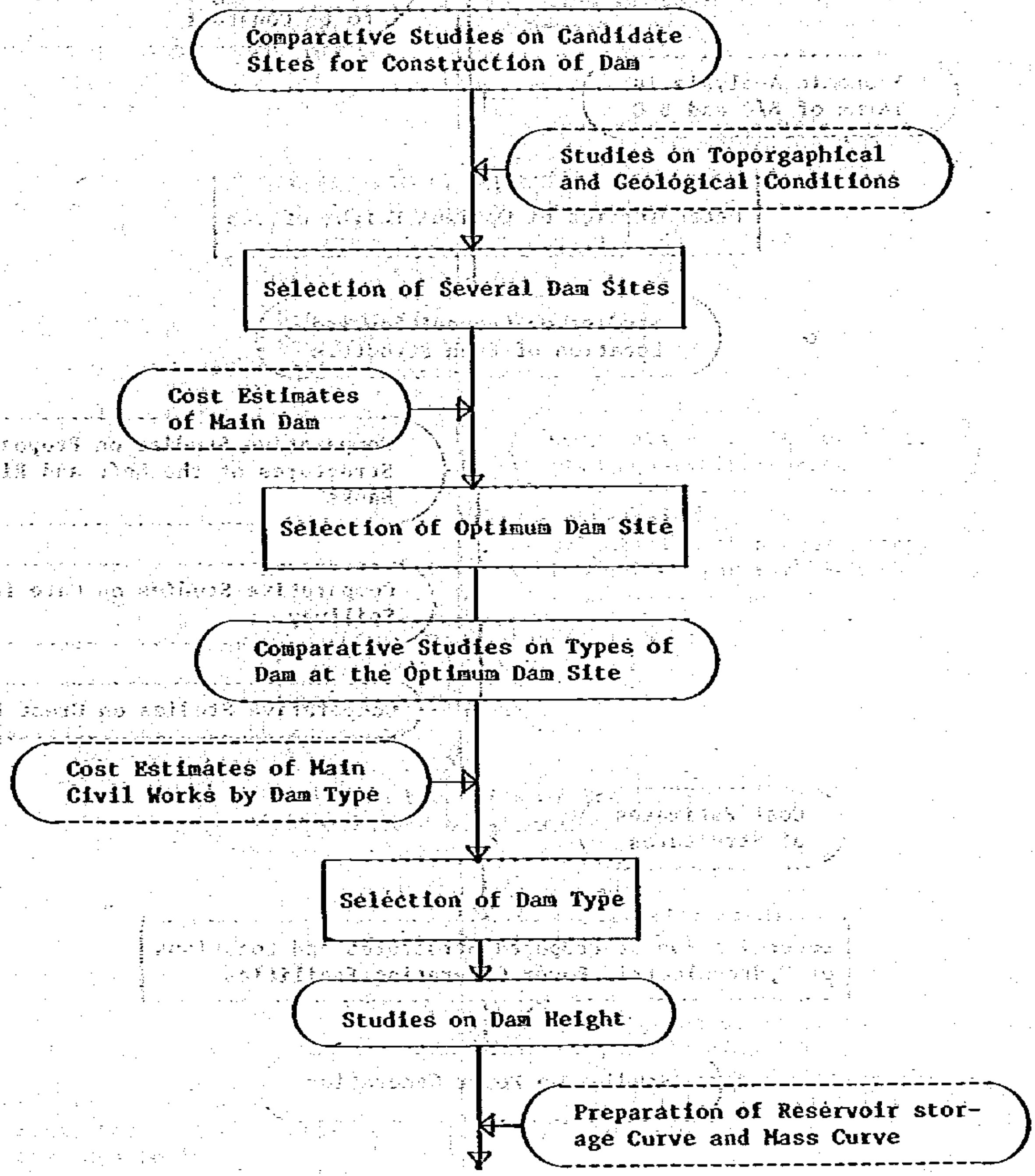
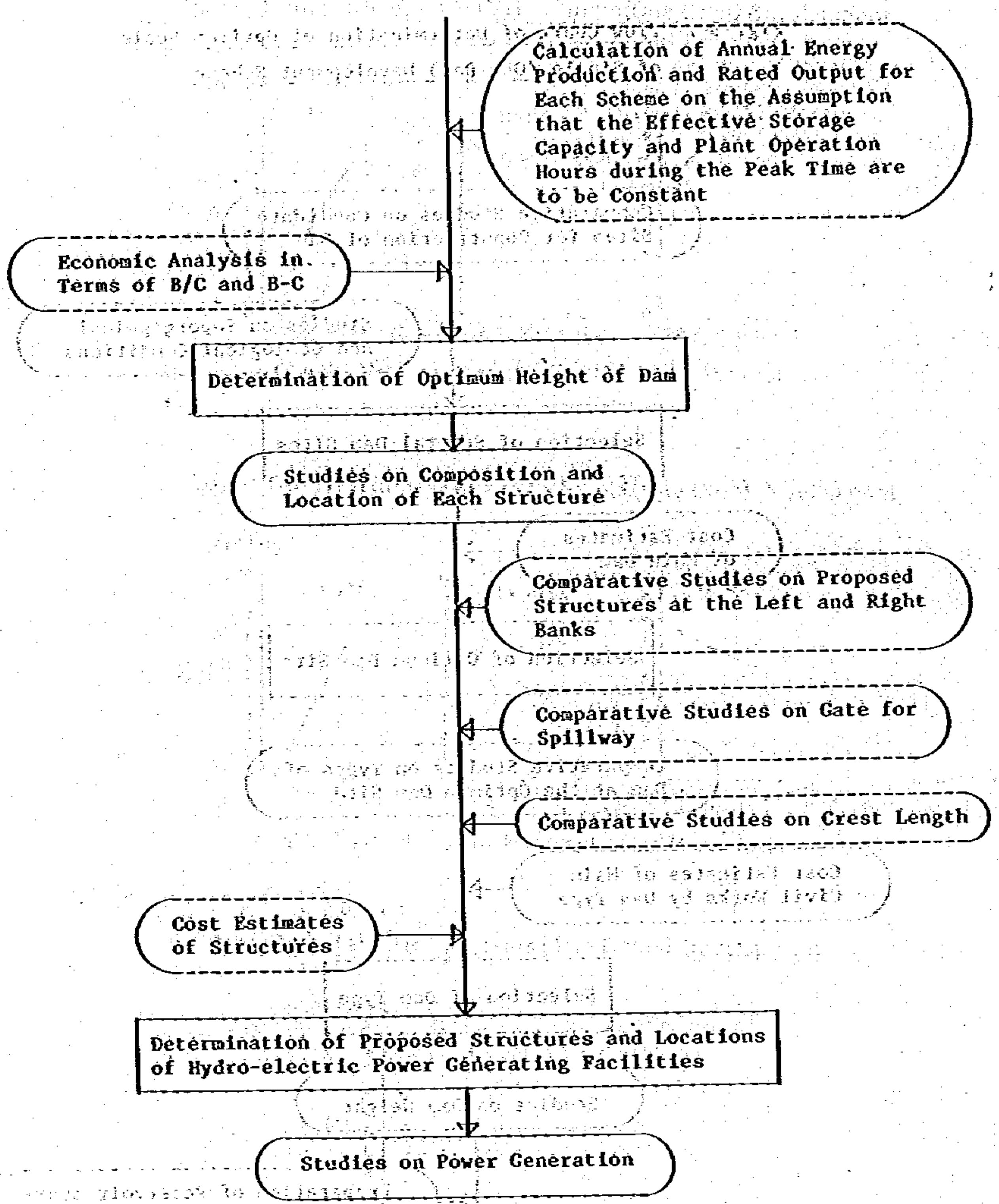
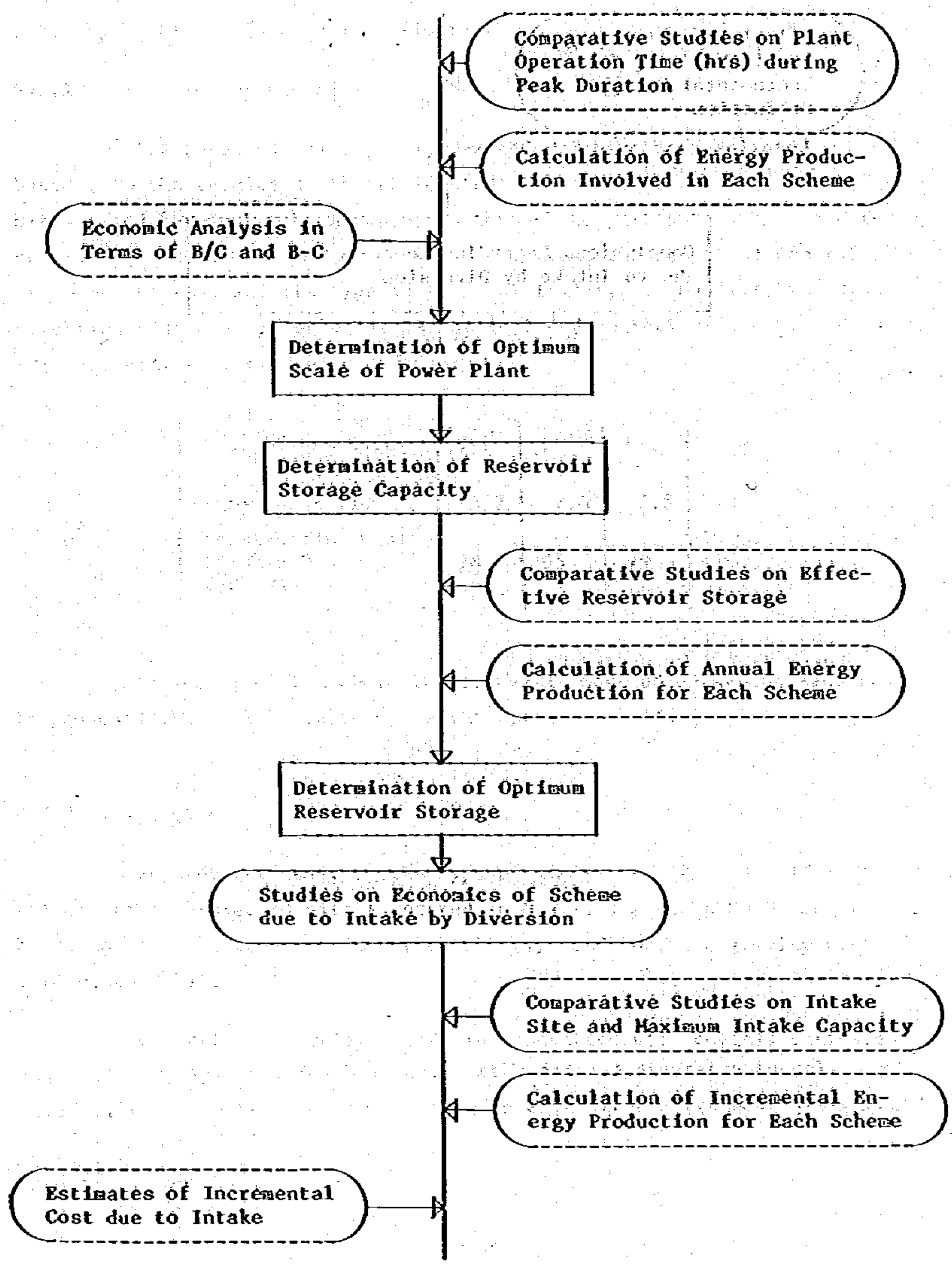
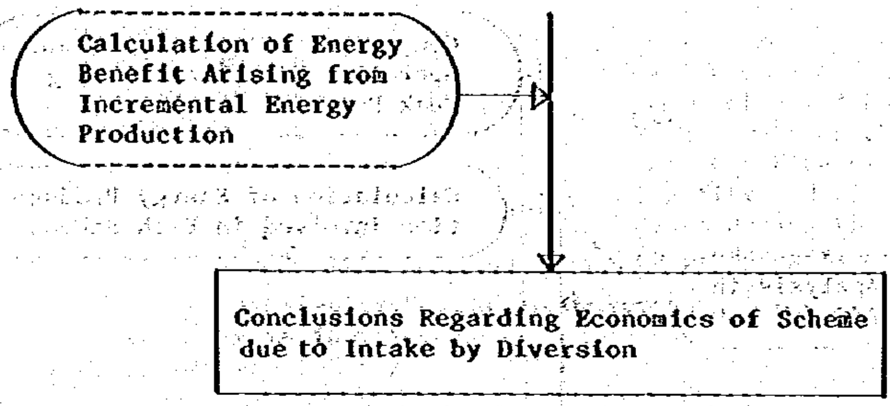


Fig. 9-2 Flow Chart of Determination of Optimum Scale of Single (One Dam) Development Scheme




Calculation of Annual Energy Production and Rated Output for Each Scheme on the Assumption that the Effective Storage Capacity and Plant Operation Hours during the Peak Time are to be Constant
Economic Analysis in Terms of B/C and B-C
Determination of Optimum Height of Dam
Studies on Composition and Location of Each Structure
Comparative Studies on Proposed Structures at the Left and Right Banks
Comparative Studies on Gate for Spillway
Comparative Studies on Crest Length
Cost Estimates of Structures
Determination of Proposed Structures and Locations of Hydro-electric Power Generating Facilities
Studies on Power Generation


Comparative Studies on Plant Operation Time (hrs) during Peak Duration
Calculation of Energy Production Involved in Each Scheme
Economic Analysis in Terms of B/C and B-C
Determination of Optimum Scale of Power Plant
Determination of Reservoir Storage Capacity
Comparative Studies on Effective Reservoir Storage
Calculation of Annual Energy Production for Each Scheme
Determination of Optimum Reservoir Storage
Studies on Economics of Scheme due to Intake by Diversion
Comparative Studies on Intake Site and Maximum Intake Capacity
Calculation of Incremental Energy Production for Each Scheme
Estimates of Incremental Cost due to Intake


Calculation of Energy Benefit Arising from Incremental Energy Production
Conclusions Regarding Economics of Scheme due to Intake by Diversion

9.2. Upper Single (One Dam) Development

9.2.1. Selection of Dam Site

The three dam sites; U-1, U-2 and U-3 have been selected, based upon the results of the field studies. The preferability of the sites sated herein has been evaluated through comparison of the estimated construction cost of the main dam, provided that the height of dam (90 m) is to be constant and its type is to be of fill type. However, the construction cost of a power plant is not included in that of the main dam. (Please refer to Fig. 9-4)

Name of Dam Site	U-1	U-2	U-3
Embankment ($10^6 m^3$)	3.7	2.6	3.8
Construction Cost of Main Dam (10^6 M$)	78	55	79

As seen from the above table, U-2 is most advantageous, and it is proposed that U-2 be taken up as the optimum dam site.

9.2.2. Type of Dam

Studies were made on the type of the dam on the assumption that the dam at the selected site as stated in 9.2.1. was to be 90.00 meters high. As for the types of dam, rockfill type and concrete gravity type were conceivable.

Comparisons were also made in connection with roughly estimated costs of dam, spillway (with gate), coffer dam and diversion tunnel. However, costs to be commonly incurred in each alternative were disregarded.

Dam Type	Main Dam	Spillway & Diversion	Total Construction Cost
	(10^6M$)	(10^6M$)	(10^6M$)
Rockfill	55	81	136
Concrete Gravity	156	10	166

As a result of this study it is judged that a rockfill type dam will be preferable.

9.2.3. Height of Dam

The maximum output and annual energy generation have been calculated, in connection with the cases of 50.00 m, 75.00 m and 90.00 m in dam height, on the assumption that a mean normal discharge of 40 m^3/sec at the upper dam site is to be firm discharge and plant operation time for peak duration is to be six hours (Refer to Fig. 9-3 Mass Curve).

The calculation of the maximum output and annual energy generation is primarily based on the following condition.

Effective Reservoir Storage = 540 x 10^6 m^3 (constant)
Maximum Turbine Discharge = 40.0 x 24/T (= 160 m^3/sec)
Tailrace Water Level = EL. 82.00 m
Maximum Output Pmax = $\eta_1\eta_2 \cdot gh \cdot Qmax$.
where,
$\eta_1\eta_2 \cdot g = 8.5$
h: Effective Head
T: Plant Operation Time (= 6 hrs.)

Dam Height (m)	50	75	90
Full Supply Level (m)	EL. 125.00	EL. 150.00	EL. 165.00
Minimum Operating Level (m)	EL. 98.50	EL. 141.50	EL. 160.50
Maximum Turbine Discharge (m^3/s)	160.0	160.0	160.0
Installed Capacity (kW)	45,000	85,000	106,000
Annual Energy Generation (MWH)	90,000	175,000	223,000
L-5 (kW)	41,000	78,000	99,000
Annual Benefit (10^6 M$)	16.60	32.15	40.87
Construction Cost (10^6 M$)	229	259	300
Annual Cost (10^6 M$)	26.12	29.52	34.20
B/C	0.64	1.09	1.19
B-C (10^6 M$)	-9.52	2.63	6.67

9.2.4 Power Generation

Studies were made in connection with three cases of six hours, eight hours and 12 hours of operation during peak duration based on a dam height of 90.00 m and in effective reservoir storage of 540 x 10^6 m^3 as stated in 9.2.3.

Maximum Discharge $Q_{max} = 40.0 \times 24/T$

Peak Plant Operation Time (hrs)	6	8	12
Full Supply Level (m)	EL. 165.00	EL. 165.00	EL. 165.00
Minimum Operating Level (m)	EL. 160.50	EL. 160.50	EL. 160.50
Maximum Turbine Discharge (m^3/s)	160.0	120.0	80.0
Installed Capacity (kW)	106,000	79,500	53,000
Annual Energy Generation (MWH)	223,000	223,000	223,000
L-5 (kW)	99,000	74,000	49,000
Annual Benefit (10^6 M$)	40.87	39.03	32.81
Construction Cost (10^6 M$)	300	288	272
Annual Cost (10^6 M$)	34.20	32.81	30.99
B/C	1.19	1.19	1.30
B-C	6.67	6.21	6.18

The case of six hours of operation for peak duration has been judged to be most advantageous in view of the economics of alternatives in terms of B/C and B-C.

9.2.5. Effective Reservoir Storage (Effective Depth)

The annual energy generation involoved in three cases of 2.50 m, 4.50 m and 10.00 m were calculated according to the features of each schems; dam height: 90.00 m, operation hours for peak duration: six hours and maximum discharge: 160m³/sec.

Effective Depth (m)	2.50	4.50	10.00
Full Supply Level (m)	EL. 165.00	EL. 165.00	EL. 165.00
Minimum Operating Level (m)	EL. 162.50	EL. 160.50	EL. 155.00
Maximum Turbine Discharge (m^3/s)	160.0	160.0	160.0
Installed Capacity (kW)	107,200	106,000	104,000
Annual Energy Generation (MWH)	216,000	223,000	225,000
L-5 (kW)	49,000	99,000	102,000
Annual Benefit (10^6 M$)	39.05	40.87	41.37
Construction Cost (10^6 M$)	300	300	300
Annual Cost (10^6 M$)	34.18	34.20	34.15
B/C	1.14	1.19	1.21
B-C (10^6 M$)	4.87	6.67	7.22

As seen from the above table, it is judged that an effective depth of 10 m will be most advantageous.

9.3. Lower Single (One Dam) Development

9.3.1. Selection of Dam Site

Two dam sites; L-1 and L-2 have been selected as a result of the field studies. The preferability of the said dam sites was judged according to the estimated construction cost of the main dam including a spillway. (Please refer to the Fig. 9-4)

The bases of comparison of the said construction cost are; the height of dam (≒ 60.00 m) and type of dam (concrete gravity type). However, the construction cost of a power plant is not included in that of the main dam.

Name of Dam Site	L-1	L-2
Main Dam Concrete Volume including spillway ($10^5 m^3$)	2.1	2.5
Construction Cost of Main Dam (10^6 M$)	50	59

This study has proved that L-1 would be the most advantageous dam site.

9.3.2. Type of Dam

The type of dam has been studied on the assumption that the dam at the selected optimum site as described in 9.3.1. is to be 60.00 m high. As for its type, a rockfill type, concrete gravity type and compound type of rockfill will be adopted for the dam. The comparative studies do not incorporate the construction cost of a power plant.

Dam Type	Main Dam	Spillway and Diversion	Total Construction Cost (10^6M$)
Rockfill	24	68	92
Concrete Gravity	50	12	62
Compound Type of Rockfill	40	50	90

As a result of this study, it is judged that a concrete gravity type dam will be preferable.

9.3.3. Height of Dam

Necessary studies were made in two cases of dam height; 52.00 m and 60.00 m (maximum scale viewed from topographical conditions) under the assumption that a mean discharge of 46 m^3/sec at the lower dam site is to be taken as firm discharge and that plant operation time for peak duration is to be 6 hours.

Effective reservoir storage = 630×10^6 m^3

Maximum Turbine Discharge Qmax = 46 x 24/T (=184 m^3/sec)

Tailrace Water Level = EL. 50.00 m

Maximum Output Pmax = $\eta_1 \eta_2 \cdot g h$ Qmax

where,

$\eta_1 \eta_2 \cdot g \fallingdotseq 8.5$

h: Effective Head

T: Plant Operation Time (= 6 hrs.)

Dam Height (m)	52.00	60.00
Full Supply Level (m)	EL. 97.0	EL. 105.0
Minimum Operating Level (m)	EL. 69.5	EL. 87.0
Maximum Turbine Discharge (m^3/s)	184.0	184.0
Installed Capacity (kW)	59,900	74,000
Annual Energy Generation (MWH)	116,000	149,000
L-5 (kW)	52,000	66,000
Annual Benefit (10^6 M$)	21.29	27.35
Construction Cost (10^6 M$)	158	185
Annual Cost (10^6 M$)	18.00	21.03
B/C	1.18	1.30
B-C (10^6 M$)	3.29	6.32

As sum from the above table, it is proposed that 60.00 m be taken as the scale of dam.

9.3.4. Power Generation

The annual energy generation and rated output were calculated in connection with three cases; plant operation hours of 6 hours, 8 hours and 12 hours for peak duration according to a dam height of 60 m, effective reservoir storage of 630 x 10^6 m and maximum discharge of Qmax = 46 x 24/T which are as determined in 9.3.3.

Peak Plant Operation Time (hrs)	6	8	12
Full Supply Level (m)	EL. 105.00	EL. 105.00	EL. 105.00
Minimum operating Level (m)	EL. 87.00	EL. 87.00	EL. 87.00
Maximum Turbine Discharge (m^3/s)	184.0	138.0	92.0
Installed Capacity (kW)	74,000	55,500	37,000
Annual Energy Generation (MWH)	149,000	149,000	149,000
L-5 (kW)	66,000	50,000	33,000
Annual Benefit (10^6 M$)	27.35	26.11	24.87
Construction Cost (10^6 M$)	185	173	160
Annual Cost (10^6 M$)	21.03	19.70	18.28
B/C	1.30	1.33	1.36
B-C (10^6 M$)	6.32	6.41	6.59

9.3.5. Effective Reservoir Storage (Effective Depth)

The annual energy generation and rated output were calculated in connection with three cases; effective depths of 10.00 m, 18,00 m and 25.00 m according to a dam height of 60.00 m, plant operation hour of 12 hours and a maximum turbine discharge of 92.0 m^3/sec which are as stated in 9.3.4.

Effective Depth (m)	10	18	25
Full Supply Level (m)	EL. 105.00	EL. 105.00	EL. 105.00
Minimum Operating Level (m)	EL. 95.00	EL. 87.00	EL. 80.00
Maximum Turbine Discharge (m^3/s)	92.0	92.0	92.0
Installed Capacity (kW)	38,700	37,000	35,000
Annual Energy Generation (MWH)	155,000	149,000	144,000
L-5 (kW)	33,000	33,000	33,000
Annual Benefit (10^6 M$)	25.72	24.87	24.05
Construction Cost (10^6 M$)	161	160	159
Annual Cost (10^6 M$)	18.35	18.28	18.10
B/C	1.40	1.36	1.33
B-C (10^6 M$)	7.37	6.59	5.94

As seen from the above table, it is judged that an effective depth of 10.00 m will be most advantageous.

9.4. Series (Two Dams) Development

Upon settlement of the optimum scale of upper single (one dam) development with a larger scale of power generation, 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 rated output.

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 bh $630 \times 10^6 - 540 \times 10^6 = 90 \times 10^6$ m^3. The features of the lower dam will be as follows;

Full Supply Level = EL. 83.00 m
Minimum Supply Level = EL. 79.00 m
Dam Height = 38.00 m

Peak Plant Operation Time (hrs)	6	12	24
Full Supply Level (m)	EL. 83.00	EL. 83.00	EL. 83.00
Minimum Operating Level (m)	EL. 79.00	EL. 79.00	EL. 79.00
Maximum Turbine Discharge (m^3/s)	185.2	92.6	46.3
Installed Capacity (kW)	48,300	24,100	12,000
Annual Energy Generation (MWH)	102,000	102,000	102,000
L-5 (kW)	46,000	23,000	12,000
Annual Benefit (10^6 M$)	18.71	17.00	16.20
Construction Cost (10^6 M$)	124	109	96
Annual Cost (10^6 M$)	14.13	12.41	10.95
B/C	1.32	1.37	1.47
B-C (10^6 M$)	4.58	4,57	5.17

Accordingly the plant operation hour of the lower dam will be 24 hours.