3.2 GEOLOGY AROUND PROPOSED RESERVOIR

3.2.1 UPSTREAM AREA OF RESERVOIR

Findings by field reconnaissance to Thaviang Region are as follows;

B.Phonyeng to B.Xiangkhong: Lower Jurassic folded formations as mudstone, conglomerate and sandstone, weak and fractured, deeply weathered near the boundary with Palaeozoic formations. River banks are found to be eroded by the Nam Ngiep River at roadsides between B.Naxay and B.Viengthong. This is caused by the continuous erosion because Nam Ngiep flow attacks the left bank and turns southward from the east. Still the erosion on the left bank is advancing. According to the aerial photographic analysis, there is west-east lineaments, but there is no landslides found around the river curve.

Near B.Xiangkhong, Palaeozoic formations and granitic rocks are distributed. From B.Phonyeng to B.Phonehom, metamorphosed rocks, greenish with schistosity (NW-SE, near B.Phonehom) conforming to topography are found. From B.Phonyeng to B.Pou, Lower Jurassic folded formations such as mudstone and sandstone, are seen in the river and riversides.

3.2.2 DOWNSTREAM AREA OF RESERVOIR

In the east of B.Muang Bo, which is 13km north of B.Hatkham, green schist is found at the excavation cut for road construction. Palaeozoic quartzite sandstones are found at the basement of small dam for agriculture on the Nam Xao River. Mesozoic sandstone was found on the ridge north of B.Nahan (3km south of B.Muangbo). Palaeozoic formation near B.Sopyouk (12km northwest of damsite) could not be surveyed due to bad road conditions. Limestone outcrops in the village B.Muanghuang (15km north-east of B.Hatkham), and quarry is working to produce aggregates. At the foot of Mt. Muang (west of B.Muang, 2.5km south-east of B.Muanghuang), Palaeozoic sandstone/slate are distributed at the basement of small agricultural intake facilities under construction. Mesozoic (Lower Jurassic to Triassic) sandstone/mudstone are distributed at the so-called "Snake" range because it ranges long from north-west to south-east about 4km east of B.Hatkham. Mesozoic sandstone/mudstone are distributed on the Mt.Tek, which ranges from west-north to south-east 2.5km north-west of B.Hatkham, but conglomerate was not found. Geological Map has been corrected based on these results.

3.3 GEOLOGY AT DAMSITE

3.3.1 GENERAL

Lower cretaceous to Middle Jurassic formations are distributed and make up almost flat to gently dipped (around 10° to the East) hills with 400m to 700m in elevation on the hilltops. Massive sandstone, conglomerate and red mudstone are distributed in this area. Hard conglomerate, sandstone and mudstone make a gorge and steep valley at about 10km east of B.Hatkham, which is the proposed damsite. Topographic profile given in the Pre-F/S Report indicates inclination of 30° to 33° on both banks around the damsite.

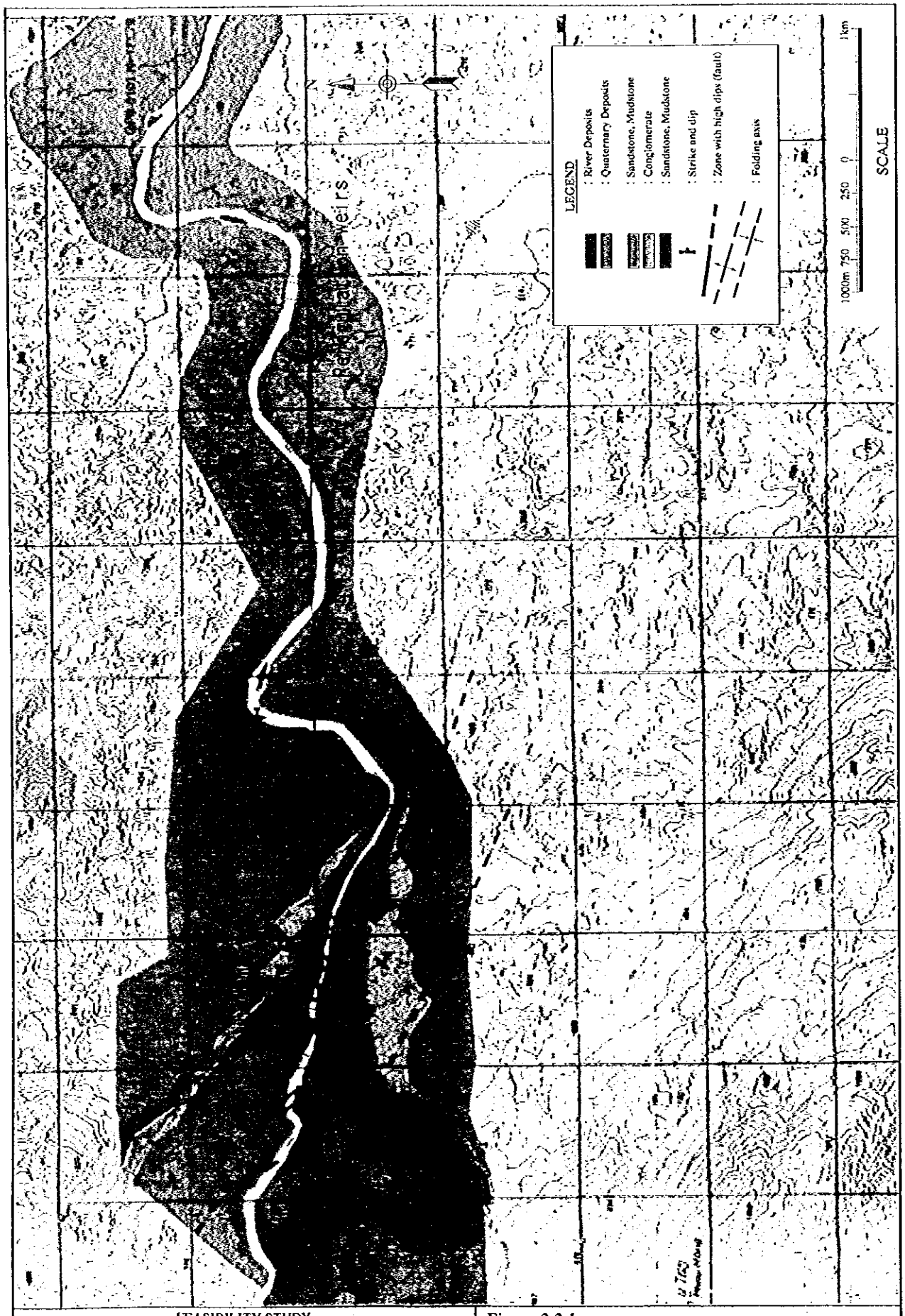
A geological map of the damsite is shown in Figure 3.3.1 including that for the re-regulation damsite. Figure 3.3.2 and Figure 3.3.3 are the survey results shown in plan and section at the damsite including the Pre-F/S survey results. Moreover, the geological profiles along the river diversion tunnel, the spillway chuteway and the headrace tunnel are shown in Figure 3.3.4, Figure 3.3.5, and Figure 3.3.6, respectively.

3.3.2 GEOLOGICAL DISTRIBUTION

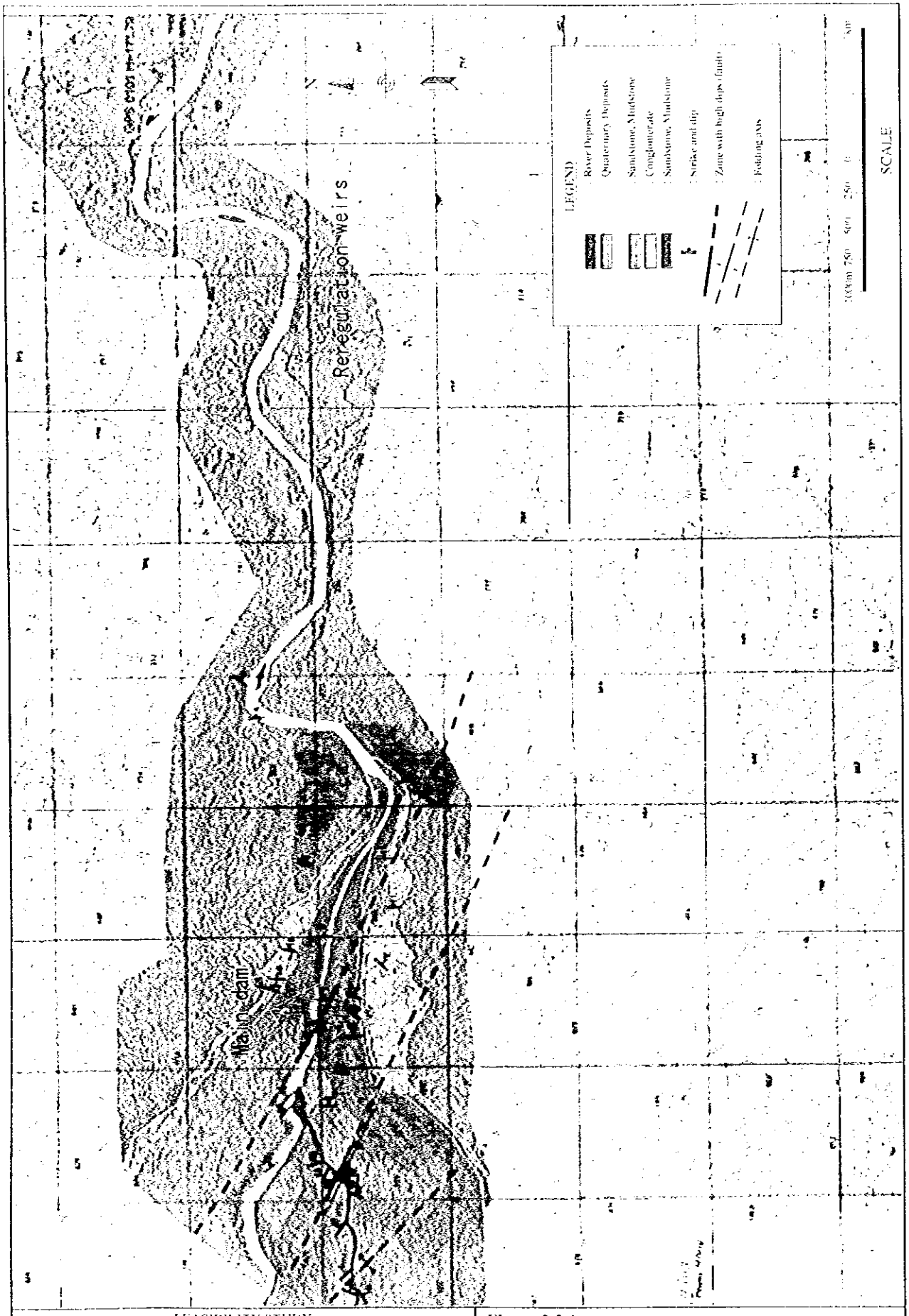
Conglomerate is distributed on the upper part of the valley, and makes up hilly gentle outcrops more than 1km long and 200m wide on the right bank. On the left bank also, it makes up hilly outcrops around EL.400m with a rather narrow area. On the hilltop, open joints are distributed still 50m from the cliff. On the right bank local people use a path which starts from the entrance of the gorge, goes along hilltop and descends the cliff 30m around the damsite (They say that there is only one place to go down and up the cliff.) and proceeds at the foot of the cliff and then goes down to the confluence with H.Katha. The path is used by ethnic people in the mountain area. Sandstone/mudstone outcrop along the foot of the vertical cliff with a 10° dip, so the thickness of conglomerate is estimated less than 100m, maybe 60-70m. Sandstone, just above the conglomerate formation level, is widely distributed outside of the entrance of the gorge. On the left bank 500m long and 100m wide conglomerate is distributed on the cliff around damsite. However, the outcropped area is relatively narrow compared to the right bank side, so sandstone/mudstone on the upper formation level are distributed in the higher mountain area.

Sandstones outcrop along the Nam Ngiep River, along the footpath on the left bank, and along the footpath going down to the confluence on the right bank. Thickness is 1 m to several meters. Big boulders with 5m to 10m diameters along the Nam Ngiep River are made of sandstone (about two thirds) and of conglomerate (about 1 third). Along H.Katha, thickness ranges from 0.5m to several meters.

Mudstone is alternated with sandstone with thickness less than 1m in general. However, reddish fine mudstone (argillite) is widely outcropped from the upstream, left bank to the right bank of damsite. Along H.Katha is distributed with thickness ranging from 20-30cm to several meters.



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 3.3.1** **Geological Map at Dam Site**



FEASIBILITY STUDY ON THE NAM NGIEP 1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC	**Figure 3.3.1** **Geological Map at Dam Site**
JAPAN INTERNATIONAL COOPERATION AGENCY	

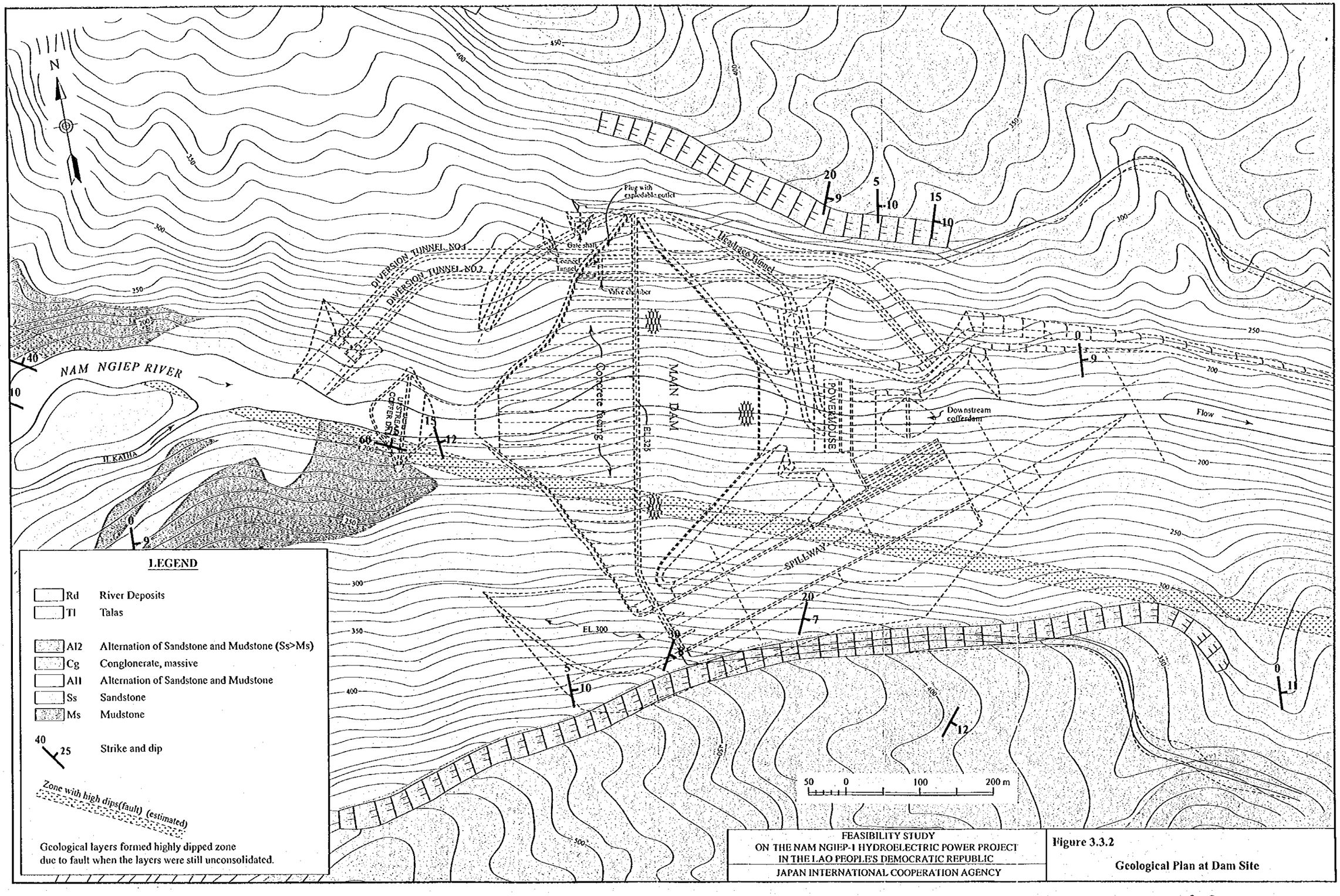


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Figure 3.3.2

Geological Plan at Dam Site

LEGEND

Rd	River Deposits
Tl	Talas
Al2	Alternation of Sandstone and Mudstone (Ss>Ms)
Cg	Conglonerate, massive
Al1	Alternation of Sandstone and Mudstone
Ss	Sandstone
Ms	Mudstone
----------	geological boundary
——·——	firm rock line
Zone with high dips (foult) estimated	Geological layers formed highly dipped zone due to foult when the layers were still unconsolidated

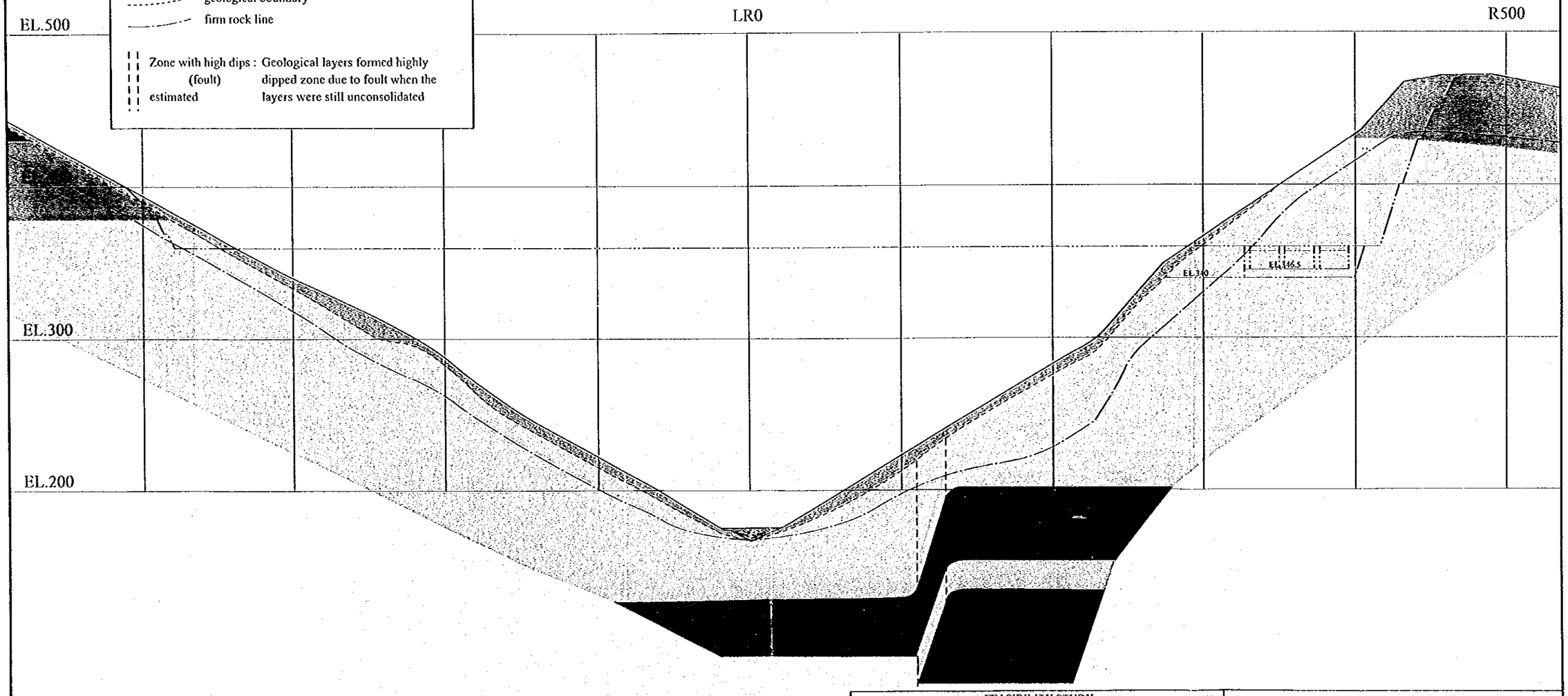

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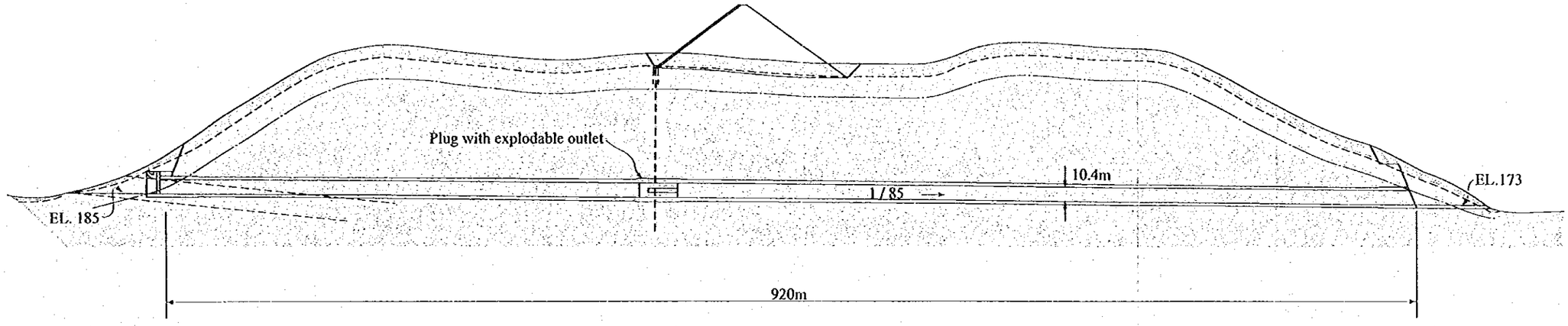
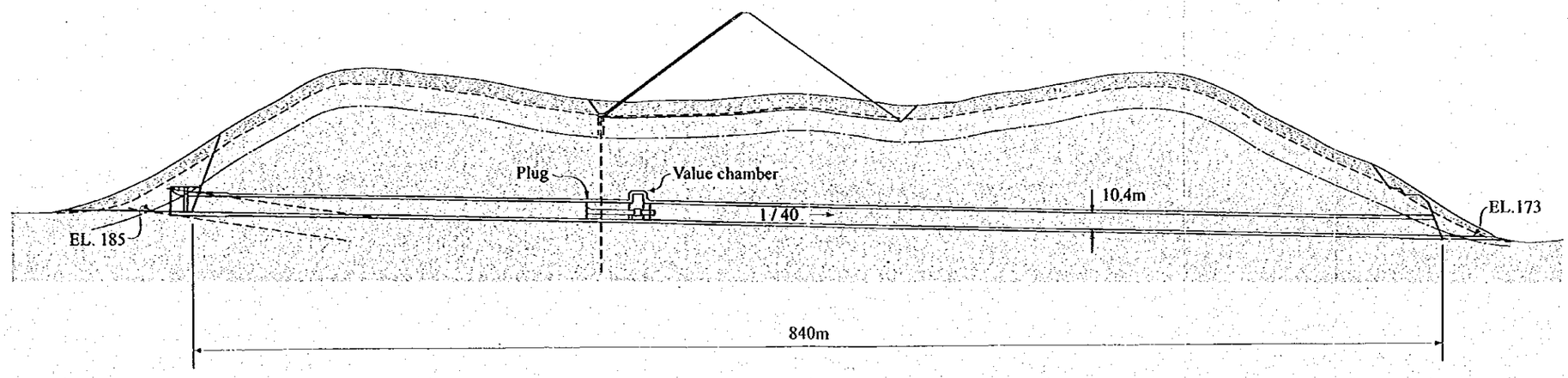
Figure 3.3.3
Geological Profile along Dam Axis



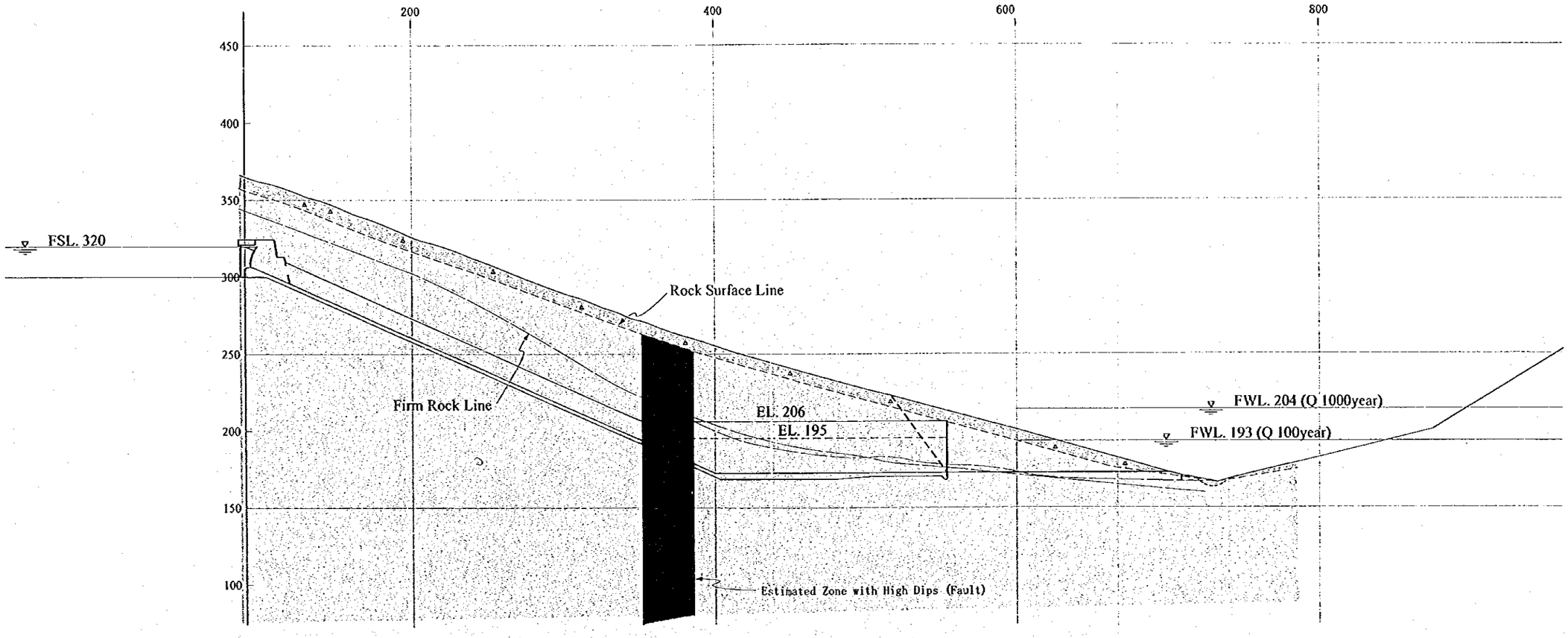
NO.1 DIVERSION TUNNEL



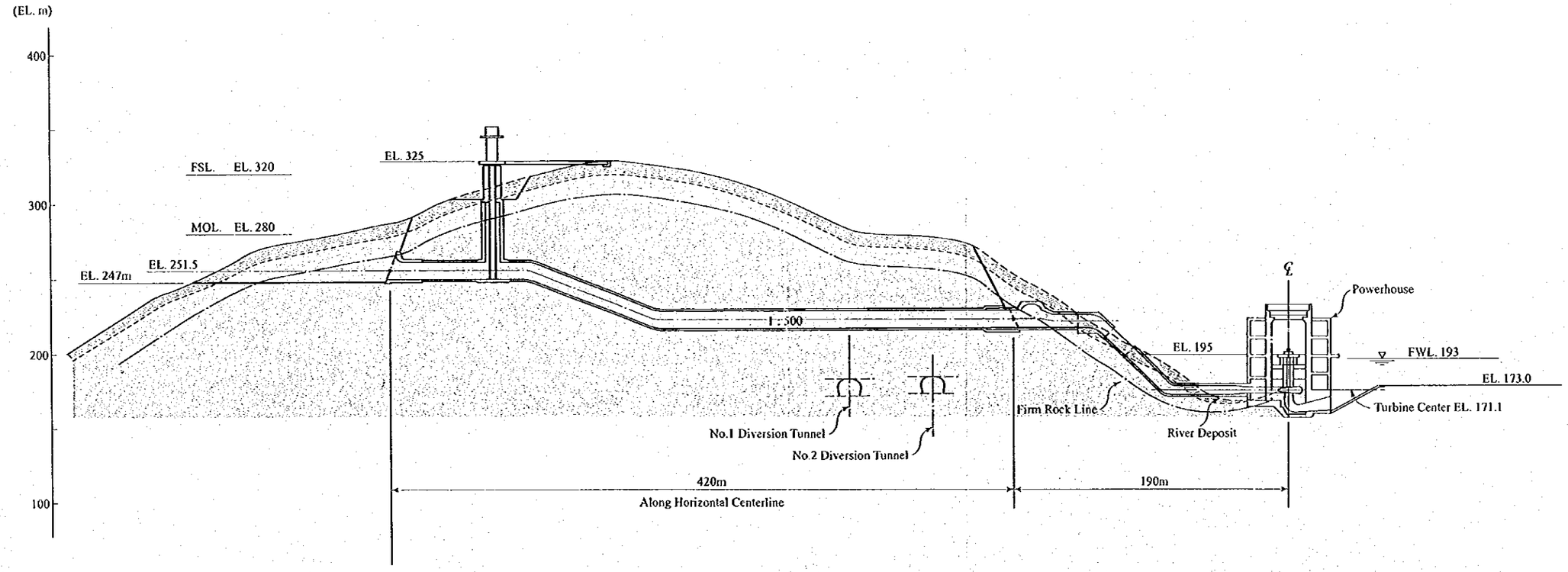
NO.2 DIVERSION TUNNEL
(BOTTOM OUTLET)

0 50 100 m
SCALE

FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.3.4 Geological Profile along Diversion Tunnel



FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 3.3.5 Geological Profile along Spillway



FEASIBILITY STUDY ON THE NAM NGIEP-I HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 3.3.6** **Geological Profile along Waterway**

3.3.3 GEOLOGICAL STRUCTURE

Zone with steep dips on the right bank of damsite (flexure): Flexure is the folding with steep dips with no apparent fault which occurs when two basement blocks move to the relatively different directions. It was produced due to fault movement in the basement rock when the formation was still unconsolidated. Sandstone/mudstone has 75°, with strike N60° W and the thickness of this zone is estimated at least 20-30m, from the limited outcrops by overburdening talus deposits. The layered sandstone/mudstone in this zone are not fractured, not altered and not deteriorated in the strength of rock. This zone ranges to the upstream to the left bank of Nam Ngiep River. Along the right bank, it recovers from 75° to 55° 30m downstream and to 12° about 50m downstream in dip. Furthermore, this zone probably ranges downstream to the cliff where conglomerate band is estimated to be dislocated. The difference of conglomerate formation level produced by flexure is estimated at 30-50m.

Another flexure and folding structure with northwest to southeast directions are observed on the outcrops along H.Katha. Minor folding in the unit formation is also observed which show folded and kinked laminations. The formations along the H.Katha belong to lower formation level compared to ones at the damsite. These lower formations look more folded compared to the formations at the damsite in gently dipped, almost flat formations.

3.3.4 LITHOLOGY

Sandstone/mudstone alternation: Thick and coarse sandstone is distributed outside of the entrance of the gorge. Alternation of reddish mudstone and sandstone is widespread downstream.

Conglomerate contains centimeters of Palaeozoic hard elements with matrix of sand, and interbedded with sandstone and mudstone. By hitting with a rock hammer it sounds half-metallic which indicates medium strength of rock. Joints do not develop. However, the rock is liable to be split by tension in case exposed to cliff and big boulders are generated (see Figure 3.3.7). In some parts, the rock surface is smooth but in some parts, the rock surface is not smooth because hard elements are exposed or hard elements are deprived to make a cavity. This may indicate the difference of strength between cement-matrix and element.

Sandstone above conglomerate is reddish sandstone. Sandstone below conglomerate is fine-to medium, white to gray, with laminations. It produces big boulders. Rhythmical fine alternation with mudstone is observed along H.Katha. It is hard and it makes sounds nearly metallic when hit by a rock hammer.

Mudstones reddish and massive are outcropped from the riverside to upstream left bank of damsite. White to gray mudstones in the fine alternation layers are sometimes laminated. When hit by a rock hammer hard mudstone interbedded in sandstone sounds vague half-metallic which indicates moderate strength of rock.

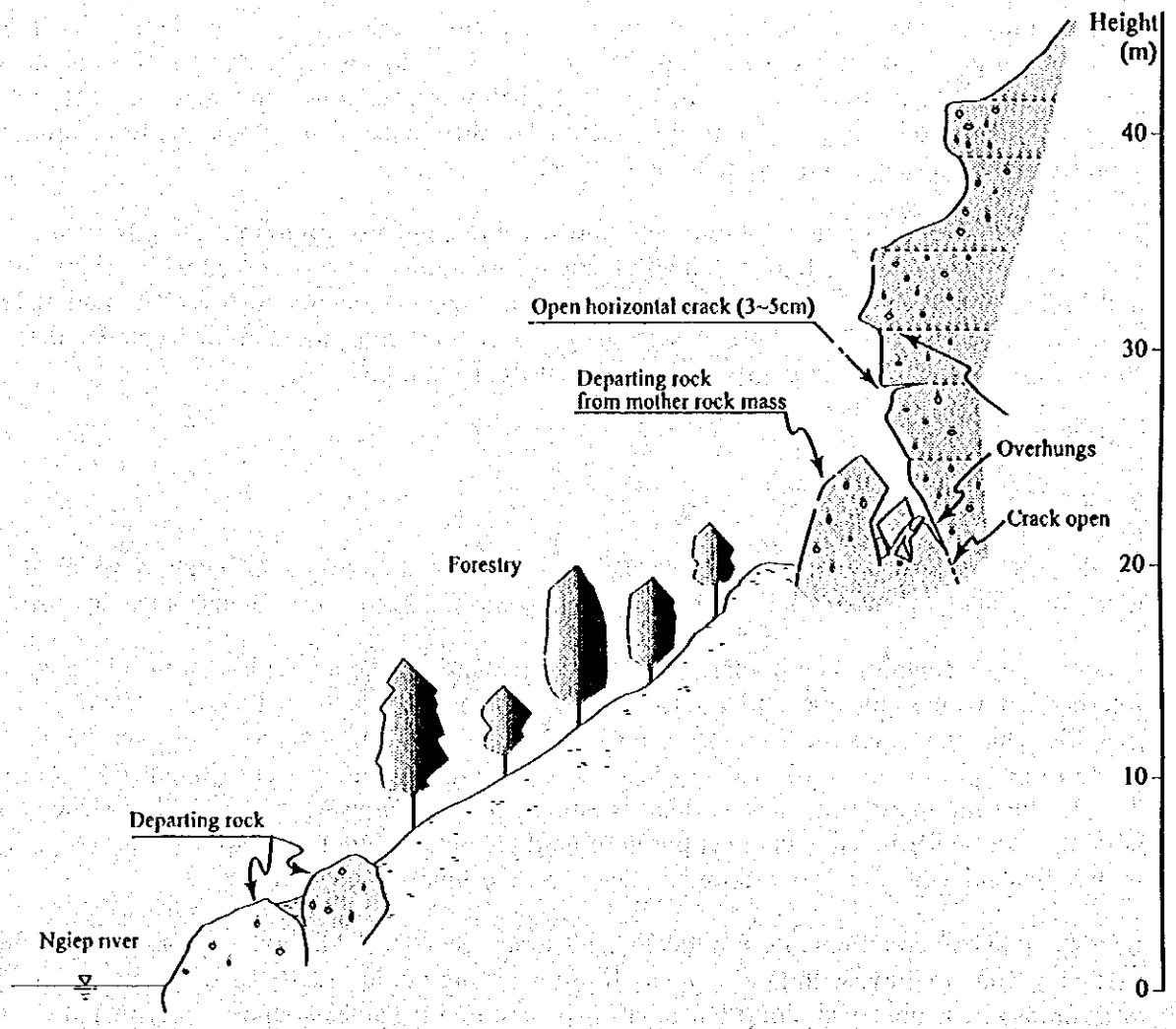


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Figure 3.3.7
Sketch of Conglomerate Cliff

3.3.5 STRENGTH AND WATER TIGHTNESS OF DAM FOUNDATION ROCKS

The foundation rock is sandstone and mudstone. On both abutments high on the cliff hard band of conglomerate and sandstone is distributed. The foundation rock is strong enough for a high dam foundation about 180m in height, because the valley is steep with high cliffs on both abutments and therefore intact foundation rock (mudstone interbedded with conglomerate and sandstone) is expected to be available not so deep in the valley. Especially, both downstream flanks of the damsite are strengthened by the dipping B.d of hard conglomerate and sandstone, which make a resistible downstream foundation, and also hard band cover keeps underlying mudstone unweathered and intact.

Water-tightness of the foundation rock is also expected to be enough for a high dam. Intact mudstone and sandstone are expected to be massive with almost no developed joints. Conglomerate is estimated with some joints especially near the cliffs where open joints and overhangs are observed, which require foundation treatments to improve water-tightness.

A zone with steep dips (flexure) runs on the riverbed where fracture and alteration are not observed. Therefore this is not serious problem as a foundation of a high dam. However, this is to be studied in detail in the next stage geotechnical survey.

The depth of weathered and firm rock zone is based on the Pre-F/S seismic survey results. The firm rock zone is estimated with to be velocity of more than 3,000m/s.

Groundwater level is expected to be high, because on the right bank there is seepage at around EL.450m on the footpath in dry season.

Seismic Analysis, summary of geotechnical survey of Pre-F/S is as follows;

(i) Debris cover is about 3m to 5m in thickness estimated from a velocity of some 500m/s to 700m/s.

(ii) Weathered zone is about 20m to 30m, at most about 50m-60m in thickness with velocities between 1,350 m/s - 2,400 m/s.

(iii) Intact rock zone is estimated with a velocity more than 4,000m/s.

(iv) Right bank thickness 50m-60m of intermediate velocity zone is explained first by sub-vertical fracture (estimated fault) and secondly by sub-horizontal layer of mudstone type liable to weathered to greater thickness although it displays better velocity once the sound rock is reached.

(v) On the valley hillsides the seismic substratum is situated around 30-40m and the velocity is generally between 3,000 and 3,500 m/s which indicates loosening by vertical joints.

3.3.6 GEOLOGY AROUND RE-REGULATING WEIR SITE

Re-regulating weir is located at 5km downstream of the damsite, where low hills develop with hilltops of 210 -230m in elevation. These hills are composed mainly of reddish mudstone and sandstone, Middle Jurassic to Lower Cretaceous. Alluvial deposits are only in the riverbed, and

terrace deposits are distributed along the riverside but do not widely develop. On parts of both banks there are outcrops of reddish mudstone, so alluvial river deposits are not expected to be so deep (maybe less than 2 m). On both banks there are many small branch valleys to be filled by banks where foundation rock, mudstone and sandstone, are expected to be met under weathered decomposed zone in shallow depth.

3.4 SEISMICITY

According to HPO, there is no seismological station in Lao PDR. The following three (3) reports were reviewed on seismicity in Lao PDR:

(i) The Nam Ngiep-I, Pre-F/S, January 1991 by Sogreah. This reports that there are very few seismic events in the region and those that were recorded during the last 20 years, are not important (magnitude below 5).

(ii) The Nam Mo HEPP, Pre-F/S Main Project Report (draft). September 1997, by Electrowatt Engineering. In this report, Seismicity Catalogue of Southeast Asia (1912-1976, National Geophysical Data Centre, Boulder, Colorado, USA) with epicenters between longitudes 96°E to 109°E and latitudes 10°N to 25°N are collected.

(iii) The Nam Ngum-3 HEPP, Pre-F/S, Final Report, March 1996 by SMEC. Here over 2100 major events up to 1995 were studied by the Seismology Research Centre at RMIT University for SMEC.

According to the above report (i), seismic activities in the Nam Ngiep river basin are rare and during the past 20 years, there is no record of an earthquake exceeding magnitude-5.

According to the report (ii), which was written for the Nam Mo river basin east of the Nam Ngiep river basin, there are no earthquake records exceeding Magnitude-6 and very few even less than magnitude-6 in the central area: 96°-109° east and 10°-25° north of Lao PDR. This report is based on the records observed from 1912 to 1976 by National Geographical Center, Colorado USA.

Also from the report (iii) showing the result of analysis made by Seismic Research Centre at RMIT University for all 2,100 seismic records in a recorded history in the south-east Asian countries, it has been confirmed that seismic activities in the central region of Lao PDR are very rare.

3.5 CONSTRUCTION MATERIAL

3.5.1 STRENGTH OF ROCK

Rock samples from the surface were brought to laboratory tests of Pre-F/S.

According to the Franklin test of Pre-F/S, samples from the ground surface indicates the strength

as shown in Table 3.5.1 under the Rock Classification by ISRM Uniaxial Strength. Rock Test Results at Pre-F/S, ISRM Classification by Unit Strength and Talus Deposits at Downstream on Main Dam are shown in the Supporting Report (VI).

Table 3.5.1 Result of Franklin Test made in Pre-F/S

No.	Rock	Uni-axial compressive strength (Mpa)	Characteristics	Natural moisture content (%)	Unit weight (kg/m^3)
1.	Conglomerate	44 - 64	Medium strength	< 2	2.5
2.	Sandstone	8 - 74	Low strength to Moderate	2 - 6	2.3 - 2.5
3.	Mudstone	2 - 10	Very low to Low strength	6 - 12	2.1 - 2.5

Rock samples from sound intact mudstone are expected to be much stronger than samples from above the ground surface. However, easily deteriorated and decomposed characteristics shown above are to be remarked and some considerations are required for the design of this kind of rock.

3.5.2 QUARRY SITES

Conglomerate and sandstone are expected to be rockfill material. Conglomerate is located (i) on the hilly cliff top area on both sides of the Nam Ngiep River, (ii) excavation of spillway etc. Sandstone is located at (i) the confluence of B.H.Katha, (ii) on the ridge on the right bank of H.Katha, (iii) outside downstream of gorge. Sandstone rich formation is to be surveyed for alternation area. In addition, big boulders along the Nam Ngiep riverside and gravel along H.Katha are available for rockfill material, some of which require crushing.

Conglomerate and sandstone are also expected as concrete aggregate. However, there still remain to be studied for:

(i) Strength of sandstone and conglomerate (crushing ability into aggregate size), and

(ii) Alkaline chemical reaction to cement (secondary silica to be checked).

Other resources for concrete aggregate are from Palaeozoic formations and from Granite intrusive. They are distributed in the northern Palaeozoic formations folded during Late-Palaeozoic which are located about 12-15km north of the damsite (Palaeozoic and granite) but nowadays there is no road along Nam Ngiep River. On the northside of B.Hatkham Palaeozoic formation, limestone and sandstone are available, and in Muanghuang Limestone quarry is on working. Direct distance from the damsite is 20 km, but it takes more than one hour via B.Muangbo from B.Hatkham and difficulties arise in traffic transportation in rainy season. Locations of site reconnaissance carried out around the damsite on rock quarries are shown in Figure 3.5.1.

River sand and gravel deposits are distributed along the Nam Ngiep River in the river course, between the damsite and B.Hatkham and also downstream of B.Hatkham, but a large amount of good material, which does not contain fine materials such as silt, is not expected, and conglomerate and sandstone are contained relatively more than Palaeozoic.

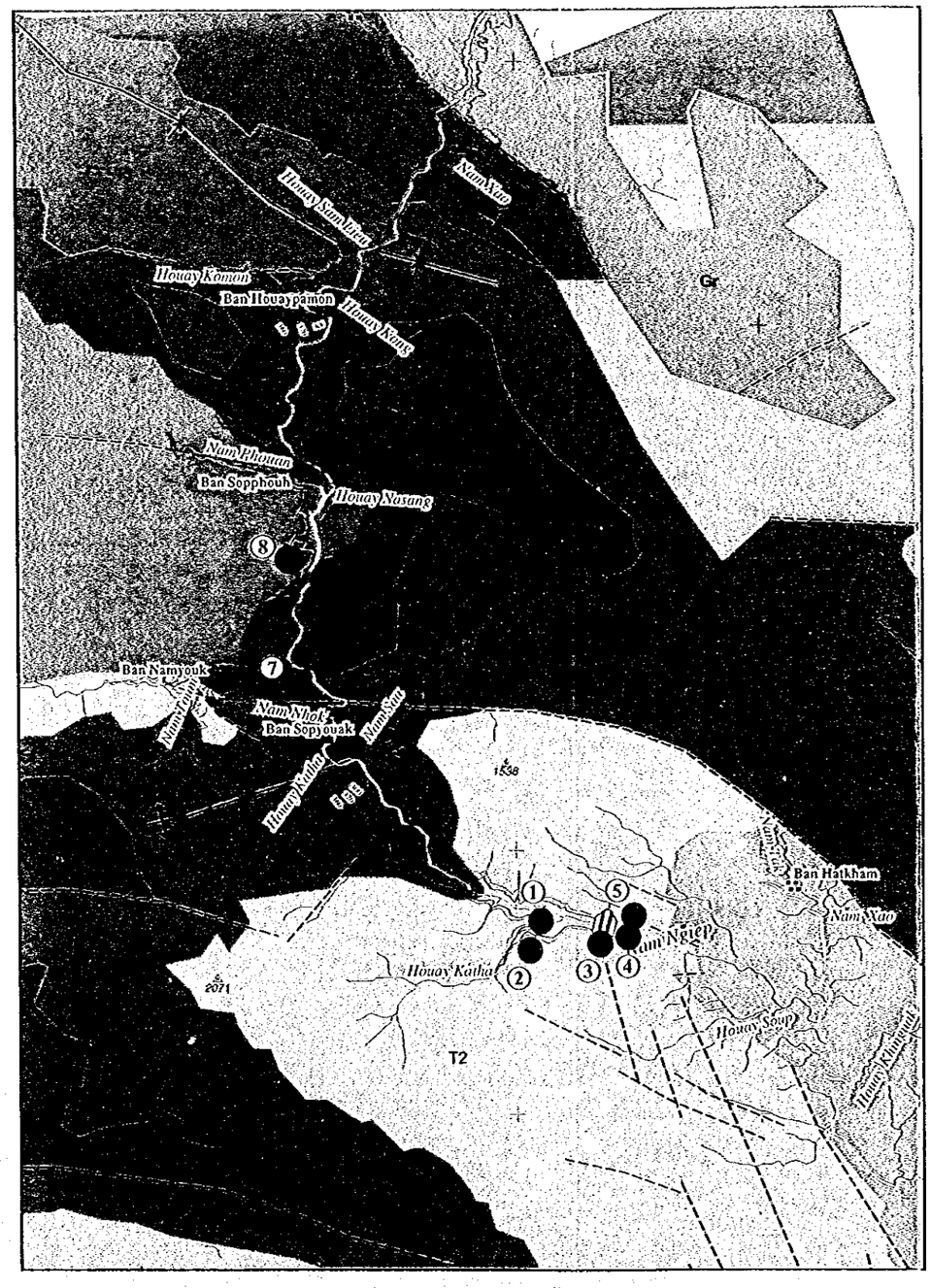


Figure 3.5.1 (a) In Proposed Reservoir Area

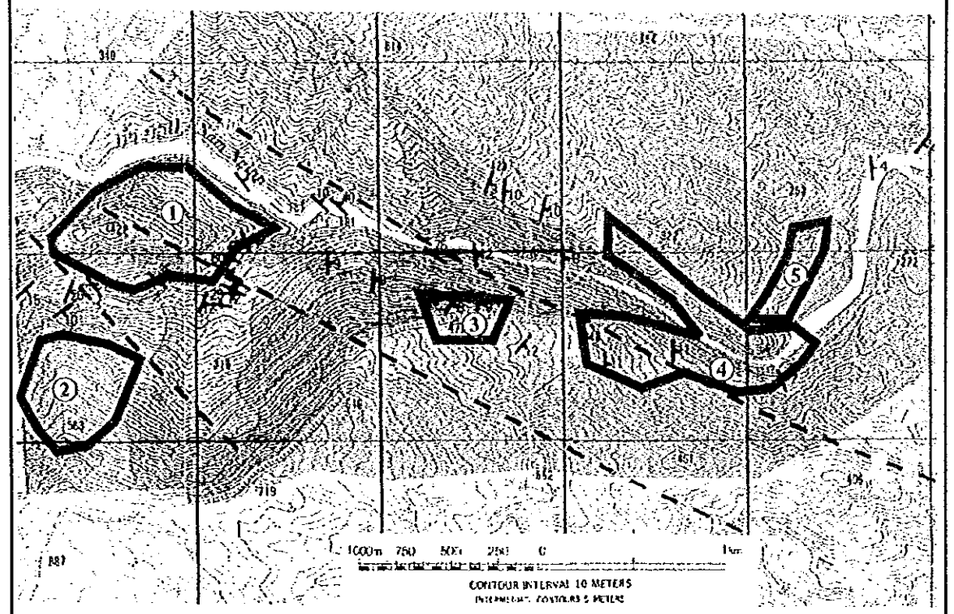
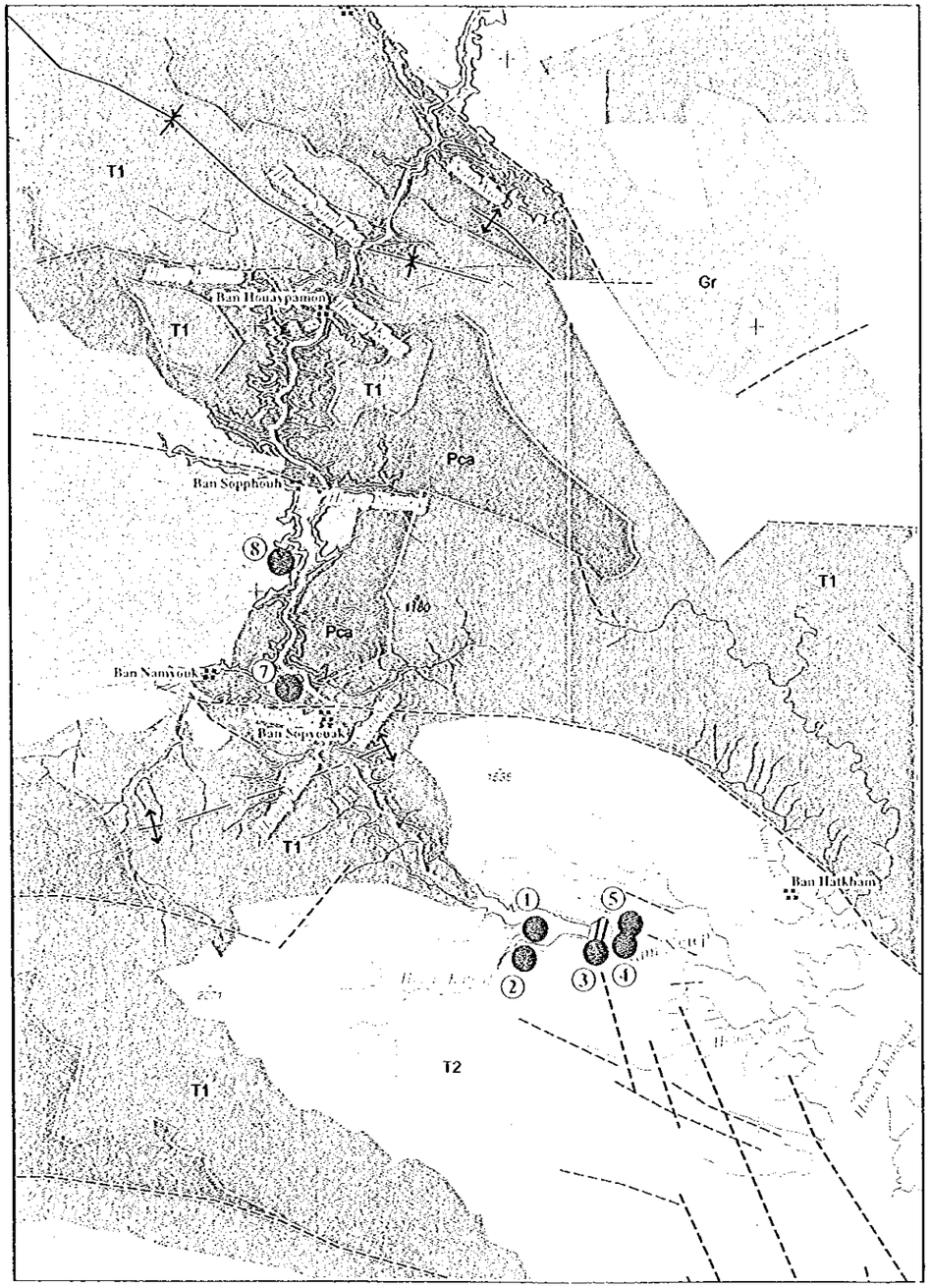


Figure 3.5.1 (b) At Proposed Dam Site

Quarry Site Candidates

1 Sandstone rich formation at the confluence of tributary Katha river
2 Sandstone rich formation at the right bank of tributary Katha river
3 Conglomete and sandstone at the right bank excavation of spillway
4 Conglomerata downstream of damsite
5 Sandstone downstream of damsite
6 Limestone (surveyed)
7 Palaeozoic sandstone expeted(but not yet surveyed due to no access road)
8 Granite expected (but not yet surveyed due to no acess road)

FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 3.5.1** **Prospective Sites for Quarry**



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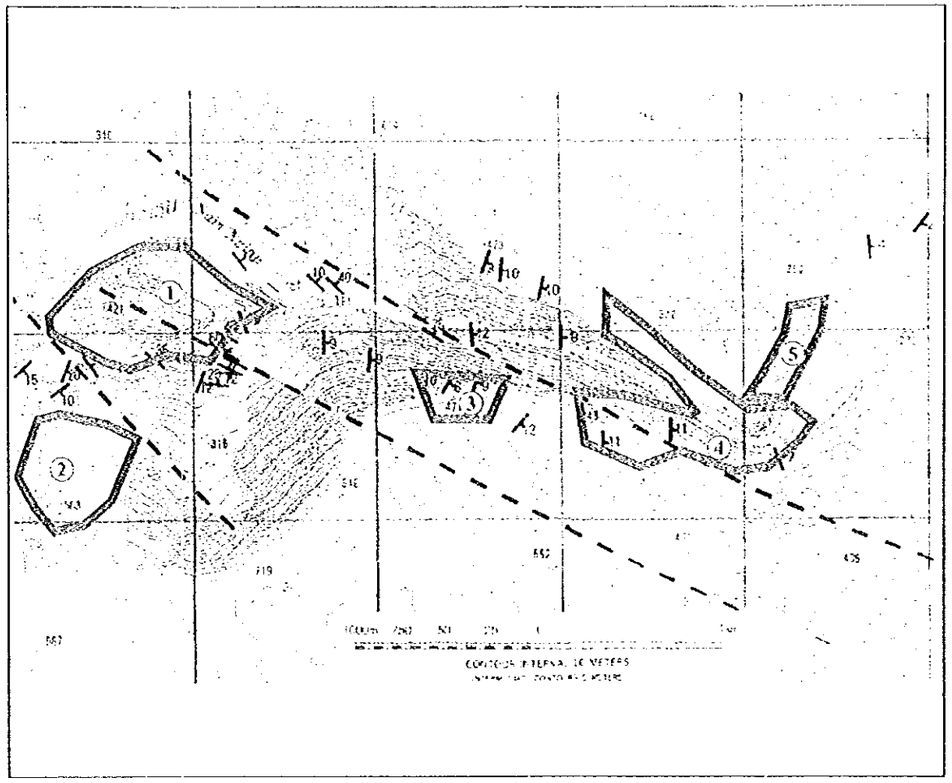

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FEASIBILITY STUDY ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT IN THE LAO PEOPLES DEMOCRATIC REPUBLIC JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 3.5.1** **Prospective Sites for Quarry**

3.5.3 FILL MATERIAL

Impervious material will be investigated in Quaternary deposits (Terrace deposits) and also in Palaeozoic formations where strongly weathered sandstone is expected about 12 km north of B.Hatkham, which still remains to be studied.

Pervious materials such as sand will be investigated in river deposits, which is not expected to be much. Otherwise it is expected to be from the quarry site.

4. METEOROLOGICAL & HYDROLOGICAL SURVEY

4.1 GENERAL

Taking into consideration that this Study would be executed on the course of investigation stage mainly for environmental impact assessment of the Project, the purpose and results of hydrological analysis at this stage were put on the following targets:

(i) Review of hydrological data and results of Pre-F/S Report,

(ii) Installation of new gauging stations for definition of basic hydrological data (basin rainfalls and river discharges), and

(iii) Collection and checking of additional hydrological data.

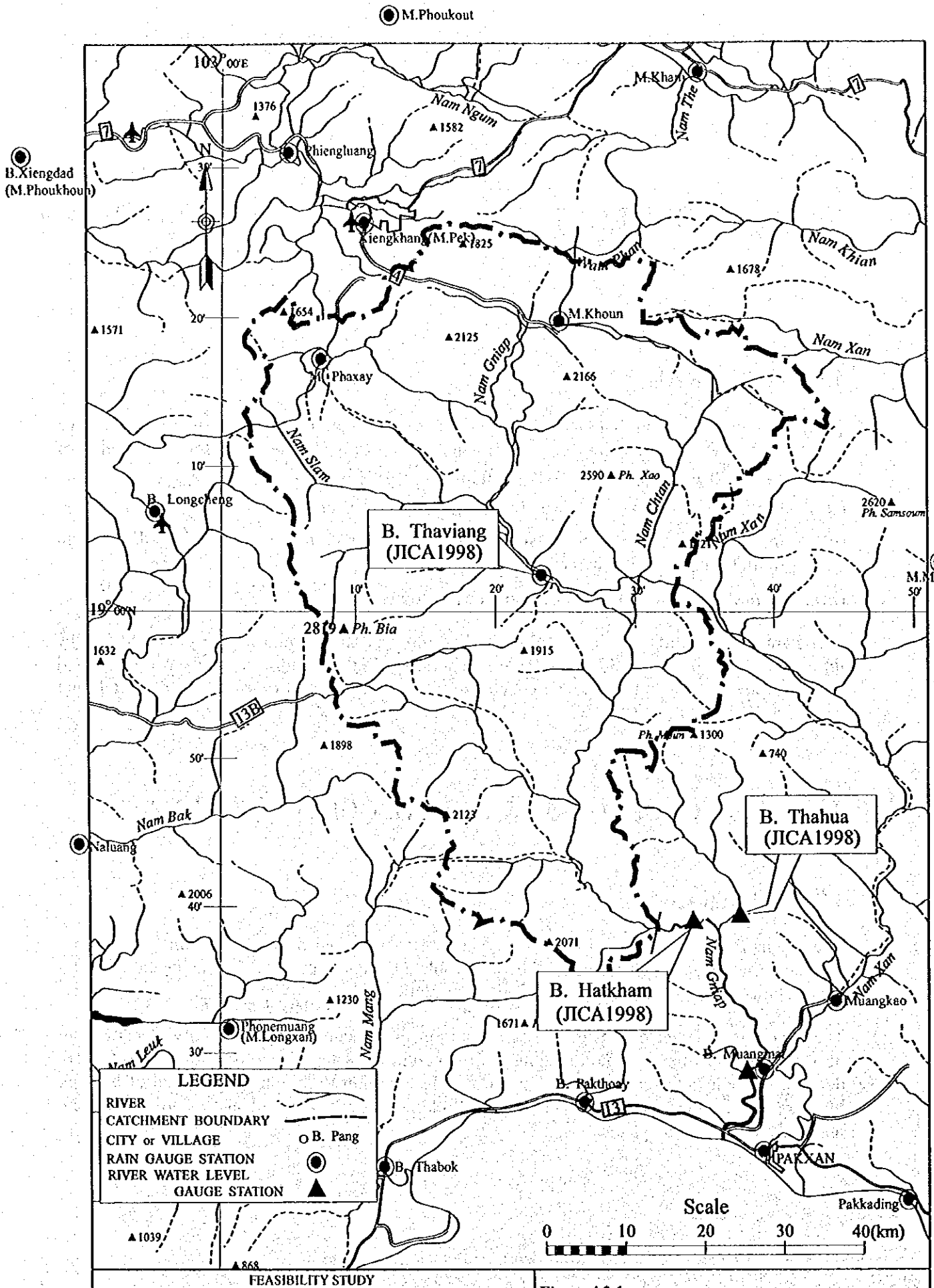
Sufficient data, records and information for hydrological study could not be collected for the limited period of the 1st Field Investigation. Therefore, in this Report, the study will be limited to an simplified one, and a decisive conclusion will not be given to the values of rainfall and discharge.

4.2 METEOROLOGICAL & HYDROLOGICAL OBSERVATION

4.2.1 GENERAL

Equipment for hydro-meteorological observation was procured during the Home Preparatory Work, and was installed at locations shown in Table 4.2.1 and Figure 4.2.1 (one location for rain gauge station, two locations for water level gauge station).

The locations were selected with due consideration of site condition, availability of permanent observation staff, surrounding topography, flow condition, safety, etc. Installation points were decided through field reconnaissance while paying attention to present distribution of existing hydrological gauging stations, operation and maintenance works and access to the station, material and counter maps etc.



FEASIBILITY STUDY
ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT
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Figure 4.2.1
Hydro-Meteorological Observation Gauge Station

Table 4.2.1 Newly Installed Hydrological Observation Stations

No.	Name of gauging stations	Date of installation	Name of point	Name of river	Reference
1.	Rain Gauge Station	Aug. 21,'98	B.Dong	Nam Ngiep River	One automatic rain gauge was installed at B.Dong in Thaviang Sub-District, which is located in the central area of the basin.
2.	Water Level Gauge Station-A	Sep.01,'98	B.Hatkham	Nam Ngiep River	Installed at B.Hatkham about 8.5km D/S of the proposed dam site, where daily observation and maintenance works can be undertaken.
3.	Water Level Gauge Station-B	Sep.01, '98	B.Thahua	Nam Xao River	The Nam Xao River meets with the Nam Ngiep River about 10km D/S of the proposed dam site. Installed at B.Thahua along the Nam Xao River about 3km U/S of confluence with the Nam Ngiep River.

4.2.2 INSTALLATION OF METEOROLOGICAL OBSERVATION EQUIPMENT

There are three (3) existing rain gauge stations installed in the Nam Ngiep River, of which two (2) are in the most upper part of the basin and one (1) is in the most lower part (at the same point as Muangmai gauge station).

As for rainfall data of the two (2) upstream gauge stations, observation records are not known because data is not reported to the Department of Meteorology, Ministry of Agriculture and Forestry in Vientiane. Thus, it was judged to be appropriate to install new rainfall gauging stations near the center of the basin in consideration of basin rainfall observation and dam operation rule etc. As a result, they were installed in Thaviang Sub-District.

Buckets of automatic rain gauge stations were installed in the flat land which is 10m or more away from houses or trees. The buckets were surrounded with fences to prevent people or animals from getting inside. Cables between buckets and recording machines were embedded underground. Automatic recording equipment was installed in the existing public building (inside army dormitory).

Operation and maintenance works depended on Mr. Kham Mang, a carpenter who installed the rain gauge, living in Thaviang. Automatic recording paper should be replaced once a month. However, it was decided that Mr. Kham should also do maintenance and checking works every morning at 9:00 and do observation of temperature and humidity with a simple measuring device.

The rainfall observation data measured by the Study Team during the period from September 1998 to November 1999 are shown in Table 4.2.2 and Figure 4.2.2.

Table 4.2.2 Rainfall Observation Data measured by the Study Team

Year	Month	Rainfall		Temperature (℃) at AM9:00			Humidity (%) at AM9:00		
		Total (mm/month)	Maximum (mm/day)	Monthly Average	Monthly Minimum	Monthly Maximum	Monthly Average	Monthly Minimum	Monthly Maximum
1998	Aug.	-	-	27.8	29.6	25.9	81.1	88.0	63.0
	Sep.	135.5	45.0	27.4	28.6	25.5	79.1	100.0	63.0
	Oct.	50.0	24.5	26.9	29.9	24.9	70.4	89.0	54.0
	Nov.	12.0	7.5	25.7	28.6	22.3	63.3	82.0	53.0
	Dec.	12.0	10.0	20.4	27.5	14.9	77.5	100.0	34.0
1999	Jan.	7.5	4.0	18.1	22.2	12.6	86.4	100.0	64.0
	Feb.	5.0	5.0	19.5	22.2	15.3	79.3	100.0	57.0
	Mar.	56.5	11.5	21.8	26.4	16.5	83.1	100.0	50.0
	Apr.	128.5	25.0	26.0	33.1	24.1	89.5	100.0	67.0
	May	697.5	56.5	24.8	27.5	20.5	95.4	100.0	70.0
	Jun.	396.0	38.0	26.0	28.3	20.5	97.2	100.0	70.0
	Jul.	-	-	26.8	28.6	24.2	99.5	100.0	85.0
	Aug.	296.0	63.0	26.1	28.0	24.4	99.2	100.0	85.0
	Sep.	519.4	51.5	-	-	-	-	-	-
	Oct.	385.0	53.0	-	-	-	-	-	-
	Nov.	129.0	44.0	-	-	-	-	-	-
	Dec.	-	-	-	-	-	-	-	-

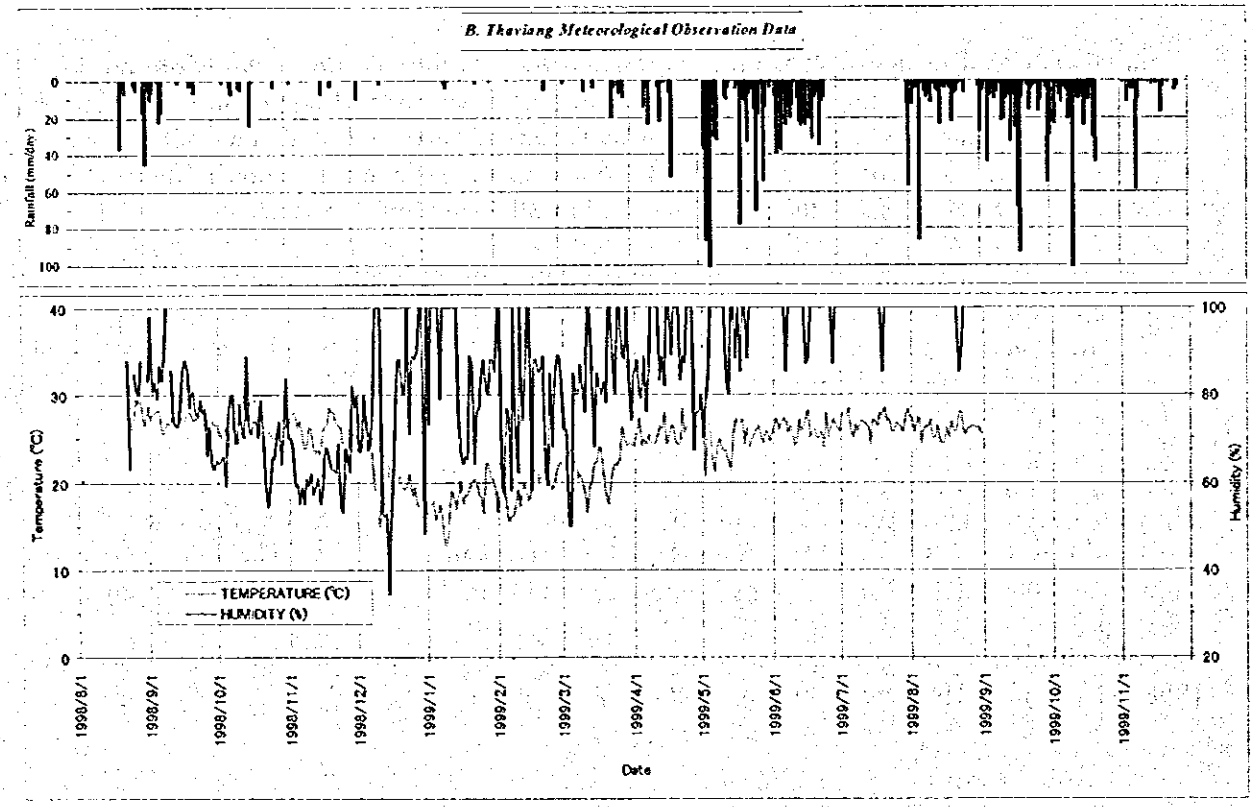

Figure 4.2.2 Rainfall Observation Data measured by the Study Team

4.2.3 INSTALLATION OF HYDROLOGICAL OBSERVATION EQUIPMENT

(1) General

A gauge station installed in the Nam Ngiep River basin has its water-level staff in B.Muangmai near the confluence with Mekong River. It has been periodically maintained by the Department of Meteorology and Hydrology since 1978. By using these data to anticipate discharges at the proposed dam site with enough accuracy, it is necessary to deduct the discharge of a tributary, the Nam Xao River, which meets with the Ngiep River at a point between B.Muangmai and the proposed dam site. It was hence necessary to install discharge measurement stations at the nearest possible point to the proposed dam site (Point A), and at the tributary of the Nam Xao River (Point B).

With regard to the selection of Point A, there was a candidate small village called B.Hatxay Kham about 3 km downstream of the proposed dam site. However, it was a village of a tribe called Mom, which is mobile, and it was thereby judged difficult to find a water level observation staff for a long continuous period. Between B.Hatxay Kham and B.Hatkham, there was no major inflow from tributaries and with due consideration of availability of reliable observation staffs, flow condition and availability of places to stay, it was decided to install a gauging station at B.Hatkham, about 8.5 km downstream of the proposed dam site. B.Hatkham has experience of executing water observation during the period of Pre-F/S in 1991.

As for the selection of Point B, a point was selected with the following conditions;

(i) No effect of backwater of the Ngiep River,

(ii) Nearest possible point to the confluence, and

(iii) Water level observation staffs are available.

As a result, a gauging staff was decided to be installed in the Nam Xao River at B.Thahua, which is about 3 km upstream from the confluence with the Nam Ngiep River.

Water level gauging staffs are made of metal plates of 1.0m long, which were installed in the riverside toward the top of the riverbank like a stairway. To fix the water-level staff, wooden piles were used, which were obtained in Pakxan. Concrete was installed for fixing the wooden piles to prevent piles from being inclined or washed away. In addition, due to abnormal meteorological condition in this rainy season of 1998 (from July to September), the related area had fewer rainfall compared to usual year, and therefore water level measuring staff could be installed up to a relatively low water level. The total length of the installed measuring staff is shown in Table 4.2.3.

Table 4.2.3 Total Length of Installed Water-Level Staff

Point Name	Place of installation	Total length
Point A	Nam Ngiep, B.Hatkham	15m=9m+6m
Point B	Nam Xao, B.Thahua	12m=8m+4m
Total		27m=17m+10m

The Study Team requested village headmen of both 2 villages to measure and record river water levels twice a day at 6:00 in the morning and at 18:00 in the evening with an accuracy of 1cm. In addition, weather should also be recorded in those stations.

(2) Additional Installation of Water Level Gauging Staff

By using the water level gauging staff installed during the 1st Field Investigation in the rainy season, it was impossible to measure water levels during the dry season when the water level was low. Therefore, at the time of the 2nd Field Investigation, the additional water level gauging staff were installed for low water measurement. Installed lengths were 6m at Point-A and 4m at Point-B, respectively. These works are to be done by HPO utilizing the water level gauging staff brought to the site by the Study Team.

(3) Discharge Measurement

The price's system current meter brought from Japan was transferred to MIH during the 1st Field Investigation and discharge measurement technique was transferred to the people in charge in MIH at two (2) observation points, namely B.Hatkham and B.Thahua.

Current measurement lines for velocity measurement were set near the installed water-level staff, in the river-crossing direction where river streams were almost straight. For both points measuring works of velocity and river cross section were done by small boats using a current meter. Results of the discharge measurement by HPO during the Study are shown in Table 4.2.4. The H-Q relation curves analyzed by using the above measured discharge data are shown in Figure 4.2.3. Discharge measurement using a float was also transferred to the staffs through preparation of several floating devices made of bamboo, which was normally adopted for flood discharge measurement.

Table 4.2.4 Result of Discharge Measurement

No.	Name of River	Name of Point	Observation Date	Observation time	Weather	Discharge observed (m^3/s)	Water level (m)	Measurement method
A-1	Nam Ngiep	B.Hatkham	Sep.02'98	13:20	Fine	535.21	12.22	Current meter method
A-2			Dec.08'98	16:15	Cloud	40.01	9.65	
A-3			Feb.09'99	13:25	Fine	23.89	9.83	
A-4			May 29'99	11:15	Cloud	169.83	10.68	
A-5			Jun.25'99	14:40	Cloud	358.28	11.57	
A-6			Aug.03'99	9:25	Cloud	229.29	11.19	
A-7			Sep.05'99	11:15	Cloud	250.91	11.14	
A-8			Oct.09'99	10:00	Cloud	184.84	10.77	
A-9			Vov.28'99	13:00	Fine	76.20	10.15	
A-10			Jan.27,2000	15:20	Fine	67.62	9.6	
B-1	Nam Xao	B.Thahua	Sep.02'98	18:30	Fine	57.16	11.61	Current meter method
B-2			Dec.09'98	12:30	Cloud	1.38	9.57	
B-3			Feb.10'99	11:30	Fine	0.34	9.44	
B-4			May 29'99	14:06	Cloud	7.91	11.48	
B-5			Jun.26'99	16:40	Cloud	22.81	11.78	
B-6			Aug.03'99	11:50	Cloud	48.14	11.52	
B-7			Sep.05'99	12:40	Cloud	21.462	10.74	
B-8			Oct.09'99	12:20	Cloud	18.83	10.32	
B-9			Vov.29'99	12:35	Fine	2.86	9.7	
B-10			Jan.27,2000	18:15	Fine	1.9	9.48	

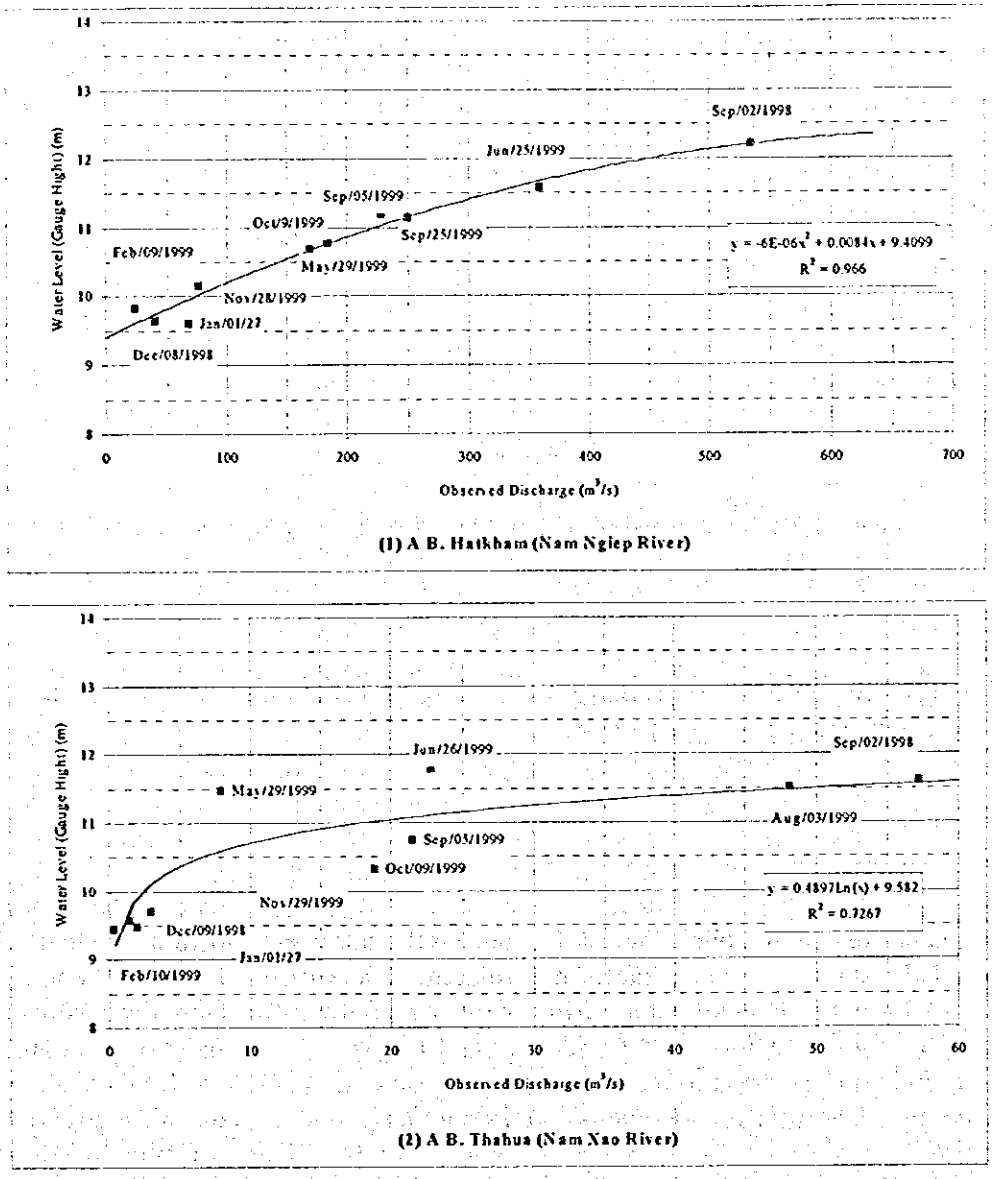

Figure 4.2.3 H-Q Relation Curves

The Study Team requested MIH to observe discharge continuously and periodically (more than once a month) from now on. The Study Team also requested MIH to be fully responsible for collecting and supplying the said rainfall record paper and doing periodical maintenance of the machine. MIH basically approved the request. However, the cost for the above works such as expenses for trip and allowances were requested to be covered by the Japanese side, since the budget allocation in Lao PDR was quite difficult.

(4) Observed Data

The rainfall and water level data measured by the Study Team during the Study are shown in Figure 4.2.4.