## 6.4 Outline of Topography and Geology in the Se Kong Basin

### 6.4.1 Topography

Se Kong River Basin covers the area on the westward of Annam Mountains which extends NNW-SSE direction along the border of Laos and Vietnam. Eastern part of Se Kong River Basin, which covers upstream are of Se Kong River (upstream of the vicinity of Se Kong No. 4 site) and upstream are of Xe Kaman River (upstream of the vicinity of Xe Kaman No. 1 site) and extends southwestward along the boarder of Laos and Kampuchea, is mountainous area having many peaks of elevation 1,000 to 2,000 m. Especially, in upstream area of Se Kong River the peaks higher than 1,500 m increase in number and the highest peak (EL. 2,193 m) is in this area. In this mountainous area valleys are generally deep and slopes are steep. On the right bank, in the midstream of Se Kong River, there is a rise called Bolaven Plateau. This Plateau extends NW-SE, about 90 km long and 60 km wide. The highest point on the Plateau is a peak located in the north of the Plateau with the elevation of 1,716 m. Most of the Plateau is flat or gentle sloped and some 1,000 m in elevation. Eastern flank of the Plateau facing to Se Kong River is continuous high scarp which reaches 900 m in height. Valleys on the Plateau are shallow. Rivers makes waterfalls where they leave from the plateau and go down to the Se Kong River valley with rapids.

Between the mountainous area covering the eastern part of Se Kong River Basing and Bolaven Plateau, there is a depression where Se Kong River flowing in a generally southern direction. Se Kong River flows the area characterized by winding low Ridges indicating the fold structure, and enters in the wide basin where Xe Kaman River and Xe Pian River join, then flows gently down to Cambodia Border.

### 6.4.2 Geology

In the Master Plan Stage, most of planned sites are inspected from the sky by helicopter. Roadside for Xe Namnoy Site, from Sekong Town to Attapu Town are observed by car. Outcrops along the Se Kong River from Se Kong No.4 dam site to Attapu Town, and along Xe Kaman River from Attapu Town to 54 km downstream of Xe Kaman No. 1 dam site are observed from the JICA's boat. Vicinity of Xe Namnoy dam site and Se Kong No.4 dam site are investigated on foot.

Prior to these field geological surveys, landsat image of 1:500,000 of Se Kong River Basin have topograpically and geologicaly interpreted (**Fig. 6.4-1**).

The outline of geology of Se Kong River Basin based mainly on the geological map (Tien, P.C. 1988 scale 1/1,000,000 **Fig. 6.4-2**) and supplemented by the results of field geological surveys and landsat image interpretation are as follows.
Se Kong River Basin is in the area technically stable after Indosina Orogency lasted from Permian to Jurassic Time.

The mountainous area of the eastern Se Kong River Basin is underlain by the strata from PreCambrian to Triassic Time. These strata consist of metamorphic rocks, sedimentary rocks and igneous rocks, and faulted and folded during Indosina and/or pre Indosina Orogencies. Midstream area of Se Kong River and Bolaven Plateau are underlain by Jurassic and Cretaceous sedimentarly rocks which are folded gently. Cenozoic basalts overlie the vicinities of Bolvaven Plateau and the part of right bank of Xe Kaman River.

The geologic sequence of the Se Kong River Basin is shown in **Table 6.4-1**.

The engineering geological features of Se Kong River Basin are as follows.

- Limestone, gypsum and rock salt are unfavorable rocks in term of keeping watertightness of the reservoir, gypsum and rock salt is not reported in the river basin. But, limestone is a member of Triassic and Paleozoic strata which are distributed in the mountainous area. Airphoto, observation by helicopter and information collected during the last site visit suggest the distribution of limestone in Se Kong No. 4 site in the upstream area of Se Kong River and Xe Kaman No. 1 site and Xe Kaman No. 2 site in the upstream area of Xe Kaman River.

- Distribution of large scale collapse, landslide, thick talus deposits should be investigated in order to study slope stability of the reservoir. Fortunately, topographies indicating these phenomena are not confirmed by airphoto, helicopter inspection and site inspection.

  Fault zones are generally recognized as lineaments. The mountainous area underlain by the strata older than Jurassic, have lineaments recognized in airphoto or satellite image, and faults shown on existing geological maps. In Se Kong River Basin, ENE-NSW to NE-SW and N-S to NNW-SSE liniaments are dominant. Each liniament is a succession of segments from several to some 10 km in length. Each segments is less than 10 km long.

Few lineaments are detected in the vicinity of Attapu Town and the southern part of Bolaven Plateau to the west of Attapu Town.

On the geological map (Tien, P.C, 1988), NNW-SSE faults are dominant. This direction is same as one of dominant trend of liniaments. Most foults on that map are more then 50 km long, and limit the distribution of geological units shown on 1/1,000,000 geological map. Large length and dislocation of faults usually indicate the wide sheared zone accompanying them. In this area, fault zones will be confirmed during the investigation in later stage. The area underlain by Jurassic and Cretaceous strata, fold structure are traced easily and dislocations indicating the faults are few. So, in this area faults are supposed to be few.

- Jurassic and Cretaceous shales are apt to be weathered easily. This shales form depression, while sandstones form ridges. Shale blocks obserbed on the surface of intake dam of Xe Set Power Station (Completed in 1991) are disintegrated to small pieces owing to slaking. (This shale is distributed in Se Kong No. 3 site).

- Cenozoic volcanic rocks sometimes cause problem on watertightness of reservoir, because of open joints and underlying weathered layer or old river gravels. Cenozoic basalt distributing in the vicinities of Bolaven Plateau may have the problem as mentioned above.

- River deposits are generally thin. Even in the basin which center is Attapu, outcrops of bedrock are observed almost every attach face of the river and suggest the thickness of river deposits generally less than 5 m.

- As underground resources Mineral Occurrence Maps (British Geological Survey 1990, UN, 1990 **Fig. 6.4-3**) show occurrence of gold, silver, copper lead bauxite, coal etc. Among them occurrence of gold and cupper are more abundant. According to UN (1990) gold is panned and collected about 20 kg a year along the Se Kong River.

Cupper is reported from Mesozoic sandstone and mudstone on the eastern and southern side of Bolaven Plateau. Gold dust is small in volume. Copper is low quality. So, these two will not cause problem in electricity development plans in Se Kong River Basin. But coal at Ban Chakeui in Se Kong Province is considered to be the most significant in the Salavan Coal field which is the best coal prospects in Lao PDR, (UN 1990, Mullins, J. et at 1987). It was about to be investigated by Canada Team in July '93. This coal bed is supposed to be distributed in the reservoir area of Se Kong No. 4 site.

Geological outline of each project is shown in **Table 6.4-2**. Among priority projects, Se Kong No. 4 and Xe Kaman No.1 site have problem of water tightness coursed by limestone, and Xe Namnoy Midstream site has similar problem caused by Cenozoic basalt. The Se Kong No. 4 site has another problem of coal bed.

**Table 6.4-1 Geological Sequence of the Se Kong River Basin**

| Age | | Geological Sequence | Formation |
|---|---|---|---|
| Cenozoic | Quaternary | Basalt | |
| | Tertiary | | |
| Mesozoic | Cretaceous | | |
| | Jurassic | Sandst., Siltst. | Champa formation |
| | | Shale, Sandstone | |
| | Triassic | Congl Sandst. Rhyolite | Manggiang formation |
| Paleozoic | Permian | Andesite | |
| | Carboniferous | Shale, Chert, Limestone | |
| | Devonian | Shale, Sandst. Limestone | |
| | Silurian | Schist, Limestone | |
| | Ordovician | Sandst, Phyllite | |
| | Cambrian | | |
| Pre-Cambrian | | Gneiss, Amphibolite, Crystalline schist | |

## Table 6.4-2 Outline of Geology of Project Areas

| Site Name (n: Priority Project) | Location | Installed Capacity (MW) | Dam Height | Investigation | | | | Geology (After Scale 1: 1 million map '88) | | Inferred Engineering Geological Problem | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Literature | Air-photo | Helico. | Geol. Survey | | | | |
| Se Kong No. 5 | Se Kong River upstream area | 305 | 200 | ○ | ○ | ○ | | Paleo Mesoz.<br>($D_{1-2}$,$T_{1-2}$) | Sandst, Shale, Limest<br>Volcanic Rocks | | |
| Se Kong No. 4 | Se Kong River upstream area | 470 | 150 | ○ | ○ | ○ | ○ | Paleo Mesoz.<br>(e-0,$D_{1-2}$,C,<br>P,$T_{1-2}$) | Sandst, Shale, Volcanic Rocks,<br>Limest. Metamorphic R. | ·Coal bed[1)] | 1) the most important in Laos |
| Se Kong No. 3 | Se Kong River midstream area | 320 | 60 | ○ | ○ | ○ | | Mesozoic<br>($J_{1-2}$) | Sandst, Shale | ·Wide and gentle valley | |
| Dak E Meule | Nam Emun River | 185 | 150 | ○ | | | | Paleozoic<br>(e-0,$D_{1-2}$) | Shale, Limest, Sandst, Metamorphic R. | | |
| H. Lamphan Gnai | Bolaven Plateau | 75 | 60 | ○ | | ○ | | Mesozoic<br>($J_3$-K) | Sandst, Shale | | |
| Xe Namnoy Midstream | Bolaven Plateau | 200* | 70 | ○ | ○ | ○ | ○ | Mesozoic<br>($J_3$-K)<br>Cenozoic<br>($BN_2$-$Q_1$) | Sandst, Shale<br>Basalt | ·Reservoir Watertightness: basalt | |
| Houay Katak-Tok | Bolaven Plateau | 118* | 70 | ○ | | ○ | | Mesozoic<br>($J_3$-K) | Congl, Sandst, Shale | | |
| Xe Namnoy Downstream | Xe Namnoy River | 36* | 70 | ○ | | | | Mesozoic<br>($J_3$-K)<br>Cenozoic<br>($B_{11}$-IV) | Congl, Sandst, Shale<br>Basalt | | |
| Xe Kaman No. 4 | Xe Kaman River upstream area | 155 | 100 | ○ | | | | Mesozoic<br>($T_{1-3}$,$s^5_4$)<br>Pre. C.<br>($PR_1$) | Sandst, Shale, Volconic R., Limest, Granite<br>Metamorphic Rocks | | |
| Xe Kaman No. 3 | Xe Kaman River | 230 | 170 | ○ | | | | Mesozoic<br>($T_{1-2}$) | Sandst, Shale, Limest, Volc. R. | | |
| Xe Kaman No. 2 | Xe Kaman River upstream area | 135 | 140 | ○ | ○ | ○ | | Mesozoic<br>($T_{1-2}$) | Sandst, Shale, Limest, Volc. R. | ·Watertightness:limestone[3)] | 3) by topography |
| Xe Kaman No. 1 | Xe Kaman midstream area | 390 | 150 | ○ | ○ | ○ | | Paleozoic<br>($D_{1-2}$,C) | Shale | ·Watertightness:limestone | |
| Xe Xou | Xe Xou River | 95 | 100 | ○ | | | | Paleozoic<br>($O_3$-S) | Andesite, Schist, Sandst | | |
| Nam Kong No. 3 | Nam Kong River | 30 | 100 | ○ | | | | Mesozoic<br>($T_{1-2}$) | Sandst, Shale, Limest, Volc. R. | | |
| Nam Kong No. 2 | Nam Kong River | 60 | 80 | ○ | | | | Mesozoic<br>($T_{1-2}$) | Sandst, Shale, Limest, Volc. R. | | |
| Nam Kong No. 1 | Nam Kong River | 150 | 130 | ○ | | | | Mesozoic<br>($T_{1-2}$) | Sandst, Shale, Limest, Volc. R. | | |
| | | *After JICA (1992)<br>Others, Mekong C. | Approximate height | | | | | PR: Pre Cambrian<br>S : Silurian<br>C : Carboniferous<br>T : Triassic<br>K : Cretaceous<br>Q : Quaternary<br>ß : Effusive rock | O: Ordovician<br>D: Devonian<br>P: Permian<br>J: Jurassic<br>N: Tertiary<br>r: Plutonic rock | | |

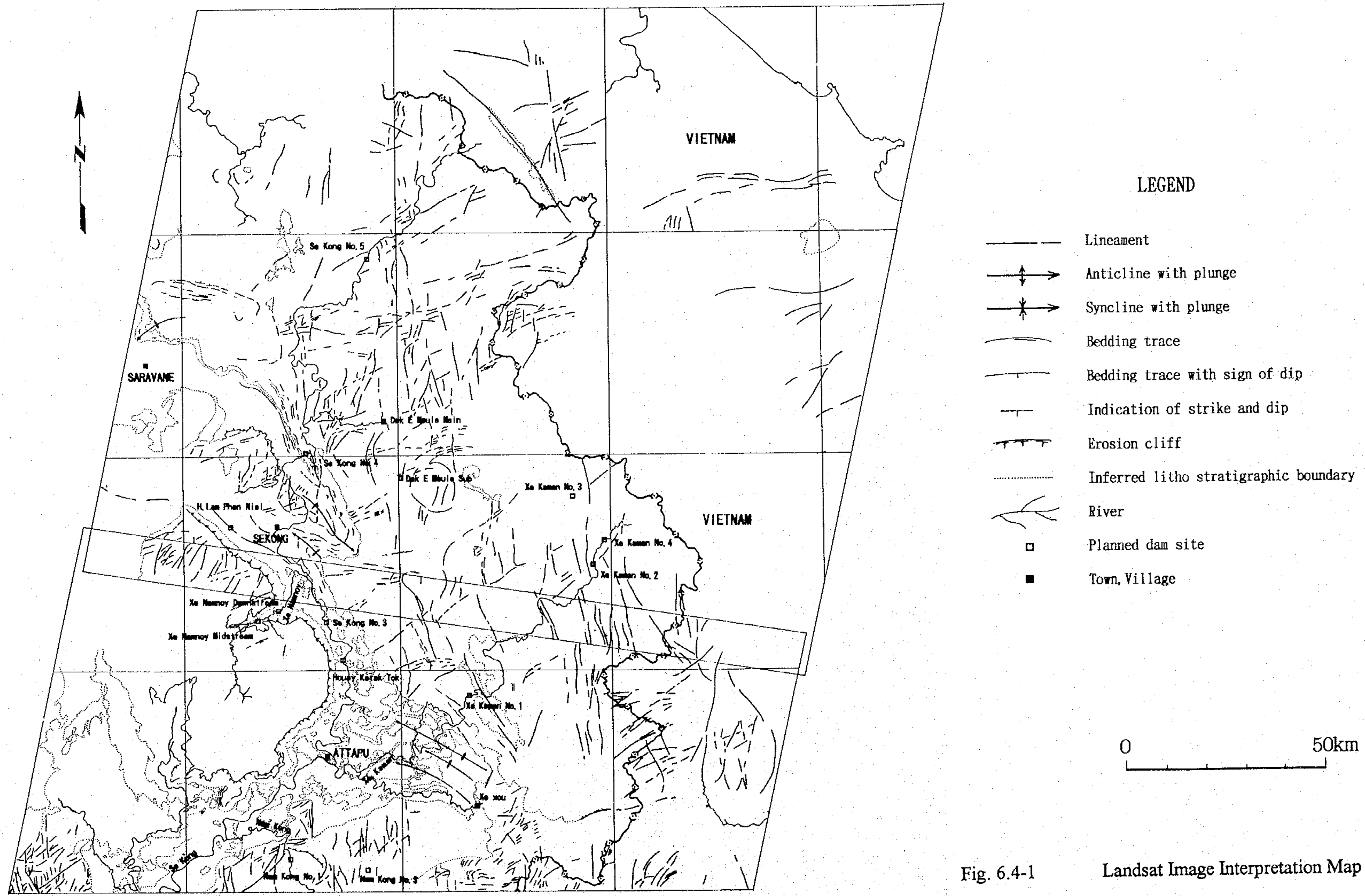
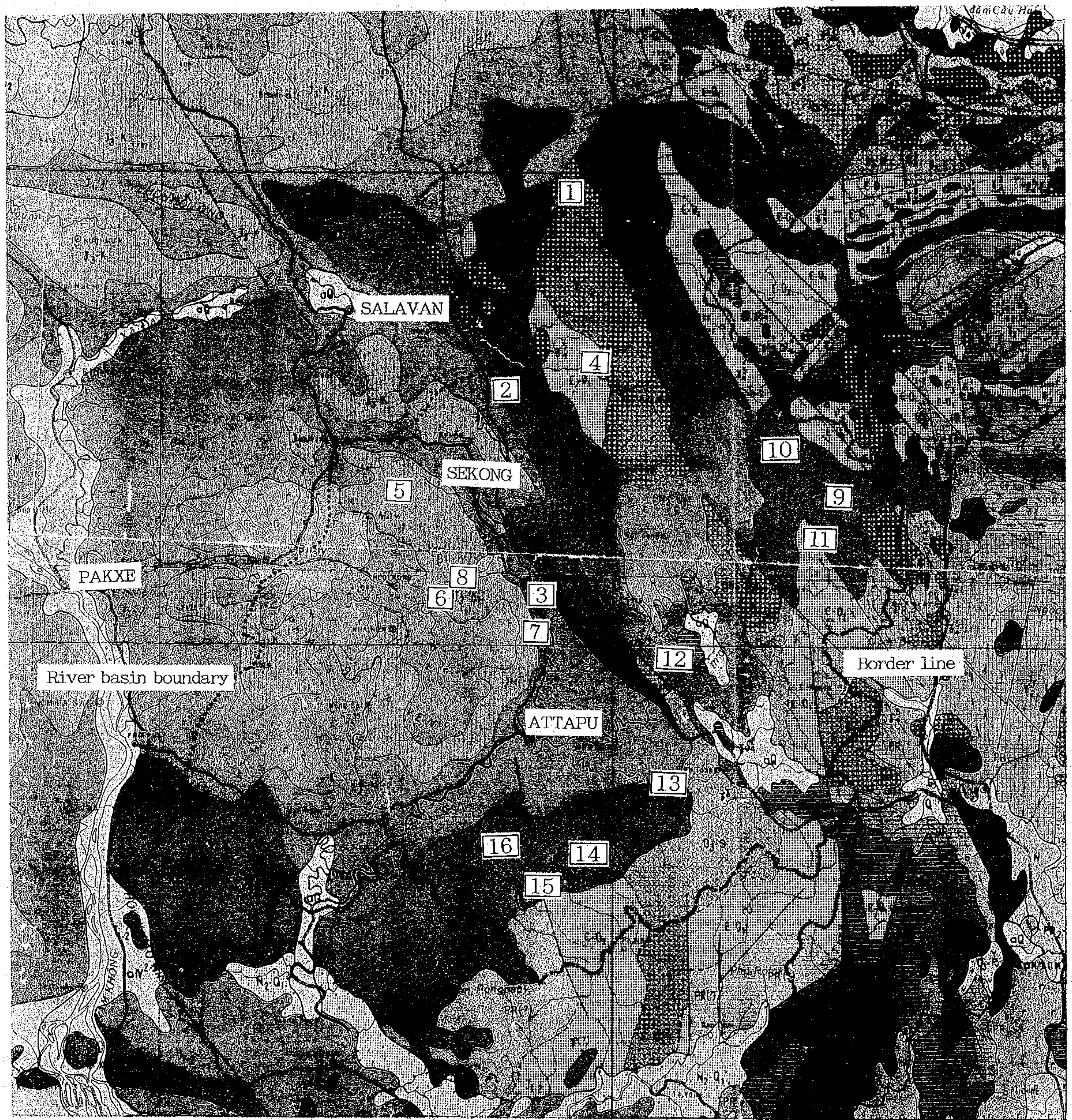



Fig. 6.4-1 Landsat Image Interpretation Map of the Se Kong River Basin



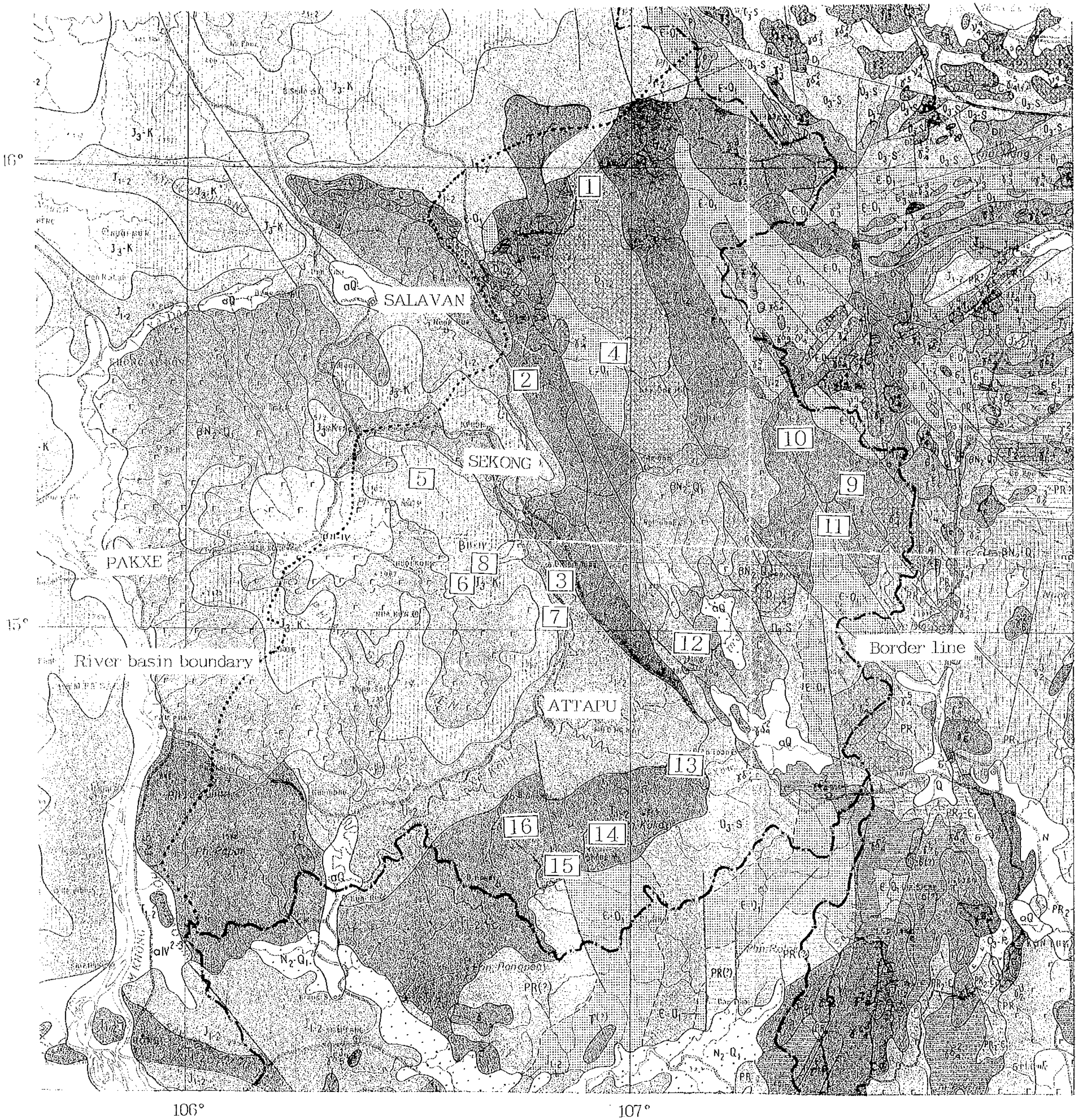

Project

- [1] Se Kong No.5
- [2] Se Kong No.4
- [3] Se Kong No.3
- [4] Dak E Meule
- [5] H. Lamphan Gnai
- [6] Xe Namnoy Midstream
- [7] Houay Katak—Tok
- [8] Xe Namnoy Downstream
- [9] Xe Kaman No.4
- [10] Xe Kaman No.3
- [11] Xe Kaman No.2
- [12] Xe Kaman No.1
- [13] Xe Xou
- [14] Nam Kong No.3
- [15] Nam Kong No.2
- [16] Nam Kong No.1

0 50km

Fig. 6.4-2 (1)

Geological Map of the Se Kong River Basin




Project

| | |
|---|---|
| [1] | Se Kong No.5 |
| [2] | Se Kong No.4 |
| [3] | Se Kong No.3 |
| [4] | Dak E Meule |
| [5] | H. Lamphan Gnai |
| [6] | Xe Namnoy Midstream |
| [7] | Houay Katak−Tok |
| [8] | Xe Namnoy Downstream |
| [9] | Xe Kaman No.4 |
| [10] | Xe Kaman No.3 |
| [11] | Xe Kaman No.2 |
| [12] | Xe Kaman No.1 |
| [13] | Xe Xou |
| [14] | Nam Kong No.3 |
| [15] | Nam Kong No.2 |
| [16] | Nam Kong No.1 |

0 50km

Fig. 6.4-2 (1)

Geological Map of the Se Kong River Basin

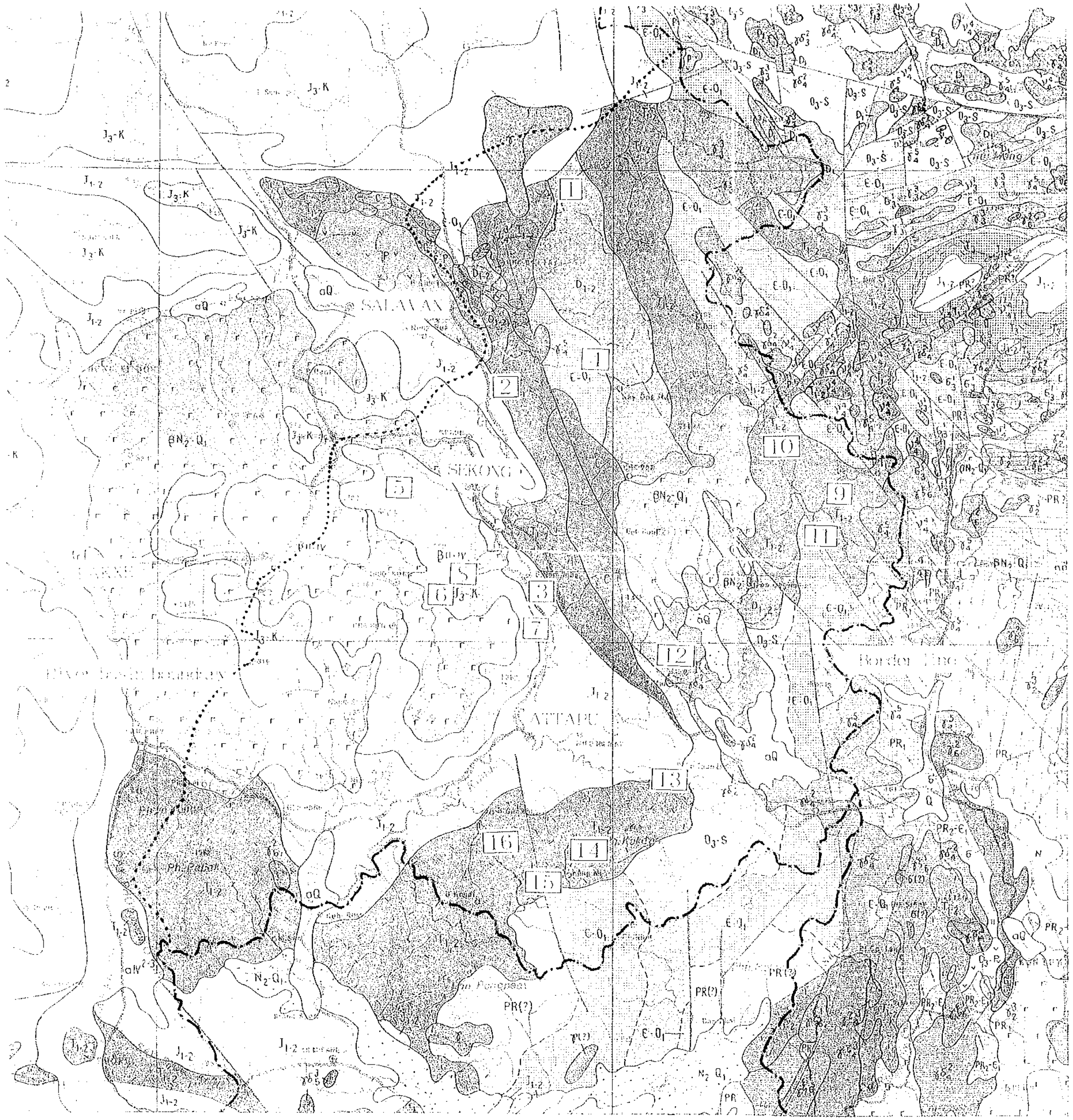



Fig. 6.4-2 (1)

Geological Map of the Se Kong River Basin

# LEGEND

### QUATERNARY

- a, apd. Boulder, pebble, gravel, sand, debris.
- $\beta_{II-IV}$. Basalt.
- m, a, am, vm, b, mb, ba (m) abl, ba. Sand, silt, clay, peat: *Thaibinh* (1), *Cuulong*, *Tonlesap* (7) Formations and *Hue* (5) Suite. Sediments of terraces (1,5-2m).
- a, m. Sand, silt, motley-coloured clay: *Vinhphuc* (2), *Moduc* (6), *Mochoa* (7) Formations, *Danang* yellow sand (5). Sediments of terraces (10-15m).

Pliocene - Pleistocene. a. Clay, silt, sand, pebble, gravel, chalky clay, laterite: *Bamieu* Formation (7) and others (3,4,5,6).
b. Basalt, lateritic-basalt, bauxite.

Upper Cretaceous. a. Red conglomerate, sandstone, claystone, siltstone: *Yenchau* Suite (3), *Mugia* Formation (5) and others (4). Rock salt, potash, gypsum, anhydrite, claystone, siltstone: *Thangon* Suite, *Donghen* Formation (5,6).
b. Rhyolite, dacite, tuffs, red sandstone, conglomerate: *Dapren*, *Laclom* (7) Formations and comendite in some places: *Ngoithia* Formation (3).

Upper Jurassic-Cretaceous. a. Red conglomerate, sandstone, siltstone, claystone: *Champa* Formation (5,6) and others (4,5). Conglomerate, sandstone, lignite and gagate-bearing beds in some places: *Phuquoc*, *Cordamon* Formations (8).
b. Red sandstone, andesite, dacite, tuffs: *Calo* Formation (7). Orthophyre, dacite, tuffs, red siltstone: *Vonchan* Formation (3) and others.

### JURASSIC

Red conglomerate, sandstone, siltstone, coaly shale in some places: *Haroi* (1,2,3), *Nampo* (4) Formations. Red conglomerate, sandstone, calcareous shale: *Tholam* (5,6), *Bandon* (7) Suites and others (7).

### TRIASSIC

- Siltstone, marl, shale, rhyolite, tuffs (1,3,4,5,7).
- Sandstone, siltstone, shale, marl, coal seams: *Suoibang* (3), *Vanlang* (2) Suites and others (4,5). Conglomerate, sandstone, siltstone, coal seams: *Hongai* (1,2), *Nongson*, *Dongdo* (5) Suites.
- a. Limestone: *Donggiao* Suite (3). Limestone, siltstone, sandstone: *Honnghe* Formation (8).
  b. Siltstone, sandstone, marl, limestone: *Quilang* (5), *Nakhuat* (1,2), *Namthom* (3) Suites and basalt, tuffs in some places: *Muongtrai* Suite. Siltstone, sandstone, limestone, rhyolite, dacite, tuffs: *Dongtrau*, *Namsam* (5), *Chuklin* (7), *Rovieng* (7) Formations.
- Conglomerate, siltstone, sandstone, shale, rhyolite, dacite, tuffs, limestone: *Manggiang* (6,7) Formation. Conglomerate sandstone, siltstone, shale, limestone, rhyolite, basalt, tuffs: *Songhien* Suite (1,2) and others (6,7).

Upper Permian. Limestone, cherty shale: *Baichay* (1), *Camlo* (5), *Tathiet* (7) Formations. Bauxite, coal lenses in some places: *Dongdang* Suite (2). Limestone, shale, chert, basalt, tuffs: *Camthuy*: Formation (3) and *Yendzuyet* Suite (3).

Permian. Limestone (8), limestone, siltstone, quartzite, andesite, rhyolite, tuffs: *Khangkhay* Formation (5).

### CARBONIFEROUS - PERMIAN

- Siltstone, conglomerate, limestone, chert and andesite, rhyolite, rhyodacite, trachyte, tuffs: *Duklin* (7), *Songda* (4) Formations; siltstone, limestone, basalt, tuffs: *Bandziel* Suite (3).
- Limestone: *Bacson* Series (1,2,3) and others (4,5).

Carboniferous. Shale, chert, siltstone, limestone, coal seams: *Chacoi*, *Namthom*, *Lukhe* Formations (5). Shale, siltstone, limestone, andesite, tuffs (4,6), limestone (3).

Devonian-Carboniferous. Shale, sandstone, limestone, rhyolite, tuffs (4,6,7,8).

### DEVONIAN

- Sandstone, shale, limestone: *Dongtho* Formation (5). Chert, siliceous limestone, manganese: *Bancai* (3) and *Toctat* (2) Suites.
- Limestone: *Cubai* Formation (5). Limestone and chert: *Loson* Suite (1). Limestone, sandstone and shale: *Quydat* Formation (5).
- Siltstone, shale, limestone *Dzuongdong* Formation (1) and others (5). Green schist in some places. *Tukhoe* Formation (3).
- a. Red sandstone, shale, conglomerate: *Doson* (1) and *Tanlam* (5) Formations.
  b. Shale, sandstone: *Songmua* Formation (3). Sandstone, shale, marl, limestone: *Nampia* Formation (3) and *Bannguon* (3), *Bacbun*, *Minle* (2) Suites. Red sandstone, shale: *Sicu* Suite (2).

Upper Ordovician - Silurian. Limestone, conglomerate, schist: *Sinhvinh* Suite (3); andesite, rhyolite, tuffs in some areas: *Longdai*, *Songcu* Formations (5). Schist, limestone, sandstone, basalt, tuffs: *Puhom* Formation (3). Siltstone, sandstone, schist, limestone, rhyolite, tuffs: *Phungu* Suite (2), *Cato* Formation (1) and others (4,5).

### CAMBRIAN - ORDOVICIAN

Schist, sandstone: *Suoimai* Formation (5), limestone in some areas: *Benkhe* Suite (3). Schist, green schist, sandstone, metabasalt, metaandesite: *Avuong* Formation (5,6). Schist, sandstone, quartzite (7).

Upper Proterozoic - Lower Cambrian. Micaschist, sericite schist, quartzite, interbeds of marble and amphibolite lenses: *Songchay* (2), *Namco* (3), *Bukhang* (5), *Poco* (6) Formations. Dolomite, marble, sericite schist, quartzite, phyllite: *Sapo* Suite (3).

### PROTEROZOIC

- Biotite - shillimanite gneiss and schist, graphite schist, migmatite, lenses of amphibolite and marble: *Songhong* Complex (3). Gneiss, amphibolite, micaschist, sericite schist, quartzite, phyllite (4,6,7).
- Amphibole - biotite gneiss, amphibolite, migmatite: *Songtranh* (6), *Suoichieng* (3) Formations. Gneiss and biotite schist, graphite schist, migmatite, interbeds of marble, quartzite and amphibolite: *Dakmi* (6) and *Sinhquyen* (3) Formations.

## INTRUSIVE ROCKS

### LATE MESOZOIC - CENOZOIC

**LATE CRETACEOUS-PALEOGENE**

- Alkaline gabbrodiorite, diorite, aegirine, riebeckite-bearing granosyenite, syenite: *Numxe*, *Tamduong* (3) and *Tralcan*, *Mangxim* (5,6) Complexes.
- Leucocratic granite, leucocratic two mica granite, garnet, fluorite-bearing granite alaskaite: *Plaoac* (2), *Songchu* (5), *Bana* (5,6), *Cana* (7), *Nakhoun* (5) Complexes and *Tuolchark* Type (8).
- Gabbro - gabbrodiorite, diorite ($\nu_6^1$): *Songkhao* (5) Complex and *Bamnak* (8) Type. Biotite - hornblende granodiorite, monzonite, granite, granite granophyre, granosyenite ($\gamma\delta_6^1$): *Banchieng* (5), *Banmuong* (5), *Deomay-Yeyensun* (3), *Burinh* (5), *Mongcai* (1), *Deoca* (5,6), *Tonghau* (5) Complexes and *Knongay-Kchon* (8) Type. Pyroxene granosyenite, quartz syenite, syenite ($\xi_6^1$): *Chodon* (2) Complex.

**LATE JURASSIC-EARLY CRETACEOUS**

- Diorite, quartz diorite, granodiorite and biotite hornblende granite: *Dinhquan* (6,7) Complex and *Ochung - Chekprek* Type.

### LATE PALAEOZOIC - EARLY MESOZOIC

**PRENORIAN**

- Adamelite, biotite melanogranite and garnet, cordierite-bearing two mica granite: *Plabloc* (2,3,4,5), *Halvan* (5,6), *Pousayvay* (5) Complexes.
- Olivine gabbro, olivine gabbro-norite, norite, gabbro, gabbro-diorite and pyroxenite, troktholite, anorthosite (2,3,5,6).

**MIDDLE TRIASSIC**

- Biotite-hornblende microgranite, granite-granophyre, granite: *Songma* (5), *Nuidleng* (2), *Vancanh* (6), *Huoitom* (4) Complexes and *Phnompreah* (7) Type.

**LATE PERMIAN - EARLY TRIASSIC**

- Gabbro-diorite, diorite, quartz diorite, biotite-hornblende granodiorite and granite: *Dienbienphu* (3,4,5), *Queson* (5,6), *Banlao* (5) *Sacay* (4) Complexes and *Phnomsangker-Phnomlasson* (7) Type.

### EARLY - MIDDLE PALAEOZOIC

**ANTE-DEVONIAN**

- Biotite melanogranite, garnet-bearing gneissose two mica melanogranite: *Songchay* (2), *Bukhang* (5), *Dailoc* (5,6), *Samhol* (5) Complexes.

**ORDOVICIAN-SILURIAN**

- Diorite, quartz diorite, hornblende biotite granodiorite, granite: *Trabong* (5), *Muonghet* (3) Complexes.

**EARLY PALAEOZOIC**

- Dunite harzburgite ($\delta_3^1$): *Nuinua* (3), *Pacnam* (3), *Hiepduc* (5,6), *Namong* (2), *Sopsan* (3) Complexes.
  Gabbro - amphibolite, gabbro - diabase, diabase ($\nu_3^1$) *Boxinh* (3), *Xiengkho* (3), *Anson* (5) Complexes.
  Biotite - hornblende plagiogranite ($\gamma\delta_3^1$) *Chiengkhuong* (3), *Muonghet* (3) Complexes.

### OTHER SYMBOLS

- Unknown in age intrusive rocks: ultramafic (a), mafic (b), granite (c) and subalkaline (d).
- Geological boundary: a-Observed, b-Inferred.
- Fault: a-Observed; b-Inferred.
- Coal-bearing sediments.
- Salt-bearing sediments.
- Clastic sediments.
- Mafic effusives.
- Intermediate effusives.
- Acidic effusives.

Fig. 6 : 4—2 (2)

Geological Map of the Se Kong River Basin

# LEGEND

QUATERNARY

- Q — a, apd Boulder, pebble, gravel, sand, debris.
- $\beta_{N-N}$ — $\beta_{N-N}$ Basalt.
- — m, a am, vm, b, mb, ba (m) abi, ba. Sand, silt, clay, peat. *Thaibinh* (1), *Cuulong*, *Tonlesap* (7) Formations and *Hue* (5) Suite Sediments of terraces (1,5-2m).
- — a, m. Sand silt, motley - coloured clay: *Vinhphuc* (2), *Moduc* (6), *Mochuo* (7) Formations, *Danang* yellow sand (5) Sediments of terraces (10-15m).

NEOGENE

- $N_2$-Q — Pliocene - Pleistocene a. Clay, silt sand, pebble, gravel, chalky clay, laterite: *Bamieu* Formation (7) and others (3,4,5,6). b. Basalt, lateritic –basalt, bauxite.

CRETACEOUS

- $K_2$ — Upper Cretaceous a. Red conglomerate, sandstone, claystone, siltstone · *Yenchou* Suite (3), *Mugia* Formation (5) and others (4). Rock salt, potash, gypsum, anhydrite, claystone, siltstone · *Thongon* Suite, *Donghen* Formation (5,6). b. Rhyolite, dacite, tuffs, red sandstone, conglomerate *Dapren*, *Loclam* (7) Formations and comendite in some places. *Ngothru* Formation (3).
- $J_3$-K — Upper Jurassic-Cretaceous. a Red conglomerate, sandstone, siltstone, claystone *Champa* Formation (5,6) and others (4,5) Conglomerate, sandstone, lignite and gagate-bearing beds in some places · *Phuquoc*, *Cardamon* Formations (8). b. Red sandstone, andesite dacite, tuffs *Cate* Formation (7) Orthophyre, dacite, tuffs, red siltstone: *Yenchon* Formation (3) and others.

JURASSIC

- $J_{1-2}$ — Red conglomerate, sandstone, siltstone coaly shale in some places *Hanoi* (1,2,3), *Nampo* (4) Formations. Red conglomerate, sandstone, calcareous shale *Thulam* (5,6), *Bandon* (7) Suites and others (7).

TRIASSIC

- T — Siltstone, marl, shale, rhyolite, tuffs (1,3,4,5,7)
- $T_3$ — Sandstone siltstone, shale marl, coal seams. *Suoibang* (3), *Luniang* (2) Suites and others (4,5) Conglomerate sandstone, siltstone, coal seams *Hongai* (1,2), *Nongson*, *Dongdo* (5) Suites
- $T_2$ — a. Limestone *Donggiao* Suite (3) Limestone, siltstone, sandstone *Hoanghe* Formation (8). b. Siltstone, sandstone, marl, limestone *Quilang* (5), *Nakhuat* (1,2), *Namtham* (3) Suites and basalt tuffs in some places. *Muongtrai* Suite. Siltstone, sandstone, limestone, rhyolite, dacite, tuffs *Dongtrau*, *Namsom* (5), *Chuklin* (7), *Roveng* (7) Formations
- $T_1$ — Conglomerate, siltstone, sandstone, shale, rhyolite, dacite, tuffs, limestone. *Manggtang* (6,7) Formation Conglomerate sandstone, siltstone, shale, limestone, rhyolite, basalt, tuffs *Songhien* Suite (1,2) and others (6,7)

PERMIAN

- $P_2$ — Upper Permian. Limestone, cherty shale: *Banchuy* (1), *Camlo* (5), *Tathet* (7) Formations. Bauxite, coal lenses in some places: *Dongdang* Suite (7) Limestone, shale, chert, basalt, tuffs *Camthuy* Formation (3) and *Yendzuyet* Suite (3)
- P — Permian Limestone (8), limestone, siltstone, quartzite andesite, rhyolite, tuffs: *Khangkhay* Formation (5)

CARBONIFEROUS - PERMIAN

- $C_3$-P — Siltstone, conglomerate, limestone, chert and andesite, rhyolite, rhyodacite, trachyte, tuffs · *Daklin* (7), *Songda* (4) Formations, siltstone, limestone, basalt, tuffs: *Bandziel* Suite (3)
- C-P — Limestone *Bacson* Series (1,2,3) and others (4,5).
- C — Carboniferous. Shale, chert, siltstone, limestone, coal seams *Chacu*, *Namthom*, *Lakhe* Formations (5) Shale, siltstone, limestone, andesite, tuffs (4,6), limestone (3)
- D-C — Devonian-Carboniferous. Shale, sandstone, limestone, rhyolite, tuffs (4,6,7,8)

DEVONIAN

- $D_3$ — Sandstone, shale, limestone · *Dongtho* Formation (5) Chert, siliceous limestone, manganese *Banchi* (3) and *Toclat* (2) Suites.
- $D_{2-3}$ — Limestone · *Cubui* Formation (5). Limestone and chert. *Loson* Suite (1) Limestone, sandstone and shale *Quydat* Formation (5)
- $D_2$ — Siltstone, shale, limestone *Dzuongdong* Formation (1) and others (5) Green schist in some places. *Takhoc* Formation (3)
- $D_1$ — a Red sandstone, shale, conglomerate: *Doson* (1) and *Tanlam* (5) Formations. b Shale, sandstone: *Songmua* Formation (3) Sandstone-shale, marl, limestone *Nampia* Formation (3) and *Banguon* (3), *Bacbun*, *Miale* (2) Suites Red sandstone, shale. *Sice* Suite (2)

SILURIAN

- $O_3$-S — Upper Ordovician - Silurian Limestone, conglomerate, schist *Sinhvinh* Suite (3), andesite, rhyolite, tuffs in some areas. *Longdo*, *Songcu* Formations (5) Schist, limestone, sandstone, basalt, tuffs *Puham* Formation (3) Siltstone, sandstone, schist, limestone, rhyolite tuffs. *Phunau* Suite (2) *Cato* Formation (1) and others (4,5).

CAMBRIAN - ORDOVICIAN

- Є-O — Schist sandstone · *Summoi* Formation (5) limestone in some areas *Henkhe* Suite (3) Schist, green schist, sandstone, metabasalt, metaandesite *Aruong* Formation (5,5) Schist, sandstone, quartzite (7).
- $PR_3$-$Є_1$ — Upper Proterozoic - Lower Cambrian Micaschist sericite schist quartzite, interbeds of marble and amphibolite lenses *Songchay* (2), *Namco* (3), *Bukhang* (5), *Poco* (6) Formations Dolomite marble, sericite schist, quartzite, phyllite *Sapa* Suite (3)

PROTEROZOIC

- PR — Biotite - shillimanite gneiss and schist graphite schist, migmatite, lenses of amphibolite and marble · *Songhong* Complex (3) Gneiss, amphibolite, micaschist, sericite schist, quartzite, phyllite (4,6,7)
- $PR_1$ — Amphibole - biotite gneiss, amphibolite, migmatite. *Songtranh* (6) *Suoichieng* (3) Formations Gneiss and biotie schist, graphite schist, migmatite, interbeds of marble, quartzite and amphibolite *Lakmi* (6) and *Sinhquyen* (3) Formations

## INTRUSIVE ROCKS

### LATE MESOZOIC - CENOZOIC

LATE CRETACEOUS-PALEOGENE

- Alkaline gabbrodiorite, diorite, aegirine, riebeckite - bearing granosyenite, syenite *Nomxe*, *Tamduong* (3) and *Traican*, *Mongxim* (5,6) Complexes
- Leucocratic granite, leucocratic two mica granite, garnet, fluorite- bearing granite alaskaite. *Plaoac* (2), *Songchu* (5), *Bana* (5,6), *Cana* (7), *Nakhoun* (5) Complexes and *Tuolchark* Type (8).
- Gabbro - gabbrodiorite, diorite ($\nu_6^1$) *Songkhao* (5) Complex and *Bamnak* (8) Type. Biotite - hornblende granodiorite, monzonite, granite, granite granophyre, granosyenite ($\gamma_6^1$) *Banchieng* (5), *Bonmuong* (5), *Deomay-Yeyensun* (3), *Burinh* (5), *Mongcai* (1), *Deoca* (5,6), *Tonghau* (5) Complexes and *Knonpay-Kchon* (8) Type Pyroxene granosyenite, quartz syenite, syenite ($\xi_5^1$) · *Chodon* (2) Complex.

LATE JURASSIC- EARLY CRETACEOUS

- Diorite, quartz diorite, granodiorite and biotite hornblende granite *Dinhquan* (6,7) Complex and *Ochung - Chekprek* Type

### LATE PALAEOZOIC - EARLY MESOZOIC

PRE NORIAN

- Adamelite, biotite melanogranite and garnet, cordierite - bearing two mice granite: *Plabioc* (2 3,4,5), *Haivan* (5,6), *Pousayvay* (5) Complexes
- Olivine gabbro, olivine gabbro - norite, norite, gabbro, gabbro - diorite and pyroxenite, troktholite, anorthosite (2,3,5,6).

MIDDLE TRIASSIC

- Biotite - hornblende microgranite, granite - granophyre, granite: *Songma* (5), *Nuidieng* (2), *Vancanh* (6), *Huoitom* (4) Complexes and *Phnompreah* (7) Type.

LATE PERMIAN - EARLY TRIASSIC

- Gabbro - diorite, diorite, quartz diorite, biotite - hornblende granodiorite and granite: *Dienbienphu* (3,4,5), *Quesen* (5,6), *Banlao* (5) *Sacay* (4) Complexes and *Phnomsangker-Phnomlasson* (7) Type.

### EARLY - MIDDLE PALAEOZOIC

ANTE-DEVONIAN

- Biotite melanogranite, garnet-bearing greissose two mica melanogranite · *Songchay* (2), *Bukhang* (5), *Dailoc* (5,6) *Sambat* (5) Complexes.

ORDOVICIAN-SILURIAN

- Diorite, quartz diorite, hornblende biotite granodiorite, granite · *Trabong* (5), *Muonghet* (3) Complexes.

EARLY PALAEOZOIC

- Dunite harzburgite ($\delta_3^1$) *Nuinua* (3), *Pacnam* (3), *Hiepduc* (5,6), *Namong* (2), *Sopsan* (3) Complexes. Gabbro - amphibolite, gabbro diabase, diabase ($\nu_3^1$) *Boxinh* (3), *Xiengkho* (3), *Anson* (5) Complexes. Biotite - hornblende plagiogranite ($\gamma\delta_3^1$) *Chienykhuong* (3), *Muonghet* (3) Complexes

### OTHER SYMBOLS

- Unknown in age intrusive rocks: ultramafic (a), mafic (b), granite (c) and subalkaline (d).
- Geological boundary a-Observed, b-Inferred
- Fault a-Observed, b-Inferred
- Coal-bearing sediments
- Salt-bearing sediments
- Clastic sediments
- Mafic effusives.
- Intermediate effusives.
- Acidic effusives.

Fig. 6 : 4—2 (2)

Geological Map of the Se Kong River Basin

# LEGEND

## INTRUSIVE ROCKS

### LATE MESOZOIC - CENOZOIC

### LATE PALAEOZOIC - EARLY MESOZOIC

### EARLY - MIDDLE PALAEOZOIC

### OTHER SYMBOLS

Fig. 6.4-2-2

Geological Map of
the Se Kong River Basin

# 7. Hydropower Potential Study in the Se Kong River Basin

# 7. Hydropower Potential Study in the Se Kong River Basin

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# 7. Hydropower Potential Study in the Se Kong River Basin

## 7.1 Basic Conditions for the Hydropower Potential Study

### 7.1.1 Scope of Study on Development Plan Inventory

**(1) Geographical Scope**

The study on development plan inventory covers the entire Se Kong basin, other than those in the territories of Vietnam and Cambodia which are located at the basin's upstream and downstream ends respectively.

**(2) Purpose of Hydropower Development**

The study covers hydropower development projects to be developed mainly for energy export to the neighboring countries.

**(3) Development Scale**

In considering the development purpose mentioned above, the study covers the medium to large scale projects. Specifically, based on discussions with the Ministry of Industry and Handicraft, the scale of the projects to be proposed in the inventory of hydropower development plan is determined to be an installed capacity of 10 MW or more in this study.

For the adjustment of the installed capacity, the establishment of the target plant factor level is essential. This matter is discussed in the following section.

### 7.1.2 Basic Policy for producing Development Plan Inventory

**(1) Purpose of the Study on Development Plan Inventory**

In this study, the development plan inventory is produced basically by focusing on the potential projects to evaluate the hydropower potential in the basin. However, the study is finally conducted toward selecting the priority development candidates from the projects in the inventory.

(2) **Policy of Inventory Study**

Considering the purposes of the inventory study mentioned above, the following basic policies are employed in this study;

a) **Project Layout**

In this study, the basic policy is to determine the hydropower potential in the basin as much as possible. Accordingly, the study is to propose a combination of dam sites and reservoir capacities (high water level) which would provide maximum net benefit for a series of development projects in close relationship.

In this study, however, each series of projects are planned as independent projects each other without regarding incorporating operation of upstream and/or downstream projects.

b) **Development Scheme**

Hydropower projects are categorized by form of plant operation into the reservoir type, the regulation pond type, and the run-of -river type, and into the dam type, dam and waterway type, and waterway type by the structural configuration to acquire an available head for power generation.

In this study, the appropriate development schemes are selected for a project from the above categories in accordance with the project's specific characteristics.

c) **Determination of Development Scale (Installed Capacity)**

Hydropower potential in terms of development scale (installed capacity) depends on the level of the plant factor. In hydropower potential studies in general, the installed capacity of a project is determined in order to provide a specified level of plant factor to evaluate the project appropriately and evenly from the viewpoints of both the hydropower potential and economic efficiency.

In this study, considering that the major purpose of project development is energy export to the neighboring countries, and that the plant factor of the existing Nam Ngum hydropower project (150 MW), which is currently exporting electricity to

Thailand, is approximately 60 %, the development scale (installed capacity) of each project is determined to provide an approximately 60 % plant factor.

d) **Project Evaluation Method**

To determine the development plan such as the reservoir scale, layout of the waterway and powerhouse location of the project, in principle, a net benefit (B-C) is employed as an indicator to maximize the hydropower potential. In addition, the cost benefit ratio (B/C), power generation cost per kWh (unit energy cost) and construction costs per kW are also used as and where required.

An alternative thermal plant method is applied to calculate the benefit of each development plan. Regarding the plant type of alternative thermal plant, a coal fired thermal power plant is applied to the benefit calculation of a reservoir type and run-of-river type projects from the stand point of putting primary concern on evaluation of energy (kWh) value as energy export purpose. A gas turbine power plant, however, is applied to the benefit calculation of the daily regulation type of a hydropower project and which must be evaluated as a power plant for peak power supply.

### 7.1.3 Basic Materials for the Study

**(1) Topographic Map**

A set of topographic 1/50,000 scale maps, the largest scale map currently available, all the basins (excluding those parts in the territories of Vietnam and Cambodia). These maps are mainly used in this study.

**(2) Hydrological Data**

The Se Kong River basin involves areas indicating different run-off characteristics and it is suspected that the levels of seasonal flow change are not always even in each area. Currently, however, as hydrological data available in the Se Kong River basin are very limited, it is impossible to estimate the precise flow data of specific sites throughout the broad reaches in the basin. However, as flow data are of prime importance for the study of the development plan, they should be estimated by any method possible.

A series of flow data at each site has been estimated by applying the method described in 6.3, Chapter 6 for the period May, 1988 to July, 1993. Among this data series, the monthly flow data for the five years from August 1988 to July 1993 is used in this study.

The accuracy of the estimated annual flow volume is essential for the development plan incorporating a reservoir which would provide a sufficient capacity for annual wide flow regulation and, therefore, variation of the monthly flow volume would not significantly affect the result of the study in this case. However, the estimate accuracy of the flow change would affect the study result most significantly in the case of a run-of-river type project or a daily regulation type project. It must, therefore, be noted that the reliability of the study results is low for relatively small scale projects.

## 7.2 Selection of Development Projects

### 7.2.1 Review of Development Plan proposed in the Previous Studies

The development plans in the Se Kong River basin proposed in the previous studies are reviewed prior to the inventory study. The development plans reviewed here are those of the Mekong Committee as first reported in 1970, and those of the Xe Namnoy river basin proposed in the report, "Feasibility Study on the Xe Katam Small-Scale Hydroelectric Power Development Project" by JICA in 1992.

The general descriptions and locations of the projects in the above studies are shown in **Tables 1.1-1** and **1.1-2**, and in **Fig. 1.1-1**, Chapter 1. The study findings of the existing development plans on each river are provided below.

**(1) Se Kong River Mainstream**

The Mekong Committee proposed three development projects along the Se Kong river's mainstream lying within Laotian territory. From downstream, these are the Se Kong No.3, Se Kong No.4 and Se Kong No.5 projects.

Of these three projects, Se Kong Nos.3 and 4 were planned as dam types. The dam sites of both projects are restricted by topographical reasons.

The Se Kong No.5 project was planned as a dam and waterway type by utilizing a rapid section of the mainstream located downstream of the confluences of the mainstream and the Xe Sap river, Xe Lon river and the Houay Axam river. The dam site of the Se Kong No.5 project is limited at the upstream end of this rapid section in order to minimize the dam scale for a certain reservoir water level. The powerhouse site of this project is determined by taking into account the efficiency of the head use in the rapid section and the reservoir water level of the Se Kong No. 4 project.
It is difficult to plan a large scale project with a dam in the area further upstream from the Se Kong No.5 project site because the catchment area is too small. Only a waterway type project could be planned economically by using the available head in a rapid section. However, the riverbed slope is relatively gentle in the upstream area and there is no site able to provide a head efficiently by a short headrace. Under these circumstances, it is impossible to plan a medium to large scale development project at this area.

Considering the above, as based on the prevailing topographic conditions, the variation of development schemes and dam sites are limited along the mainstream of the Se Kong river, the development plan proposed by the Mekong Committee is basically appropriate. Since no significant geological problems are reported for the Se Kong river mainstream at this time, determining the development scale of the dams will be the major point in this study. In the Se Kong No.3 project, there is also the problem of inundating Sekong Town, the central township of Se Kong Province.

(2) **Xe Kaman River**

The Mekong Committee proposed three development projects on the Xe Kaman river, from down- stream, the Xe Kaman No.1, Xe Kaman No.2 and Xe Kaman No.3 projects.

Regarding the Xe Kaman No.1 project, although several alternative dam sites are available near the site proposed by the Mekong Committee, there is no room to change the basic concept of the development scheme.

The Xe Kaman No.2 project is a dam type located upstream from the Xe Kaman No.1 reservoir. Its damsite is restricted between the backwater of Xe Kaman No.1 reservoir and the confluence of the Nam Poay-O river.

The Xe Kaman No.3 project was planned as a dam and waterway type. Its dam site is located on the middle reaches of the Nam Poay-O River with the water led through a 8,800 m long headrace tunnel to the backwater of the Xe Kaman No.2 reservoir. While the basic concept of this plan is appropriate, there would be certain alternatives in the location and size of the dam, in the layout of the power plant and in the waterway route to be studied further from the viewpoints of the efficient use of both the river flow and the head.

The Xe Kaman No.4 project was planned as a dam and waterway type with several reservoirs along the upstream area of the Xe Kaman mainstream and along its tributary, the Nam Laka river. These reservoirs would be connected by waterways to lead the water to the Xe Kaman No.2 reservoir. While the basic concept of this plan is also appropriate, as in the Xe Kaman No.3 project, there would be certain alternatives in the location and size of the dam, and in the layout of the power plant and the waterway route to be studied further from the viewpoints of the efficient use of both the river flow and the head.

As the Xe Kaman No.3 and No.4 projects were planned to develop hydropower potential in the uppermost reaches of the Xe Kaman River, there is no possibility for further development plan in this area.

### (3) Xe Namnoy River

The Mekong Committee proposed a dam and waterway type project in the Xe Namnoy river basin. In this development scheme, the main reservoir is planned on the mainstream of the Xe Namnoy River which flows through the Bolaven Plateau, and sub-reservoirs are planned on the Houay Katak Tok river, Xe Katam river, Houay Makchan river and the Xe Pian river. These reservoirs would be connected by waterway to lead the water to the powerhouse planned at the southern foot of the Plateau.

Following the Committee's study, JICA conducted a basic development plan study in its "Feasibility Study of the Xe Katam Small-scale Hydroelectric Power Project" during the period November, 1990 to March, 1992. This study covered the entire Xe Namnoy river basin, and included a review of the development plan proposed by the Committee. In this study, four development projects (three medium to large scale dam and waterway type projects and one small scale waterway type project) were proposed; the Xe Namnoy Midstream project with a reservoir on the midstream of the Xe Namnoy river and a headrace tunnel to lead the water to the powerhouse at the downstream reaches of a rapid section, the Xe Namnoy Downstream project being a daily regulation type using a head available along the downstream of the midstream project, the Houay Katak Tok project with a reservoir on the middle reaches of the Houay Katak Tok river with a headrace tunnel to lead the water to the powerhouse at the river side of the Se Kong river mainstream which flows along the eastern foot of the Bolaven Plateau, and the Xe Katam small-scale project as a run-of-river type for rural electrification using a head available at the downstream sectiont of the Xe Katam river.

Since JICA's study of 1992 confirmed the merits of the development plan which divided the Mekong Committee's development plan into four projects, the plan proposed by JICA is regarded as the base plan for this study. However, as the Xe Pian river basin was not included in that study, it is, therefore, required for this study that the development plan of Xe Namnoy river basin be reviewed together with the use of the Xe Pian river.

The upstream reaches of the Xe Namnoy River run through flat terrain forming the upper surface of the Bolaven Plateau. The catchment area at the damsite of the Xe Namnoy Midstream project is relatively small at 500 $km^2$. The conditions of this area provide runoff characteristics wherein the river flow is unstable throughout the year with large differences in the flow volume between the dry and wet seasons. Consequently, a reservoir of adequate capacity is required to regulate the annual flow in order to supplement the draught flow. It is also required to provide a development plan which effectively uses the high head provided by the remarkable topography of the Bolaven Plateau.

**(4) Nam Kong River**

The Mekong Committee proposed three dam and waterway type development projects on the middle to upstream reaches of the Nam Kong river, which flows through the southernmost part of Laos, close to the Cambodian border. These projects are, from downstream, the Nam Kong No.1, Nam Kong No.2 and Nam Kong No.3 projects.

The terrain along the Nam Kong River is gentle throughout and the average riverbed slope is also relatively gentle. The catchment area is also not large. The basin is, therefore, inappropriate for the development plan of a dam type project with a large reservoir or a waterway type project dependent only on the potential of the river head. Accordingly, a development plan for the Nam Kong river would require an appropriate combination of the available heads acquired from the river gradient of the rapid sections partialy distributed along the river and from the height of the dam, and the flow regulation function of the reservoir. Considering these factors, the dam sites of the three projects proposed by the Mekong Committee seem almost appropriate.

Regarding the further upstream basin from the Nam Kong No.3 project, the catchment area is small and no acquisition of a head using a rapid section can be expected.

**(5) Xe Xou River**

The Mekong Committee proposed the Xe Xou project on the Xe Xou river, which is a tributary of Xe Kaman river, using the topography of a valley along the middle reaches of the river. Since the slopes of the Xe Xou River are gentle, the proposed plan was made as a dam type incorporating a large reservoir.
There are several alternative dam sites besides that proposed by the Committee. However, there are almost no differences between the alternatives and they will not change the basic scheme of the development plan. Accordingly, the proposed plan of the Xe Xou project is appropriate when the characteristics of the topography of the Xe Xou river basin and the riverbed slope are considered.

As the slopes along the upstream reaches of the Xe Xou river are also gentle and its catchment area is small, it is difficult to provide a development plan in the upstream basin of the Xe Xou project.

### (6) Nam Emun River

The Nam Emun river is a tributary flowing into the reservoir planned in the Se Kong No.4 project. Its mid-upstream reaches consist of several small tributaries. The riverbed slopes are relatively gentle in the upstream basin, but are very steep in the midstream reaches, indicating a complicated topographic situation throughout.

Focusing on this remarkable topography, the Mekong Committee proposed the Dak E Meule project as a two-stage development of a dam and waterway type project. According to this plan, five reservoirs are planned on each tributary in the upstream basin of the Nam Emun river. These would be connected with a waterway for the first power generation. The water would then be led to the backwater of the Se Kong No.4 reservoir spreading into the downstream reaches of the Nam Emun river for further power generation.

The basic concept of this plan appears appropriate. Considering the effective use of the river flow and head, however, alternative project layouts should be studied regarding the locations and sizes of the dams, the location of the powerhouse, and the waterway routes.

### (7) Houay Lamphan Gnai River

The Houay Lamphan Gnai River flows along the north-eastern edge of the Bolaven Plateau to the north and flows down a rapid slope at the northern end of the Plateau. It then turns south along the outer foot of the Plateau to join the mainstream of the Se Kong river. Using these topographic conditions, the Mekong Committee proposed the Houay Lamphan Gnai project as a two-stage development of a dam and waterway type project. According to this plan, a medium scale reservoir is planned on the midstream of the Houay Lamphan Gnai river with the water led through a waterway tunnel under the northeastern slope of the Bolaven Plateau to the first power generation at the downstream reaches of the river. The water would then be led to a neighboring tributary for further power generation.

This development plan provides an efficient use of the topographic characteristics of the Bolaven Plateau by combining an appropriate sized reservoir and waterway, similar to that in the Houay Katak Tok project. However, it is considered that the stipulated two-stage power generation plan can be changed to a single stage plan, and alternative damsites can also be proposed in the study for more efficient production of a reservoir capacity.

As the catchment area of Houay Lamphan Gnai river is small, there is no room for another development plan in the upstream basin.

### 7.2.2 Development Projects for the Development Plan Inventory

From the review of the development plans proposed in the previous studies explained in 7.2.1, it was confirmed that the layout of the development projects is almost appropriate based on the topographic conditions of the Se Kong river basin. Also, assuming medium to large scale development, it was concluded that the plan covers almost all of the hydropower potential of the Se Kong river basin, so that there is almost no room remaining for another development plan other than the project sites proposed in the previous studies.

Consequently, the development plan inventory to be proposed in this study will be produced based on projects proposed in the previous development plan.

## 7.3 Study on Development Plan Inventory

As described in 7.2, it is confirmed that the basic concept of the development plan proposed in the previous studies is almost appropriate. In this section, therefore, the development plan is studied based on the development projects proposed in the previous plan and employing the basic study policy proposed in 7.1.2 following the purpose of this study.

The contents of the study are provided below.

### 7.3.1 Conditions for Determination of Development Scale

**(1) Determination of Effective Reservoir Capacity**

At first, the firm discharges produced by various effective reservoir capacities are calculated by mass-curve calculations with the monthly flow data. The effective reservoir capacity is then determined to provide the most efficient flow regulation performance. Here, the period of available flow data is five years which is too short to apply the carry-over reservoir operation policy which regulate river flow for over several years. In this study, therefore, the reservoir operation of the annual regulation base is applied for the calculation of the firm discharge.

The firm discharges for each project were calculated with inflow data varying the reservoir capacities. According to these calculations, it is seen that a sufficient regulating performance is expected when the effective reservoir volume is 20% to 30% of the average annual inflow volume in the case of the Se Kong River basin. As a larger reservoir volume does not produce an increased firm discharge, a regulation ratio of 20% to 30% is employed as the criteria in this study.

Where the regulating ratio of 20% to 30% is not provided due to a restricted gross reservoir capacity and a sediment volume, the largest possible capacity is used as the effective reservoir capacity, considering the installation of an intake between the sediment level and low water level of the reservoir.

**(2) Determination of Sediment Volume of the Reservoir**

The sediment volume for 100 years estimated in Chapter 6 is used for this study.

### (3) Determination of Maximum Discharge

As described in 7.1, the installed capacity is determined to provide a plant factor of approximately 60% for each project. Concerning this policy, the relationship between the available firm discharge, maximum discharge, and plant factor was examined.
According to the above examination, in the case of a project with a reservoir (with a capacity for annual flow regulation), when the maximum discharge is twice that of the firm discharge, wherein the firm discharge provides a dependable peak discharge for a 12 hour duration, the plant factor consequently becomes approximately 60%. Therefore, the maximum discharge is set at double the amount of the firm discharge.

However, in the case of a daily regulation or run-of-river project, the firm discharge is small because a reservoir capacity for annual flow regulation is unavailable. Here, although the plant factor becomes large when the doubled amount of the firm discharge is deemed to be the maximum discharge, the spilled amount of river flow becomes large in the rainy season so that river flow cannot be utilized and development efficiency becomes low. Accordingly, the maximum discharge is determined by case study to determine a maximum discharge which would provide a plant factor of approximately 60%.

## 7.3.2 Conditions for Project Cost Estimation

### (1) Civil Works and Hydraulic Equipment

Construction costs of civil works and hydraulic equipment such as gates and pen-stock steel are estimated based on basic project parameters such as the dam scale (height and crest length) by the high water level (HWL) of the reservoir or regulating pond, waterway length, maximum discharge and effective head for power generation, which are determined by using 1/50,000 scale topographic maps.

For the spillway, the construction cost is estimated based on the type of dam employed and the design flood discharge estimated in Chapter 6 as probable maximum flood.

The unit prices of each work item shown in **Table 7.3-1** are applied for cost estimation.

### (2) Electrical Equipment

The cost of electrical equipment is estimated by selecting the type of turbines deemed appropriate for the determined maximum discharge and rated standard effective head. Considering plant maintenance and operation, the minimum number of units is assumed as two.

### (3) Transmission Line

It is necessary to include the cost of the transmission line in the total project cost for evaluation of the development projects in the selection of priority projects.

In this study, the cost of the transmission line is estimated by assuming the receiving substation, transmission line capacity and transmission line route according to the installed capacity of each project and with the condition that each site is developed individually.

### (4) Access Road

The cost of access roads is also estimated by assuming that each project is developed individually. In this study, the construction cost of new road and bridges, and the improvement cost of existing roads and bridges is made by assuming the access route from main existing road to the project site.

### (5) Compensation

The cost of compensation is assumed to be 5% of the cost of civil works evenly for each development project since the objective of the compensation is unclear at the moment.

## 7.3.3 Conditions for Project Evaluation

### (1) Annual Benefit (B)

As described in 7.1.2 (2), project benefit is calculated by applying the alternative thermal power plant method. In this study, a constant unit benefit is used. The annual benefit of each project is calculated by multiplying the following figures of unit benefits to the dependable peak output (90% dependability) and to the annual energy (primary and secondary) respectively.

| Project Type | Plant type | kW Benefit (US$/kW) | kWh Benefit (US$/kWh) (firm) | (secondary) |
|---|---|---|---|---|
| Reservoir(Annual Reg.) | Coal Fired | 212 | 0.0162 | 0.0145 |
| Daily Regulation | Gas Turbine | 71 | 0.0512 | 0.0506 |

**(2) Annual Cost (C)**

The annual cost of the project is calculated by multiplying the construction cost of the project by an annual cost rate of 11% assuming that the discount rate is 10%, the plant life is 50 years, and the operation and maintenance cost rate is 2% of construction cost.

**(3) Indexes for Project Evaluation**

In principle, an index of net benefit (B-C) is employed in the study on development plan inventory since the major study objective is to evaluate the hydropower potential of the basin. Accordingly, the development scale of each project is determined to maximize the net benefit.

Also, as other indexes, the benefit cost ratio (B/C), unit energy cost (US$/kWh), and unit construction cost (US$/KW) are calculated for each case.

### 7.3.4 Study on Development Plan Inventory

The study on the development plan inventory of the Se Kong River basin is conducted based on the study conditions described in the above sections. The study produced a development plan inventory of the Se Kong River basin as summarized in **Fig.7.3-1** and **Table 7.3-2**. The contents of the study are provided by the rivers in the basin as follows;

**(1) Projects on the Mainstream of the Se Kong River**

The development projects on the mainstream of the Se Kong River are limited to three, Se Kong Nos.3, 4 and 5, as proposed in the previous study because of its river profile, the locations of candidate sites for dam construction, and the distribution of the tributaries flowing into the mainstream.

(1-1) **Se Kong No. 3 Project (Fig.7.3-6)**

Although the dam site of the Se Kong No.3 project forms a wide valley and requires a crest length of 2,000m or more, there are no alternative dam sites.

Two alternative dam axes seem to be available at the dam site. One is the upstream alternative which connects the right and left banks directly at the narrowest distance between the major mountains. The second is the downstream alternative which uses a small ridge coming out toward downstream from the mountain on the left bank. Of these alternatives, as the downstream axis is seen as unreliable geologically, the upstream axis is selected.

Sekong Town, the central township of Sekong Province, is located in the reservoir area of the Se Kong No.3 project and the environmental effect and compensation caused by the inundation of this town presents a major problem. At this stage, however, the compensation cost is accounted at the same basis as that for other sites.

A practical upper limit of the reservoir water level (HWL) of the Se Kong No.3 project is set at EL.160m since the river bed elevation at the dam site of the Se Kong No.4 project is approximately EL.160m. Accordingly, the development scale in the reservoir water level is studied by varying the HWL at 140, 150, and 160m, as shown in **Table 7.3-3**. Consequently, a plan with a 160m HWL is selected due to its performance in B-C. In this case, an area of approximately 280 $km^2$ which includes the Sekong Town area, would be inundated. Although this presents great impact on the environment, a plan with a 160m HWL is listed in the inventory from the viewpoint of hydropower potential evaluation.

(1.2) **Se Kong No. 4 Project (Fig. 7.3-7)**

Due to the topographic conditions, the only dam site available for the Se Kong No.4 project is that proposed in the previous plan. The terrain on both banks of this site is relatively gentle thus requiring a fairly long dam crest of approximately 1,000m. However, there is no other alternative dam site because of the scale and stability of the mountains on both banks required for dam construction.

The development scale in the reservoir water level is studied with varying HWLs of 280, 300, and 320m, as shown in **Table 7.3-4**. From this, a plan with a 300m HWL which provides the best net benefit (B-C) is selected. In this case, no large towns or villages lie within the reservoir area. However, the impact on the environment would be quite large as the inundated area would be approximately 145 $km^2$ and many small villages and a wide forest area would be submerged.

At this stage, a plan with a 300m HWL is listed in the inventory from the viewpoint of hydropower potential evaluation. However, a plan with a 280m HWL would provide an equivalent B/C and would reduce the submerged area to 114 $km^2$. Accordingly, in the next stage, a development plan with lower dam height could be an alternate for further study.

(1.3) **Se Kong No. 5 Project (Fig. 9.8)**

The dam site in the Se Kong No.5 project is practically restricted to the location proposed in the previous study due to the river profile and the distribution of tributaries in the project basin. A rapid river section with a gradient of approximately 1:20 runs from the riverbed elevation at 340m to 300m. This section is located approximately 13 km downstream from the confluence of the mainstream of the Se Kong river and its tributary, the Houay Axam River. A project layout is selected with a dam installed upstream and a power plant downstream of the above rapid section and by connecting these with an approximately 1km long headrace tunnel.

In actuality, the maximum HWL should be 500m or less because the reservoir backwater would cross the border into Vietnam if it exceeded 500m. Therefore, a plan with an HWL exceeding 500 m in elevation cannot be an alternate.

Accordingly, the development scale in reservoir water level is studied by varying HWLs of 460, 480, and 500m, as shown in **Table 7.3-5**. From this, a plan with a 500m HWL which would provide the optimum net benefit (B-C) is selected.

In this case, there are very few villages and a minimal cultivated area.

The plan with a 500m HWL would require a inundation area of approximately 53 $km^2$. However, as there are very few villages and very little cultivated areas within the reservoir area, only minimal impact is provided to the social environment. Although a rockfill type dam was selected at this stage, it is possible that in further studies a concrete gravity type would be selected if highly accurate topographic maps and discharge data are available because of the availability of construction material for impervious core and conditions for river diversion works. A concrete dam could also be deemed more beneficial to reduce the dam volume by reducing its height.

## (2) Projects on the Xe Kaman River

The basic development plan of the Xe Kaman river in terms of efficient use of its hydropower potential is understood to be that of four projects, Xe Kaman No.1, No.2, No.3 and No.4, proposed in the previous studies, due to the conditions of the river gradients, locations of dam sites and the distribution of tributaries in the basin.

### (2.1) Xe Kaman No. 1 (Fig. 7.3-9)

The Xe Kaman River forms a canyon through a part crossing three mountain ranges which run in parallel from the south to the north just before coming into the beginning of its downstream section. As the river gradient in the midstream section of the Xe Kaman river is gentle, a large reservoir would be produced by constructing a dam across the canyon described above. Accordingly, the Xe Kaman No.1 project is planned as a dam- type project. Although a number of alternative dam sites are conceivable along this canyon, a site is selected in that part of the canyon where it crosses the central mountain range due to the topographical conditions of the area around the site as well as in the canyon proper for the reservoir and dam construction.

The elevation of the river bed at the confluence of the Xe Kaman river mainstream and its tributary, the Nam Poay-O river is EL.280 m. Therefore, the practical limit of the HWL for the Xe Kaman No.1 project is at EL.280 m, considering riverbed elevation at the Xe Kaman No.2 Project. In this plan, as the dam height is expected to be around 170 m, it would undesirable, both in terms of technology and capital investment, to further increase the HWL.

In view of this, the development scale is studied by varying the HWL with 3 cases of 260 m, 270 m and 280 m in elevation respectively as shown in **Table 7.3-6**. As a result, the plan with a HWL of 280 m, which provides the largest B-C value, is selected.

In this case, although there are no large towns or villages in the potential reservoir area, its environmental impact would not be trivial due to a wide flooding area which would reach approximately 220 $km^2$. At this stage, the plan with a 280 m HWL is selected for the inventory in view of its hydropower potential. However, the plan with the 260 m HWL is most advantageous in terms of the B/C, and its inundation area is approximately 190 $km^2$. Accordingly, the plan with lower dam height and smaller flooding area is worth while studying in the further stages.

(2.2) **Xe Kaman No. 2 Project (Fig. 7.3-10)**

When the HWL of the Xe Kaman No. 1 Reservoir is set at 280 m, the dam site of the Xe Kaman No.2 project is automatically determined at a location immediately downstream of the confluence with the Nam Poay-O river where the river bed elevation is at EL.280 m, this in view of the longitudinal geometry of the river and the conditions of the geographical distribution of the tributaries.

The Xe Kaman No.3 and No.4 Projects, both located upstream of the Xe Kaman No. 2 project, are planned as dam and waterway type projects. Therefore, the reservoir HWL does not affect the selection of the dam sites of the Xe Kaman No.3 and No.4 projects, and there is no particular upper limit on the HWL of the Xe Kaman No.2 Project. On the other hand, the lower limit of the HWL is set at 380 m for No.2 project in order to secure a storage capacity with a regulation rate of 20% in consideration of the reservoir sediment volume.

Based on the above, four cases, with a HWL of 380 m, 400 m, 420 m and 440 m are studied to obtain the optimal development scale. It is , however, seen that the figures of the B/C are substantially lower than 1.0 in these cases as shown in **Table 7.3-7**. At this stage, the 380 m HWL is provisionally selected as the reservoir development scale for the evaluation of hydroelectric power potential, taking into account the river bed elevation at the powerhouse sites of Xe Kaman Nos.3 and 4 Projects.

(2.3) **Xe Kaman No.3 Project (Fig. 7.3-11)**

Xe Kaman No.3 project is planned as a dam and waterway type project which utilizes the head provided by a rapid section in the midstream of the Nam Poay-O river, a tributary of the Xe Kaman river. A dam site is selected in a section upstream of the rapid section. Due to the conditions of topography and longitudinal river geometry of the sites, however, the dam has to be large at any site when it is attempted to secure a substantial reservoir capacity. Even when the dam site is selected near the location where the riverbed elevation is 860 m and the river gradient is relatively gentle, a dam approximately 100 m high would be required to secure a reservoir capacity of 20 % in regulation rate. The construction cost would also be too high for the energy generated.

Therefore, to fit the dam scale to the site conditions, the daily regulation type is applied as the development scheme of the Xe Kaman No.3 project. The dam and powerhouse sites are selected at locations where the river bed elevations are approximately 770 m and 370 m respectively to make the ratio of available head to the waterway length maximum, taking the conditions of the river gradients and topography of the waterway route into account. Based on the above layout, the optimum development scale is studied by assuming the tailrace water level at EL.380m the reservoir HWL of Xe Kaman No.2 project. In this study, cases with a ratio of the maximum discharge to the firm discharge of 2 times, 3 times and 4 times are examined. From this it is seen that the case with a maximum discharge of 24 $m^3/s$, which is four times the firm discharge, is selected as the optimum plan because this plan provides a plant factor of 63% and is the most economical, as shown in **Table 7.3-8**.

**(2.4) Xe Kaman No. 4 Project**

Xe Kaman No.4 project is planned as a dam and waterway type utilizing a head provided between the most upstream section of the Xe Kaman river and the reservoir of the Xe Kaman No.2 project. As the river branches into a number of tributaries in its upstream basin, and based on examination on both the superficial distribution and longitudinal river profile of each tributary, Reservoirs A, B, C, D and E are selected on the five tributaries respectively as shown in **Fig. 7.3-9**.

Based on the above reservoir layout, in this study, the waterway routes connecting each reservoir are also studied and two alternative plans which appear the most effective, are compared. Here, Case 1 has three sets of waterway tunnels which connect Reservoirs A, B and C, Reservoirs E, D and C, and Reservoir C and the powerhouse located by the reservoir of the Xe Kaman No.2 project respectively. Case 2 excludes Reservoirs D and E from the layout of Case 1.

As a result of the study, both plans provide a B/C less than 1.0, as shown in **Table 7.3-9**. At this stage, however, Case-1, which provides a larger B/C value is selected for the inventory from the viewpoint of evaluating the basin's hydropower potential.

**(3) Projects on the Xe Namnoy River (including the Xe Pian River)**

As the Xe Namnoy river has complicated longitudinal geography in locational relationship with its tributaries and neighboring rivers, a number of alternative plans are conceivable. However, the geographical conditions of the basin severely restrict the number of dam sites where sufficient reservoir capacities can be secured.

Here, the basic development plan consisting of three large to medium scale projects proposed in the previous study by JICA is referenced as the basis, and the optimum plans of each project are studied to provide an efficient use of the particular geographical features of the Bolaven Plateau including the neighboring Xe Pian river.

### (3.1) Independent Plans on the Xe Namnoy and Xe Pian Rivers

The mainstream of the Xe Namnoy river has a rapids at its midstream section where the river bed elevations is approximately 720 m at the beginning and approximately 180 m at the end of the rapids. In this section, a head is available for power generation. On the other hand, the river flows across the upper plains of the Bolaven Plateau with a gentle gradient in its upstream section with a riverbed elevation of more than EL.720 m. Accordingly, a reservoir providing efficient storage capability could be constructed on the upstream section of the river.

For the development of the Xe Namnoy River, plans diverting water from the neighboring tributaries of the Xe Namnoy or Xe Pian Rivers to a reservoir on the mainstream of the Xe Namnoy river are conceivable. At first, however, the study is independently conducted by utilizing the mainstream only.

#### (3.1.1) Xe Namnoy Midstream Project

The Xe Namnoy Midstream Project is planned as a dam and waterway type using its particular site condition which provides an available head between points where the riverbed elevations are approximately 720m and 280m respectively. (see **Fig. 7.3-13**)

The dam site is selected in the upstream section from the site with a riverbed elevation of 720m, where the rapids start. Several alternate dam axis are available depending on the selection of the optimum reservoir HWL which would provide an adequate storage capacity, and also depending on the layout of an intake which would serve to make the headrace tunnel as short as possible. When the HWL is 760m or higher, the dam axis is selected at a site approximately 2 km upstream from where the riverbed elevation is EL.720 m and taking the intake layout into consideration. When the HWL is 750 m or less, the dam axis is selected where the riverbed elevation is EL.720m. The powerhouse site is selected where the river bed elevation is 280m, considering the waterway route and the geographic condition for the penstock.

Based on the above conditions, the development scale of the reservoir is studied in four cases, with an HWL of 750m, 760m, 770m and 780m, respectively, as shown in **Table 7.3-10**. This study indicates that both the B-C and B/C are maximized in the case of a 760m

HWL, which provides the minimum dam scale among the cases with a reservoir capacity corresponding to 30% of regulation ratio. Therefore, the reservoir HWL of the project is selected at El.760m. The plan with a 750m HWL has a smaller dam, but a reservoir capacity of only 10% regulation ratio could be secured. This plan is, therefore, economically inferior to the plan with a 760m HWL.

**(3.1.2) Xe Namnoy Downstream Project**

The Xe Namnoy Downstream Project is planned as a daily regulation type development using the discharge released from the Midstream Project and the natural discharge from the sub-basin downstream from the Midstream Project, together with the remainder of the available head in the rapid section of the Xe Namnoy river below the 280m riverbed elevation. (see **Fig. 7.3-13**) For a dam and waterway type, the available head is relatively small. However, this Project is based on the regulated inflow conditions provided by the reservoir of the Xe Namnoy Midstream Project. In this connection the Xe Namnoy Downstream Projects should be treated as one project and combined with the Midstream Project as a single development scheme.

Here, the inflow conditions of the Xe Namnoy Downstream Project depend on whether it is undertaken with or without the Houay Katak Tok Project which would divert the discharge directly into the mainstream of the Se Kong River. In this study, the inflow of the Downstream Project is calculated based on the condition with a selected development plan of the Houay Katak Tok Project.

In this plan, the dam site is selected to be just below the confluence of the Houay Katak Tok River due to the effective use of the discharge from the sub-basin downstream of the Houay Katak Tok Project and the topographic constraints on the waterway layout. Due to an available head being efficiently provided by a waterway tunnel, the powerhouse site is selected on the right bank where the riverbed elevation is 200m.

In this study, cases with the ratio of the maximum discharge to the firm discharge of 3 times, 4 times and 4.5 times are examined. The study shows that the case with a maximum discharge of 75 $m^3/s$, being 4.5 times the firm discharge, provides a plant factor of approximately 60% and provides superior economic performance as almost same as the case with a maximum discharge of 66 $m^3/s$, as shown in **Table 7.3-11**.

### (3.1.3) Xe Pian Project (Independent Plan)

Prior to the study of the river diversion plan from the Xe Pian river to the Xe Namnoy Midstream Reservoir, an independent development plan of Xe Pian River is studied as an alternative. (see **Fig. 7.3-4**) As the Xe Pian River midstream is rapid from a riverbed elevation of 780m to 340m, a development utilizing the head available in this section is conceivable. In this concept, as there is no terrain above the riverbed elevation of 780m capable of securing an adequate storage capacity, the Project is a waterway type with a regulating pondage. In addition, to effectively utilize the head with a short waterway route, a layout utilizing the nearby tributary to the east of the Xe Pian River's main stream, such as that shown in **Fig. 7.3-4**, is advantageous.

In this study, cases with the ratio of the maximum discharge to the firm discharge of 3 times, 4 times and 5 times are examined. The study shows that the case with a maximum discharge of 15 $m^3/s$, that is 5 times of the firm discharge, is the optimum plan because it provides a plant factor of approximately 60% and is, therefore, the most economical, as shown in **Table 7.3-12**.

### (3.2) Projects on Xe Namnoy River with River Diversion of Xe Pian River (Fig. 7.3-13)

Next to the independent development plans on the Xe Namnoy river and the neighboring Xe Pian river, a development plan with a river diversion from the Xe Pian River to the Xe Namnoy Midstream Reservoir, based on the Xe Namnoy Midstream Project with a reservoir HWL of 760m which was selected as an optimum plan of the independent development scheme.

Here, the maximum discharge of the Xe Pian diversion is set at 5 times the firm discharge following the study result of the independent development plan of the Xe Pian Project. The river flow of the Xe Pian River is diverted to the reservoir of the Xe Namnoy Midstream Project by the waterway route shown in **Fig. 7.3-13**. The development plan of the Xe Namnoy River is studied for both the Xe Namnoy Midstream and Downstream Projects under these conditions.

The result compared with a case with no diversion from the Xe Pian River is shown in **Table 7.3-13**. As the result indicates the advantage of the development plan incorporating the diversion scheme of the Xe Pian River, the development plan of the Xe Namnoy Project (Midstream and Downstream Projects) with the Xe Pian diversion scheme is listed on the development plan inventory.

(3.3) **Houay Katak Tok Project (Fig. 9.14)**

The Houay Katak Tok River flows along the eastern edge of the Bolaven Plateau. A head of approximately 800m is available between the mid to upstream basin on the Plateau and downstream from the dam site of the Se Kong No.3 project on the mainstream of the Se Kong River. Similar to the Xe Namnoy River, the Houay Katak Tok river has a gentle gradient along its upstream, and the topography of the basin provides a dam site able to provide an adequate storage capacity. The Houay Katak Tok Project is planned as a dam and waterway type which utilizes the annual flow volume in the upstream basin. The particular geographical features provide a high head down to the mainstream of the Se Kong River.

Although a number of alternative dam sites are available, the site at the riverbed elevation of 820m, where the dam scale becomes smallest under the condition of setting the storage capacity required for the annual flow regulation, is selected. The tailrace site is selected at approximately 5 km downstream from the dam site of the Se Kong No.3 Project, with which the overall length of the waterway is shortest.

Regarding the waterway and powerhouse connecting the reservoir and tailrace, because it is technically difficult to install a penstock of an approximately 800m head on the extremely steep slopes of the eastern side of the Bolaven Plateau, a layout consisting of a vertical shaft type embedded penstock, an underground powerhouse, and a tailrace tunnel is selected.

Based on the above, the project scale is studied by 3 cases with an HWL of 870m, 880m and 890m, as shown in **Table 7.3-14**. These studies show the development plan with an HWL of 880m, which provides the highest B-C value being selected.

(4) **Projects on the Nam Kong River**

It is reasonable that the medium to large scale development plan of the Nam Kong River be studied based on the three projects, Nam Kong No.1, No.2 and No.3, proposed in the previous studies due to the conditions of its river profile (see **Fig. 7.3-5**) and its topography which is suitable for dam sites and reservoirs.

(4.1) **Nam Kong No.1 Project (Fig. 7.3-15)**

The Nam Kong No. 1 Project is planned in the downstream section of the river as a dam and waterway type which utilizes the gentle river gradient in the upstream at a riverbed elevation of 260m for a reservoir, and the head available in the rapid section from the riverbed elevations of 260m to 120m of the Nam Kong River. The dam site is restricted to a location at the riverbed elevation of 285m where the canyon is the narrowest. The reservoir HWL is limited to 340m due to the geographical conditions of the dam site and the area around the reservoir. The powerhouse site is selected at a riverbed elevation of 160m due to geographical constraints on the waterway route.

Based on the above, the project scale is studied by three cases, with HWLs of 320m, 330m and 340m respectively, as shown in **Table 7.3-15**. From these studies, the development plan with a 340m HWL which would provide the highest B-C value is selected.

**(4.2) Nam Kong No. 2 Project (Fig. 7.3-16)**

The Nam Kong No.2 Project is planned as a dam and waterway type which utilizes the meandering midstream section of the Nam Kong River. The dam site is limited to a location at the riverbed elevation of approximately 400m, where the canyon is the narrowest and where the ridges on both banks are relatively thick and stable. The reservoir HWL is limited to 480m due to the geographical conditions of the dam site and the area surrounding the reservoir. In addition, a 460m HWL would be efficient in view of its relationship to the geographical conditions of the Nam Kong No.3 project site mentioned in (4.3). The waterway route and the powerhouse site are selected to minimize the length of the waterway connecting the reservoir of the Nam Kong No.1 and No.2 Projects. The tailrace water level is set at EL.340m, which is the reservoir HWL of the Nam Kong No.1 Project.

Based on the above, the project scale is studied by three cases, with HWLs of 460m, 470m and 480m respectively. In all cases, the B/C fell short of 1.0, as shown in **Table 7.3-16**. At this stage, however, the development plan with a 460m HWL is selected for the evaluation of hydropower potential in the basin, considering its relationship to the Nam Kong No.3 Project.

**(4.3) Nam Kong No. 3 Project (Fig. 7.3-17)**

The Nam Kong No. 3 Project is planned in the midstream section of the river as a dam and waterway type which utilizes the gentle river gradient in the upstream where the riverbed elevation is 500m for a reservoir, and the head available in the rapid section from a riverbed elevation of 500m to 460m of the Nam Kong River. The dam site is limited to a location at a riverbed elevation 490m, where the canyon is narrowest at the upstream end of the rapid section. Reservoir HWL is limited to 540m due to the topographic conditions of the area around the reservoir in reference to the reasonable scale of the reservoir and dam. The powerhouse site is selected at a riverbed elevation of 460m where the downstream end of the rapid section is provided downstream from the dam site.

Based on the above, the project scale is studied by two cases, with HWLs of 530m and 540m respectively. In both cases, the B/C fell short of 1.0, as shown in **Table 7.3-17**. At this stage, the development plan with a 540m HWL, which is the larger project, is selected for the evaluation of hydropower potential in the basin.

**(5) Project on the Xe Xou River**

The Xe Xou River flows in the southern region and runs parallel to the Xe Kaman River. The topography of the river in the midstream basin presents features similar to those of the Xe Kaman River. As the catchment area is not overly large, and as the river gradient is relatively gentle in this section of the river, the Xe Xou Project proposed in the previous study is the only project in the basin which would be a medium to large scale development.

**(5.1) Xe Xou Project (Fig. 7.3-18)**

The Xe Xou Project is planned as a dam type development with a large reservoir, similar to the Xe Kaman No.1 Project. In view of the topographic conditions and the catchment areas in the basin, the dam site is limited to near a location at a riverbed elevation of 120m, where the Xe Xou river runs from its midstream section to the downstream plains through a canyon. Considering the above, the dam site was selected at the location shown in **Fig. 7.3-18**.

Based on the above, the project scale is studied by four cases with an HWL of 160m, 180m, 200m and 220m respectively, as shown in **Table 7.3-18**. The study shows that the B-C and B/C are both highest in the 180m HWL plan. However, the B/C value of this plan is still substantially below 1.0.

This is because the catchment area of this Project is smaller than those of Xe Kaman No.1 or others and the river flow is insufficient to plan a project in which the head is provided only by the height of the dam. Further, even a plan with an HWL of 180m presents a flood area amounts of approximately 100 $km^2$. Population relocation would be substantial as there are many villages in the flood area of this project.

The possibility of a development plan of diversion from the Xe Xou Reservoir to the Xe kaman No.1 reservoir is also examined. In this case, however, an HWL of 220m or more with a large scale dam are required for the Xe Xou project, even though the HWL of the Xe Kaman Project is reduced. Therefore, a diversion scheme is economically unfeasible.

**(6) Projects on the Nam Emun River**

The Nam Emun River consists of small tributaries in its mid to upstream basin. These flow into the mainstream of the Se Kong River after forming into a single stream in the downstream section. Its confluence with the Se Kong River is located 10km upstream from the site of the Se Kong No.4 Project. The downstream of the Nam Emun river consists of a part of the Se Kong No.4 reservoir.

Regarding the above described feature of the basin, a medium to large scale development plan in the Nam Emun river basin is planned by a scheme consisting of reservoirs on a number of tributaries in the upstream basin and using the head available between those reservoirs and the Se Kong No.4 reservoir, as proposed in the previous study.

In this report, the term, 'Dak E Meule Project', as used in the previous study by the Mekong Committee, shall be employed.

**(6.1) Dak E Meule Project (Fig. 7.3-19)**

The Dak E Meule Project is planned as a dam and waterway type with two stages of power generation based on the conditions of the basin described above. As the river branches into a number of tributaries in its upstream basin, Reservoirs A, B, C, D and E are selected on the 5 tributaries respectively, and Regulating Pond F is planned on the mainstream of the Nam Emun River for intermediate power generation, as shown in **Fig. 7.3-19**, based on the examination of both the superficial distribution and longitudinal river profile of each tributary.

In planning this scheme, two alternative waterway routes connecting each reservoir are studied. In the first case (Case-1), Reservoirs E, A and F and Reservoirs D, C, B and Regulating Pond F are connected by waterway tunnels in this sequence for the first power generation, utilizing the head between Reservoir A and Regulating Pond F. Then, discharge released from the fist power plant is diverted together with the discharge from Reservoirs D, C and B to the reservoir of the Se Kong No.4 Project for the second power generation. In the second case (Case-2), Reservoir B and Reservoir E are excluded from Case-1.