APPENDIX II

CONSTRUCTION MATERIAL

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CHAPTER 1. INTRODUCTION

1.1 Scope of Investigation

Project of Medamit-2 hydropower generation consists of an intake dam, a headrace tunnel and a powerhouse. The concrete gravity intake dam site is proposed at the midstream of the Medamit River which is a tributary of the Limbang River. The powerhouse site is planned at the middle reaches of the Limbang River, and the headrace tunnel connects the two sites.

Construction materials were investigated for the concrete aggregates as the main materials of the dam, the headrace tunnel, the powerhouse, etc.

The field investigation was carried out to examine the riverbed deposits which are scattered in the Medamit and Limbang rivers around the proposed dam site and the powerhouse site. Rock samples were also taken from the proposed quarry site located 0.1 km downstream of the dam site.

First investigation was performed in order to select the borrow areas, and to estimate the collectable volume for the concrete aggregates.

The samples for the laboratory tests were obtained from test pits which were dug in the proposed borrow areas.

The laboratory tests were carried out to obtain the characteristics of the samples and to judge whether or not they were suitable for the concrete aggregates.

1.2 Prospective Material Sources

The concrete volume of the Medamit-2 project is approximately 33,000 m^3 which is the sum of the dam, the headrace tunnel, the powerhouse, etc., so that the volume of sand and gravel requires approximately 43,000 m^3 as the concrete aggregates.

The investigation was carried out to select the riverbed deposits which had sufficiently collectable volume for the concrete aggregates and to obtain the samples for the laboratory tests.

The Medamit River is a mountain stream with a width of only 10 m to 20 m and rapid. It has few riverbed deposits and each deposit has little volume and contains many big cobbles and boulders with a grain size of 30 cm to 50 cm and few sand and gravel.

Rock type around the dam site consists of mainly shale and sandstone, and the rock is pretty hard. There is sufficient sandstone for the development of a quarry 0.1 km to 0.2 km downstream of the dam site.

The river width around the powerhouse site in the middle reaches of the Limbang River is 50 m to 100 m. There exist many areas with the sufficient riverbed deposits. The deposits contain many cobbles and boulders, the maximum grain size of which is about 50 cm but few sand.

The total volume of the collectable aggregates which are obtained from each riverbed deposit around the powerhouse site, is sufficient for the required volume.

Rock type around the powerhouse site consists of mainly shale and partly sandstone and limestone.

The field investigation and sampling for the laboratory tests were carried out around the middle of June in 1987.

1.3 Laboratory Tests

The laboratory tests were carried out to obtain characteristics of the samples which were collected at the riverbed deposits and quarry site, and then to judge whether or not the samples were suitable and usable for the concrete aggregates.

Moreover, the laboratory tests were carried out in regard to drilled cores to obtain the characteristics and compressive strength.

The samples were transported from the riverbed deposits and the drilled cores site to the Kuching city for the laboratory tests.

The test pitting, the sampling and the laboratory tests were performed under the supervision of the SESCO expert based on the technical assistance of the JICA team.

Table II-1 shows the items and the quantities of the material investigation.

CHAPTER 2. CONCRETE AGGREGATES

2.1 Field Investigation

Investigation of the riverbed deposits was carried out at both areas around the dam site along the Medamit River and along the Limbang River between about each 3 km up and downstream from the powerhouse site.

The sampling areas were selected on condition that the volume of the deposit had more than 500 m^3 in the Medamit River and 5,000 m^3 in the Limbang River, respectively.

As a result of the investigation, two (2) and five (5) candidates of the sampling areas were selected in the Medamit and Limbang rivers, respectively. The maximum grain size of the deposits of both rivers was bigger than 30 cm.

Samplings were carried out at one test pit in each deposit. The samples for the laboratory tests were collected as to sand and gravels whose maximum grain size was less than 80 mm.

The samples were sealed up in 30 kg vinyl bags and transported to Kuching, where tests were carried out.

Locations, volume, maximum grain size and weight of the samples are shown in Fig. II-1 and Table II-2.

2.2 Laboratory Tests

Samples were taken from seven (7) riverbed deposits, and the following laboratory tests were carried out:

(1) Sieve analysis of sand and gravel,

(2) Specific gravity and absorption of sand and gravel,

(3) Organic impurities of sand, and

(4) Scratch hardness of soft particles of gravel.

Furthermore, the following tests were carried out on the samples from three (3) of the larger deposits:

(5) Soundness of sand and gravel,

(6) Abrasion of gravel, and

(7) Unit weight of sand and gravel.

Samples from the quarry underwent the following tests in addition to the above:

(8) Aggregate Impact Value

(9) Aggregate Crushing Value

As to seven (7) samples of the drilled cores, the following tests were carried out:

(10) Unconfind compression, and

(11) Specific gravity and absorption.

ASTM standards 1986 and BS812 are the relevant technical specifications.

Table II-1 shows the items and the quantities, and Table II-3 and Table II-4 show the results of the tests.

Furthermore, the evaluation for the test results is mentioned in the following Section 2.3.

2.3 Evaluation for the Test Results

2.3.1 River bed deposits of the Medamit River (TME - 1,2)

(1) The riverbed deposits around the dam site are not suitable for the concrete aggregates judging from the original grain size distribution; the maximum grain size of about 50 cm.

Since the maximum grain size less than 100 mm is generally used for concrete aggregates of dam, it is necessary to take away the big grain size of gravel as well as cobles and boulders.

The total volume of the deposits around the dam site is about 2,000 m^3, however, the available volume of sand and gravel of them is only less than a quarter of the total volume because of the above-mentioned reason, and so it is insufficient for the required volume, about 27,000 m^3.

(2) Although the gravels contain a few soft stone, the abrasion rate is not so high that these gravels are usable for the concrete aggregates without any problem.

The sand is also usable without any problem although the property of the sand is a bit coarse, light, and has a high absorption rate.

2.3.2 Riverbed Deposits of the Limbang River (TME - 3,4,5,6,7)

(1) The riverbed deposits are not directly usable as the concrete aggregates with the original grain size distribution, since the maximum grain size is about 50 cm

and the volume of the sand is less than 10% of them. Therefore, it is necessary to sift big gravels of the deposits in order to take the sand and gravel with the suitable grain size.

The total volume of the deposits is about 70,000 m^3 within the field investigation areas, but the usable volume for the concrete aggregates is about 24,000 m^3 because of the above-mentioned reason.

Although this usable volume of the Limbang River is sufficient for the required volume of the powerhouse, the tunnel, etc., about 16,000 m^3, it would be insufficient for the total required volume, about 43,000 m^3, if it includes the dam and the tunnel of the Medamit side.

(2) Although the gravels contain a few soft stone, they are usable for the concrete aggregates without big problem.

Sand has a high rate of organic impurities such as fine wood splinter, resulting in light specific gravity, high abrasion rate and high soundness rate.

Therefore, it is necessary to wash it by clean water before use. Then it will be usable for the concrete aggregates, since it has good grading curve.

2.3.3 Proposed Quarry Site

The hard samples from the quarry site are fresh sandstone with slight staining obtained from outcrops on the cliff of the river bank. The results of the laboratory tests indicate that the rock has good physical properties suitable for use as concrete aggregates.

The quantity available would be more than the required volume as the sandstone formation is massive as shown by geological mapping.

CHAPTER 3. CONCLUSIONS AND RECOMMENDATIONS

(1) The volume of the riverbed deposits

Since the usable volume of the Medamit River around the dam site is insufficient for the required volume, it would be necessary to use the sand and gravel of the Limbang River for the concrete aggregates. But the hauling distance is long, about 25 km, from the dam to the powerhouse site and the hauling route passes through the mountainous area with undulation, so that the conveyance of sand and gravel from the Limbang River to the intake site would not be economical.

A quarry is proposed to obtain the crushed stones and sand for the concrete aggregates, since the area of the sandstone exists on the left bank of the Medamit River immediately downstream from the dam site.

Around the powerhouse site, the collectable volume of the deposits in the Limbang River is sufficient for the required volume.

These deposits are considered to be used in two ways for the concrete aggregates. One is to use many deposits and the other is to use only a few big deposit area.

In case of the former, the usable volume of the concrete aggregates with the suitable grain size must be collected from each deposit, but this case needs many deposits because of poor volume of the suitable grains in them, only 30%, and many works for the sifting big gravels and moreover stretching the hauling distance.

In the latter case, the usable concrete aggregates are made of crushed cobbles and boulders and the deposits with the suitable grains are used for the concrete aggregates, so that this case needs only one or two big deposit areas.

The selection of either way relies on the economical comparison of both cases, but the latter way is at this moment recommended.

(2) The proposed quarry site around the dam

The quarry is proposed on the left bank of the Medamit River immediately downstream from the dam site in order to obtain the crushed sand and gravel of the volume, about 27,000 m^3.

The rock type of the quarry is sandstone and its properties are sufficient with the high strength and the good quality of the specific gravity and absorption for the concrete aggregates according to the test results of the drilled cores and quarry samples.

(3) The quality of the sand and gravel of the Medamit and Limbang rivers

Although the gravels have good quality for the abrasion resistance according to the test results, the tests should be performed before use of them for the concrete structures which need high abrasion resistance, since they have a few soft stones.

It should be considered that the sand has light specific gravity to the design of concrete structure due to containing many organic impurities such as fine wood splinters and so on. It is therefore necessary to wash it by clean water before use.

Table II-1 Quantity of Material Investigation

Work Item		Quantity
1.	Field Investigation	
	a. Test pitting	7
	b. Sampling	7
2.	Laboratory Test	
2.1	River deposits	
	a. Sieve analysis (ASTM C136)	7
	b. Specific gravity and absorption (ASTM C128 & C127)	6 (Sand) 7 (Gravel)
	c. Organic impurities of sand (ASTM C40)	6
	d. Scratch hardness of soft particles in gravel (ASTM C235)	7
	e. Soundness (ASTM C88)	2 (Sand) 3 (Gravel)
	f. Abrasion of gravel (ASTM C131 & C535)	3
	g. Unit weight (ASTM C29)	2 (Sand) 3 (Gravel)
2.2	Drilled Core Sample	
	a. Unconfined compression (ASTM D2938)	6
	b. Specific gravity and absorption (ASTM C127)	6
2.3	Quarry Samples	
	a. Specific gravity and absorption (ASTM C128 and C127)	1
	b. Scratch hardness (ASTM C235)	1
	c. Soundness (ASTM C88)	1
	d. Abrasion (ASTM C131 and C535)	1
	e. Aggregate impact value (BS 812)	1
	f. Aggregate crushing value (BS 812)	1

Table II-2 Places of Test Pitting and Sampling

Sampling No.	Distance from dam or powerhouse site	Volume of river deposit (m^3)	Maximum size of particles (cm)	Sampling weight (kg)
TME - 1	0.85 km upsteam from dam site (Middle of river)	1,000 (250)	30 - 50	120
TME - 2	0.60 km upstream from dam site (Right bank)	600 (150)	30 - 50	90
Quarry Sample	0.03 km upstream from dam site (Left bank)	more than required	50 x 20 (average)	120
TME - 3	2.50 km upstream from powerhouse (Left bank)	9,000 (3,000)	30 - 50	90
TME - 4	1.70 km upstream from powerhouse (Right bank)	18,000 (6,000)	30 - 50	180
TME - 5	0.70 km upstream from powerhouse (Left bank)	21,000 (7,000)	30 - 50	90
TME - 6	1.80 km downstream from powerhouse (Right bank)	7,800 (2,600)	20 - 30	90
TME - 7	2.20 km downstream from powerhouse (Left bank)	10,000 (5,000)	20 - 30	180
	Total volume	67,400 (24,000)		

Notes 1 : Figures in parentheses show the estimated volume of grain size under 10 cm.

2 : Rock type of TME - 1 and TME - 2 is shale and sandstone, while shale, sandstone and limestone for TME - 3 to 7.

Table II-3 Summary Results of Laboratory Tests (1/2)

Places Item of Tests	Medamit River (TME-1 - TME-2)	Limbang River (TME-3 - TME-7)	Values Generally Accepted
A. Fineness Modulus of Gravel (F.M)	8.18	8.61	6.5 - 9.0
Fineness Modulus of Sand (F.M)	3.68	2.96	2.3 - 3.5
B. Specific Gravity of Gravel	2.553	2.588	2.5 - 2.7
Specific Gravity of Sand	2.438	2.361	2.5 - 2.7
C. Absorption of Gravel (%)	1.54	1.20	less than 3.0
Absorption of Sand (%)	3.12	3.72	less than 3.0
D. Organic Impurities of Sand	passed	not passed	
E. Scratch Hardness of Gravel (%)	5.6	4.6	less than 5.0
F. Soundness of Gravel (%)	1.8	4.2	less than 12.0
Soundness of Sand (%)	-	19.1	less than 10.0
G. Abrasion of Gravel (%)	13.6	15.7	less than 40.0
H. Unit weight of Gravel (t/m^3)	1.768	1.768	1.5 - 1.9
Unit weight of Sand (t/m^3)	-	1.335	1.4 - 1.8

TABLE II.3 SUMMARY RESULTS OF LABORATORY TESTS (2/2)

Item of Tests	Proposed Quarry QME-1	Value in General
a. Specific Gravity	2.635	2.5-2.7
b. Absorption (%)	0.77	less than 3.0
c. Scratch Hardness	0.3	less than 5.0
d. Soundness (%)	1.09	less than 12.0
e. Abrasion (%)	17.8	less than 40.0
f. Aggregate Impact Value (%)	18	less than 45.0
g. Aggregate Crushing Value (%)	19	less than 45.0

Table II-4 Result of Laboratory Tests

Place and Sample No.		Sieve Analysis (Percentage Passing) mm 75 (%)	mm 63 (%)	mm 50 (%)	mm 37.5 (%)	mm 19.0 (%)	mm 9.5 (%)	mm 4.75 (%)	mm 2.36 (%)	mm 1.18 (%)	mm 0.60 (%)	mm 0.30 (%)	mm 0.15 (%)	mm 0.075 (%)	Fineness Modulus (F.M.)	Specific gravity (SSD)	Absorption (%)	Organic Impurities	Scratch Hardness (%)	Soundness (%)	Abrasion (%)	Unit Weight (t/m^3)
River bed deposit																						
TME-1	Coarse	100	76	52	26	5	0	-	-	-	-	-	-	-	8.69	2.558	1.39	-	6.4	1.8	13.6	1.768
	Fine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Original	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TME-2	Coarse	-	100	87	71	40	22	0	-	-	-	-	-	-	7.67	2.548	1.68	-	4.7	-	-	-
	Fine	-	-	-	-	-	-	100	68	35	20	7	2	0	3.68	2.438	3.12	Passed	-	-	-	-
	Original	-	100	91	81	62	50	35	24	12	7	3	1	0	5.93	-	-	-	-	-	-	-
TME-3	Coarse	-	100	72	44	7	0	-	-	-	-	-	-	-	8.56	2.600	1.07	-	6.7	-	-	-
	Fine	-	-	-	-	-	100	85	69	57	35	17	6	2	3.31	2.350	3.88	Not Passed	-	-	-	-
	Original	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TME-4	Coarse	100	93	87	66	28	11	0	-	-	-	-	-	-	7.95	2.566	1.70	-	12.1	8.2	21.0	1.779
	Fine	-	-	-	-	-	-	100	79	62	37	9	3	0	3.10	2.336	4.13	Not Passed	-	15.8	-	1.382
	Original	100	94	89	71	38	23	13	10	8	5	1	0	0	7.31	-	-	-	-	-	-	-
TME-5	Coarse	100	74	16	0	0	0	0	-	-	-	-	-	-	9.00	2.591	1.06	-	0	-	-	-
	Fine	-	-	-	-	-	100	99	97	91	50	14	5	0	2.52	2.363	4.44	Not Passed	-	-	-	-
	Original	100	79	31	18	18	18	18	18	17	10	3	1	0	7.79	-	-	-	-	-	-	-
TME-6	Coarse	100	83	50	29	3	0	-	-	-	-	-	-	-	8.69	2.590	1.14	-	1.8	-	-	-
	Fine	-	-	-	-	-	100	93	79	68	46	13	3	0	2.98	2.393	3.42	Not Passed	-	-	-	-
	Original	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TME-7	Coarse	100	96	53	22	1	0	-	-	-	-	-	-	-	8.86	2.593	1.01	-	2.6	0.2	10.3	1.756
	Fine	-	-	-	-	-	100	97	89	77	33	11	2	1	2.91	2.363	2.75	Not Passed	-	22.4	-	1.367
	Original	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Drilled Core	Condition of Sample Cores: Depth (m)	Ground Water	Rock Type	Diameter (cm)	Hights (cm)	Specific gravity (SSD)	Absorption (%)	Compressive Strength (Kg/cm^2)	Remarks
BME-1	15.05 - 15.80	Saturated	Sandstone	5.40	10.25	2.630	0.53	499.76	
BME-2	19.60 - 19.80	Saturated	Shale	5.40	9.97	2.690	0.29	21.52	
BME-3	5.30 - 5.55	Saturated	Shale	5.18	9.80	2.640	1.40	86.0	
BME-4	3.07 - 3.33	Saturated	Sandstone	5.17	9.90	2.620	0.20	561.8	
BME-4	17.15 - 17.35	Saturated	Sandstone	5.19	9.70	2.640	0.20	643.2	
BME-5	26.40 - 26.55	Saturated	Shale	5.40	9.60	2.570	1.83	172.74	

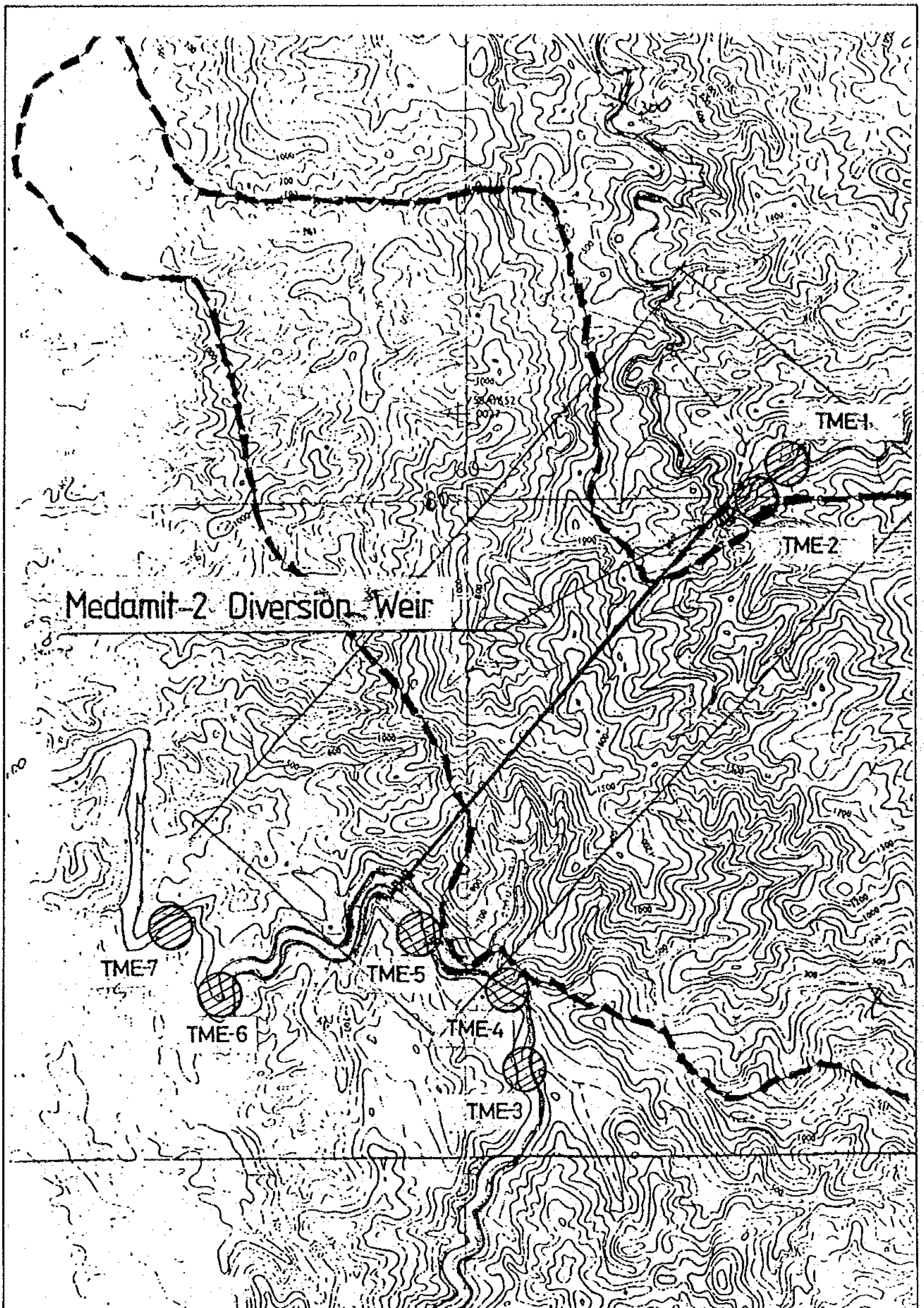

Fig. II-1 Sampling Location for Laboratory Test

GOVERNMENT OF MALAYSIA
FEASIBILITY STUDY
SMALL SCALE HYDROELECTRIC POWER PROJECT IN SARAWAK
JAPAN INTERNATIONAL COOPERATION AGENCY

APPENDIX III

HYDROLOGY

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CHAPTER 1. GENERAL

The preliminary meteo-hydrological assessment on identified potential sites was carried out from August 1986 to November 1986, followed by the meteo-hydrological investigation for the feasibility study of Medamit-2 hydroelectric power project.

The objectives of meteo-hydrological investigation are enumerated below:

- To collect and review meteo-hydrological data in and around the Medamit and Limbang river basins,
- To establish new water level and rainfall gauging stations in the vicinity of the Medamit-2 project site, and to develop the rating curve at the new water level gauging station site,
- To determine the long-term discharge at the intake site of Medamit-2,
- To determine the flood discharge and volume for several return periods at both intake and powerhouse sites,
- To estimate the rate of sediment transportation at the intake site, and
- To clarify water quality of the Medamit and Limbang rivers.

CHAPTER 2. METEOROLOGY

2.1 Climatology

2.2.1 Whole Sarawak

The climate of Sarawak is classified into the tropical rain forest zone characterized by constantly moist days throughout the year. The northeast monsoon generally begins in the middle of October and lasts until the middle of April, while the southwest monsoon prevails from the middle of April to the middle of October. Prevailing patterns of monsoons are illustrated in Figure III-1.

Since the southwest monsoon is generally less vigourous than the northeast one, the rainy season of Sarawak coincides with the period of northeast monsoon. The southwest part of Sarawak having the distinctive rainy and dry seasons is well affected by the prevailing of northeast monsoon, while the northeast part, especially in the vicinity of state boundary between Sabah and Sarawak, has no distinctive rainy and dry seasons because of rainfall brought by the southwest monsoon.

Meteorological data have been recorded for relatively longer period at four (4) stations under the control of Malaysian Meteorological Service (hereinafter called MMS). The location and altitude of the stations are summarized in Table III-1.

The daily mean temperature is invariable at about 26 C throughout the year, and the variation of temperature depends upon the diurnal change. Mean, maximum and minimum temperatures recorded in each month are shown in Figure III-2. The mean relative humidity is also almost constant in a range from 85 per cent to 87 per cent as shown in Figure III-3, although a slight seasonal change can be seen.

Mean sunshine is 5.7 hours a day on an arithmetic average of the stations. It corresponds to annual sunshine hours of 2,080 hours. A mean monthly pattern of sunshine hour is shown in Figure III-4.

Maximum surface wind speed of 31.8 m/sec was recorded at Kuching aerodrome on September 1964. The mean surface wind velocity has been recorded in a range from 0.9 m/sec to 1.3 m/sec. Maximum surface wind speed recorded in each month is shown in Figure III-5.

2.1.2 Project site

The meteorological data recorded at Ukong are available for the project. The station has been managed by DID since 1976.

The data show that the monthly mean evaporation varies in a range from 104.1 mm in February to 128.5 mm in May. The annual mean evaporation is estimated at 1,382 mm.

The daily mean temperature is almost at about 27° C throughout the year. The variation of temperature with a fluctuating range of 12.5° C depends upon the diurnal change, while the mean relative humidity is also almost invariable at about 82.5% on an monthly average.

Monthly mean sunshine hours vary in a range from 5.41 hours/day in February to 7.11 hours/day in May. The annual sunshine hour is estimated at 2,310 hours.

Mean surface wind velocity has been recorded in a range from 0.36 m/sec to 0.41 m/sec. No record or maximum surface wind velocity is available.

The meteorological data at the Ukong station are illustrated in Figure III-6.

2.2 Rainfall

2.2.1 Whole Sarawak

The Sarawak Hydrological Year Book 1981-1982 published by DID in 1986 contains the values of daily rainfall recorded at 136 rainfall gauging stations. Annual rainfall depth at the selected stations having ralatively longer recording period is enumerated in Table III-2. The isohyetal map of annual mean rainfall depth is illustrated as shown in Figure III-7.

Mean annual rainfall depth over Sarawak is estimated at about 3,700 mm for the past 20 years. The wettest year is 1970 with annual rainfall depth of 4,310 mm, and the rainfall depth of 3,272 mm was recorded in 1972 which is the driest year. The variation of annual rainfall depth at three (3) representative stations, Kuching station for southwest part, Kapit station for middle part and Ukong station for northeast part, is shown in Figure III-8.

The distribution of mean monthly rainfall given in Figures III-9 to III-20 shows that there is a distinctive rainy season from October through February in Divisions I to IV, VI and VII, while in the Division V the monthly rainfall is evenly distributed all the year round.

2.2.2 Project site

Among 136 rainfall gauging stations over the state of Sarawak, Long Napir is the nearest station to the Medamit-2 project site as shown in Figure III-21. The rainfall records, however, are not reliable. Around the project site, the logging activities are carried out by the private companies. The rainfall data at Lubok Lalang, which is located about 8.5 km downstream of the intake site, have been recorded by the logging company for the period from 1979 to 1986. Although the daily rainfall records for the period from 1979 to 1983 are missing, the data for remaining periods are available.

The data show the mean annual rainfall depth of 4,487 mm at the project site by applying the correlation analysis for monthly rainfall depths of Lubok Lalang and Ukong recorded for 24 years from 1963 to 1986 as given in Table III-3. The correlation coefficient is estimated at 0.662.

The wettest year is 1968 with annual rainfall depth of 5,286 mm, and the driest year is 1985 with the depth of 3,751 mm. According to the simulated monthly rainfall data, there is no distinctive dry season, although the rainfall depth from October to January is higher than that for remaining months. Variation of monthly mean, maximum and minimum rainfall depths at Lubok Lalang is prepared based on the data from 1979 to 1986 and is illustrated in Figure III-22.

CHAPTER 3. HYDROLOGY

3.1 Low Flow Analysis

3.1.1 General

Run-of-river type schemes are generally elaborated on the basis of daily discharge records for a decade. The daily discharge records at the intake site, however, cover only the period of a few months. In the Study, the daily discharge data are generated for six (6) years by applying the tank model method, the parameters for which are calibrated using data at Kpg. Git and Buan Bidi water level gauging stations in Division I.

The flow duration curve at the intake site is used to determine the development scale of run-of-river scheme. The flow duration curve is a figure to express daily discharges against their excess rates by arranging the daily discharge data in the numerical descending order.

3.1.2 Tank model

Tank model is a widely practiced method to estimate long-term discharge data from rainfall data. Tank model is normally composed of three (3) or four (4) tanks connected subsequently to each other by their bottom outlets. Each tank has side holes, which contribute directly to the outflow of the river. The basic equation for outflow computation is below:

$$
\begin{aligned}
Qn &= 0 && (Xn < H1) \\
Qn &= A1\ (Xn - H1) && (H1 < Xn < H2) \quad \text{(Eq.III.1)} \\
Qn &= A2\ (Xn - H2) + A1\ (Xn - H1) && (H2 < Xn)
\end{aligned}
$$

$$Zn = b\ Xn \qquad \text{(Eq.III.2)}$$

$$Xn' = Xn - Qn - Zn - En \qquad \text{(Eq.III.3)}$$

$$Xn+1 = Xn' + In + 1 \qquad \text{(Eq.III.4)}$$

where, Xn : storage depth of n-th day
Qn : outflow from side holes of n-th day
Zn : outflow from bottom hole of n-th day
En : evaporation rate at n-th day
Xn' : storage depth at the end of n-th day
In+1 : inflow at (n+1)th day
A1,A2 : coefficient of side holes
H1,H2 : depth of side holes
b : coefficient of bottom hole

3.1.3 Coefficient of tank model

Tank model is assumed to consist of four (4) tanks and the coefficients of hole are calibrated on the basis of the discharge data at Kpg. Git and Buan Bidi water level gauging stations having a catchment area as small as 440 km^2 and 217 km^2 respectively and the rainfall data in and around their catchments. The location maps of the stations are shown in Figure III-23.

Taking the available period and continuity of rainfall records and the location of rainfall gauge into consideration, the Krokong rainfall station is selected for Buan Bidi. Segu Bunuk, Kpg. Embahn and Padawan are selected for Kpg. Git. The average basin rainfall for the latter is estimated by the Thiessen's method. The period of simulation is seven (7) years from 1978 to 1984 for the former and two (2) years from 1977 to 1978 for the latter.

Through the trial and error method, the best fitting between the observed and estimated discharges is elaborated for both stations. The rating curves at both stations are not reliable for high discharge because of lackness of discharge measurements during high discharge and overtopping at riverbanks, so that the best fitness is tried weighing on low flow. Figures III-24 and III-25 show the results of calibration for Kpg. Git, while Figures III-26 and III-27 depict the results for Buan Bidi.

In order to apply the above results to the project site, the coefficient for the bottom hole of lowest tank is adjusted in proportion to their catchments as shown in Figure III-28.

3.1.4 Flow duration curve at intake site

Since no rainfall gauging station is located in the catchment of Medamit-2 project, the rainfall data at Lubok Lalang, which is the nearest station to the intake site among 136 rainfall gauging stations over Sarawak, is applied to the analyses using tank model.

The rainfall data at Lubok Lalang are recorded for the period from 1984 to 1986. Since the continuous daily rainfall data throughout the year are required to apply tank model, the daily rainfall data for three (3) years, i.e. 1984 to 1986, are adopted. The generated daily discharge data for three (3) years are given in Tables III-4 to III-6.

The flow duration curves at the intake site are obtained for three (3) years by arranging the generated daily discharge data in the numerical descending order, which are shown in Fig. III-30.

3.1.5 Long-term daily mean discharge

A flow duration curve on a weighted average is obtained by assuming that the annual rainfall depth at the Ukong station is normally distributed as shown in Figure III-29.

The weight for each year is calculated as the ratio of representative area covered by normal distribution curve for each year to the whole area of 1.0. Then, the flow duration curve is adopted as a weighted average as shown in Figure III-30. The long-term daily mean discharge is also calculated by applying the weight on normal distribution curve to the daily mean discharge for each year. The long-term mean daily discharge is estimated at 15.0 m^3/sec at the intake site.

The adopted flow duration curve at the intake site is compared with that of representative gauging stations having relatively small catchment area as shown in Figure III-31.

3.2 High Flow Analysis

3.2.1 Rainfall analysis

(1) Frequency analysis

Frequency analysis of rainfall depth at the Long Semado station, which has the record for relatively longer period and is the second nearest to the project site, is made for various durations and return periods. Probable rainfalls with the recurrence intervals of 2, 5, 10, 20, 50, 100 and 200 years are analysed for the rainfall duration of 1, 2, 3 and 5 days.

Three (3) methods, (i) Gumbel, (ii) Iwai and (iii) Log Pearson Type III, are applied to verify the fitness to the plotting position of recorded data. The results of frequency analysis for rainfall depth are given in Table III-7.

The above results do not show significant difference in their values estimated with three (3) methods. Therefore, the results of Gumbel method which is adopted by DID in his publications are applied to further studies.

(2) Conversion factor to average basin rainfall

The average basin rainfall generally tends to decrease with the increase of catchment area. Although the development of depth-area-duration curve for each storm is required to estimate the conversion factor of point rainfall to average basin rainfall, the lack of sufficient data in the Medamit and Limbang river basins prevents the derivation of conversion factor by the statistical procedure. The conversion factor is recommended by DID in his publications as shown in Figure III-32 and is applied to estimate the average basin rainfall for the site. The conversion factor of 0.95 is adopted for the site.

(3) Depth duration analysis

None of hourly rainfall data has been recorded at the Long Semado station. Thus, the heavy rainfall data at Kuching aerodrome are adopted to estimate the distribution of hourly rainfall.

The four (4) heavy rainfall data are adopted in the study as given in Table III-8.

The above data show that the heavy rainfall occurs for the duration within 24 hours and has such characteristic that about 80 per cent of 24-hour rainfall concentrates in 15 hours after rainfall starts. These torrential showers are normally observed from the evening to next early morning.

The average hourly rainfall distribution pattern as shown in Figure III-33 is obtained as an arithmetic mean of the above four (4) heavy rainfalls. The ratio of every 3-hour rainfall depth to 1-day rainfall depth is estimated as given in Table III-9.

(4) Design rainfall

Probable flood hydrographs at Batang Ai Hydro-electric Power Project having catchment area of 1,200 km^2 are referred for estimating the duration of design rainfall.

According to the said project, the probable flood hydrographs for various recurrence interval of 2, 10, 20, 50, 100 and 200 years were estimated on the basis of the five (5) flood hydrographs observed at the dam site. The duration of direct runoff for various probable floods is roughly estimated at about 30 hours which correspond to the duration of heavy rainfall within 24 hours. This suggests that an assumption of 24-hour rainstorm would be prudential for Medamit-2 with a small catchment.

The design rainfall depth at the site is, therefore, developed for the duration of 24 hours by the following equation:

$$R_{24} = C_f \times R_f \quad \text{.................................} \quad (\text{Eq.III.5})$$

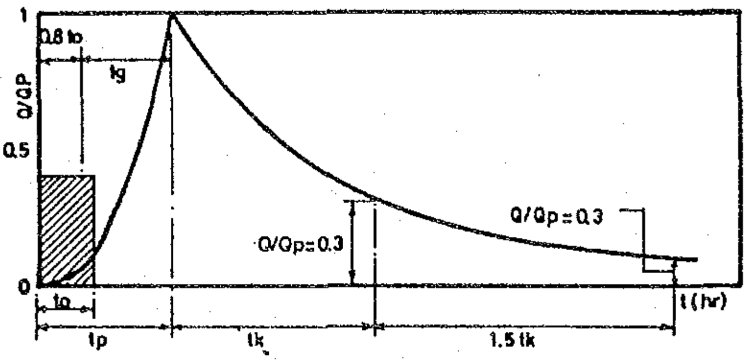
where, R_{24} : design rainfall depth for the duration of 24-hour (mm)
C_f : conversion factor of point rainfall to average basin rainfall (= 0.95)
R_f : 1-day probable point rainfall depth (mm)

Design rainfall at the catchment of Medamit-2 intake site is divided into eight (8) by every three (3) hours on the basis of aforementioned depth duration analyses. The design rainfall is given in Table III-10.

3.2.2 Flood analysis at intake site

(1) Derivation of unitgraph

A unitgraph at the project site is developed by the Nakayasu's synthetic unit hydrograph method. The unitgraph is derived by the following procedures:



(i) Lag time of peak discharge

$tg = 0.5 + 0.058L$ (L<15 km) .... (Eq.III.6)
$tg = 0.21 \times L \exp(0.7)$ (L>15 km) .... (Eq.III.7)

where, tg : lag time of peak discharge (hr)
L : river channel length (km)

$tk = 0.47 (A L) \exp(0.25)$ .... (Eq.III.8)

where, tk : recession time period from the time of peak discharge to 30 per cent of peak discharge (hr)
A : catchment area (km^2)

(ii) Time of concentration

$tp = T1 = 0.8to + tg$ .... (Eq.III.9)
$t1 = T2 = tp + tk$ .... (Eq.III.10)
$t2 = T3 = tp + tk + 1.5tk$ .... (Eq.III.11)

(iii) Peak discharge

$Qp = A\ Ro / [\ 3.6\ (0.3\ tp + tk)\ ]$ .... (Eq.III.12)

where, Qp : peak discharge (m^3/sec)
Ro : unit effective rainfall (mm)

(iv) Unitgraph

- Rising limb

$$Qr = (t / tp) \exp(2.4) \quad (0<t<tp) \ldots \text{(Eq.III.13)}$$

- Recession limb

$$Qr = 0.3 \exp[(t-tp)/tk] \quad (T1<t<T2)\ldots \text{(Eq.III.14)}$$

$$Qr = 0.3 \times 0.3 \exp[(t-T2)/1.5tk] \quad (T2<t<T3)\ldots \text{(Eq.III.15)}$$

$$Qr = 0.3 \times 0.3 \times 0.3 \exp[(t-T3)/2tk] \quad (t>T3) \ldots\ldots \text{(Eq.III.16)}$$

The values required to obtain a unit hydrograph are the catchment area of 186 km^2 and the river length of 38.0 km.

(2) Loss rate

Initial rainfall loss is disregarded by assuming that the whole basin is saturated by antecedent rainfall, resulting in the estimate of a conservative side. While the retention loss rate after the saturation is assumed to be constant at 2.5 mm per hour.

The rate of 2.5 mm per hour as retention loss is estimated on the basis of other hydroelectric projects in Sarawak and Peninsula Malaysia as enumerated in Table III-11.

The retention loss rate generally tends to increase with the increase of catchment area. Therefore, the minimum retention loss rate of 2.5 mm per hour is adopted in view that the Medamit River basin is located in the steep-sloped mountainous area with relatively small catchment and that future logging activities will lead to reduce its retention loss rate.

(3) Probable flood hydrograph

Probable flood hydrographs are calculated under the following conditions:

(1) A unitgraph is obtained by the Nakayasu's synthetic unit hydrograph method.

(2) Design hyetographs of 24-hour duration for various return periods are applied to synthesize the hydrographs.

(3) A retention loss rate of 2.5 mm per hour is subtracted from the design hyetograph to estimate rainfall excess.

(4) Base flow is assumed to be equivalent to the annual average discharge.

The probable flood hydrographs at the intake site are shown in Figure III-34. The peak discharges, flood volumes and their specific discharges are summarized in Table III-12.

3.2.3 Flood analysis at powerhouse site

(1) General

The Limbang River with a catchment area of 3,650 km^2 originates at southeast mountainous area of Division V. The powerhouse of Medamit-2 scheme is proposed to locate at the right bank of the middle reaches in the River. The catchment area at the proposed powerhouse site is 1,907 km^2.

Two (2) water level gauging stations along the Limbang River, (i) Nanga Medamit and (ii) Insungai, were managed under the control of DID for the period from 1966 to 1984 for the former and for the period from 1982 up to present for the latter. In the Study, the data at Nanga Medamit are used taking relatively longer recorded period into consideration.

Nanga Medamit water level gauging station, having a catchment area of 2,810 km^2, is located downstream from the confluence with the Medamit River. Water levels in low flow have slight affect of backwater caused by tidal changes, but negligible in high flow. Flood records are then available for the period from 1967 to 1984.

(2) Rating curve at powerhouse site

The rating curve at the powerhouse site is established by the Manning's formula; that is,

$$Q = n^{-1.0} AR^{0.667} I^{0.5} \quad \text{(Eq. III-17)}$$

where,
- Q : discharge (m^3/sec)
- n : Manning's roughness coefficient (=0.050)
- A : flow area (m^2)
- R : hydraulic depth (m)
- I : water surface gradient.

The water surface gradient of 1 to 122 is estimated using the maps with the scale of 1 to 50,000. The rating curve established is shown in Figure III-35.

(3) Flow duration curve at powerhouse site

A flow duration curve at the powerhouse site is estimated on the basis of that of Nanga Medamit for the period from 1966 to 1975 in proportion to their catchment areas.

Flow duration curves for both Nanga Medamit amd powerhouse site are shown in Figures III-36 and III-37, respectively. The annual mean daily discharges are estimated at 310 m^3/sec for Nanga Medamit and 210 m^3/sec for the powerhouse site. While the annual mean daily water level at the powerhouse site is estimated at El.55.740 m.

(4) Frequency analysis

Annual maximum peak discharges and their specific discharges at Nanga Medamit are enumerated as given in Table III-13. Frequency analysis for annual maximum peak discharges is made for various return periods. Three (3) methods, (i) Gumbel, (ii) Iwai and (iii) Log-Pearson Type III, are applied to verify the fitness to the plotting position of recorded data. The results are given in Table III-14.

Frequency analysis of flood volume is also made for various durations and return periods by Gumbel method. The results are given in Table III-15.

(5) Probable peak discharge at powerhouse site

The probable peak discharges are converted from Nanga Medamit to the powerhouse site by using the following Creager's curve:

$$q = 46\ C\ A^{b}$$

$$b = 0.864\ A^{-0.048} - 1 \qquad \text{(Eq. III-18)}$$

where, q : specific discharge ($ft^3/sec/mile^2$)
C : constant
A : catchment area ($mile^2$)

The results of calculation are given in Table III-16.

(6) Probable flood hydrograph at powerhouse site

The shape of flood hydrograph at the powerhouse site is estimated on the basis of the flood hydrographs recorded at Nanga Medamit.

Six (6) flood hydrographs, namely, 1968, 1970, 1971, 1974 to 1976 as shown in Figures III-38 to III-40, are adopted to obtain their dimensionless shapes. The dimensionless flood hydrograph at Nanga Medamit is obtained on an arithmetic average as shown in Figure III-41.

The probable flood hydrographs are calculated under the following conditions:

(i) Dimensionless flood hydrographs on an arithemic average are applied to the powerhouse site.

(ii) Flood hydrographs for various return periods are dimensionalized by multiplying probable peak discharge by non-dimensional Q/Qp (discharge at certain time/peak discharge).

(iii) The volume of probable flood hydrograph for various return periods is adjusted in the recession limb in order to coincide with the flood volume obtained by the frequency analysis.

(iv) Base flow at Nanga Medamit obtained by taking an arithmetic average of discharge is shifted to powerhouse site by multiplying the ratio of catchment areas.

The probable flood hydrographs at the powerhouse site are shown in Figure III-42.