# 2. PROJECT IMPLEMENTATION PLAN

## 2.1 GENERAL

According to the practice of Japanese ODA, low interest JBIC soft loans are one of the funding sources available for a developing country to implement a social/economic infrastructure project, provided the development studies by JICA prove the project's viability and the host country desires for it to be implemented. In such cases, the government of the host country usually acts as the owner of the project, and construction works are carried out by contractors selected by international competitive bidding procedures. The Nam Leuk Hydroelectric Power Project (60 MW) in Lao PDR, which commenced power generation in September 2000, was co-financed by both JBIC and ADB and is representative of this pattern.

The Nam Ngiep-I Hydroelectric Power Project is planned to be implemented by mostly private sector funds because of its huge project scale compared with the state budget of the Lao PDR. Naturally, the mitigation of investment risks will be a major concern for private investors in a developing country. Meanwhile, as the Lao government (GoL) will also join the Project as one of the shareholders, GoL has to seek fund sources with low interest rates. These are the two main difficulties which confront the Project.

In additon to the current financial deterioration in Lao PDR, one of the LLDC countries, the following recent background surrounding Japanese ODA Loans has become a hindrance to infrastructure development projects such as the large dams for hydropower:

(i) Difficult fiscal and economic situation in Japan,

(ii) Increased recognition of need for considering environment and social issues,

(iii) Poverty and increasing income disparities of developing countries,

(iv) Increasingly serious global issues on environmental, energy and water resources, and

(v) Growing concern about the debt problem of developing countries.

Despite the above, the Study Team believes that the Project could be implemented immediately by applying the following project formation and project financing stratagem, because our 4-year study results included environmental impact assessment and public involvement from the outset. Furthermore, we should not forget that the Project would generate valuable foreign currency every year with 10% investment by GOL for the total project cost at the beginning stage only.

## 2.2 PROJECT FORMATION

Figure 2.2.1 shows the proposed project organization and contract structure among key players. First, private companies (Thai investors, foreign power companies/consultants, contractor/suppliers, etc) interested in the project will form a private developer (consortium) and make a concession agreement with GoL.

The private developer and GoL will then invest in a project company (special purpose company or SPC) under a shareholder agreement. Then the project company will make a power purchase agreement (PPA) with prospective power purchasers. At the same time, the project company will sign a loan agreement with lenders and start work on the project.

The project company will hire an EPC (engineering, procurement and construction) contractor to construct the project. This will usually be a turnkey contract for detailed design, construction and commissioning. There may also be an operation and maintenance (O & M) contract if the project company is not intending to operate the plant. The project company will pay off the loans and recover investment from power sales revenues during the concession period (say 25 years after commissioning). At the end of the concession period, the project facilities will be transferred to GoL under specified conditions, either at zero value or at an amount agreed in the concession agreement.

The project finance will be a mixture of equity and loans. Here the developer (including GoL) will put up the equity covering 30% of the project cost, while loans cover the remainder. The equity share of GoL will be 30% of the total equity.

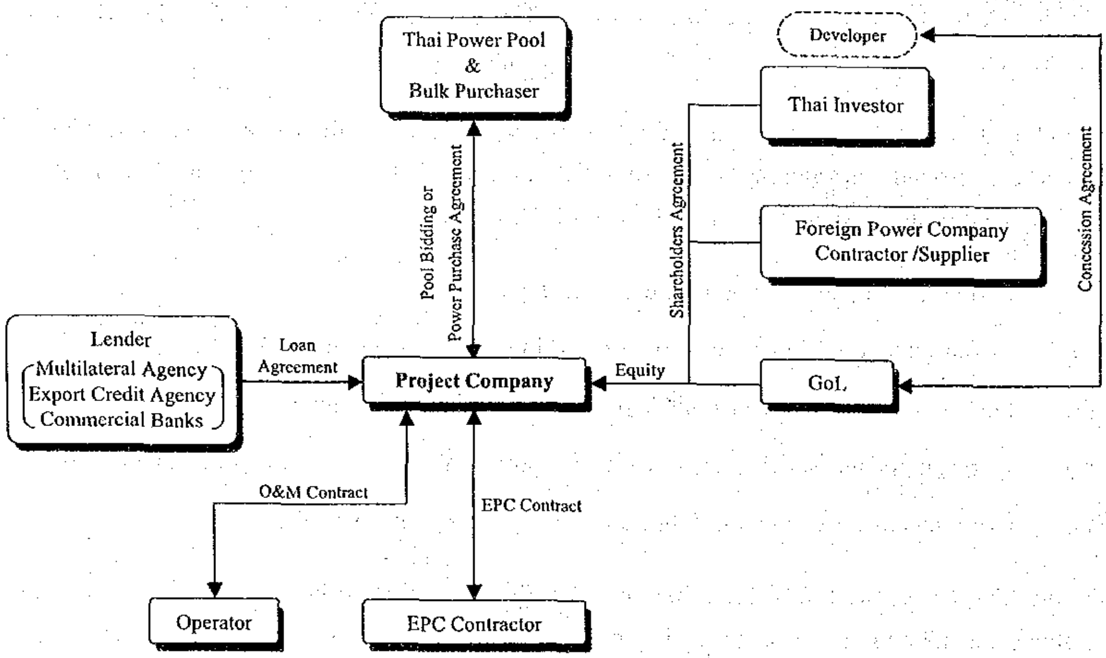



Figure 2.2.1 Project Contract Structure

Total project cost is estimated at about US$ 343.7 x $10^6$ (equivalent to Japanese Yen 41,250,000,000 with exchange late 120 Yen/$) as summarized below.

Table 2.2.1 Total Project Cost (Units: US$)

| No. | Particular | Cost |
|---|---|---|
| **1.** | Construction Cost | **291,781,840** |
| 1.1 | Civil Works | 178,411,440 |
| 1.2 | Metal Works | 20,287,000 |
| 1.3 | Generating Equipment | 59,137,400 |
| 1.4 | Transmission Line and Substation | 33,946,000 |
| **2.** | Environmental Cost | **16,473,260** |
| 2.1 | Environmental Monitoring and Planning | 9,669,000 |
| 2.2 | Resettlement Cost | 6,804,260 |
| **3.** | Operation Cost for SPC | **10,290,100** |
| 3.1 | Site Investigations and Tender Design | 4,125,000 |
| 3.2 | Administration for SPC | 6,165,100 |
| **Sub-total** | **Project Cost** (1 to 3) | **318,545,200** |
| **4.** | Price Contingency | **25,167,410** |
| **Total** | **Total Project Cost** (1 to 4) | **343,712,610** |

## 2.3 PROJECT RISK PROFILE

Private financing of infrastructure projects in developing countries commonly carries certain risks, and hydropower projects are perceived to pose particular difficulties. There are many hydropower projects that are competitive if evaluated over the long-term. However, as the initial investment cost per kW is higher than that of thermal plants, generally by two or three times, hydropower plants are evaluated as less competitive from the viewpoint of short-term financing. Despite their economical feasibility, the high interest rates of short-term loans become a financial burden for these types of project.

It is planned that 70% of the total cost of this Project will be covered by loans. An appropriate risk management mechanism should be set up, otherwise it will become rather difficult to sign a loan agreement with lenders and start construction.

Table 2.3.1 shows the risks which are particular to this Project and possibly will affect the profitability. Methods for mitigating such risks have been examined during this Study, but there still remain uncertain factors that cannot be solved completely at this moment. Impact by these risks to financial evaluation is analyzed in Chapter 11.4, Sensitivity Analysis.

Table 2.3.1 Risk of the Nam Ngiep-I Hydroelectric Power Project

| No. | Risk of Hydropower | Obstacles due to Risk |
|---|---|---|
| 1. | Natural Condition (1) / Initial Cost (1) | Cost over-run due to geological problem |
| 2. | Natural Condition (2) | Decrease of energy due to less run-off in the river |
| 3. | Construction Delay | Less profitability due to construction delay |
| 4. | Initial Cost (2) | Cost over-run due to change of T/L connection |
| 5. | Market | Decrease of power tariff due to PPA negotiation |
| 6. | Environmental Impact | Natural environment / resettlement issue |

Examination results on these risks are described below:

### (1) Cost Over-run due to Geological Risk

In this Study, a geological investigation was carried out, and then the dam site and project layout were carefully selected. Especially during Phase II, core drillings were carried out so as to analyze the full details of geological structures. However, the risk due to geology is still inevitably a factor of concern.

Issues that are conceivable to arise are slope stability, foundation treatment, excavation depth, rock support, etc. Among these, one of the critical issues in this Project might be the availability of materials for the main dam embankment.

It is assumed in this Study that approximately half of the total requirement for the dam embankment will be rock material excavated from the spillway. Meanwhile, the remainder will be obtained from a quarry site identified near the main dam. Unit prices for both dam embankment and spillway excavation are determined based on these assumptions. If the geological conditions at the spillway significantly differ, or if the quantity of available materials is much less, the unit prices and project cost will increase. If the available quantity of embankment material from the spillway is 50% of that assumed, the project cost might increase around 5%. This risk is studied as Case 2 of a sensitivity analysis in Chapter 11.4.

### (2) Reduced Power Generation due to Hydrological Risk

There are three main types of hydrological risk as follows:

(i) Flood damage during construction;

(ii) Sustained production deficits arising from incorrect original assessment of the average runoff, or subsequent changes in the hydrological regime; and

(iii) Short-term production deficits arising from a sequence of dry years

**Flood Damage during Construction**

Flood management during construction is a matter of balancing the incremental costs of increased flood protection against the probability and consequence of a specific flood magnitude occurring. In this Study, the 25-year recurrence probable flood is adopted for the main dam construction, and this is considered as safe enough for construction of a concrete faced rockfill dam (CFRD), which has the characteristics of both rockfill and concrete dams. It seems that the risk of the construction progress being hampered due to overtopping of the diversion is small.

**Average Runoff in Long Term**

The long-term discharge for 30 years (1971-2000) was estimated using a rainfall-runoff model as 147.2 $m^3/s$ on a monthly average basis. According to the annual rainfall record at Vientiane for the 93 year period 1907-2000, the average rainfall in the simulation period of this Study (1971-2000) is almost the same as the average of the whole period. The accuracy of the model was duly checked against the observed long-term records at the existing Muang Mai gauging station. The specific yield of the estimated runoff is almost the same as the average of the central (Nam Theun area) or north-west (Nam Ngum area) zones near the project site. Moreover, the estimated runoff is rather conservative compared with previous hydrological studies, which provided estimates of between 281 $m^3/s$ and 152 $m^3/s$. Thus, it is considered that the runoff assessment in this Study is reliable, and the risk of sustained production deficits occurring due to insufficient runoff or hydrological regime change is small.

**Short Term Production Deficit**

As with any hydropower project, there is a possibility of encountering short-term production deficits arising from a sequence of dry years. According to the results of the reservoir operation study, annual energy fluctuates periodically, and in the driest period of the 30 years simulated, in two successive years (1974-1975), the estimated annual firm energy drops to around 80% of the average of the whole 30 years. This risk is studied as Case 4 in the sensitivity analysis of Chapter 11.4.

### (3) Construction Delay Risk

In case of this Project, the critical path of the overall construction schedule is as follows:

Table 2.3.2 Critical Path of Overall Construction Schedule

| No. | Work/Event | Schedule |
|---|---|---|
| 1. | Site investigation and tender design | 2003 |
| 2. | EPC contract | End of Jun., 2005 |
| 3. | Permanent/temporary access road construction | End of Jun., 2005 |
| 4. | Diversion tunnel construction | End of Jan., 2006 |
| 5. | River diversion | End of Sep., 2007 |
| 6. | Main dam construction | End of Sep., 2008 |
| 7. | Reservoir impounding | End of Apr., 2010 |
| 8. | Wet test of generating equipment | End of Jun., 2010 |
| 9. | Commissioning of generating unit 1 | End of Sep., 2010 |
| 10. | Commissioning of generating unit 2 | End of Oct., 2010 |

Construction of the permanent/temporary road is scheduled to start in the rainy season, thus there is some risk that the progress will be hampered due to weather conditions. The diversion tunnel will mainly be driven in $C_H$ class rock, thus no serious delay is anticipated. For excavation of the main dam, there is possibility that progress will be hampered due to thick talus at the right bank. The duration of embankment was calculated calculated assuming 350,000 $m^3$ per month, and this is a conservative estimate compared with the actual achievements of other projects, which vary between around 400,000 to 500,000 $m^3$. The duration of impoundment filling will depend on when it commences, and will be between 4 months and 9 months.

There exists a risk that construction will be delayed, but considering the aforementioned, the additional duration will be limited to 6 months at the most (2 months for the access road, main dam excavation and impounding). This risk is studied as Case 1 in Chapter 11.4, Sensitivity Analysis.

(4) Transmission Interconnection Risk

In this Project, it is assumed that the construction of a 500 kV trunk line to Udonthani in Thailand and the high voltage collector substation in Nabong will be completed when the Nam Ngiep power station is ready for commissioning. However, the realization of this trunk line and substation will largely depend on the progress of other power development projects such as Num Ngum-2 and 3, etc.

In the event that all these related facilities are not yet completed as of commissioning of the Nam Ngiep power station, the Project will have the alternative of connecting to Nam Theun-2. The length of the transmission line would increase by around 80 to 100 km and the impact on the project cost would be less than 10%.

(5) Decrease of Power Tariff due to Market Risk

The Nam Ngiep-I power station will commence operation at the end of the year 2010. This Study estimates that the intermediate peak power prices in Thailand at this time will be 6-7 ¢/kWh or more. A conservative value of 6.0 ¢/kWh is adopted as the expected export tariff in financial and economic evaluations. Any further price reduction,would be less than 10%. This risk is studied as Case 3 in Chapter 11.4, Sensitivity Analysis.

(6) Environment Risk

The full supply level of the reservoir is set at EL.320 m so that no substantial impact of permanent inundation occurs in Thaviang Sub-District. Moreover, the spillway capacity has been designed so that the 1,000-year recurrence probable flood can be discharged so as to prevent temporary inundation during flood.

This Project has been designed to minimize environment impacts. But, a large scale reservoir of 66.94 $km^2$ will be created and peak power operation will change the flow regime downstream of the dam.

To mitigate the latter effect, a re-regulating weir will be provided and the residual head there, as well as the re-regulated discharge for 24 hours, will be utilized to generate power for domestic consumption.

As seen in disputes associated with the Nam Theun 2 hydropower project, which have continued for the last 10 years, the argument on environmental risk is difficult to resolve completely. It is anticipated that some dispute will still occur in the Nam Ngiep-I HEPP . Notwithstanding, the Study Team believes that the Nam Ngiep-I HEPP will contribute to poverty reduction in Laos without serious adverse environmental effect, so is worthy of implementation.

(7) Sensitivity Analysis

The Project is subject to various risk factors which lower the profitability of the project. The following adverse cases are considered as the worst case scenarios:

Table 2.3.3 Case Scenarios for Sensitivity Analysis (Same as Table 11.4.1)

| Scenario | Risk Case | Cause and Effect |
|---|---|---|
| Case 1 | half –year construction time overrun | which results in half-year delay in commissioning |
| Case 2 | 10% increase in capital cost | which results from increase in work quantity, increased costs of materials, additional works, etc |
| Case 3 | 10% reduction in tariff | which results from unexpected low tariff caused by low pool prices |
| Case 4 | 20% drop in power output for first 3 years | which results from very dry hydrological conditions hitting the first three years of operation, which causes reduced water flows |

A sensitivity analysis has been carried out under the above four adverse scenarios. As indicated in Table 2.3.4, the Project remains viable under all such adverse conditions though Cases 2 and 3 result in marginal values of FIRR. From the table the cases which are most sensitive to the profitability of the Project are 10% increase in capital cost and 10% reduction in tariff.

Table 2.3.4 Sensitivity Analysis Result (Same as Table 11.4.2)

| No. | Scenario | FIRR (%) | Si[a] | EIRR (%) | SI[a] | ROE (%) | Min. DSCR |
|---|---|---|---|---|---|---|---|
| Base case | Normal operation | 13.1 | - | 19.5 | - | 16.3 | 1.4 |
| Case-1 | Half-year construction time overrun | 12.6 | 0.5 | 17.9 | 0.8 | 14.7 | 1.3 |
| Case-2 | 10% increase in capital cost | 11.9 | 0.9 | 17.7 | 0.9 | 14.5 | 1.3 |
| Case-3 | 10% reduction in tariff | 11.8 | 1.0 | 17.6 | 1.0 | 14.3 | 1.3 |
| Case-4 | 20% drop in power output for first 3 year | 12.2 | - | 18.9 | - | 14.8 | 1.1 |

[a] SI (Sensitivity indicator) is a ratio of percent change in FIRR or EIRR to percent change in sensitivity parameters.

# 3. GEOPHYSICAL SURVEY

## 3.1 GENERAL

This report describes activities relevant to the topographic survey works for the Study. The works involved the items shown in the following table:

Table 3.1.1 Geophysical Survey in the Study

| No. | Scale | Description |
|---|---|---|
| 1. | 1 : 10,000 | Photogrammetric mapping of the reservoir area, including large-scale dam plan (FSL.360m) and temporary facilities such as relocation/temporary roads and quarry sites, with a total area of approx. 240 $km^2$ |
| 2. | 1 : 1,000 | Photogrammetric mapping from the main dam axis to B.Hatkham along the Nam Ngiep River, including main dam site, access road and re-regulating weir site, with a total area of approx. 8 $km^2$ |
| 3. | - | River cross-section survey from the dam axis to the main stream of the Mekong River; a total length of 55 km |

Survey works, such as aerial photographs, digital photo image data preparation and the river cross-section survey, were executed by a local survey firm, FINNMAP LAO. Aerial triangulation, digital plotting, digital editing and data output work was carried out by Pasco International in Japan in accordance with the terms, conditions and requirements of the Contract Agreement and Technical Specifications under the supervision of the JICA Study Team.

## 3.2 AERIAL PHOTO SURVEY AND MAPPING OF RESERVOIR / DAM AREAS

### 3.2.1 AERIAL PHOTOGRAPH

Because access to the Xaysomboon Special Zone and the dam site was difficult, when the survey was conducted between July and November 2001, a photographic shooting and photographical map preparation method that did not require a physical ground survey was adopted.

Positional accuracy of aerial photography was undertaken using GPS equipment in the aircraft controlled by AGAC (Airborne GPS Aero Control System). To transform the coordinates system from WGS84 to the local (Lao National Datum 1997) system, the location of existing control points and benchmarks on the photographs was necessary. A total of 23 GPS points, in the photography area established during the Phase I Study, used the Lao National Grid Coordinate System. Accordingly, pricking works on aerial photographs were only carried out to confirm these positions substituting new control point establishment.

Principal data and information of the new aerial photography are as follows:

## (1) Datum Definition

The Lao National Datum 1997 is defined by the following parameters.

Table3.2.1 Data of Datum Definition

| No. | Item | Specifications |
|---|---|---|
| 1. | Spheroid | Krassovsky |
| 2. | Semi Major Axis | 6,378,245.000 m |
| 3. | Semi Minor Axis | 6,356,863.018 m |
| 4. | Flattering | 298.30 |
| 5. | Origin Station | Vientiane Astronomic Pillar (36201) |
| 6. | Latitude | 18° 01 ´ 31.3480" N |
| 7. | Longitude | 102° 30 ´ 57.1367" E |
| 8. | Spheroid Height | 223.824 m |
| 9. | Transformation parameters to be added to Lao National Datum 1997 to produce WGS84 Cartesian coordinates | ΔX= +44.585 meter<br>ΔY= - 131.212 meter<br>ΔZ= -39.544 meter |
| 10. | Projection System | U.T.M 48 |
| 11. | False Northing | 0.000 m |
| 12. | False Easting | 500,000.000 m |
| 13. | Scale Factor | 0.9996 |

## (2) Equipment Used

(a) Aircraft : Rockwell Turbo Commander 690A

(b) Aerial Camera : Leica RC-30

(c) Film Processor : Hope Garfield-90 10''Aerial Film Processor

(d) Contact Printer : Spek Electronics 3050 Contact Printer

## (3) New Aerial Photo Index Map

A new aerial photo index map was prepared as shown in Figure 3.2.1.

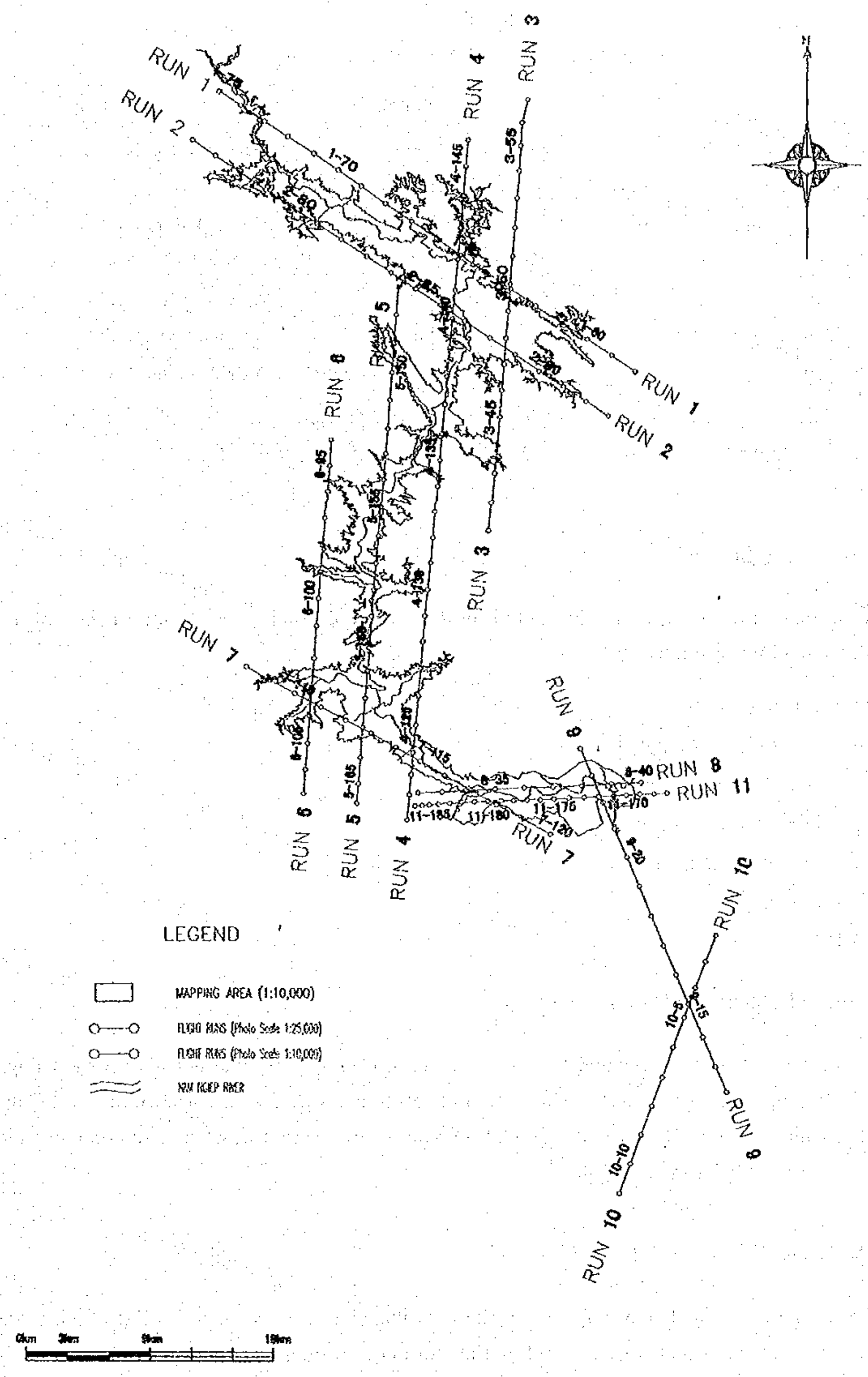



Figure 3.2.1 Aerial Photo Index Map

### (4) Aerial Photography

Table 3.2.2 Data of Aerial Photography

| No. | Item | 1 : 25,000 Scale | 1 : 10,000 Scale |
|---|---|---|---|
| 1. | Scale of aerial photographs | Approx. 1:25,000 | Approx.1:10,000 |
| 2. | Area Covered by aerial photos | Approx. 1,000 $km^2$ | Approx.30 $km^2$ |
| 3. | Focal length of aerial photos | F=153.474 mm | F=153.474 mm |
| 4. | Over lapping | Approx.60% ±5% | Approx.60% ±5% |
| 5. | Side lapping | Approx.30% ±5% | Approx.30% ±5% |
| 6. | Flight altitude | Approx.4,500 m±5% | Approx.2,000 m±5% |
| 7. | Aerial film | Agfa Aviophot PAN 80 PE1 | Agfa Aviophot PAN 80 PE1 |
| 8. | Photo Print | Agfa Rapitone Paper P-2-2 | Agfa Rapitone Paper P-2-2 |
| 9. | Number of photos | 201 sheets | 21 sheets |

### (5) Film Annotation

The following titles and information were noted on the outside of each photo frame of the negative film at both the beginning and the end.

(a) Name of project
(b) Date of photography
(c) Scale of photography
(d) Flight course number
(e) Serial number of camera and lens
(f) Flight altitude
(g) Photo number

### (6) Digital Photo Image Data Preparation

Digital photo image data were prepared by direct scanning from the original negative films using a Zeiss SCAI photogrammetric scanner. The scanning resolution was 14 microns, approx 1800 dpi, which made each photo file 270 megabytes in size. Digital photo image data were stored on CD-ROM media in compressed TIFF format.

## 3.2.2 AERIAL TRIANGULATION

The purpose of aerial triangulation is to obtain the coordinates (X, Y, Z) of the aerial photo points necessary for orientation of each stereo model on the plotting instrument. Then the coordinates (X, Y, Z) of the ground control points resulting from the pricking (GPS and leveling) can be transferred to 1:10,000 and 1:1,000 topographic maps.

Using a 1:25,000 scale photo scanning image and results of pricking (control point and leveling), aerial triangulation for 1:10,000 scale digital mapping was done analytically with the automatic block adjustment method in accordance with the manner and accuracy of the Technical Specifications.

The locations of pass points were identified on the photo images. The pass points were established as control points and spot heights by stereoscopic leveling with a stereo image plotter. The photo coordinates obtained with stereo plotter measurement were processed by a digital data processing system for automatic analytical aerial triangulation. After preparing the results of aerial triangulation of 1:10,000 scale photogrammetric mapping, aerial triangulation for 1:1,000 scale digital mapping was done using the stereo image matching method, by automatic fully controlled models using 1:10,000 scale photo scanning image and the results of pricking.

The total numbers of photo models, equipment, program and accuracy of aerial triangulation using the computation of both aerial triangulations, were as follows:

(1) Number of Photo Models

One-hundred-and-six models of aerial triangulation work were carried out. The quantity of models for each flight run was as follows:

Table 3.2.3 Number of Models

| Run Number | Photo Scale | Number of Photos | Number of Models |
|---|---|---|---|
| Run 1 | 1:25,000 | 18 | 17 |
| Run 2 | 1:25,000 | 18 | 17 |
| Run 3 | 1:25,000 | 17 | 16 |
| Run 4 | 1:25,000 | 26 | 25 |
| Run 5 | 1:25,000 | 20 | 19 |
| Run 6 | 1:25,000 | 14 | 13 |
| Run 7 | 1:25,000 | 13 | 12 |
| Run 8 | 1:25,000 | 9 | 8 |
| Run 9 | 1:25,000 | 13 | 12 |
| Run 10 | 1:25,000 | 10 | 9 |
| Run 11 | 1:10,000 | 21 | 20 |
| Total | | 179 | 168 |

(2) Equipment and Program

- Leica Co. : Socet SET
- Program : PAT B

(3) Accuracy of Aerial Triangulation

Accuracy of aerial triangulation for two blocks is as follows:

(i) Residuals of control points were within values of 0.08‰ of the flight altitude.

(ii) Discrepancies of pass points were within values of 0.08‰ of the flight altitude for the planimetry and height.

### 3.2.3 DIGITAL PLOTTING

Digital mapping, at a scale of 1:10,000 with 5 m contours and 1:1,000 with 1 m contours, was carried out based on scanned aerial photo images at a scale of 1:25,000 and 1:10,000. The results of control point survey, leveling, river cross section survey and aerial triangulation, were in accordance with the manner and accuracy specified in the Technical Specifications and Map Symbols. Planimetric details on the photo image were digitized using a stereo image plotter. The following equipment and programs were used in digital mapping:

(a) Image plotter : Diap
(b) Workstation : Dell, Precision420
(c) Program : Diap, photogrammetric system.
(d) Work Volume

Table 3.2.4 Quantity of Digital Mapping

| Map Scale | Quantity | |
|---|---|---|
| | Plan | Actual |
| 1:10,000 | 220 $km^2$ | 237 $km^2$ |
| 1:1,000 | 7.5 $km^2$ | 7.7 $km^2$ |

Land use maps were established based on the digital map at a scale of 1:10,000 and at a scale of 1:1,000. Land use classification is as follow:

Table 3.2.5 List of Land Use Classes

| Number | Code | Land Use |
|---|---|---|
| 11 | DEF | Dry Evergreen Forest |
| 12 | MDF | Mixed Deciduous Forest |
| 13 | RGF | River Gallery Forest |
| 14 | BV | Bamboo - Main Vegetation |
| 15 | RSFR | Ray, Scrub, Forest Regeneration |
| 16 | PF | Plantation Forest – Pine, Eucalyptus |
| 17 | RP | Rice Paddy – Flat lowland (Bunded) |
| 18 | AL | Agricultural Land – Lowland |
| 19 | GL | Other Cleared Agriculture – Grass Land |
| 20 | V | Villages, Road, Tracks |
| 30 | W | Water bodies – River, Fishpond, Small dams |

### 3.2.4 DIGITAL EDITING AND DATA OUTPUT

The digital editing system of Dmpro and Microstation were used to edit the digitized planimetric data and contours for topographic mapping at a scale of 1:10,000 and 1:1,000. After editing, the final digital mapping data was transferred to CAD format and transferred to CD-ROM. The following equipment and programs were used in digital mapping:

(a) Digital editor : Dmpro and Microstation
(b) Workstation : Dell Precision420

(c) Program : Dmpro and photogrammetric system

# 3.3 RIVER CROSS-SECTION SURVEY

## 3.3.1 SETTING UP OF CROSS SECTION LINE

A total of 58 cross-section lines, (including three water gauge stations) extending from the dam axis to the Mekong River main stream, were set at 1 km intervals. Control points (concrete monuments) were established on both banks of the cross section line, and their coordinates were calculated by GPS. All elevations were calculated by direct leveling.

All cross section lines are shown in Figure 3.3.1. Coordinates and elevations of benchmarks on left and right banks of each section are tabulated in Table 3.3.1.

## 3.3.2 CROSS SECTION SURVEY

The height and distance of each change in slope was measured relative to a control point on the bank using a Total Station. The riverbed was measured at 10 m intervals.

## 3.3.3 LONGITUDINAL PROFILE SURVEY

The profile survey was carried out along the Nam Ngiep River from the mouth of the Mekong River to the proposed dam axis, with a total length of 55,000 m including three (3) water gauge stations. The riverbed was measured at approx. 200 m intervals.

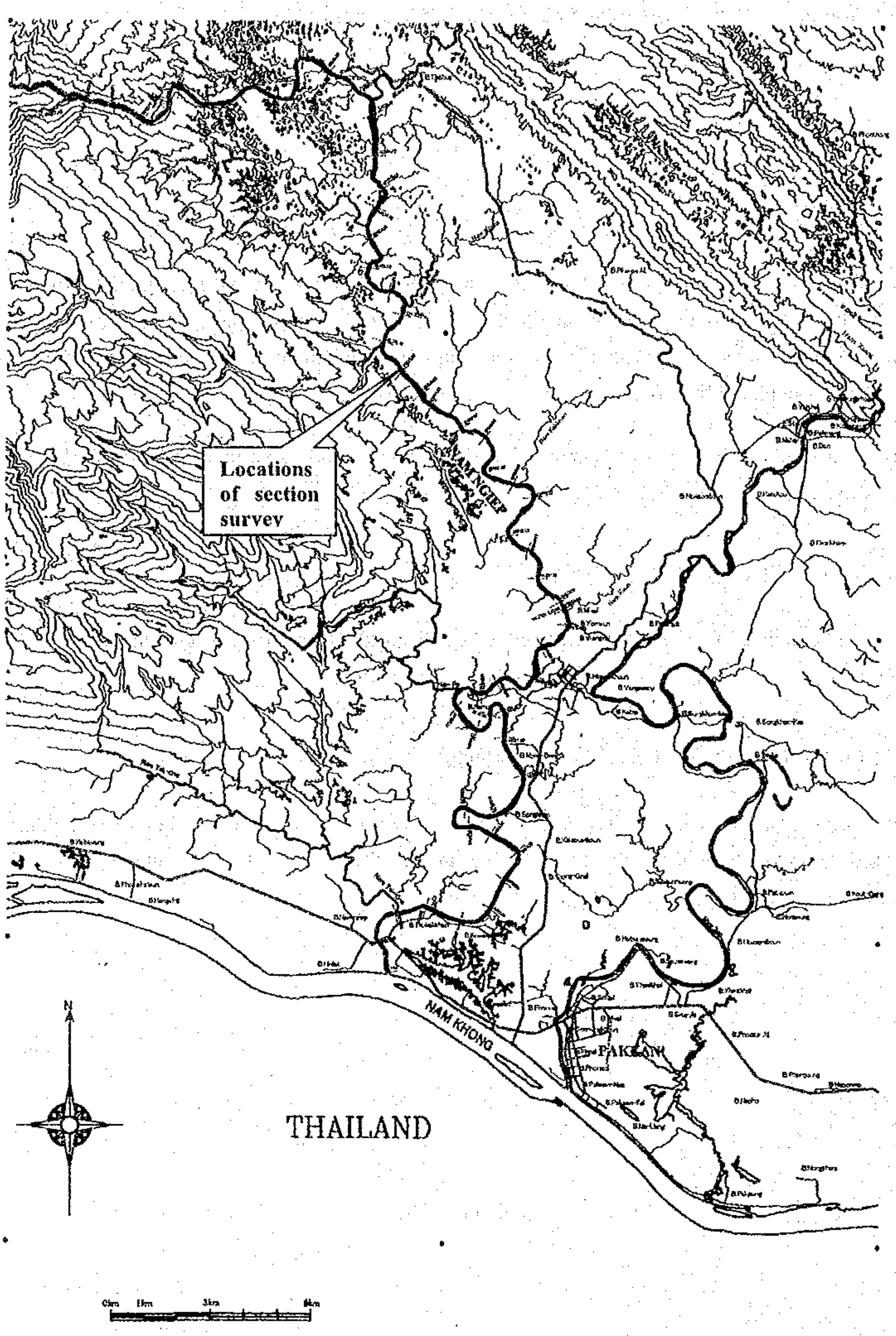



Figure 3.3.1 Location of River Cross-Section Survey

# Table 3.3.1 List of Benchmarks for Cross-Section Survey

| Station Name | Left Bank | | | Right Bank | | |
|---|---|---|---|---|---|---|
| | Easting | Northing | Elevation | Easting | Northing | Elevation |
| 0.00 | 352,576.17 | 2,036,087.83 | 153.99 | 352,427.94 | 2,036,062.28 | 151.23 |
| 1,066.88 | 352,290.74 | 2,037,088.50 | 153.18 | 352,172.76 | 2,037,048.85 | 154.38 |
| 2,210.24 | 352,786.41 | 2,037,812.53 | 156.14 | 352,752.31 | 2,037,957.56 | 152.04 |
| 3,197.17 | 353,700.61 | 2,038,034.55 | 155.12 | 353,740.75 | 2,038,161.07 | 156.47 |
| 4,329.24 | 354,743.14 | 2,037,590.26 | 164.57 | 354,780.61 | 2,037,718.17 | 153.10 |
| 5,402.81 | 355,735.16 | 2,038,001.36 | 156.46 | 355,633.18 | 2,038,073.74 | 154.86 |
| 6,365.04 | 356,153.15 | 2,038,857.25 | 155.93 | 356,059.82 | 2,038,942.33 | 155.60 |
| 7,387.58 | 356,569.02 | 2,039,816.98 | 152.57 | 356,481.26 | 2,039,737.36 | 156.01 |
| 8,360.34 | 355,744.29 | 2,040,344.42 | 156.45 | 355,671.88 | 2,040,234.79 | 156.29 |
| 9,104.95 | 355,017.56 | 2,040,583.44 | 154.72 | 355,010.53 | 2,040,459.64 | 156.64 |
| 10,228.36 | 354,905.09 | 2,041,022.55 | 157.46 | 354,909.09 | 2,041,171.09 | 156.12 |
| 11,233.74 | 355,872.29 | 2,040,814.64 | 152.90 | 355,820.18 | 2,040,919.37 | 156.87 |
| 12,833.16 | 356,754.26 | 2,042,112.24 | 154.73 | 356,627.39 | 2,042,075.22 | 156.85 |
| 14,101.60 | 356,210.29 | 2,043,223.45 | 158.19 | 356,069.69 | 2,043,219.58 | 154.82 |
| 14,942.71 | 356,157.93 | 2,044,062.98 | 155.13 | 356,058.00 | 2,044,015.45 | 158.06 |
| 15,626.32 | 355,633.95 | 2,043,935.47 | 153.98 | 355,743.89 | 2,043,901.40 | 159.14 |
| 16,384.37 | 355,300.46 | 2,043,517.87 | 159.01 | 355,256.75 | 2,043,373.39 | 156.54 |
| 17,328.36 | 354,669.23 | 2,044,138.64 | 155.53 | 354,614.79 | 2,044,074.13 | 158.94 |
| 18,623.22 | 355,408.72 | 2,044,487.07 | 159.71 | 355,399.98 | 2,044,619.80 | 158.66 |
| 19,243.86 | 355,933.99 | 2,044,829.00 | 155.09 | 355,882.44 | 2,044,925.74 | 159.12 |
| 20,665.38 | 357,076.76 | 2,045,039.59 | 158.97 | 356,958.33 | 2,045,070.53 | 157.45 |
| 21,626.55 | 357,277.88 | 2,045,875.99 | 161.12 | 357,218.19 | 2,045,999.73 | 159.92 |
| 22,768.21 | 358,106.82 | 2,046,647.76 | 159.41 | 357,968.98 | 2,046,656.30 | 159.42 |
| 23,258.86 | 357,966.33 | 2,047,133.44 | 161.94 | 357,859.34 | 2,047,084.95 | 159.47 |
| 23,523.35 | 357,846.04 | 2,047,373.01 | 162.11 | 357,698.12 | 2,047,291.43 | 160.41 |
| 24,552.69 | 357,177.76 | 2,048,067.64 | 160.45 | 357,066.88 | 2,048,064.90 | 156.15 |
| 25,532.57 | 356,874.04 | 2,048,950.66 | 159.42 | 356,841.93 | 2,048,845.15 | 157.18 |
| 26,309.00 | 356,327.98 | 2,049,386.76 | 160.37 | 356,236.60 | 2,049,376.81 | 155.71 |
| 27,743.72 | 357,067.92 | 2,050,544.58 | 156.72 | 356,971.86 | 2,050,537.24 | 161.01 |
| 28,589.03 | 356,434.82 | 2,050,972.06 | 161.14 | 356,384.44 | 2,050,874.10 | 157.31 |
| 29,602.40 | 355,570.59 | 2,051,311.91 | 160.97 | 355,453.67 | 2,051,303.44 | 158.84 |
| 30,842.58 | 355,588.85 | 2,052,388.59 | 165.22 | 355,521.34 | 2,052,312.47 | 161.08 |
| 31,652.87 | 354,892.53 | 2,052,668.59 | 165.10 | 354,775.76 | 2,052,594.64 | 162.58 |
| 32,811.62 | 353,946.75 | 2,053,339.65 | 159.89 | 353,890.12 | 2,053,254.55 | 160.17 |
| 33,309.93 | 353,688.75 | 2,053,737.23 | 166.50 | 353,533.21 | 2,053,623.83 | 158.83 |
| 34,219.53 | 353,057.87 | 2,054,395.10 | 166.09 | 352,956.65 | 2,054,292.01 | 165.16 |
| 35,409.47 | 352,514.02 | 2,055,246.36 | 165.45 | 352,407.44 | 2,055,279.22 | 159.43 |
| 36,412.53 | 353,059.72 | 2,056,062.79 | 159.39 | 352,957.98 | 2,056,086.46 | 167.19 |
| 37,371.56 | 352,639.76 | 2,056,815.86 | 161.05 | 352,618.20 | 2,056,678.14 | 161.86 |
| 38,505.67 | 352,086.52 | 2,057,482.16 | 166.15 | 351,949.26 | 2,057,497.28 | 169.20 |
| 39,625.30 | 352,099.86 | 2,058,375.99 | 168.68 | 352,000.47 | 2,058,311.57 | 162.81 |
| 40,674.66 | 352,303.38 | 2,059,286.08 | 163.52 | 352,194.60 | 2,059,334.89 | 167.55 |
| 41,279.37 | 352,430.01 | 2,059,882.36 | 164.83 | 352,302.61 | 2,059,819.00 | 169.89 |
| 42,353.77 | 352,323.83 | 2,060,833.37 | 171.33 | 352,199.12 | 2,060,825.68 | 161.88 |
| 43,606.37 | 352,262.11 | 2,062,113.24 | 173.21 | 352,079.72 | 2,062,036.42 | 172.15 |
| 44,509.29 | 351,748.34 | 2,062,776.66 | 170.49 | 351,667.39 | 2,062,701.90 | 172.31 |
| 45,549.55 | 350,896.85 | 2,063,342.11 | 172.57 | 350,824.01 | 2,063,243.09 | 169.56 |
| 46,476.75 | 350,054.92 | 2,063,737.74 | 165.27 | 350,045.41 | 2,063,626.39 | 172.37 |
| 47,357.52 | 349,768.91 | 2,062,945.29 | 173.99 | 349,924.15 | 2,062,953.04 | 166.22 |
| 48,210.94 | 349,299.60 | 2,062,564.88 | 170.23 | 349,294.88 | 2,062,473.31 | 175.71 |
| 49,479.10 | 348,129.66 | 2,062,672.02 | 169.51 | 348,203.77 | 2,062,580.95 | 177.23 |
| 50,626.79 | 347,094.97 | 2,062,404.96 | 177.32 | 347,097.84 | 2,062,311.12 | 169.96 |
| 51,471.59 | 346,430.89 | 2,062,893.91 | 173.31 | 346,387.80 | 2,062,750.36 | 181.11 |
| 52,369.24 | 345,895.50 | 2,062,294.71 | 184.40 | 346,043.53 | 2,062,194.07 | 174.33 |
| 53,242.79 | 345,273.47 | 2,061,921.59 | 177.89 | 345,247.65 | 2,061,888.31 | 176.58 |
| 54,226.61 | 344,374.70 | 2,062,351.56 | 185.82 | 344,371.47 | 2,062,299.81 | 185.54 |
| 55,053.56 | 343,568.18 | 2,062,502.21 | 195.36 | 343,552.69 | 2,062,463.06 | 196.78 |

# 4. GEOLOGICAL SURVEY

## 4.1 GENERAL

### 4.1.1 GEOLOGICAL DATA COLLECTION

*During the field investigations, the following geological maps and a report were collected:*

Table 4.1.1 Geological Data Collection

| No. | Title | Scale | Published | Origin |
|---|---|---|---|---|
| 1. | Geological Survey for Vietnam, Geology of Cambodia, Laos and Vietnam | 1:1,000,000 | Hanoi, Vietnam, 1988 | Metal and Mining Industrial Agency, Resources Information Center Japan |
| 2. | Report of DMR-COOP-MMAJ Joint Seminar on Application of Satellite Image Analysis in Mineral Exploration | - | 17-19 February 1988, Bangkok, Thailand, p36-38 Khampha Phommakaysone | Application of Satellite Image Analysis in Mineral Exploration in Lao PDR |
| 3. | Photo Geological Reconnaissance Map PAKSANE and BANBAN | 1:250,000 | 1973 by the Institute of Geological Science, London | Geology and Mines, Ministry of Industry and Handicraft (MIH) |
| 4. | Lao PDR Geological and Mineral Occurrence Map | 1:1,000,000 | British Geological Survey and Department of Geology and Mines | Ministry of Industry and Handicraft 1990 |
| 5. | Aerial photographs | 1:30,000, in 1981 | - | 32 sheets (surrounding area of reservoir) |
| 6. | Aerial photographs | 1:25,000 | - | 8 sheets (damsite) |

### 4.1.2 GEOLOGICAL STRUCTURES OF INDOCHINA

The Nam Ngiep basin is situated in the central part of Lao PDR. Mesozoic-Palaeogene flat formations are distributed around the proposed dam site where high cliffs are found with outcrops of flat or gently sloped formations. Palaeozoic formations folded and separated into blocks by faults while Late-Palaeozoic are distributed in the reservoir area. General geology is summarized in Figure 4.1.1. Lineaments (NW-SE, W-E and NE-SW) are found, which were produced by old geological structures and tectonic movements. There are no reports on active faults.

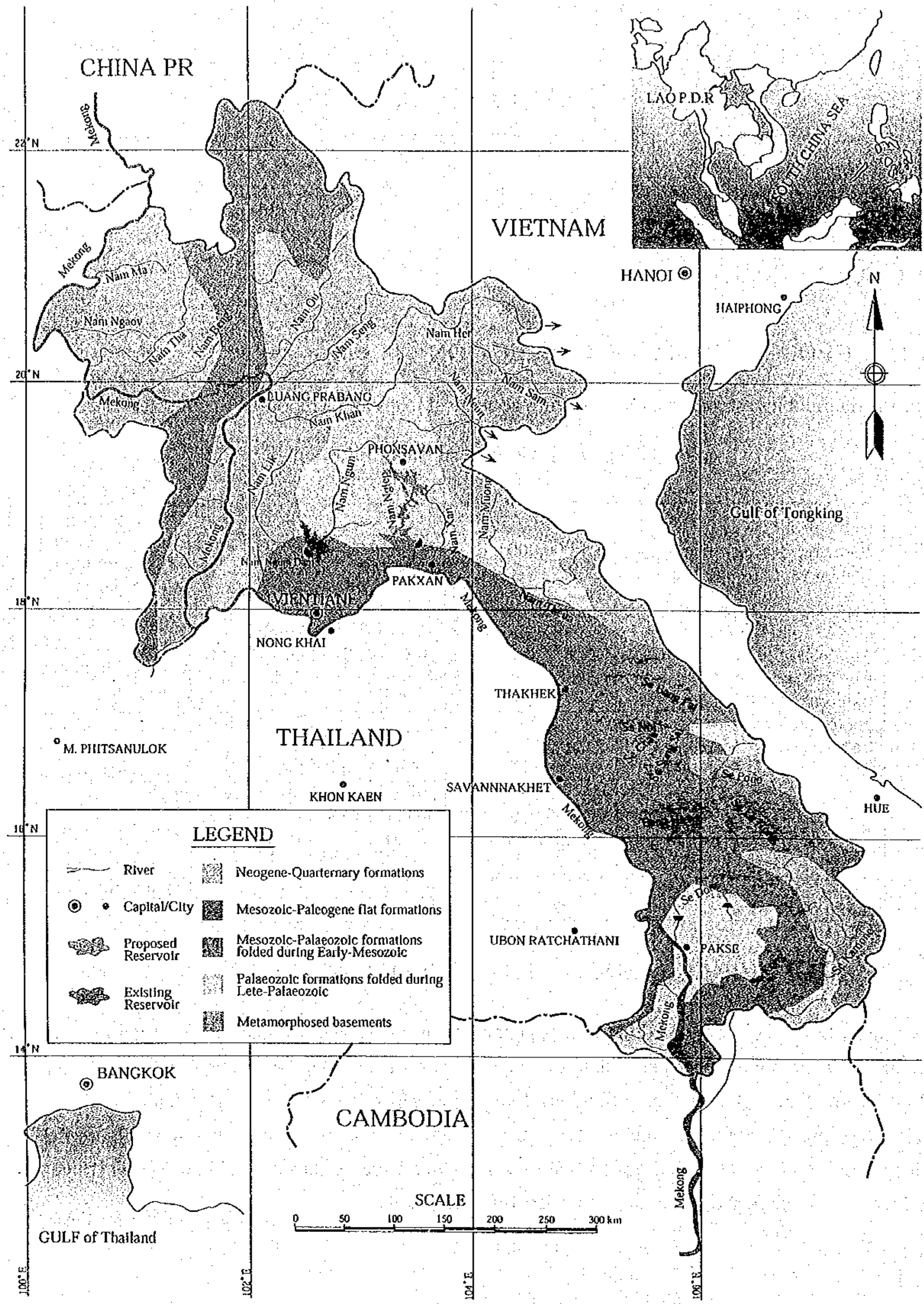
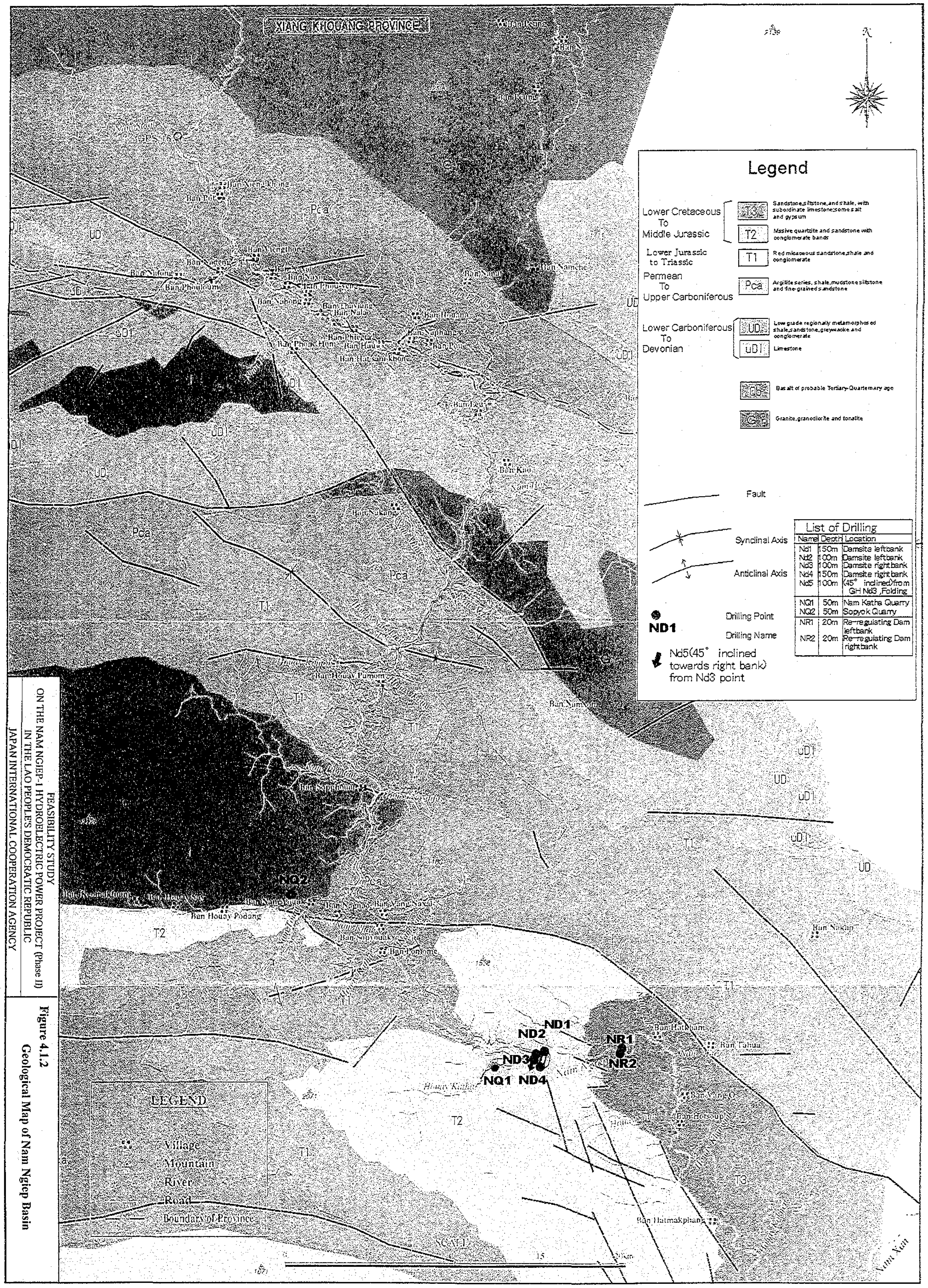



Figure 4.1.1 Geological Map of Indochina




FEASIBILITY STUDY
ON THE NAM NGIEP-1 HYDROELECTRIC POWER PROJECT (Phase II)
IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC
JAPAN INTERNATIONAL COOPERATION AGENCY

**Figure 4.1.2**
**Geological Map of Nam Ngiep Basin**

Geological descriptions are mainly based on "Photo Geological Reconnaissance Maps PAKSANE and B.B." at a scale of 1:250,000 prepared in 1973 by the Institute of Geological Science, London and "Lao PDR Geological and Mineral Occurrence Map" at scale of 1:1,000,000, both of which were compiled in England and contain more detailed field information than the "Geological Survey for Vietnam" and "Geology of Cambodia, Lao PDR and Vietnam", at scale of 1:1,000,000, Hanoi, Vietnam, 1988.

### 4.1.3 GEOLOGY OF NAM NGIEP BASIN

The geological map of the Nam Ngiep basin is shown in Figure 4.1.2, which is mainly based on photo-geological reconnaissance maps PAKSANE and B.B., but distribution of the granite mass and Palaeozoic formations in the middle reach of the Nam Ngiep River are corrected according to the Geological and Mineral Occurrence Map and as a result of field investigations. Locations of the core drillings are also shown on the figure.

Devonian-Permian, shale, mudstone, calcareous series and sandstone intruded by granite are widely distributed.

Limestone blocks are scattered as relatively small blocks of Lower Carboniferous to Devonian age. Calcareous series, mainly of massive limestone, are not found in this area amongst Permian to Upper Carboniferous formations, which are distributed from north of Phonsavan to the Jars plain, outside of the Nam Ngiep basin. Granite is widespread as intrusive to Palaeozoic. Lower Jurassic series are distributed as graven in parallel along folded Palaeozoic basements.

Most of the rocks forming the substratum underlying the future reservoir are sedimentary. The geology of the reservoir falls basically into four (4) types.

(i) Mesozoic, Jurassic to Cretaceous flat formations with sandstones, conglomerates and mudstones are located around the dam site and in the lower part of the planned reservoir area. Sandstones and conglomerates are very thick, homogeneous and massive and are found on the upper slopes where they form the crests and summits. Mudstones are interbedded with rather thin siltstones, sandstone and conglomerates.

(ii) Palaeozoic, Devonian to Permian, formations folded and separated into blocks by faults during Late-Palaeozoic are located in the middle to upper parts of the reservoir area, including shales, mudstones, sandstones and schists. They are consolidated formations and hardly permeable.

(iii) Late-Palaeozoic granites are located as intrusive to Palaeozoic formations in the middle of the reservoir area. They are highly fractured and sometimes deeply weathered.

(iv) Mesozoic, Triassic to Jurassic, sandstones, shales and conglomerates are located in the middle part of the reservoir area as graven parallel along folded Palaeozoic basements. They are partly fractured and deeply weathered.