# CHAPTER 4

# GEOLOGY

## CHAPTER 4 GEOLOGY

### 4.1 Nam Chon Site

#### (1) Reservoir Geology

##### (a) Reservoir Scale and Investigation Method

The reservoir scale of the Upper Quae Yai Project is as indicated below.

| | |
|---|---|
| Dam height | 185 m |
| Normal high water level | 370 m |
| Catchment area | 4,908 $km^2$ |
| Reservoir surface area | 137 $km^2$ |

The investigations and study methods used to clarify the reservoir watertightness were as listed below.

- Aerial photogeological interpretation
- Summit level analysis
- Drainage pattern analysis
- Surface geologic survey
- Chemical analysis of river water and rocks

The summarizations of these investigations and studies are shown in Figs. 4-1, 4-2 and 4-3, and Tables 4-1 and 4-2.

##### (b) Topography

The topography may be broadly divided into the two areas below.

- Area along Quae Yai mainstream

  The area is along the mainstream excluding the vicinity of the confluence with the Mae Chan River. The slopes at the right and left banks are extremely steep and the whole valley is in the form of a long gorge. The average valley width at the high water level elevation of 370 m is less than 420 m. The river gradient is approximately 1/400 and many rapids are formed at the riverbed.

- Area along Mae Chan river

  The Mae Chan river is the largest tributary in the project area which joins the Quae Yai river at the right bank approximately 28 km upstream from the damsite. The river width is large and as a whole a hill area of gentle relief is indicated. The maximum reservoir width at El. 370 m is approximately 7 km.

(c) Geology

The general geological stratigraphic sequence of the project area is indicated in Table 4-1. Excepting the area along the Mae Chan river, river deposit, slope wash and large-scale landslide topography are not seen in the reservoir area, and therefore, descriptions of these will be omitted in this Report.

Regarding the formations distributed, Tertiary deposits consists of unconsolidated sand-gravel and silt. Formation D consists of limestone and dolomite, Formations C and B of calcareous sandstone, shale, etc., and Formation A of sandstone, shale, slate, etc.

Besides these sedimentary rocks, there are distributions of metamorphic and igneous rocks in the vicinities of the eastern and western watersheds.

Of the formations distributed, the one requiring the most attention in connection with watertightness of the reservoir is Formation D. Regarding the other formations, judged by data on the water flow conditions of tributaries, results of chemical analysis of rocks, etc., they are regarded as the impervious or semi-impervious rocks.

The detail of geology and geologic structure of the reservoir is reported in Appendix 2 and the reasons assured the reservoir watertightness are described below.

(d) Conclusions

- The formations comprising the backbones of the eastern and western watersheds consist of non-calcareous rocks. These rocks can serve as reliable barriers against leakage to other catchment areas.

- Formation D which is considered as a risky rock with respect to leakage is widely distributed in the northeastern part of the catchment area. However, this distribution is gradually narrowed at the left bank (eastern side) of the damsite and vanishes at a place of elevation approximately 700 m in the southern part of the left bank of the damsite. Consequently, this Formation D is enclosed on the whole by Formations A, B and C.

- Formation D distributed at places other than the above, especially the right bank at the damsite, is at an elevation above the high water level of 370 m. Further, Formation D seen at the right bank approximately 5 km upstream of the damsite is continuous to below the reservoir surface, but the thickness of this Formation D is small, and it is judged from results of geological investigations that the boundary between Formation D and the underlying Formation B is above the reservoir high water level.

- Swallets have not been found in formations other than Formation D, while running water is seen throughout the year at the main gullies having formations other than Formation D as their basement rocks. This indicates that formations other than Formation D, even if calcareous, have adequate resistance against karstic erosion, and that ample watertightness is possessed as a whole.

- According to chemical analysis results of rock samples collected from various formations, as indicated in Table 4-2, there are fairly large differences in $CaCO_3$ and $MgCO_3$ contents of samples from Formation D and samples from other formations. And, these differences in contents indicate that Formation A, B and C have stronger resistances against karstic erosion compared with Formation D.

- On comparisons of $SiO_2$ contents in rocks, the contents in Formation D samples are less than 1%, whereas samples from other formations contain 5% or more. Other than $SiO_2$ contents, according to microscopic examinations of the rocks, a layer arrangement of several millimeters of $SiO_2$ mineral is recognized on the calcareous sandstone of Formation B. And, according to results of drillholes, karstic erosion has not progressed at deep parts in Formation B at the left bank of the damsite. It may be judged from this phenomenon that the above-mentioned $SiO_2$ contents and mineral arrangement provide strong resistance against karstic erosion.

(2) Site Geology

(a) Selection of Damsite

As mentioned below, the detailed studies of the damsite selection were carried out on the previous stages (preliminary and pre-feasibility stages) and the two site (No.6 and No.9A sites) were selected from 12 alternative as the representative damsites to evaluate development scheme of this Project.

However, No.5 and No.6 sites are close each other and they have similar topographic conditions.

Some detailed surface geological investigations were, therefore, done to compare both sites, and it was judged that No.6 site (Nam Chon site) is superior to No.5 site. Consequently, the Nam Chon site was selected as a representative damsite to compare with No.9A site, because No.5 site has many unknown geological problems as mentioned in the Chapter of Damsite Selection in Appendix 2.

Regarding the proposed damsites of this Project, comparison studies of the development schemes were made for the Nam Chon site (Site No.6) and the No.9A site in the Preliminary Report (August

1978, EGAT) and the Pre-feasibility Report (June 1979, EGAT). As a result, superiority of the Nam Chon site is cited in the two reports. Studies of the two sites (Nam Chon site and No.9A site) are made in Chapter 6 of this feasibility report, and a conclusion has been obtained that Nam Chon site is suitable as the damsite for this Project. It may be said from geological viewpoints also that subjects to be solved would be fewer with the Nam Chon site.

(b) Otuline of Geology

The surface deposit distributed at the damsite is as a whole thick on the right bank and thin on the left. On the right bank, it is widely distributed at high portion above El. 360 m, and according to seismic prospecting, the thickness is from 4 m to 10 m. Besides the above, in the vicinity of approximately 600 m upstream of Huai Tong Thai, talus deposit of horizontal thickness of approximately 9 m and approximately 18 m has been confirmed by Test Adits AR-1 (El. approximately 206 m) and AR-2 (El. approximately 302 m), respectively. Judging by geological conditions inside the adits, the slope which the adits are located is considered to be a creep zone. At the left bank, deposit of thickness approximately 12 m has been confirmed by Drillhole L-6 near the river bank, but at all other drillholes the surface deposit is thin at less than 1 m.

The rocks distributed at the dam and other structure sites are karstic limestone, dolomite, conglomerate and calcareous sandstone.

At the left bank, all areas in which structures are to be layouted consist of good calcareous sandstone.

The four kinds of rocks mentioned above are distributed at the right bank. The stratigraphic sequence and qualities of the rocks at the right bank are a s indicated below.

| | | |
|---|---|---|
| Karstic Limestone and Dolomite | — | Dipped 25° - 35° to west (toward mountain) |
| | | Unconformity |
| Conglomerate | | |
| | | Unconformity |
| Calcareous Sandstone | — | Dipped 10° - 30° to west (toward mountain), anticlinal axis exists near river bank |

The rocks at the right bank are prominently weathered and cracked as a whole. Particularly, karstic erosion is remarkably seen in the limestone and dolomite at the top. The elevation of this karstic limestone is low in the downstream of the damsite, and is high in the upstream. In order words, the karstic limestone crops out at the riverbed in the vicinity of the confluence at Huai Tong Thai, but is at an elevation of about 400 m approximately 850 m upstream from the confluence. This karstic limestone is a rock mass which continues further downstream from Huai Tong Thai, and since sink holes and underflow streams are seen in the rock mass, this is an important geological point which requires attention to selection of the dam axis.

The conglomerate is prominently weathered near the ground surface and is deteriorated, but is well cemented at fresh portions. Since the gravels in the conglomerate are all calcareous rocks, as has been confirmed with Drillhole R-5, many porous parts which will require careful foundation treatment are found.

The calcareous sandstone which is the basement rock at the right bank is more prominently weathered, cracked, and deteriorated compared with that at the left bank.

The permeability of left bank foundation rock is low as a whole, with 2 to 20 Lu (Lugeon) indicated. The ground-water table is located below 60 m from the ground surface (September 17, 1979). The left bank foundation rock can be judged to be in good condition from the data on permeability and ground-water table in addition to the data of the drillholes.

The permeability of the right bank foundation rocks indicates more than 20 Lu while the ground-water table is generally deep being from 50 m to 85 m from the surface. Particularly, ground-water has not yet been confirmed in the karstic limestone rock mass. It is necessary for additional investigations to confirm the ground-water table at the wider area of the right bank.

The fault at this site may be summarized as described below.

- Faults have been confirmed by a number of drillholes made at the right bank, but these faults have not yet been verified at the ground surface because of covering by slope wash. On the whole, faults at the right bank are more soft and brittle than those at the left bank.

- There are two prominent cliffs formed at the left bank. There are faults of dips of 30° - 40°S (toward mountain), and sheared zone widths of 1-2 m at the bottoms of these cliffs, but these sheared zones are tight, with some parts reconsolidated. Other faults confirmed by drillholes are tight compared with sheared zones at the right bank.

- It was confirmed that faults exist at the riverbed through Drillholes R-1 and L-4. Sheared zones are tight and permeability low, but the permeability of cracked zones in the surroundings is high.

- It has been confirmed through Drillholes PH-2, 3 and 5 that fault exists at the gully at the left bank immediately downstream of the damsite.

(c) Geological Investigation Works Completed

The geological investigations carried out between April 1978 and August 1979 are as indicated below.

- Surface geological investigations of dam and other structure sites, 1/1,000 geological maps

- Surface geological investigations of quarry and soil borrow areas, 1/5,000 geological maps

- Drilling Investigations

| | Drillhole | |
|---|---|---|
| Damsite | 16 | 1,199 m* |
| Powerhouse site | 5 | 184 m* |
| Penstock site | 3 | 400 m* |
| Quarry (2 sites) | 5 | 200 m |
| Total | 29 | 1,983 m |

* Including permeability tests

- Test Adit

  Damsite 3 adits (left bank 1, right bank 2) 90 m

- Seismic Prospecting

  Area of talus deposited at high elevations on right bank

  9 measuring lines 4.77 km

(d) Geological Considerations Regarding Design and Construction

According to the geological investigations completed, the foundation rock at the left bank consisting of hard and massive calcareous sandstone is low in permeability (2 - 20 Lu), while groundwater distribution is also good, and it can be judged that there are no serious problems regarding the dam abutment and foundation rock for other structures.

Faults exist at the riverbed of this site which consists of calcareous sandstone similar to that at the left bank, but these riverbed faults can be coped with by thorough foundation treatment.

The foundation rocks at the right bank are complex compared with the left bank and the riverbed, and karstic limestone, dolomite, conglomerate and calcareous sandstone are seen. These rocks are prominently weathered and cracked on the whole, and judged from the permeability (more than 20 Lu) and the groundwater distribution, it may be said they are deteriorated compared with foundation rock at the left bank. Particularly, there is a creep zone near the downstream end of the proposed damsite, whole above approximately El. 320 m at this place, there is distribution of karstic limestone continuing to Huai Tong Thai.

Needless to say, geological problems as described above can be solved by means of removal of poor quality portions and careful foundation treatment. However, in the event of the dam axis is selected upstream as shown on Fig. 4-4, it will be possible to avoid these geological problems. Especially, the karstic limestone continuing to Huai Tong Thai is distributed above El. 400 m at this place, and this may be said to be a favorable condition from the viewpoints of reservoir watertightness near the dam and of dam foundation treatment.

Furthermore, the additional geological investigations recommended in (3) of this Chapter are necessary for detail design and should be carried out without delay.

(3) Recommendations for Additional Geological Investigations

The additional geological investigations indicated in Table 4-3 and Fig. 4-4 should be completed before detail design is started.

The additional investigation work quantities including the quarry and filter material borrow areas are as indicated below.

° Dam and Other Structure Sites

| | | |
|---|---|---|
| Drillhole | 21 | 1,930 m |
| Test adit | 2 | 120 m |

° Quarry and Filter Material Areas

| | | |
|---|---|---|
| Drillholes | 32 | 750 m |

Total

| | | |
|---|---|---|
| Drillholes | 32 | 2,680 m |
| Test adits | 2 | 120 m |

## 4.2 Thi Khong Site

### (1) Geology of Regulating Pond

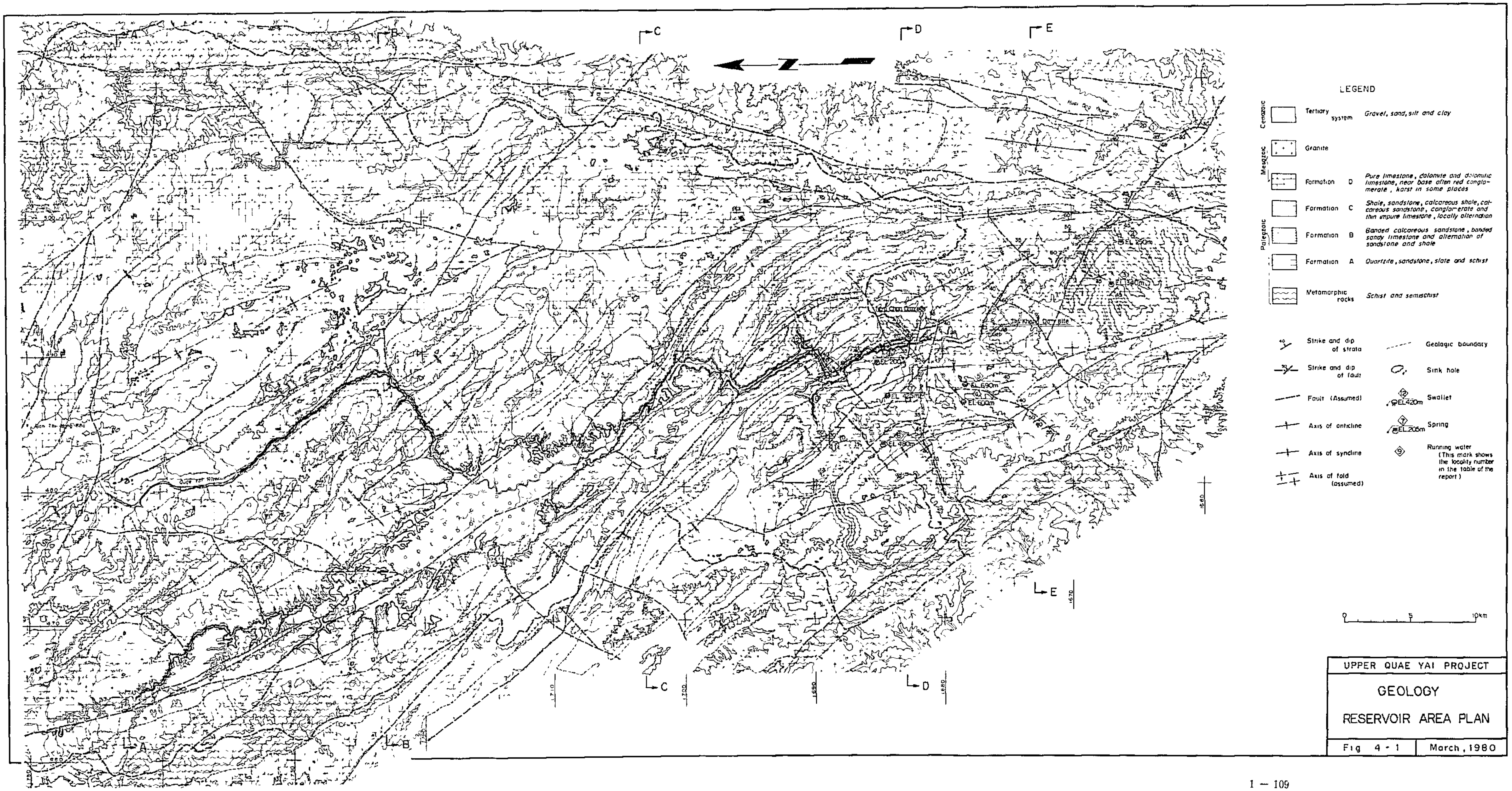
The Thi Khong damsite is located approximately 8 km downstream of the Nam Chon damsite. The geology between the two sites, except for the vicinity of the Thi Khong damsite, consists of limestone at parts of high elevation. Consequently, caves are formed here and there at cliffs facing the river, and this comprises a problem as the foundation of a large-scale reservoir. However, the high water level of this regulating pond will be at El. 197 m, only a raise in water level of about 10 m above the present river surface. Further, as a result of surface geological investigations, it has been confirmed that the low elevation parts in the pond area consist mainly of dolomite, and that at the tributaries in the regulating pond there are confirmed outcrops of calcareous sandstone and shale as the basement rock under the dolomite. Based on these geological conditions, it may be judged that the watertightness of this regulating pond will be no problem.

### (2) Foundation Rock of Structure

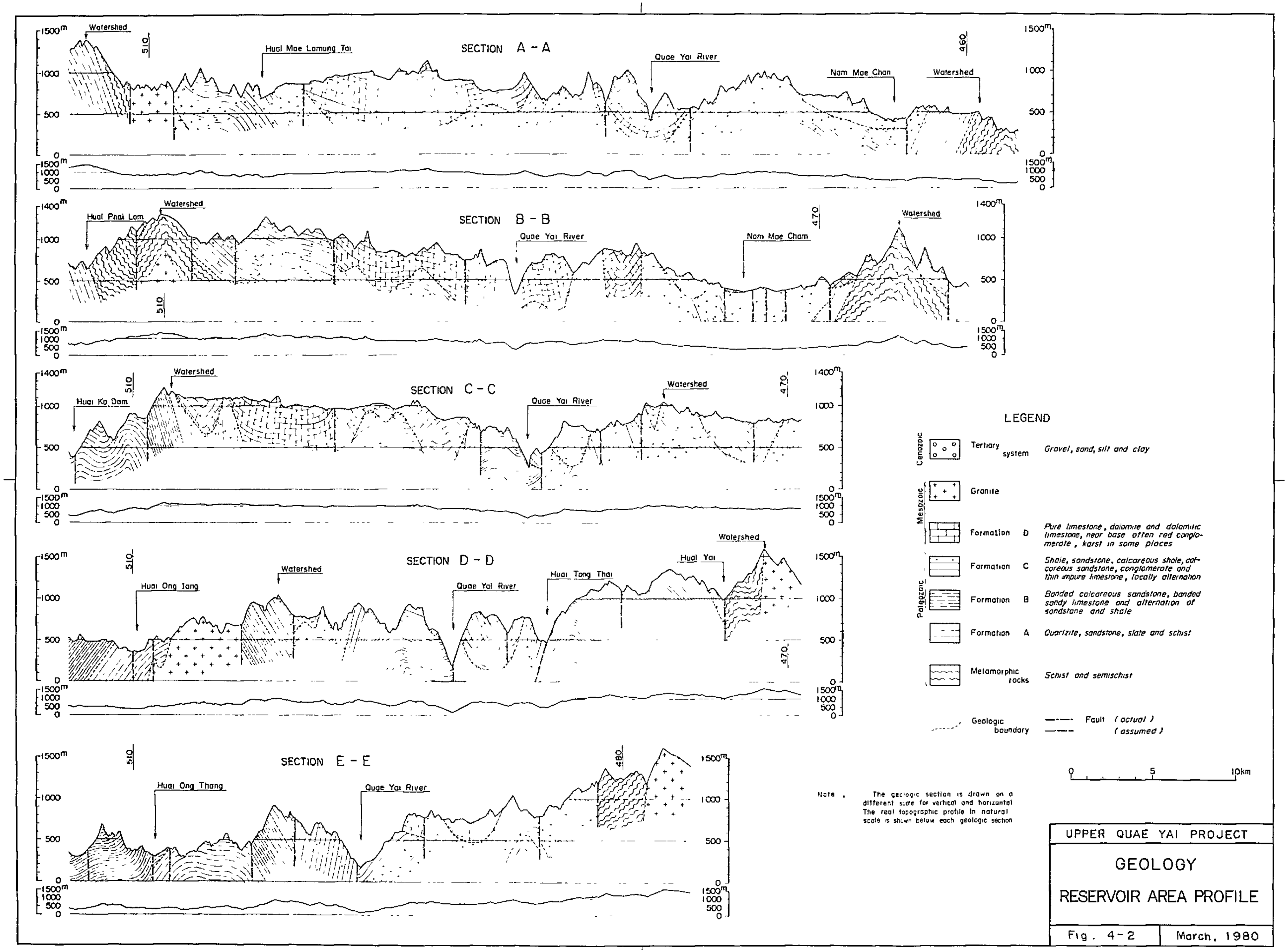
The topography at the damsite shows slopes of approximately 25° at the right bank and approximately 30° at the left bank. The left bank shows a uniform slope as a whole, but at the right bank there is a cliff formed at a location approximately 200 m distant from the river bank. In selection of the dam axis, care was exercised to make it as distant as possible from the cliff to avoid collapses. The riverbed elevation is 180 m and the width approximately 40 m.

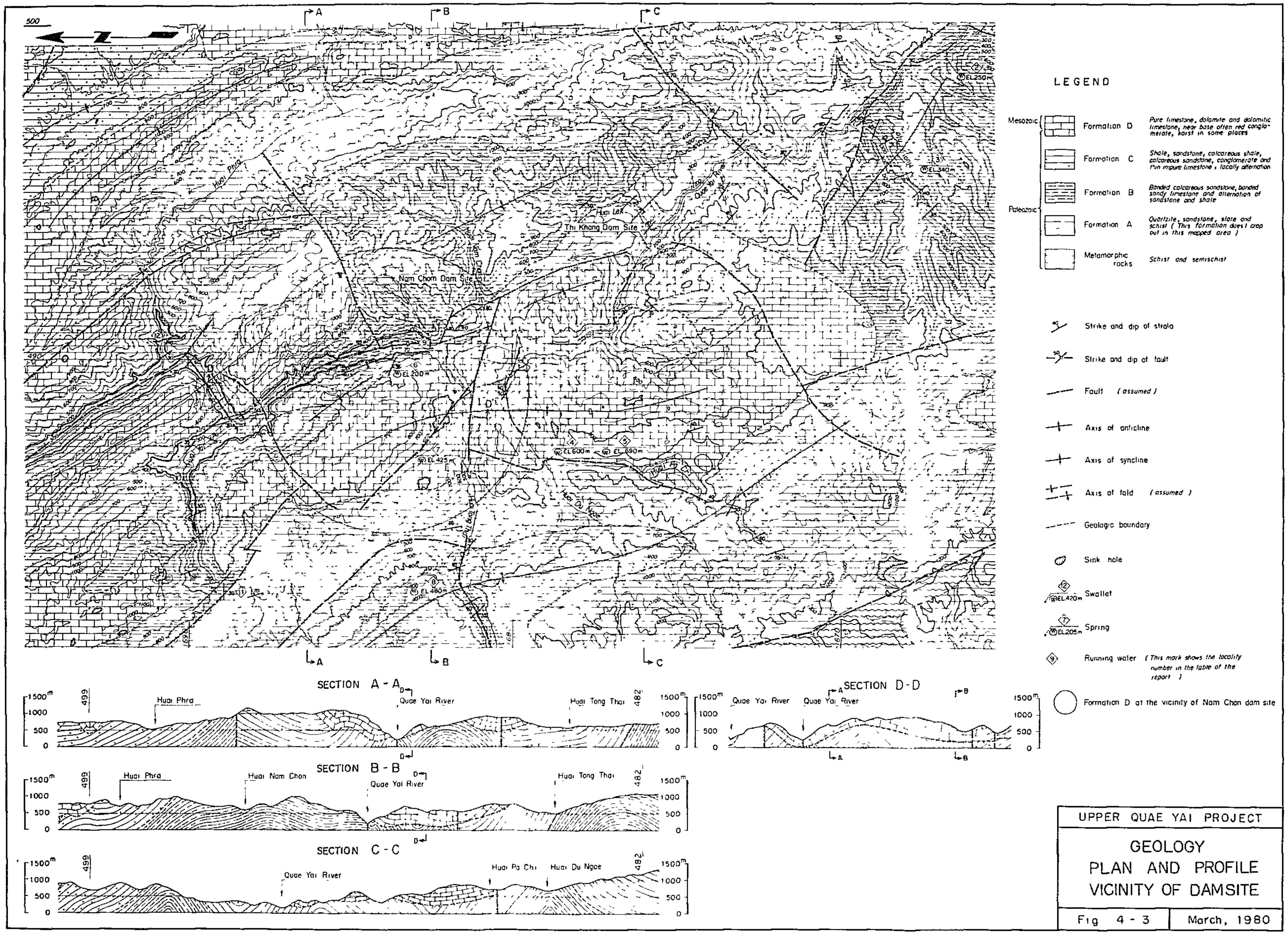
The damsite, except for localized outcrops at the riverbed, is covered as a whole by slope wash. The thickness of the cover is approximately 4 m at the right bank dam axis, and approximately 8 m at the left bank dam axis. The foundation rock is red-to-light green calcareous siltstone, and according to the results of drillholes carried out at both abutments, good cores have been collected, while with regard to permeability, 10 to 47 Lu are indicated at the right abutment between 0 to 20 m in depth, and 5 to 19 Lu between 20 to 30 m in depth, while similarly, at the left abutment, 20 - 30 Lu are indicated between 0 and 20 m, and then 4 - 20 Lu. According to these data, the permeability of the foundation rock is high as a whole, but drilled cores have few seams and good cores have been recovered so that it may be judged that the bedrock can be adequately improved by means of grouting.

Although there are no geological problems as the foundations for the planned dam and powerhouse, it will be necessary for the recommended riverbed drillhole to be carried out.

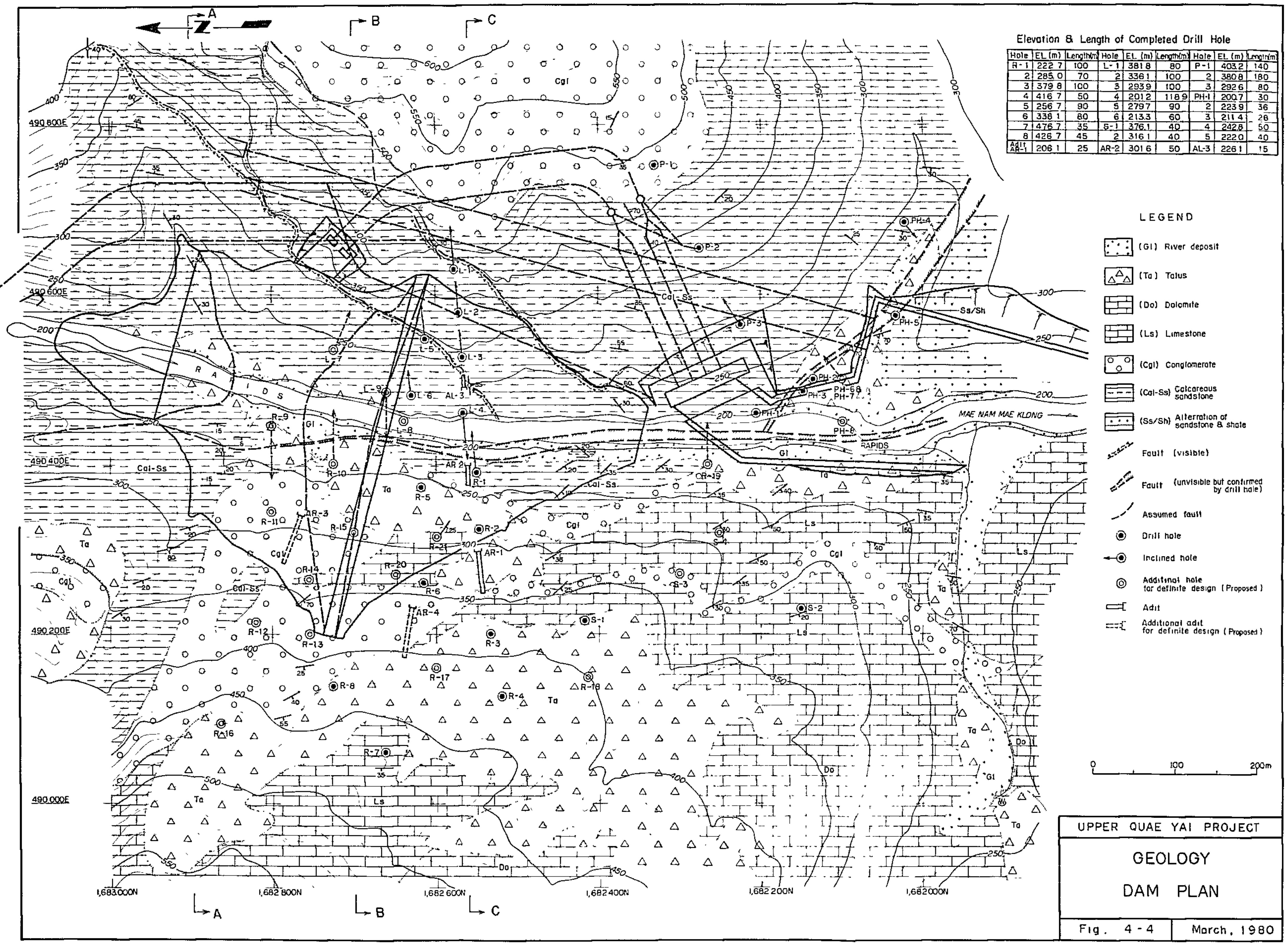


A
B
C
D
E
LEGEND
Cenozoic
Tertiary system
Gravel, sand, silt and clay
Mesozoic
Granite
Formation D
Pure limestone, dolomite and dolomitic limestone, near base often red conglomerate, karst in some places
Paleozoic
Formation C
Shale, sandstone, calcareous shale, calcareous sandstone, conglomerate and thin impure limestone, locally alternation
Formation B
Banded calcareous sandstone, banded sandy limestone and alternation of sandstone and shale
Formation A
Quartzite, sandstone, slate and schist
Metamorphic rocks
Schist and semischist
Strike and dip of strata
Strike and dip of fault
Fault (Assumed)
Axis of anticline
Axis of syncline
Axis of fold (assumed)
Geologic boundary
Sink hole
EL420m
Swallet
EL.205m
Spring
Running water (This mark shows the locality number in the table of the report)
0
5
10km
UPPER QUAE YAI PROJECT
GEOLOGY
RESERVOIR AREA PLAN
Fig 4 - 1
March, 1980


SECTION A - A
Watershed
Huai Mae Lamung Tai
Quae Yai River
Nam Mae Chan
Watershed
510
460
SECTION B - B
Huai Phai Lam
Watershed
Quae Yai River
Nam Mae Cham
Watershed
470
510
SECTION C - C
Huai Ka Dam
Watershed
Quae Yai River
Watershed
510
470
SECTION D - D
Huai Ong Iang
Watershed
Quae Yai River
Huai Tong Thai
Huai Yai
Watershed
510
470
SECTION E - E
Huai Ong Thang
Quae Yai River
510
480
LEGEND
Cenozoic
Tertiary system
Gravel, sand, silt and clay
Mesozoic
Granite
Paleozoic
Formation D
Pure limestone, dolomite and dolomitic limestone, near base often red conglomerate, karst in some places
Formation C
Shale, sandstone, calcareous shale, calcareous sandstone, conglomerate and thin impure limestone, locally alternation
Formation B
Banded calcareous sandstone, banded sandy limestone and alternation of sandstone and shale
Formation A
Quartzite, sandstone, slate and schist
Metamorphic rocks
Schist and semischist
Geologic boundary
Fault (actual)
(assumed)
0 5 10km
Note . The geologic section is drawn on a different scale for vertical and horizontal. The real topographic profile in natural scale is shown below each geologic section
UPPER QUAE YAI PROJECT
GEOLOGY
RESERVOIR AREA PROFILE
Fig. 4-2
March, 1980

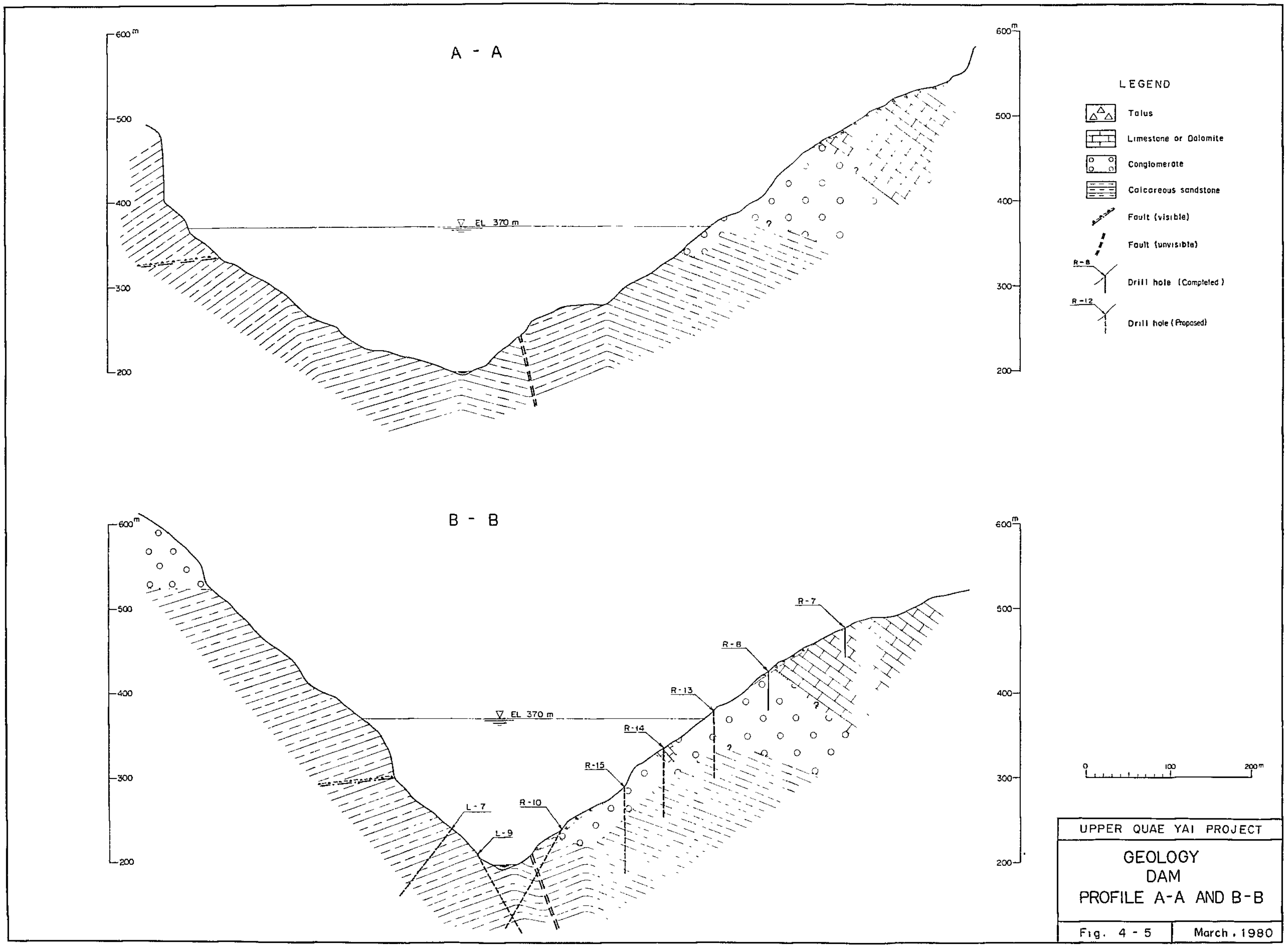


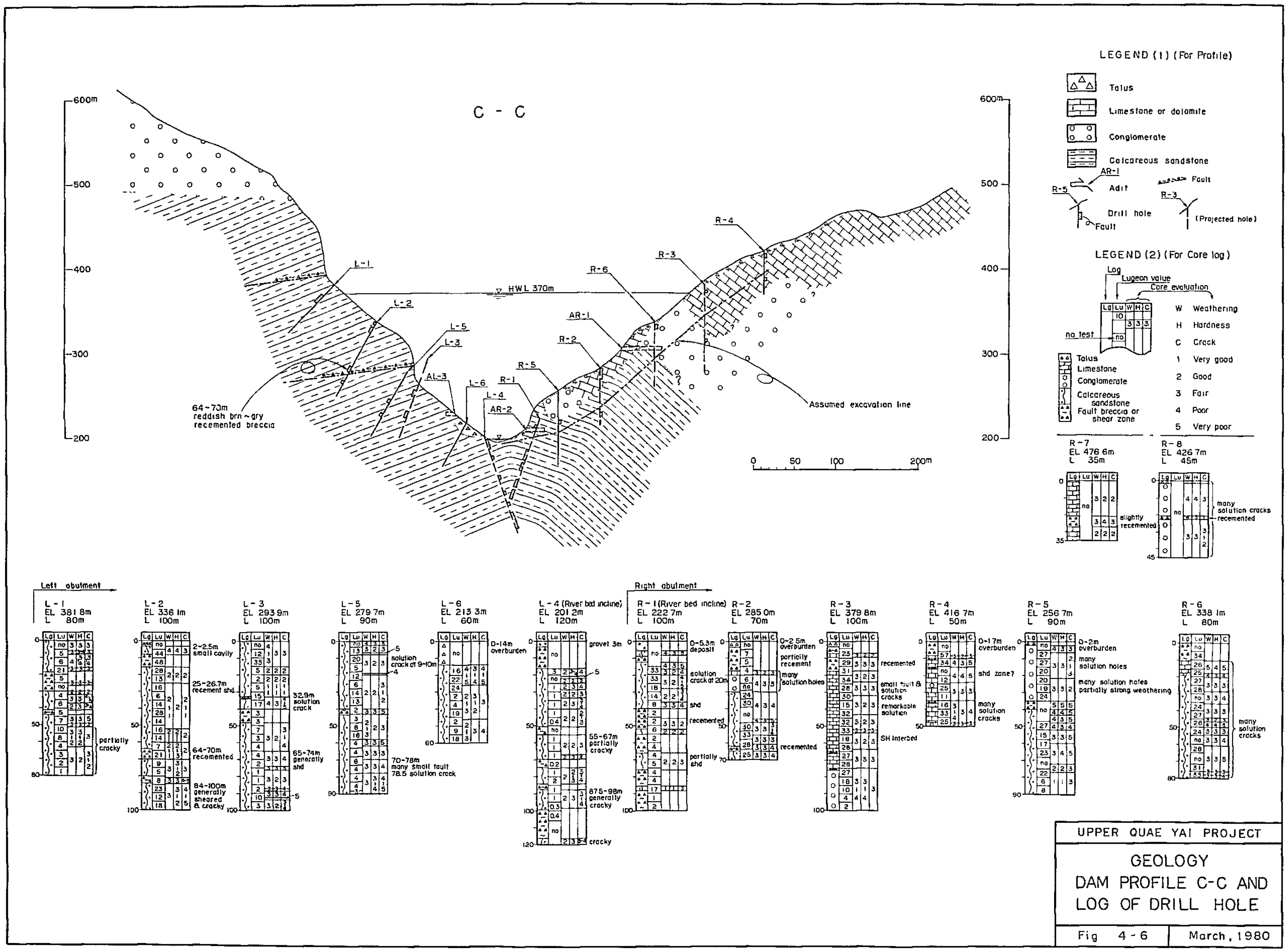
LEGEND
Mesozoic
Formation D
Pure limestone, dolomite and dolomitic limestone, near base often red conglomerate, karst in some places
Formation C
Shale, sandstone, calcareous shale, calcareous sandstone, conglomerate and thin impure limestone, locally alternation
Paleozoic
Formation B
Banded calcareous sandstone, banded sandy limestone and alternation of sandstone and shale
Formation A
Quartzite, sandstone, slate and schist ( This formation does not crop out in this mapped area )
Metamorphic rocks
Schist and semischist
Strike and dip of strata
Strike and dip of fault
Fault (assumed)
Axis of anticline
Axis of syncline
Axis of fold (assumed)
Geologic boundary
Sink hole
Swallet
Spring
Running water (This mark shows the locality number in the table of the report)
Formation D at the vicinity of Nam Chon dam site
Thi Khong Dam Site
Nam Chon Dam Site
Huai Phra
Quae Yai River
SECTION A - A
SECTION B - B
SECTION C - C
SECTION D - D
Huai Tong Thai
Huai Nam Chon
Huai Pa Chi
Huai Du Ngae
UPPER QUAE YAI PROJECT
GEOLOGY
PLAN AND PROFILE
VICINITY OF DAMSITE
Fig 4 - 3
March, 1980

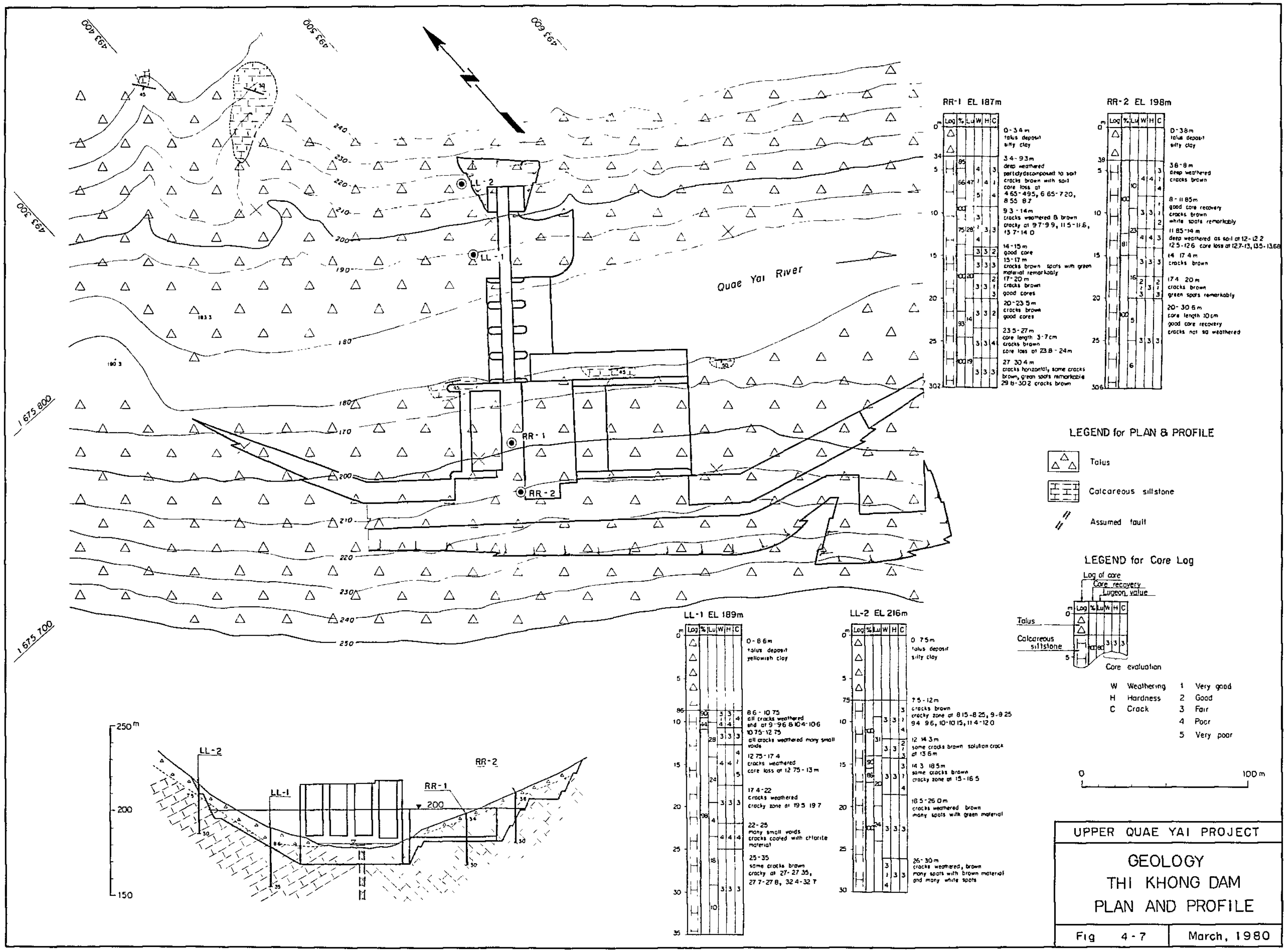



Elevation & Length of Completed Drill Hole

| Hole | EL (m) | Length(m) | Hole | EL (m) | Length(m) | Hole | EL (m) | Length(m) |
|---|---|---|---|---|---|---|---|---|
| R-1 | 222.7 | 100 | L-1 | 381.8 | 80 | P-1 | 403.2 | 140 |
| 2 | 285.0 | 70 | 2 | 336.1 | 100 | 2 | 380.8 | 180 |
| 3 | 379.8 | 100 | 3 | 293.9 | 100 | 3 | 292.6 | 80 |
| 4 | 416.7 | 50 | 4 | 201.2 | 118.9 | PH-1 | 200.7 | 30 |
| 5 | 256.7 | 90 | 5 | 279.7 | 90 | 2 | 223.9 | 36 |
| 6 | 338.1 | 80 | 6 | 213.3 | 60 | 3 | 211.4 | 28 |
| 7 | 476.7 | 35 | S-1 | 376.1 | 40 | 4 | 242.8 | 50 |
| 8 | 426.7 | 45 | 2 | 316.1 | 40 | 5 | 222.0 | 40 |
| Adit AR-1 | 206.1 | 25 | AR-2 | 301.6 | 50 | AL-3 | 226.1 | 15 |


A - A
B - B
600 m
500
400
300
200
EL 370 m
LEGEND
Talus
Limestone or Dolomite
Conglomerate
Calcareous sandstone
Fault (visible)
Fault (unvisible)
R-8
Drill hole (Completed)
R-12
Drill hole (Proposed)
R-7
R-8
R-13
R-14
R-15
R-10
L-7
L-9
0
100
200 m
UPPER QUAE YAI PROJECT
GEOLOGY
DAM
PROFILE A-A AND B-B
Fig. 4-5
March, 1980


C - C
HWL 370m
L-1
L-2
L-5
L-3
AL-3
L-6
L-4
R-1
AR-2
R-5
R-2
AR-1
R-6
R-3
R-4
64~70m reddish brn ~ gry recemented breccia
Assumed excavation line
LEGEND (1) (For Profile)
Talus
Limestone or dolomite
Conglomerate
Calcareous sandstone
Adit
Fault
Drill hole
(Projected hole)
LEGEND (2) (For Core log)
Log
Lugeon value
Core evaluation
no test
W Weathering
H Hardness
C Crack
1 Very good
2 Good
3 Fair
4 Poor
5 Very poor
Talus
Limestone
Conglomerate
Calcareous sandstone
Fault breccia or shear zone
R-7 EL 476 6m L 35m
R-8 EL 426 7m L 45m
Left abutment
Right abutment
L-1 EL 381 8m L 80m
L-2 EL 336 1m L 100m
L-3 EL 293 9m L 100m
L-5 EL 279 7m L 90m
L-6 EL 213 3m L 60m
L-4 (River bed incline) EL 201 2m L 120m
R-1 (River bed incline) EL 222 7m L 100m
R-2 EL 285 0m L 70m
R-3 EL 379 8m L 100m
R-4 EL 416 7m L 50m
R-5 EL 256 7m L 90m
R-6 EL 338 1m L 80m
UPPER QUAE YAI PROJECT
GEOLOGY
DAM PROFILE C-C AND
LOG OF DRILL HOLE
Fig 4-6
March, 1980



Quae Yai River
LL-1
LL-2
RR-1
RR-2
493 400
493 500
493 600
493 300
1 675 800
1 675 700
RR-1 EL 187m
RR-2 EL 198m
LL-1 EL 189m
LL-2 EL 216m
Log % Lu W H C
0-3.4m talus deposit silty clay
0-3.8m talus deposit silty clay
0-8.6m talus deposit yellowish clay
0-7.5m talus deposit silty clay
LEGEND for PLAN & PROFILE
Talus
Calcareous siltstone
Assumed fault
LEGEND for Core Log
Log of core
Core recovery
Lugeon value
Talus
Calcareous siltstone
Core evaluation
W Weathering
H Hardness
C Crack
1 Very good
2 Good
3 Fair
4 Poor
5 Very poor
0
100m
250m
200
150
UPPER QUAE YAI PROJECT
GEOLOGY
THI KHONG DAM
PLAN AND PROFILE
Fig 4-7
March, 1980

Table 4-1 General Geologic Sequence of Upper Quae Yai Project Area

| Era | Stratigraphic Unit | Rock | Main Distribution | Characteristic |
|---|---|---|---|---|
| Cenozoic | Quaternary to Tertiary System | Gravel, Sand, Silt and Clay | Junction between Mae Chan & Quae Yai | Moderatly consolidated, horizontal bedding |
| | Unconformity | | | |
| Mesozoic | Intrusive rock Intrusion | Granite | at eastern & western divide | Medium to coarse biotite Granite |
| Mesozoic | Formation D | Massive pure LS (locally bedded), cataclastic Dolomite, Dolomitic LS, near base often Red Conglomerate | Many places, especially eastern half of catchment area, except both divides | Remarkable karstic phenomena, folded |
| | Unconformit or Disconformity | | | |
| Palaeozoic | Formation C | Shale, Sandstone, calcareous Sandstone, Conglomerate and thin impure LS. locally alternation | Whole project area | Thick deposit, folded |
| Palaeozoic | Formation B | Banded calcareous Sandstone, banded sandy LS. alternation of Sandstone & Shale and locally lenticular LS. | Along main river including proposed damsite and other many places | Massive, folded, partially strongly folded and rock like Schist locally |
| Palaeozoic | Formation A | Quartzite, Sandstone, Slate and like Schist | Along eastern divide and continuously from Srinagarind reservoir area | Very hard, thick deposit |
| Palaeozoic | Metamorphic rocks | Schist and semi Schist | At both divides and about 20 km downstream of damsite | Locally show gneissose structure |

# Table 4-2 Quantitative Analysis of Calcareous Rock

| Locality No. | Locality | Rock Name | Result of analysis |  | 1/ Result of norm calculation |  | 2/ Result of norm calculation |  | 4/ |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Composition | % (wt) | Composition | % (wt) | Composition | % (wt) |  |
| (1) | Right bank near No. 6 site | Dolomitic limestone | CaO | 51.6 | $CaCO_3$ | 92.0 | $CaCO_3$ | 87.2 | 1 |
|  |  |  | MgO | 2.4 | $MgCO_3$ | 4.5 | $CaMg(CO_3)_2$ | 9.3 |  |
|  |  |  | $SiO_2$ | 2.3 | —— | —— | $SiO_2$ | 2.3 |  |
|  |  |  | $Al_2O_3$ | 0.36 | —— | —— | $Al_2O_3$ | 0.36 |  |
|  |  | (Formation D) | Total | 56.66 | Total | 96.5 | Total | 99.16 |  |
| (2) | Sink hole at left bank of Huai Tong Thai | Calcitic dolomite | CaO | 35.1 | $CaCO_3$ | 62.64 | $CaCO_3$ | 19.93 | 2 |
|  |  |  | MgO | 17.2 | $MgCO_3$ | 35.98 | $CaMg(CO_3)_2$ | 78.69 |  |
|  |  |  | $SiO_2$ | 0.2 | —— | —— | $SiO_2$ | 0.2 |  |
|  | EL.470m | (Formation D) | Total | 52.5 | Total | 98.62 | Total | 98.64 |  |
| (3) | Right bank of Huai Tong Thai | Dolomite | CaO | 32.3 | $CaCO_3$ | 57.64 | $CaCO_3$ | 8.72 |  |
|  |  |  | MgO | 19.7 | $MgCO_3$ | 41.21 | $CaMg(CO_3)_2$ | 90.13 |  |
|  |  |  | $SiO_2$ | 0.1 | —— | —— | $SiO_2$ | 0.1 |  |
|  | EL.250m | (Formation D) | Total | 51.6 | Total | 98.85 | Total | 98.86 |  |
| (4) | Right bank of Huai Tong Thai | Dolomite | CaO | 30.9 | $CaCO_3$ | 55.14 | $CaCO_3$ | 2.75 |  |
|  |  |  | MgO | 21.1 | $MgCO_3$ | 44.13 | $CaMg(CO_3)_2$ | 96.52 |  |
|  |  |  | $SiO_2$ | 0.2 | —— | —— | $SiO_2$ | 0.2 |  |
|  | EL.430m | (Formation D) | Total | 52.2 | Total | 99.27 | Total | 99.47 |  |
| (5) | Huai Du Ngae | Calcitic dolomite | CaO | 30.8 | $CaCO_3$ | 55.0 | $CaCO_3$ | 14.6 |  |
|  |  |  | MgO | 20.3 | $MgCO_3$ | 38.1 | $CaMg(CO_3)_2$ | 78.5 |  |
|  |  |  | $SiO_2$ | 1.3 | —— | —— | $SiO_2$ | 1.32 |  |
|  |  |  | $Al_2O_3$ | 0.33 | —— | —— | $Al_2O_3$ | 0.33 |  |
|  | EL.590m | (Formation D) | Total | 52.73 | Total | 93.1 | Total | 94.73 |  |
| (6) | Left bank near No. 2 site | Dolomite | CaO | 30.6 | $CaCO_3$ | 54.61 | $CaCO_3$ | 1.72 |  |
|  |  |  | MgO | 21.3 | $MgCO_3$ | 44.55 | $CaMg(CO_3)_2$ | 97.44 |  |
|  |  |  | $SiO_2$ | 0.1 | —— | —— | $SiO_2$ | 0.1 |  |
|  |  | (Formation D) | Total | 52.0 | Total | 99.16 | Total | 99.26 |  |
| (7) | Huai Pachi | Calcareous shale | CaO | 2.2 | $CaCO_3$ | 3.9 |  |  | 5 |
|  |  |  | MgO | 1.8 | $MgCO_3$ | 3.4 |  |  |  |
|  |  |  | $SiO_2$ | 58.8 | —— | —— |  |  |  |
|  |  |  | $Al_2O_3$ | 19.20 | —— | —— |  |  |  |
|  | EL.790m | (Formation C) | Total | 82.0 | Total | 7.3 |  |  |  |
| (8) | Left bank at Nam Chon damsite | Banded sandy limestone | CaO | 39.3 | $CaCO_3$ | 70.13 | $CaCO_3$ | 65.42 | 7 |
|  |  |  | MgO | 1.9 | $MgCO_3$ | 3.97 | $CaMg(CO_3)_2$ | 8.68 |  |
|  |  |  | $SiO_2$ | 20.2 | —— | —— | $SiO_2$ | 94.3 |  |
|  |  | (Formation B) | Total | 61.4 | Total | 74.1 | Total | 94.3 |  |
| (9) | Left bank near Nam Chon damsite | Banded sandy limestone | CaO | 2.2 | $CaCO_3$ | 84.6 | $CaCO_3$ | 78.8 |  |
|  |  |  | MgO | 1.2 | $MgCO_3$ | 2.3 | $CaMg(CO_3)_2$ | 4.66 |  |
|  |  |  | $SiO_2$ | 7.3 | —— | —— | $SiO_2$ | 5.16 |  |
|  |  |  | $Al_2O_3$ | 3.43 | —— | —— | 3/ $CaAl_2Si_2O_8$ | 9.45 |  |
|  |  | (Formation B) | Total | 59.33 | Total | 86.9 | Total | 98.07 |  |
| (10) | Huai Tong Thai | Banded sandy limestone | CaO | 49.9 | $CaCO_3$ | 89.1 | $CaCO_3$ | 87.9 |  |
|  |  |  | MgO | 0.6 | $MgCO_3$ | 1.13 | $CaMg(CO_3)_2$ | 2.33 |  |
|  |  |  | $SiO_2$ | 5.9 | —— | —— | $SiO_2$ | 5.9 |  |
|  |  |  | $Al_2O_3$ | 1.54 | —— | —— | $Al_2O_3$ | 1.54 |  |
|  | EL.480m | (Formation D) | Total | 57.94 | Total | 90.23 | Total | 97.67 |  |
| (11) | Huai Ong Thang Yai (downstream of Nam Chon damsite) | Quartzite | CaO | 0.0 |  |  |  |  | 10 |
|  |  |  | MgO | 0.6 |  |  |  |  |  |
|  |  |  | $SiO_2$ | 89.1 |  |  |  |  |  |
|  |  |  | $Al_2O_3$ | 4.44 |  |  |  |  |  |
|  | EL.250m | (Formation A) | Total | 94.14 |  |  |  |  |  |

1/ All CaO are calculated as $CaCO_3$ and all MgO are calculated as $MgCO_3$.

2/ All MgO are calculated as $CaMg(CO_3)_2$ and remaining CaO are calculated as $CaCO_3$.

3/ $Al_2O_3$ is calculated as $CaAl_2Si_2O_8$ (Anorthite) by way of example.

4/ Locality No. for micrograph of rock sample.

Quantitative Analysis of Limestone at Khao Laem Damsite (Quae Noi River)

| Locality | Rock Name | Result of analysis |  | Result of norm calculation |  | Result of norm calculation |  |
|---|---|---|---|---|---|---|---|
|  |  | Composition | % (wt) | Composition | % (wt) | Composition | % (wt) |
| Inside of gallery at right bank | Limestone | CaO | 54.2 | $CaCO_3$ | 96.72 | $CaCO_3$ | 94.24 |
|  |  | MgO | 1.0 | $MgCO_3$ | 2.09 | $CaMg(CO_3)_2$ | 4.57 |
|  |  | $SiO_2$ | 0.2 | —— | —— | $SiO_2$ | 0.2 |
|  | (Formation D) | Total | 55.4 | Total | 98.81 | Total | 99.01 |

Table 4-3

Location of Additional Drill Hole

| Site | Hole No. | X | Y | $EL_{(m)}$ | Direction | $Length_{(m)}$ |
|---|---|---|---|---|---|---|
| Dam | R-9 | 490445E | 1682800N | 220 | N90°W 50° | 100 |
| | R-10 | 490400 | 1682725 | 240 | N90°E 60° | 130 |
| | R-11 | 490345 | 1682800 | 280 | 90° | 80 |
| | R-12 | 490215 | 1682820 | 360 | 90° | 80 |
| | R-13 | 190200 | 1682755 | 380 | 90° | 80 |
| | R-14 | 490265 | 1682755 | 335 | 90° | 80 |
| | R-15 | 490320 | 1682700 | 290 | 90° | 100 |
| | R-16 | 490095 | 1682865 | 470 | 90° | 150 |
| | R-17 | 490160 | 1682600 | 410 | 90° | 130 |
| | R-18 | 490150 | 1682415 | 400 | 90° | 100 |
| | R-19 | 490400 | 1682265 | 200 | N90°E 60° | 100 |
| | L-7 | 490535 | 1682725 | 240 | S65°E 50° | 100 |
| | L-8 | 490450 | 1682640 | River bottom | 90° | 50 |
| | R-20 | 490270 | 1682650 | 335 | 90° | 130 |
| | R-21 | 490315 | 1682600 | 285 | 90° | 100 |
| | L-9 | 490485 | 1682660 | 210 | N90°W 60° | 110 |
| Sub-Total | 16 Holes | | | | | 1,620m |
| | S-3 | 490270 | 1682650 | 335 | 90° | 130 |
| | S-4 | 490320 | 1682250 | 290 | 90° | 60 |
| | PH-6 * | 490500 | 1682100 | 220 | N50°E 45° | 50 |
| | PH-7 * | | | | 90° | 40 |
| | PH-8 * | 490450 | 1682100 | River bank | 90° | 30 |
| Sub-Total | 5 Holes | | | | | 310m |

| Site | Hole No. | X | Y | $EL_{(m)}$ | Direction | $Length_{(m)}$ |
|---|---|---|---|---|---|---|
| Quarry | Q-4 | 487000E | 1681600N | 540 | 90° | 60 |
| | Q-5 | 487600 | 1681600 | 540 | 90° | 60 |
| | Q-6 | 488100 | 1681400 | 560 | 90° | 80 |
| | NQ-1 | 489290 | 1681300 | 475 | 90° | 80 |
| | NQ-2 | 489430 | 1681300 | 530 | 90° | 100 |
| | NQ-3 | 489500 | 1681130 | 530 | 90° | 100 |
| | NQ-4 | 489290 | 1681050 | 475 | 90° | 50 |
| | NQ-5 | 489430 | 1680920 | 530 | 90° | 100 |
| Sub-Total | 8 Holes | | | | | 630m |
| Borrow | BB-1 | 485300E | 1682810N | 580 | 90° | 10 |
| | BB-2 | 485300 | 1682300 | 560 | 90° | 40 |
| | BB-3 | 485300 | 1681860 | 540 | 90° | 40 |
| Sub-Total | 3 Holes | | | | | 120m |
| | Drill Holes Total 32 Holes | | | | | 2,680m |

* No permeability test hole

Location of Adit

| Site | Adit No. | X | Y | $EL_{(m)}$ | Direction | $Length_{(m)}$ |
|---|---|---|---|---|---|---|
| Dam | AR-3 | 490340 | 1682765 | 280 | N70° W | 60 |
| | AR-1 | 490230 | 1682630 | 360 | N80° W | 60 |
| Adits Total | | | | | | 120m |

# CHAPTER 5

# MATERIALS

# CHAPTER 5 MATERIALS

## 5.1 Materials for Nam Chon Dam

### (1) Impervious Soil Core Materials

Borrow areas for impervious soil core materials are located at both sides of Huai Tong Thai approximately 6 km west of the Nam Chon Damsite. The foundation rock of this site consists of sandy limestone, shale and dolomite. Soil materials investigations were mainly made on the shale layer distributed in the north-south direction in the form of a belt approximately 2 km in width, and 30 test pits of depths ranging from 1 to 5 m were excavated. The locations of the test pits are indicated in Fig. 5-1.

As a result of surface reconnaissance and observations of test pits, the materials at this site may be broadly divided into weathered shale, talus deposit of shale, fine-grained terrace deposit, coarse-grained terrace deposit, and talus deposit of dolomitic limestone depending on the topography, mother rock, and degree of weathering.

#### (a) Test Items and Test Quantities

The items and quantities of tests performed on samples taken from every 1 m depth of the test pits and representative samples classified based on gradation are as indicated below.

| Test Item | Sample from Every 1 m Depth | Representative Sample |
|---|---|---|
| Water content on arrival | 100 | - |
| Specific gravity | 11 | 9 |
| Gradation | 97 | - |
| Atterberg's limits | 100 | 6 |
| Compaction | | |
| ASTM D 698, A Method | 10 | - |
| ASTM D 698, C Method | 22 | 6 |
| ASTM D 1557, C Method | --- | 6 |
| ASTM D 1557, D Method | -- | 3 |
| Permeability | - | 9 |
| Triaxial compression | - | 3 |
| Gradation after compaction | - | 6 |

(b) Selection of Representative Samples

Based on the test results of samples collected from every 1 m depth in the test pits, the materials at this site were classified as indicated below depending on content of materials passing 0.075 mm sieve and under.

| | |
|---|---|
| Fine, -0.075 mm content | 30%+ |
| Medium, -0.075 mm content | 30 - 15% |
| Coarse, -0.075 mm content | 15%- |

Representative samples were selected from the weathered shale, talus deposit of shale, and fine-grained terrace deposit.

(c) Test Results and Considerations

The test results of representative samples are indicated in Table 5-1, and the conditions of distributions of the various materials in Fig. 5-2. Based on field reconnaissances and test results, the following can be considered regarding the materials at this site:

- The impermeability of the core materials at this site are considered to be the following based on results of gradation tests and permeability tests on representative samples.
  The coefficients of permeability of fine-grained and medium-grained materials at optimum water contents are from $1.3 \times 10^{-8}$ to $3.8 \times 10^{-8}$ cm/sec. The contents of gravels larger than 19.1 mm (3.4") in these materials are less than 25%, and it is judged that an impermeability of core materials can be obtained.
  Permeability tests of coarse-grained materials were performed on samples of minus 0.075 mm size content more than 9%. As a result, the coefficients of permeability were indicated to be from $2.0 \times 10^{-7}$ to $4.5 \times 10^{-8}$ cm/sec. However, since there are coarse-grained materials containing more than 40% of sizes over 19.1 mm (3/4"), it is desirable for permeability tests using large-sized mold to be carried out.
- The strength constants of soil, according to triaxial compression tests performed at AIT, in terms of angle of internal friction ($\bar{\phi}$) obtained by effective stress analysis were 20° to 27°, while in terms of cohesion ($\bar{c}$) they were 0.8 to 1.3 kg/cm$^2$.
- Judging the materials of this site from the results of the various tests, the talus deposit of weathered shale has relatively fine-grained material at the ground surface and tends to become coarser as the depth increases. However, the coarse materials are also comparatively weathered, and considering crushing and mixing during borrowing by heavy machinery, it is thought material in a fairly depth can be used.

Terrace deposit having high contents of fine-grained soil is of 27 to 74% contents of sizes 0.075 mm and under, and especially, the contents around P-25 are 54 to 74%. It is desirable for this fine-grained material to be blended with coarse-grained weathered shale distributed in the vicinity to improve quality.

- Talus deposit with dolomitic limestone as the base rock comprises silty soil with low dry density of 1.35 to 1.45 $t/m^3$ to indicate different properties from other materials, and are not desirable as impervious core materials.

(d) Estimated Available Quantities

Based on the above, the estimated available quantities at this site are the following:

| | |
|---|---|
| Weathered shale | 2,050,000 $m^3$ |
| Talus deposit of shale | 840,000 $m^3$ |
| Terrace deposit of fine-grained soil | 1,560,000 $m^3$ |
| Total | 4,450,000 $m^3$ |

The requirement for 1,800,000 $m^3$ of impervious core material of Nam Chon Dam will thus be satisfied.

(2) Filter Materials

Since riverbed deposit having suitable particle sizes is not found in the vicinity of the Nam Chon damsite, it will be necessary to make filter materials artificially from quarry materials, or, to investigate materials having the proper particle sizes. One candidate site will be Area A-1, but it is also desirable for investigations to be made of deeper parts of the borrow areas.

(3) Rock Materials

The quarry site A-1 originally planned is at the right bank of the Huai Tong Thai approximately 2 km to the west from the Nam Chon Damsite. Three drillholes were made at this quarry site. According to the boring cores, the rock here is crushable dolomite and readily becomes fragmented. Consequently, it cannot be collected in the form of large blocks, but it is conceivable for use as a part of rock materials or as transition materials.

EGAT carried out two drillholes at Site B along the Huai Nam Chon approximately 1.8 km downstream from the damsite as another quarry site. As a result, it was found that Site B consists of calcareous sandstone and extremely good cores were recovered. Judging from these investigations, this site is a fairly good candidate source of rock materials and concrete aggregates.

However, when conditions such as transportation roads are considered, it is desirable for the investigation area at Area A along the Huai Tong Thai indicated in Fig. 5-1 to be expanded.

Other than the above, the excavation material from sites of structures such as the powerhouse and spillway consists of calcareous sandstone and can be used as good rock material.

(4) Concrete Aggregates

Regarding concrete aggregates, since natural materials are not seen in this vicinity, it will be necessary for them to be manufactured artificially from quarry materials. Materials from the rock material candidate site A-1 cannot be expected very much to serve as concrete aggregates.

Site B at the Huai Nam Chon consists of calcareous sandstone which has been judged to be material of good quality as a result of boring. On looking at the results of tests on materials collected from outcrops at Site B, values of 1.55% for soundness and 15.1% for abrasion loss are indicated, and this site can be said to be superior as a source of concrete aggregates.

(5) Recommendations for Additional Investigations

(a) Impervious Soil Core Materials

The investigations required to be made based on the results of studies up to the present in order to carry out future detail design are the following:

- Location of Test Pit

  22 pits (locations shown in Fig. 5-1)

- Test Item

  Tests on samples taken at every 1 m depth in all test pits:

  Water content on arrival
  Specific gravity
  Gradation (full-size sample)
  Atterberg's limits

  Tests on representative samples:

  * Selection of representative samples

  Representative samples are classified as indicated below according to geological conditions and grain-size distributions.

  Weathered Shale

| | | |
|---|---|---|
| Fine, -0.075 mm | content: | 30%+ |
| Medium, -0.075 mm | content: | 15 - 30% |
| Coarse, -0.075 mm | content: | 15%- |

Talus Deposit of Shale

Fine, -0.075 mm content: 20%+

Coarse, -0.075 mm content: 20%-

Terrace Deposit with fine-grained soil

Terrace deposits with fine-grained soil are distributed at three locations around this site. One test pit at each site or a total of three test pits are selected from these three places.

* Test items and numbers of test samples

The test items and the numbers of test samples selected are indicated in Table 5-2.

(b) Filter Materials

On investigations for filter materials, 3 drillholes have been planned in the shale formation at the borrow area as indicated in Chapter 4. If judged to be suitable as filter materials as a result of investigations, test adits or test pits will be excavated and specific gravity, gradation, permeability and shear tests required for filter materials carried out.

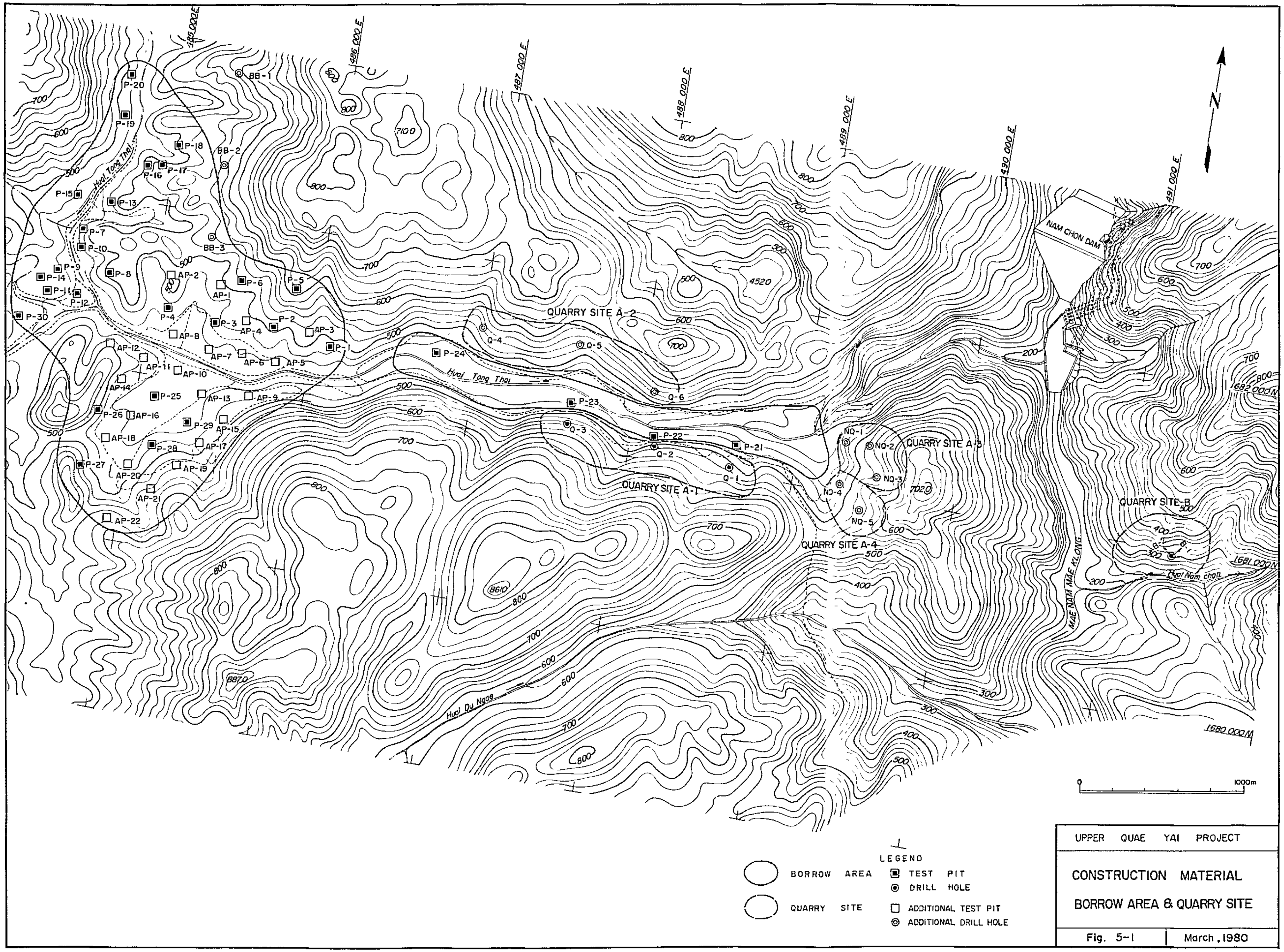
(c) Rock Materials and Concrete Aggregates

In addition to the A-1 and B sites which have been investigated up to the present, 8 drillholes have been planned at the A-2, A-3 and A-4 sites along the Huai Tong Thai as indicated in Chapter 4, Geology, and Fig. 5-1. The test items and test quantities are as listed below.

| Site | A-1 | B | A-2 | A-3 | A-4 |
|---|---|---|---|---|---|
| Specific Gravity | 1 | 1 | 1 | 1 | 1 |
| Soundness | - | - | 1 | 1 | 1 |
| Abrasion | - | - | 1 | 1 | 1 |
| Unconfined compression strength | 3 | 3 | 3 | 3 | 3 |

## 5.2 Materials for Thi Khong Dam

The surroundings of Thi Khong Damsite consists of limestone. The results of surface investigations show this limestone to be hard and it can be expected to serve adequately as concrete aggregate.




UPPER QUAE YAI PROJECT

CONSTRUCTION MATERIAL

BORROW AREA & QUARRY SITE

Fig. 5-1 March, 1980

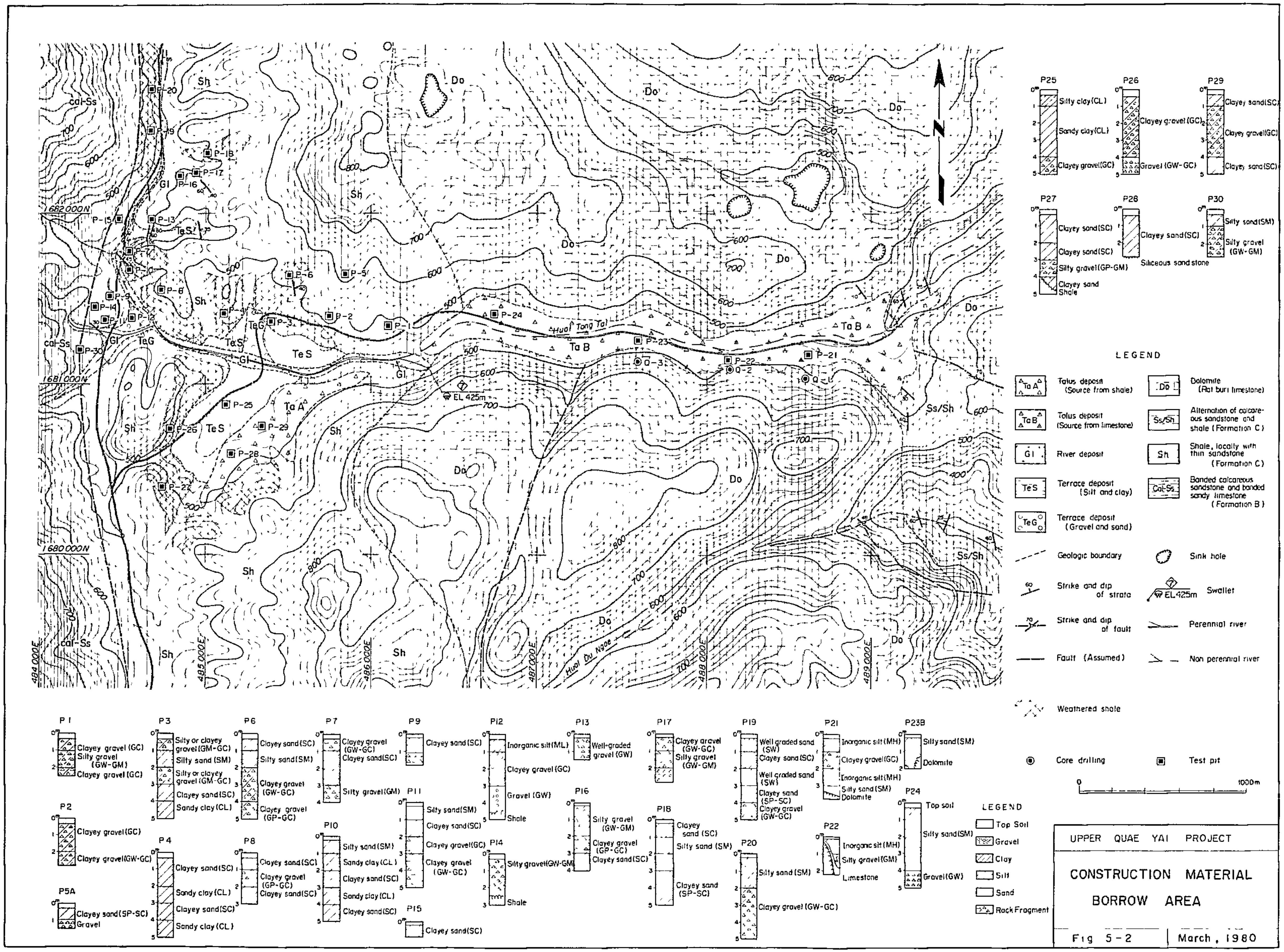

LEGEND
Talus deposit (Source from shale)
Talus deposit (Source from limestone)
River deposit
Terrace deposit (Silt and clay)
Terrace deposit (Gravel and sand)
Dolomite (Rat buri limestone)
Alternation of calcareous sandstone and shale (Formation C)
Shale, locally with thin sandstone (Formation C)
Banded calcareous sandstone and banded sandy limestone (Formation B)
Geologic boundary
Sink hole
Strike and dip of strata
Swallet
Strike and dip of fault
Perennial river
Fault (Assumed)
Non perennial river
Weathered shale
Core drilling
Test pit
0
1000m
LEGEND
Top Soil
Gravel
Clay
Silt
Sand
Rock Fragment
UPPER QUAE YAI PROJECT
CONSTRUCTION MATERIAL
BORROW AREA
Fig 5-2
March, 1980

Table 5-1 Results of Soil Tests for Representative Samples

| Area No. | Sample No. | Depth (m) | Soil Classification: Unified System | Soil Classification: Revised P.R. System | Water Content as received (%) | Specific Gravity | Atterberg Limits: L L (%) | Atterberg Limits: P L (%) | Atterberg Limits: P I | Gradation: -38.1 mm (1 1/2") (%) | Gradation: -19.0 mm (3/4") (%) | Gradation: -4.75 mm (No.4) (%) | Gradation: -2.0 mm (No.10) (%) | Gradation: -0.425 mm (No.40) (%) | Gradation: -0.075 mm (No.200) (%) | Compaction*1 & Permeability (I): Optimum Water Content (%) | Compaction*1 & Permeability (I): Maximum Dry Density ($t/m^3$) | Compaction*1 & Permeability (I): Coefficient of Permeability (cm/sec.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ( Fine Materials ) | | | | | | | | | | | | | | | | | | |
| | P – 10 | 2.5 | SC | A-7-6(2) | 14.5 | 2.71 | 42.2 | 23.2 | 19.0 | | 100 | 90 | 76 | 52 | 37 | 20.0 | 1.680 | $2.8\times10^{-8}$ |
| | P – 25 | 3 0 | CL | A-6 (5) | 12 2 | 2.61 | 30.8 | 17.2 | 13.6 | 100 | 98 | 92 | 84 | 74 | 54 | 17.8 | 1.773 | $1.3\times10^{-8}$ |
| | P – 27 | 1.5 | SC | A-7-6(3) | 14 8 | 2.64 | 40.6 | 22.8 | 17.8 | | 100 | 86 | 70 | 52 | 41 | – | – | – |
| ( Medium Materials ) | | | | | | | | | | | | | | | | | | |
| | P – 19 | 1 5 | SC | A-2-6(1) | 9.9 | 2.67 | 36.2 | 22.1 | 14.1 | | 100 | 83 | 60 | 37 | 29 | 18.5 | 1.790 | $2.6\times10^{-8}$ |
| | P – 26 | 2.5 | GC | A-2-6(0) | 7.2 | 2.70 | 34.2 | 20.8 | 13.4 | 100 | 89 | 49 | 31 | 24 | 21 | – | – | – |
| | P – 29 | 4.5 | SC | A-2-6(0) | 14.8 | 2.71 | 37.0 | 19.8 | 17.2 | 100 | 93 | 66 | 52 | 36 | 22 | 15.2 | 1.792 | $3.3\times10^{-8}$ |
| ( Coarse Materials ) | | | | | | | | | | | | | | | | | | |
| | P – 20 | 4.5 | GW-GC | A-2-6(0) | 10.4 | 2.77 | 36.4 | 21.5 | 14.9 | 100 | 56 | 29 | 19 | 13 | 10 | 17.2 | 1.753 | $4.5\times10^{-8}$ |
| | P – 25 | 4.7 | GC | A-2-6(0) | 12.0 | 2.65 | 28.1 | 15.7 | 12.4 | 100 | 89 | 49 | 32 | 21 | 16 | 14.6 | 1.880 | $1.3\times10^{-8}$ |
| | P – 27 | 3.7 | GP–GM | A-2-6(0) | 15.6 | 2.64 | 33.3 | 24.0 | 9.3 | | 100 | 42 | 27 | 15 | 9 | – | – | – |

| Sample | Compaction** & Permeability (II): Optimum Water Content (%) | Compaction** & Permeability (II): Maximum Dry Density ($t/m^3$) | Compaction** & Permeability (II): Coefficient of Permeability (cm/sec.) | Compaction** & Permeability (II): Water Content (%) | Triaxial Compression Strength $(\overline{CIU})$ *4 — Total Stress: C ($kg/cm^2$) | Total Stress: $\phi$ (deg.) | Effective Stress: $\bar{C}$ ($kg/cm^2$) | Effective Stress: $\bar{\phi}$ (deg.) |
|---|---|---|---|---|---|---|---|---|
| P–10 | 17.5 | 1.812 *2 | – | – | – | – | – | – |
| P–25 | 14.0 | 1.910 *2 | – | – | – | – | – | – |
| P–27 | 12.2 | 1.923 *3 | $3.8\times10^{-8}$ | 12.2 | 1.2 | 22.5 | 0.78 | 27.0 |
| P–19 | 14.0 | 1.904 *2 | – | – | – | – | – | – |
| P–26 | 11.2 | 2.010 *3 | $2.1\times10^{-8}$ | 11.2 | 0.5 | 19.6 | 0.96 | 20.9 |
| P–29 | 12.4 | 1.910 *2 | – | – | – | – | – | – |
| P–20 | 13.6 | 1.910 *2 | – | – | – | – | – | – |
| P–25 | 12.2 | 1.968 *2 | – | – | – | – | – | – |
| P–27 | 11.3 | 1.952 *3 | $2.0\times10^{-7}$ | 11.3 | 2.2 | 17.8 | 1.35 | 27.0 |

*1 ASTM D 698-70 METHOD C

*2 ASTM D 1557-70 METHOD C

*3 ASTM D 1557-70 METHOD B

*4 Specimens were compacted by ASTM D 1557-70 METHOD B and they were at optimum water content, maximum dry density.

In permeability tests, falling head permeability tests were performed on specimens compacted by ASTM D 698-70. METHOD C (*1) and constant head permeability tests were performed on specimens compacted by ASTM D 1557-70 METHOD B (*3).

Coefficient of permeability is at optimum water content.

Table 5-2 Items of Tests and Quantity of Test Samples

| Items of Tests | Weathered Shale | | | Talus Deposit of Weathered Shale | | Terrace Deposit | Total | Note |
|---|---|---|---|---|---|---|---|---|
| | Fine | Medium | Coarse | Fine | Coarse | | | |
| Water Content as received | 3 | 3 | 3 | 2 | 2 | 3 | 16 | ASTM D 2216 |
| Specific Gravity | | | | | | | | |
| Fine Particle | 3 | 3 | 3 | 2 | 2 | 3 | 16 | ASTM D 854 |
| Coarse Particle | 3 | 3 | 3 | 2 | 2 | 3 | 16 | ASTM C 127 |
| Gradation (Full Size) | 3 | 3 | 3 | 2 | 2 | 3 | 16 | ASTM D 422 |
| Atterberg Limits | | | | | | | | |
| Liquid Limit | 3 | 3 | 3 | 2 | 2 | 3 | 16 | ASTM D 423 |
| Plastic Limit | 3 | 3 | 3 | 2 | 2 | 3 | 16 | ASTM D 424 |
| Compaction | 3 | 3 | 3 | 2 | 2 | 3 | 16 | * 1 |
| Permeability | 3 | 3 | 3 | 2 | 2 | 3 | 16 | * 2 |
| Triaxial Compression | 1 | 1 | 1 | 1 | 1 | 1 | 6 | * 3 |
| Gradation after Compaction Test | 3 | 3 | 3 | 2 | 2 | 3 | 16 | |

* 1 ASTM D698-70 Method C Used specimens are not to be used

* 2 5 different water content specimens compacted by ASTM D698-70 Method C shall be tested from each sample. Large Permeability Test shall be applied for coarse samples.

* 3 4 different confined pressure x 2 different water content (Wopt and Wopt+2%) 8 specimens per sample.

# CHAPTER 6

# DEVELOPMENT SCHEME

# CHAPTER 6 DEVELOPMENT SCHEME

## 6.1 Fundamentals

Investigations were carried out by EGAT from the backwater end of Srinagarind Reservoir to approximately 160 km upstream in order to effectively utilize the undeveloped water power remaining upstream of Srinagarind Reservoir. According to the results of these investigations, prospective damsites on the Upper Quae Yai where it is judged possible to provide large reservoirs are the Nam Chon site approximately 141 km upstream of Srinagarind Power Station and the No. 9A site located about 20 km still farther upstream.

The study in this Chapter consists of comparing these two sites to select the most suitable one for a large-scale reservoir, and further, of determining the optimum development scheme for the Upper Quae Yai Project.

In order to effectively utilize the abundant flow of the Quae Yai River which is a precious domestic hydro-resource for Thailand, and moreover, is a circulating resource, considerations were given in this study not to remain idle head between Upper Quae Yai and Srinagarind Reservoir.

As described in Chapter 2, the increasing electric power demand in Thailand has been prominent in recent years, and especially, the trend is for the peak portion to be extremely sharp. The power station to be developed as the Upper Quae Yai Project is to be a large-scale peaking power station to carry the peak portion of the demand curve.

The dam constructed at Nam Chon or the No. 9A site is developed to provide a large-scale reservoir as much as possible within limits permitted by topographical and geological conditions and by economical aspects.

In study of the reservoir high water level, the influence of fill-up of this reservoir on the power generating capability of the downstream Srinagarind Power Station is to be taken into consideration, and an optimum scheme is decided.

The electric power increased at the downstream Srinagarind Power Station after completion of the Upper Quae Yai Project is added to the benefit of this Project.

Regarding economic analysis, a detailed one will be made in Chapter 12, but in this Chapter an economic evaluation of the Project with construction costs at 1980 price level without escalation is made, and the optimum scheme will be selected from comparison schemes. Comparison studies were made by B/C and (B-C) and annual cost (C) and benefit (B) during the service life concerned.

The expenses of a hydroelectric power station consist of interest, depreciation, repair costs, and operation and maintenance costs, and the annual cost, considering the service life of this Project, is estimated to be 11.586% of the construction cost. The benefit of a hydroelectric power station is taken to be the annual cost of an alternative power station possessing a capacity equal to that of the hydroelectric power station.

As the alternative for this site, the combined power sources of the gas turbine and oil-fired thermal plant (200 MW x 1) indicated in Table 12-3 were selected.

The fuel cost of the oil-fired thermal plant for calculation of the benefits is nearly equal to US$24 per barrel which is the minimum price decided at the OPEC meeting held in Caracas in December 1979.

The kW and kWh prices obtained based on the above are as shown below.

| | | |
|---|---|---|
| Unit kW price : | | 1,224 Bahts |
| Unit kWh price : | Firm | 1.013 Bahts |
| | Secondary | 0.864 Bahts |

## 6.2 Reservoir Operation Plan and Electric Energy Calculation

### (1) Reservoir Operation Plan

The operation rules of the reservoir at Nam Chon or No. 9A to be the key point of the Upper Quae Yai Project are determined considering the following:

- The reservoir is to be operated to store and regulate the inflows of wet years for supplementing in dry years to increase the firm discharges of dry years as much as possible.
- During a year, the reservoir is also to be operated to store inflows during the wet season for supplementing in the dry season.
- Operation of the reservoir is to be done to make it possible for stable electric power to be secured for as long a period as possible.

- The water requirements at the downstream Vajiralongkorn Diversion Dam are to be secured through comprehensive operation of Khao Laem Reservoir and Srinagarind Reservoir.

(2) Electric Energy Calculation

The electric energy is calculated by computer based on the conditions described below and the procedure as shown in Fig. 6-1.

- The monthly runoffs obtained by the seasonal correlation method are used, considering the evaporation from the reservoir surface, calculations are made for the 26 years from April 1952 to March 1978.

- Calculations to determine the reduction in energy production at the downstream Srinagarind Power Station with filling up reservoir of this Project are to be simulated for commence of fill-up from May 1985. For the natural inflow during the filling up period, 1964 - 1966 where the 3 years total inflow is taken to be average is corresponded.

- The downstream water requirements are satisfied with comprehensive operation of Srinagarind Reservoir and Khao Laem Reservoir. Under those requirements, as shown in Table 6-1, used in the calculation during fill-up the values from May 1985 were adopted. And for the calculation after completion of the Project, values at the year 2,000 onward were adopted.

- The operation of Srinagarind Power Station is to secure the minimum energy production 1,440 MWh/day (60 MW). The operation of Khao Leam Power Station is also to secure 1,080 MWh/day (45 MW), same as figures in the Pre-feasibility Report on Upper Quae Yai Project by EGAT.

- The effective output is to be the samller of the critical maximum output and the equivalent output in the required peaking generation hours.

- The electric energy produced during the required peaking generation hours is to be taken as firm and the energy produced at other times as secondary.

- The Second Stage Project of Srinagarind Power Station (pumped storage) is scheduled to be completed in October 1985 according to the plans of EGAT. Consequently, in the energy calculation after completion, in order to effectively utilize Srinagarind Dam as a multi-purpose one, in case the downstream water requirement is satisfied with the Quae Noi and the remaining catchment area runoff, Srinagarind Reservoir be stored as much as possible, and the minimum energy to be secured at Srinagarind Power Station will be met by the second stage pumped storage power station.

  Regarding the period of fill-up, since the downstream water requirements are comparatively small, operation of Srinagarind Reservoir is considered without the operation of the pumped storage power station.

- Storage during fill-up is to be done considering the rate of surface rise of the reservoir and within limits that the downstream water requirements or the minimum energy production to be secured at Srinagarind Power Station can be satisfied.

## 6.3 Study of Development Scheme

### (1) Study of Nam Chon Damsite

#### (a) Effective Storage Capacity

The mass curve for the Nam Chon damsite based on monthly inflows between 1952 and 1977 is as shown in Fig. 6-2.

The runoff characteristics at this site, as described in Chapter 3, "Hydrology", are that periodical cycle is of about 10 years and the driest year is occurring approximately in the seventh year from top of the mass curve as shown in Fig. 6-2.

The study of the effective storage capacity, as described in the reservoir operation plan of 6.2, is for water of wet years to be carried over to increase the firm discharges of dry years as much as possible, and studies were made for the 3 cases of carry-over of 5 years, 7 years, and, corresponding to the maximum-size development at this site, 10 years.

The firm discharges for the these cases are 81.8 $m^3$/sec, 87.9 $m^3$/sec and 93.4 $m^3$/sec. The effective reservoir capacities required to secure these firm discharges are 1,670 x $10^6 m^3$, 2,940 x $10^6 m^3$, and 4,100 x $10^6 m^3$. As a result of study, and as can be seen in Tables 6-2, 6-3, and Fig. 6-3, in case of the reservoir high water level being lower than about 365 m, it is slightly more advantageous to make the effective capacity on the small side, while in case of being higher, it will be more advantageous to make the effective capacity 4,100 x $10^6 m^3$, approximately the maximum capacity at this site. This is because a small-scale dam requires a large available drawdown to secure effective capacity.

On comprehensive judgment, it was found that effective capacity of 4,100 x $10^6 m^3$, with which the inflow at this damsite would be about completely regulated, would be the most advantageous. The storage capacity curve of Nam Chon Reservoir used for this study is shown in Fig. 6-4.

(b) High Water Level

It was decided to study the high water level at Nam Chon Dam between elevations of 350 m and 380 m taking into consideration the topographical and geological conditions at the damsite and the reservoir.

Since Nam Chon Dam is to be built upstream of Srinagarind Power Station having a large-scale reservoir, study was made from the hydrological and economical aspects with respect to the period required for fill-up and the reduction in energy production at Srinagarind Power Station during fill-up.

Firstly, the study from the standpoint of hydrology was carried out on the possibility of fill-up from May 1985 to October 1987 when power operation is to be started as indicated in the construction schedule (Fig. 10-1) for this Project. That is, using runoff data for 1952 to 1978, and as a result of studying the storable volume during the fill-up period by stochastic techniques, it was found that up to approximately 5,000 x $10^6 m^3$ can be stored without the influence on the downstream area (see Fig. 6-5).

Because of the above, it was decided to make comparison studies of 13 cases from dead storage of 584 x $10^6 m^3$ to 5,769 x $10^6 m^3$ as indicated in Tables 6-2 and 6-3.

The amounts of energy reduction during fill-up for carrying out economic analyses were estimated by the methods described below.

As can be seen Fig. 3-5, the year 1985 when fill-up is to be started corresponds to an average water year from the standpoint of hydrologic cycles. Then the average years of 3 years total inflows were adopted for the calculations.

Regarding the energy reduction due to fill-up, since there is ample reserve capacity from the standpoint of demand and supply balance, the electric energy reduction was evaluated merely by the unit cost of secondary kWh of thermal, and this was added to the construction cost.

The results of studies are also as indicated in Tables 6-2, 6-3, and Fig. 6-3, and it was found that a high water surface level of 370 m would be the most advantageous.

(c) Maximum Available Discharge

Firm discharge is obtained from inflow and effective storage capacity, but for the firm discharge, it is necessary to decide the maximum available discharge and installed capacity corresponding to the equivalent peaking generation hours demanded from the aspect of demand and supply balance.

As described in Chapter 2, according to studies from the aspect of demand and supply, it will be desirable for the Upper Quae Yai Project to take charge of peaking generation of 5 hours in the daily load curve.

However, based on discussions with EGAT, it was decided to make comparison studies for peaking generation of 4 hours and 5 hours.

In this study, it was assumed there would be no latent capacity in any case. The results of studies, as indicated in Tables 6-4 and 6-5, show that peaking generation of 5 hours is slightly more advantageous from the economical aspects.

In this study, latent capacity was ignored, but since it is considered that the possibility of latent capacity is greater with the case for peaking generation of 4 hours, there is a risk of the economics of the 4-hour case to be further impaired.

(d) Power Plant Location

In order to select the optimum location for the power plant, a dam-type power plant and a water-way type (2 cases), comparison studies of the cases indicated in Fig. 6-6 and Table 6-6 were made between immediately downstream of the Nam Chon damsite and the end of the Srinagarind Reservoir backwater. The results of the studies are as indicated in Table 6-7.

It was made clear that the dam-type power plan in which a power station of maximum available discharge of 460 $m^3$/sec and maximum output of 580 MW is provided would be the most advantageous.

However, by adopting a dam-type power plan, there will be a head remaining between the power station and Srinagarind Reservoir, and it is necessary to make studies from a different viewpoint of schemes such as a two-stage development project as explained in the next section.

(2) Study of Thi Khong Site

As mentioned in the previous section, in order to effectively utilize the head remaining downstream of Nam Chon Power Station, a scheme to provide a dam-type power station having a regulating pond at the Thi Khong site near the end of the backwater of Srinagarind Reservoir was studied.

(a) High Water Level of Regulating Pond

In deciding the high water level of Thi Khong Regulating Pond, the study was made on the premise that the head would be utilized to the maximum within limits that the backwater of Thi Khong Dam does not affect the tailwater level of Nam Chon Power Station. As a result, the high water level of Thi Khong Regulating Pond was at 197 m corresponding with the maximum available discharge at Nam Chon Power Station of 460 $m^3$/sec.

(b) Maximum Available Discharge

Since Thi Khong Power Station would carry out power generation corresponding with the power generation discharge of Nam Chon Power Station intact, the operation is peaking generation of 5 hours to be in step with the peaking generation hours of Nam Chon Power Station. Therefore, the maximum available discharge was selected to be 480 $m^3$/sec, the maximum available discharge of Nam Chon Power Station of 460 $m^3$/sec to which was added the daily-regulated runoff of the remaining catchment area at the Thi Khong site.

(c) Regulating Pond Capacity

In order to effectively utilize the remaining runoff at the Thi Khong site during the wet season, an effective capacity of $0.3 \times 10^6 m^3$ was set for Thi Khong Regulating Pond during normal operation. As can be seen by the reservoir capacity curve indicated in Fig. 6-7, the available drawdown required to secure this effective capacity is 0.2 m.

Further, since Thi Khong Power Station has 2 units, decided basing on comprehensive viewpoints such as operation, manufacturing, and transportation of electrical equipment, the intake orifice beds were made as low as possible so that even in case one unit cannot be operated for a long period due to faulting or other cause, operation of Nam Chon Power Station will not be hindered and waste overflow will not be produced at Thi Khong. The regulating capacity required under such unusual conditions was estimated approximately $4.3 \times 10^6 m^3$. Available drawdown required in these conditions was secured with 3.5 m taking into consideration manufacture and operation of electrical equipment.

It can be said that Thi Khong power plan is economical, as indicated in Table 6-7, according to the results of studies on the conditions without producing remaining head between Nam Chon Power Station and Srinagarind Power Station.

(3) Study of No. 9A Site

The No. 9A site is located approximately 20 km upstream of the Nam Chon site, and the accessibility of this site is worse than that of Nam Chon site. However, a comparison study was made of a large-scale reservoir scheme at the No. 9A site to formulate the optimum scheme for the Upper Quae Yai Project.

(a) No. 9A Dam

- High Water Level

  Regarding high water level, comparison studies were made of elevations between 370 m and 390 m taking into account the topographical and geological conditions of this site.

  The alternative schemes were studied comparatively and the results of the studies are as indicated in Tables 6-8, 6-9, and Fig. 6-8, and as a high water level elevation 380 m is the most advantageous.

- Effective Storage Capacity

  As the result of study on the Nam Chon site, it was found that a plan where the reservoir inflow could be completely regulated would be advantageous. Because of this, the effective storage capacity for the No. 9A site was made $3,860 \times 10^6 m^3$ according to the same kind of manner. The storage capacity curve is shown in Fig. 6-9.

- Maximum Available Discharge

  The maximum available discharge was made 430 $m^3$/sec with peaking generation of 5 hours similarly to Nam Chon Power Station.

- Power Plant Location

  In order to select the optimum location for the power plant, a dam-type power plan and a water-way type, as shown in Fig. 6-10, comparison studies were made between immediately downstream of the No. 9A site and the Nam Chon site. The schemes of the study and the results are indicated in Tables 6-10 and 6-11. As seen in the figure and tables, the dam-type power plan with maximum available discharge of 430 $m^3$/sec and maximum output of 380 MW is more advantageous than the water-way type.

  However, the scheme for the No. 9A site was found to be much poorer in economic effect than the scheme for the Nam Chon site.

(4) Optimum Plan of Development Scheme

As the results of the studies of the development scheme for the Upper Quae Yai Project, it is the most advantageous, a large-scale dam-type power plan with a large reservoir at the Nam Chon site which can immediately cope with peak demand and a dam-type power plan with a regulating pond at the Thi Khong site located in the vicinity of the backwater of Srinagarind Reservoir. Plan of this optimum schemes is indicated in Tables 6-12 to 6-14. Reservoir simulations of the Nam Chon are also indicated in Figs. 6-11 and 6-12.

Fig. 6-1 Procedure of Calculation of Power, Energy and Water Requirement

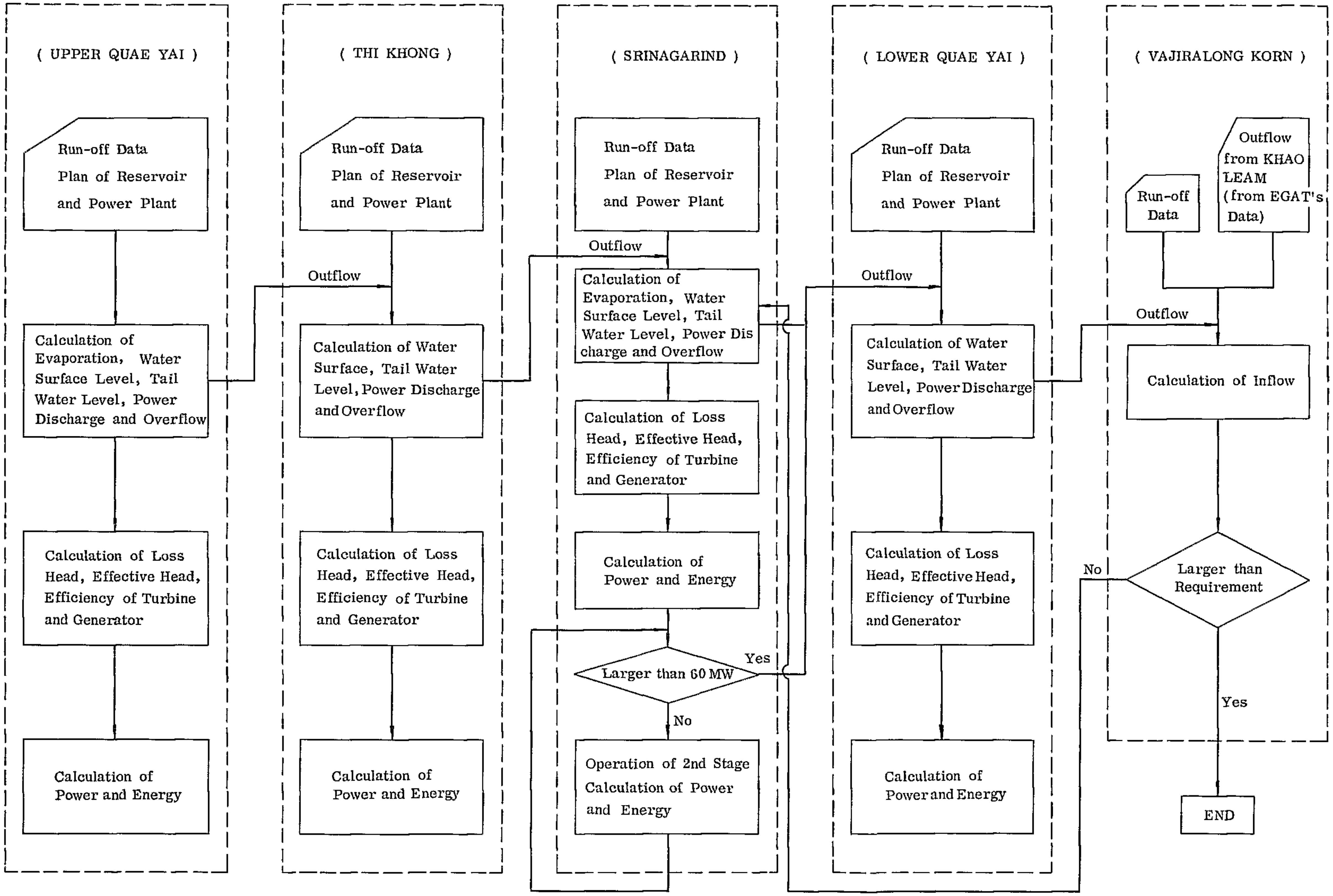
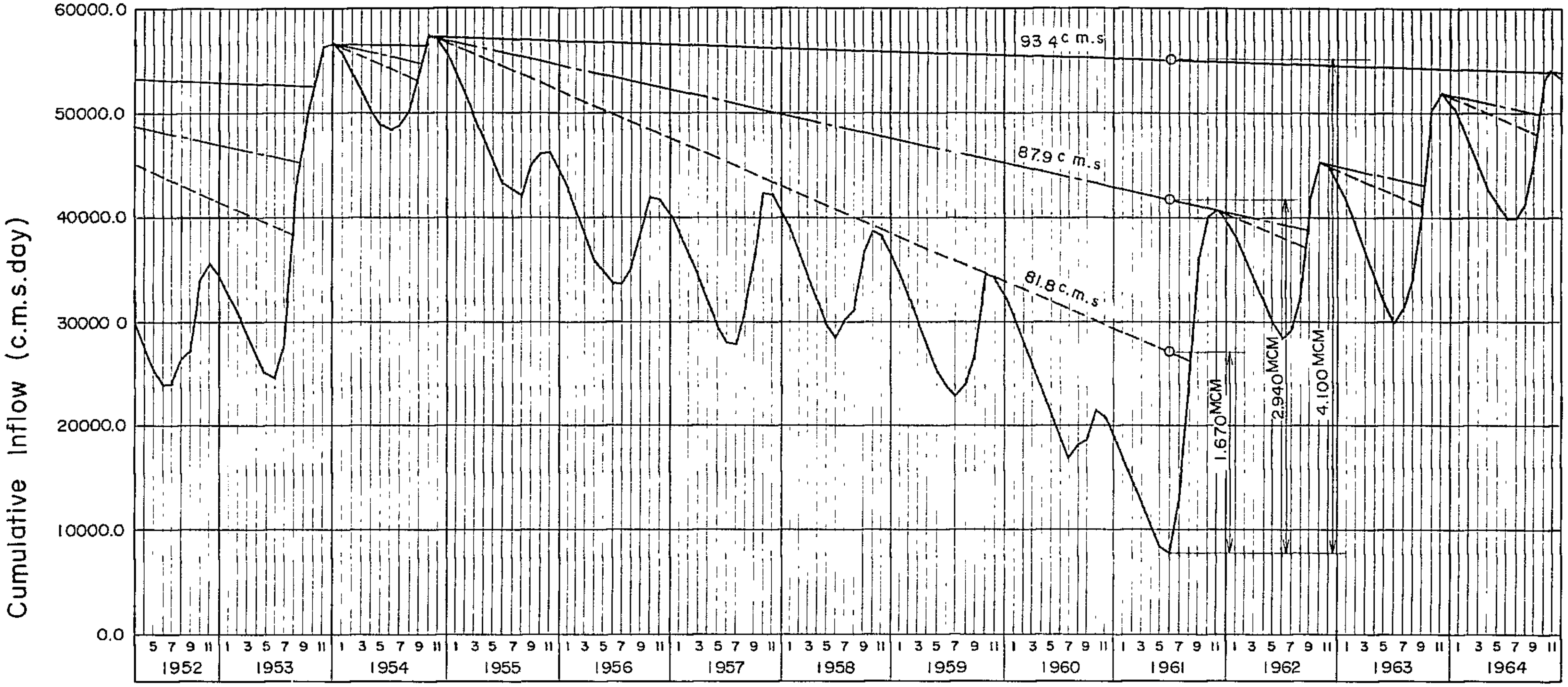


Fig 6-2 Mass Curve at Nam Chon Site



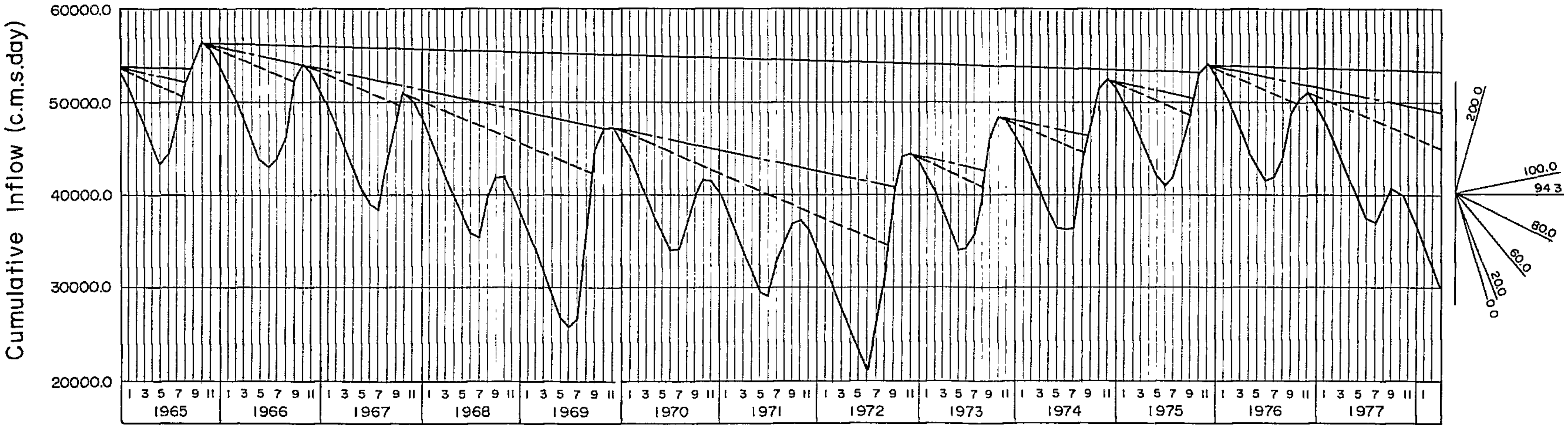
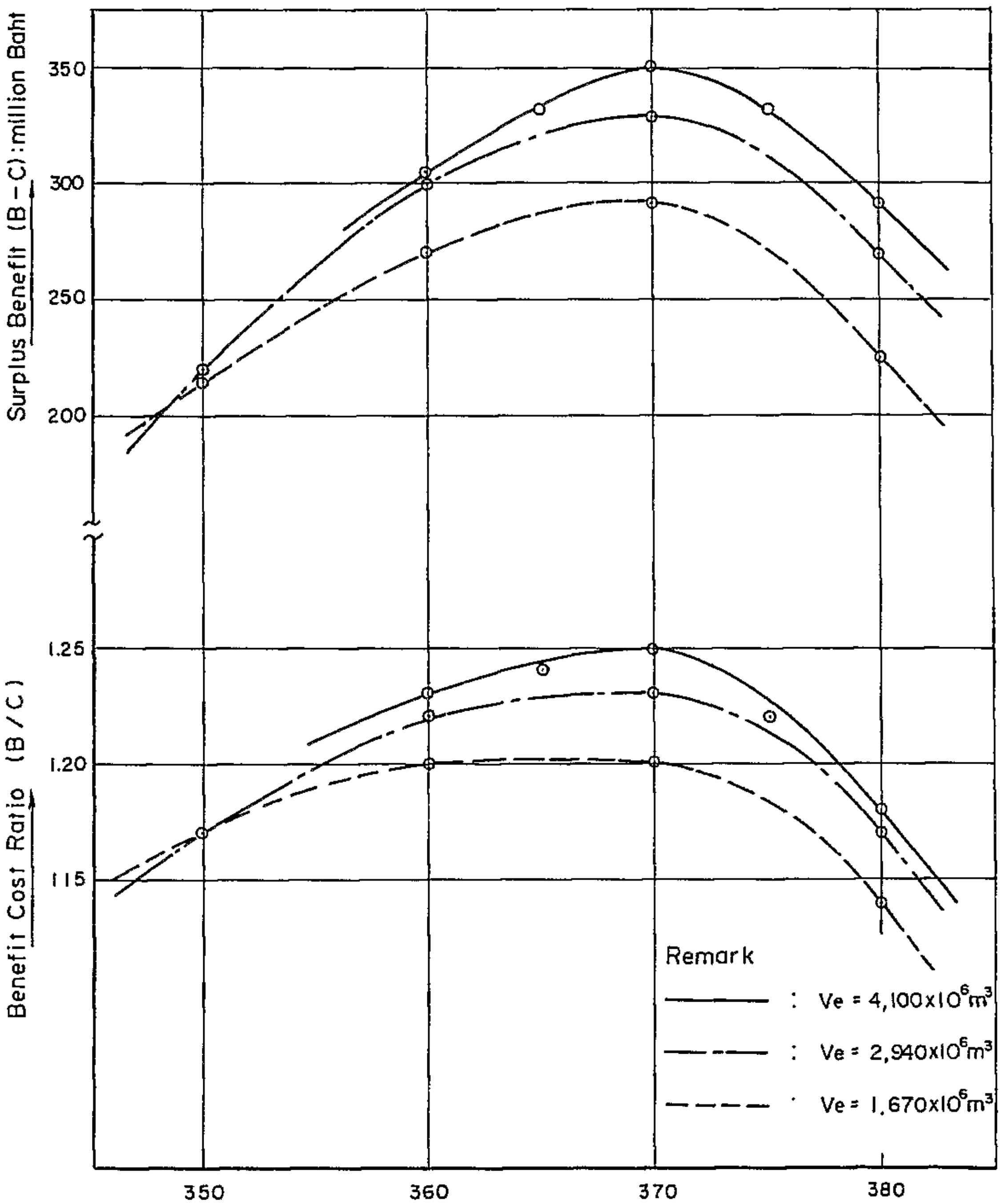
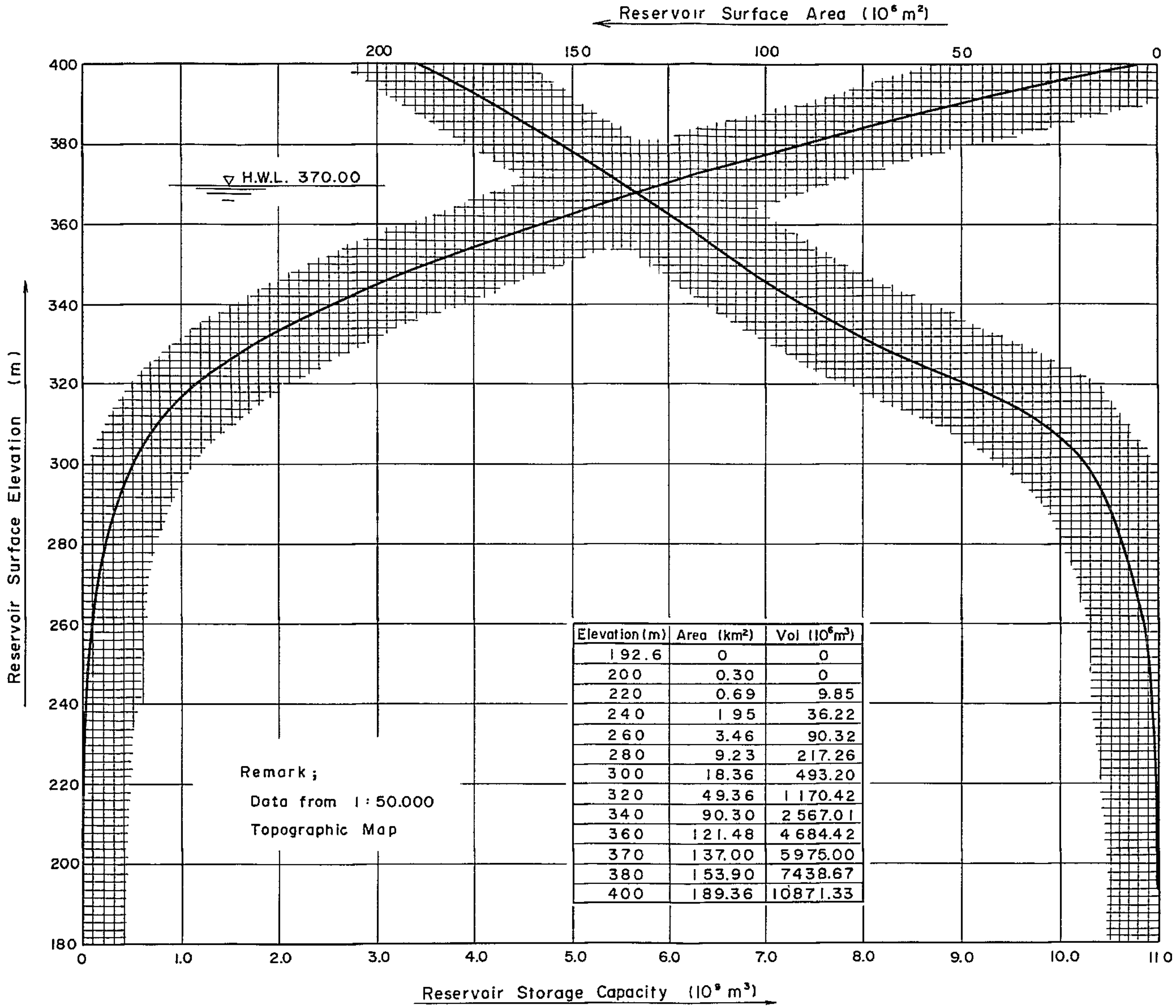



Fig.6-3 Comparison of H.W.L. and Effective Storage Capacity of Reservoir at Nam Chon Site

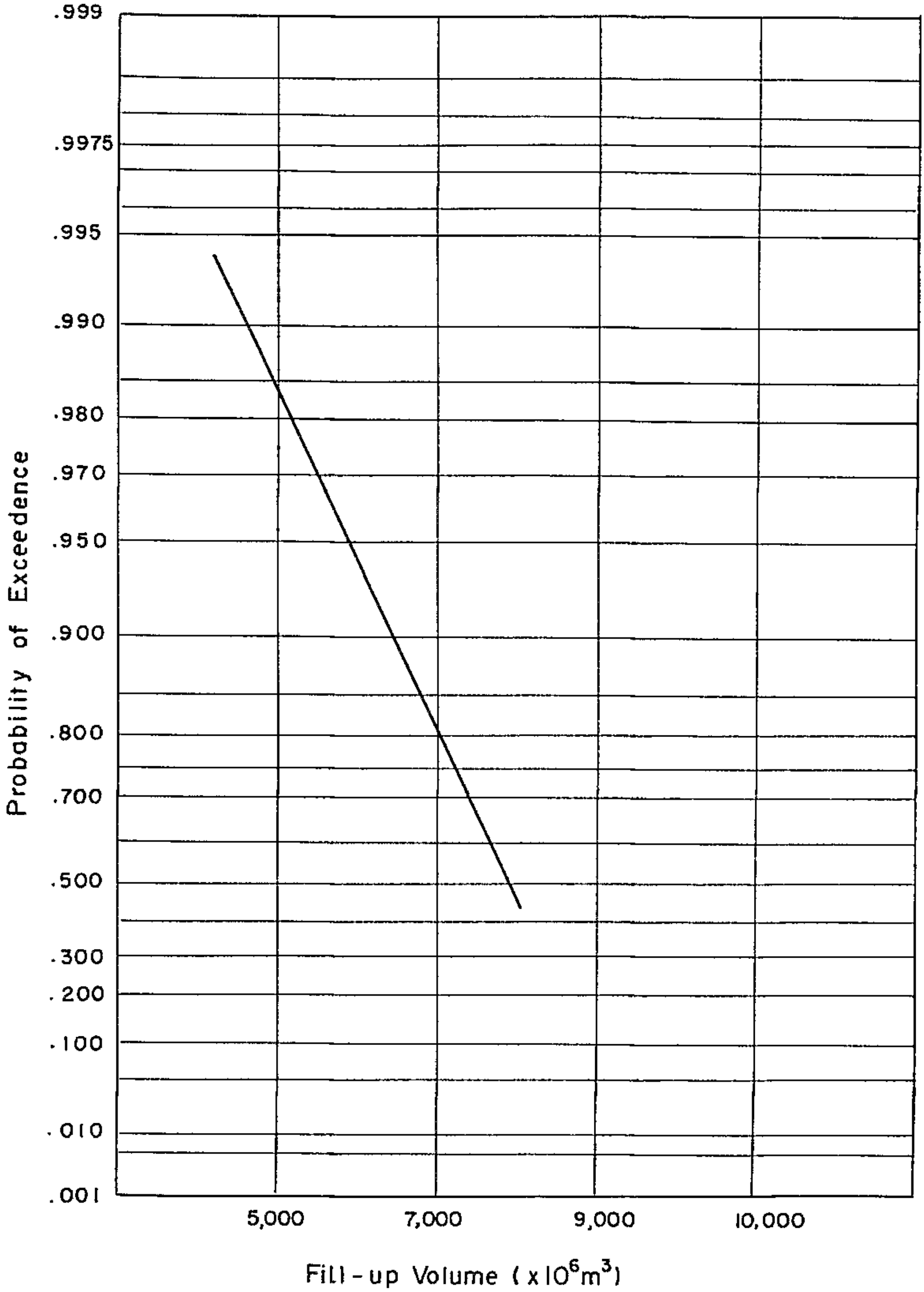


## Fig. 6-4 Storage Capacity and Surface Area at Nam Chon Site




| Elevation (m) | Area (km²) | Vol ($10^6$m³) |
|---|---|---|
| 192.6 | 0 | 0 |
| 200 | 0.30 | 0 |
| 220 | 0.69 | 9.85 |
| 240 | 1 95 | 36.22 |
| 260 | 3.46 | 90.32 |
| 280 | 9.23 | 217.26 |
| 300 | 18.36 | 493.20 |
| 320 | 49.36 | 1 170.42 |
| 340 | 90.30 | 2 567.01 |
| 360 | 121.48 | 4 684.42 |
| 370 | 137.00 | 5975.00 |
| 380 | 153.90 | 7438.67 |
| 400 | 189.36 | 10871.33 |

Fig.6-5 Relation between Fill-Up Volume and Probability of Exceedence at Nam Chon Site



# Fig. 6-6 Alternative Location of Nam Chon Power Plant

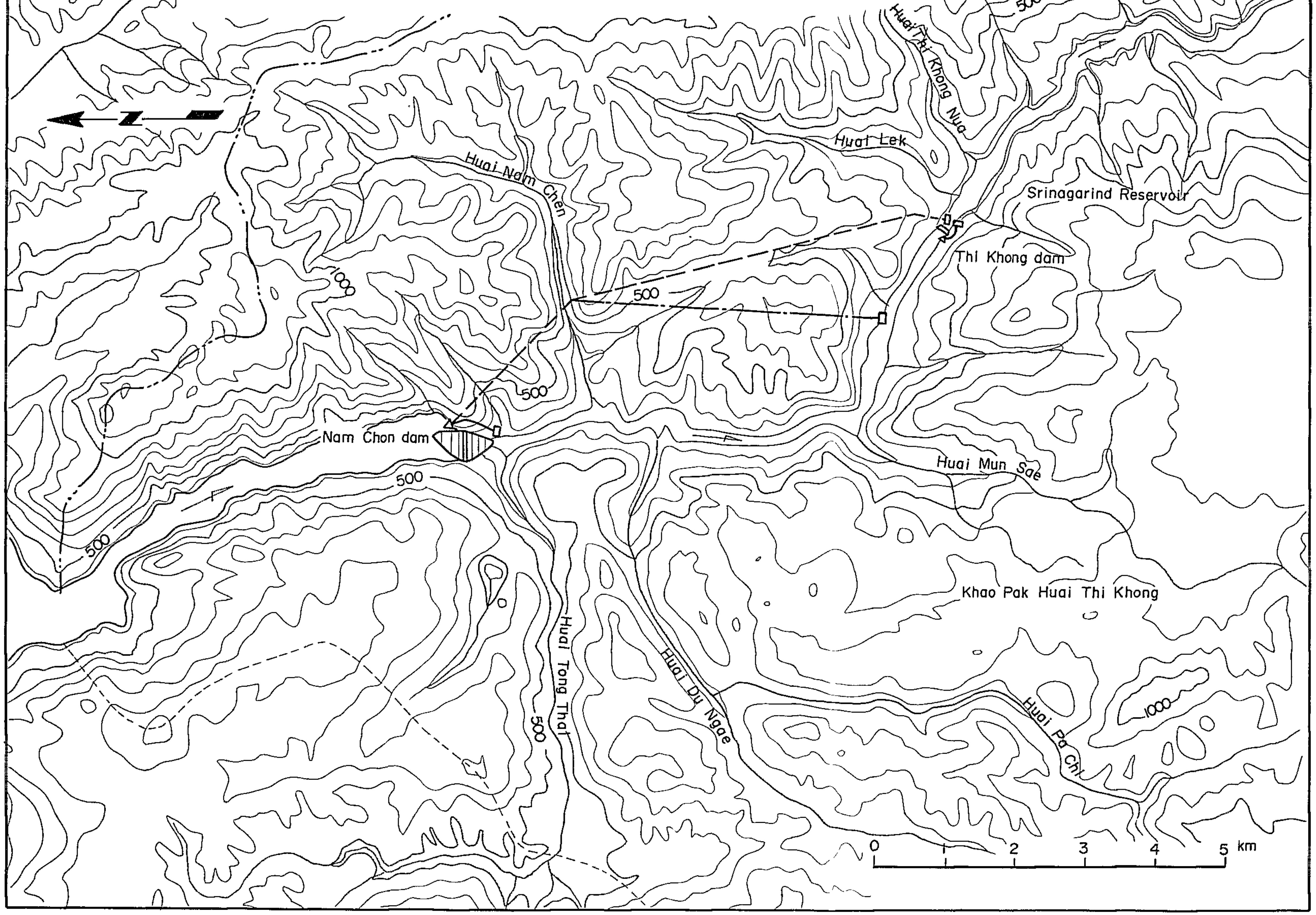
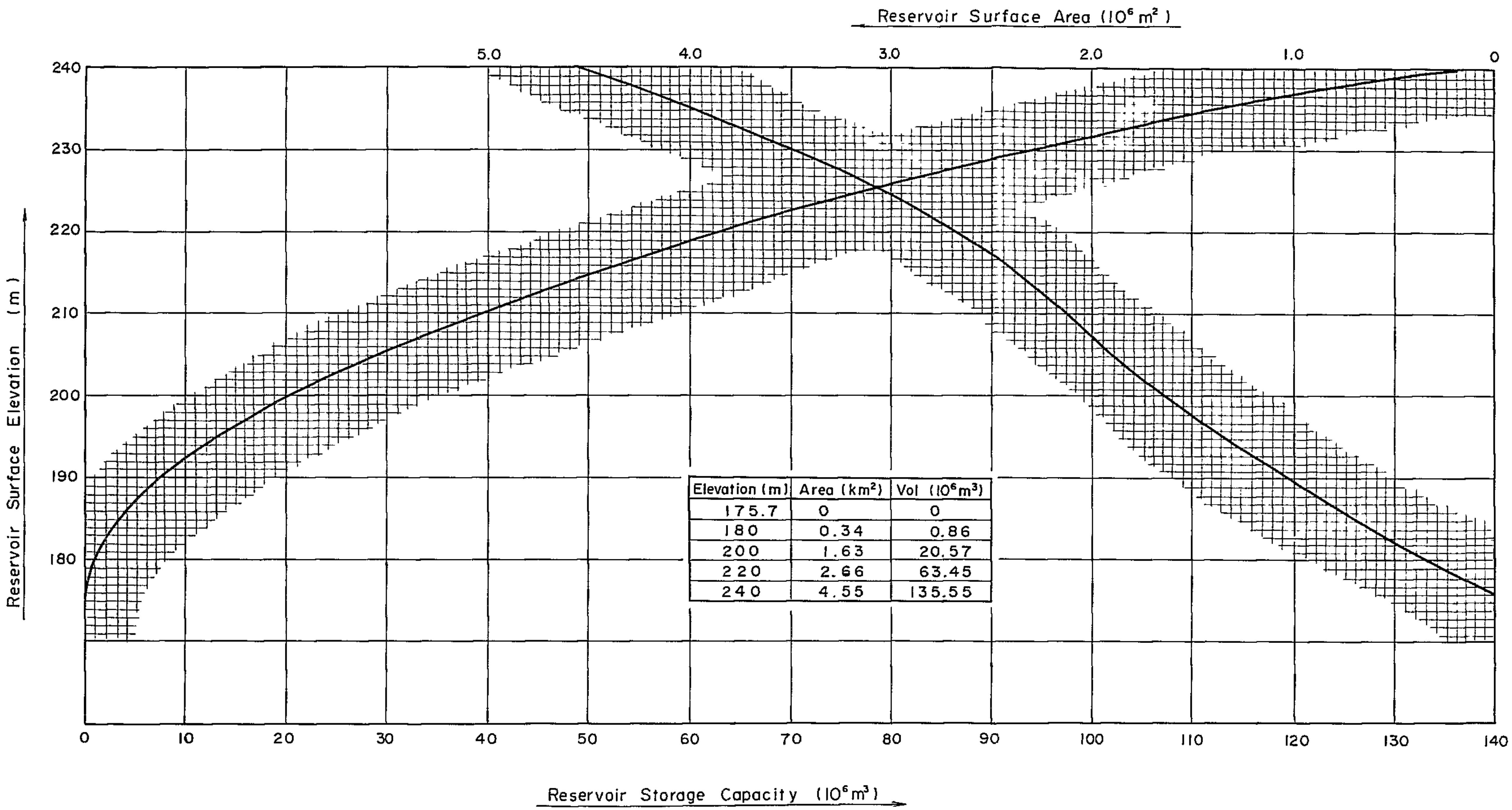


Fig. 6-7 Storage Capacity and Surface Area at Thi Khong Site




| Elevation (m) | Area (km²) | Vol ($10^6$ m³) |
|---|---|---|
| 175.7 | 0 | 0 |
| 180 | 0.34 | 0.86 |
| 200 | 1.63 | 20.57 |
| 220 | 2.66 | 63.45 |
| 240 | 4.55 | 135.55 |

Fig. 6-8 Comparison of H.W.L. of Reservoir at No. 9A Site.

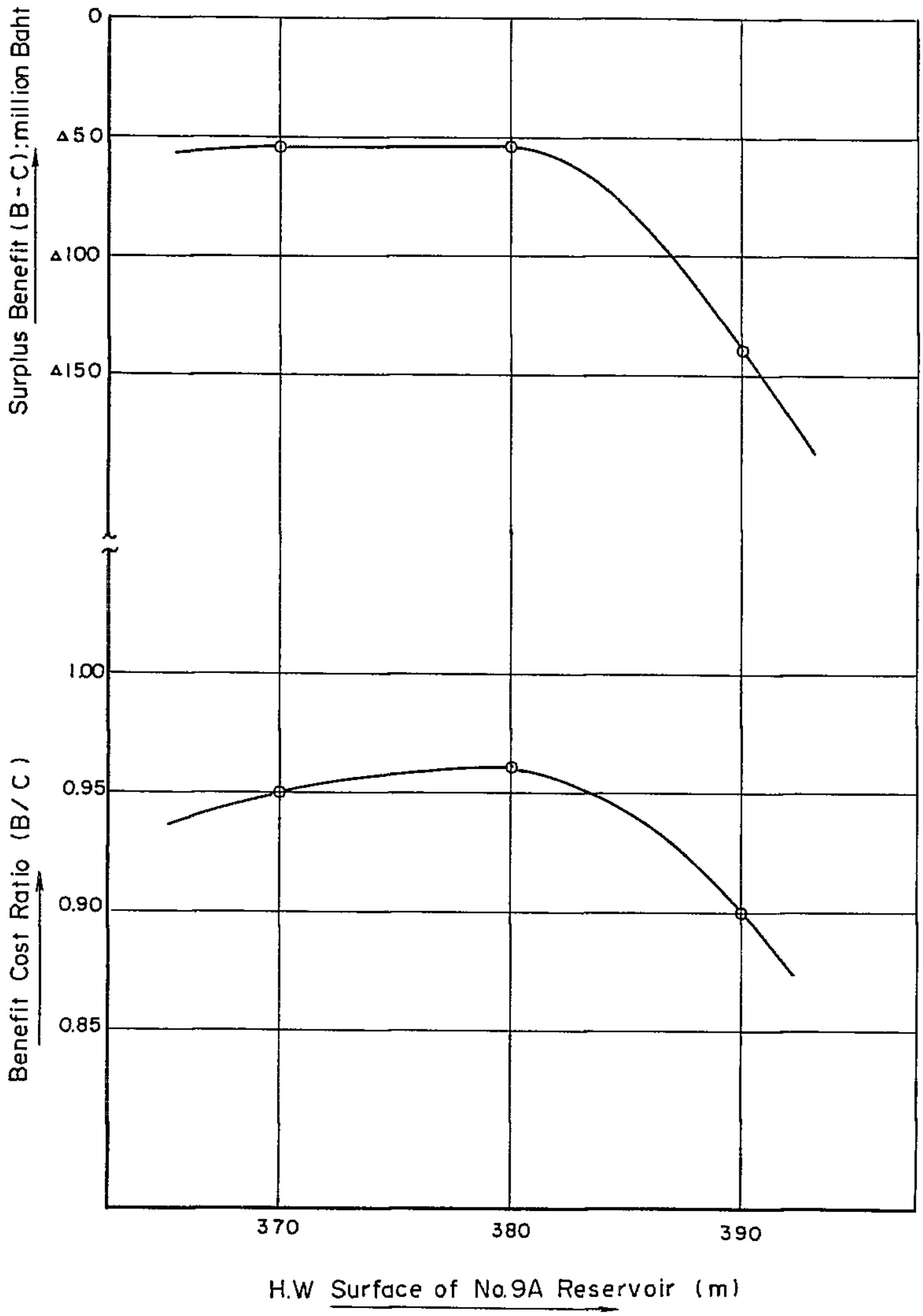
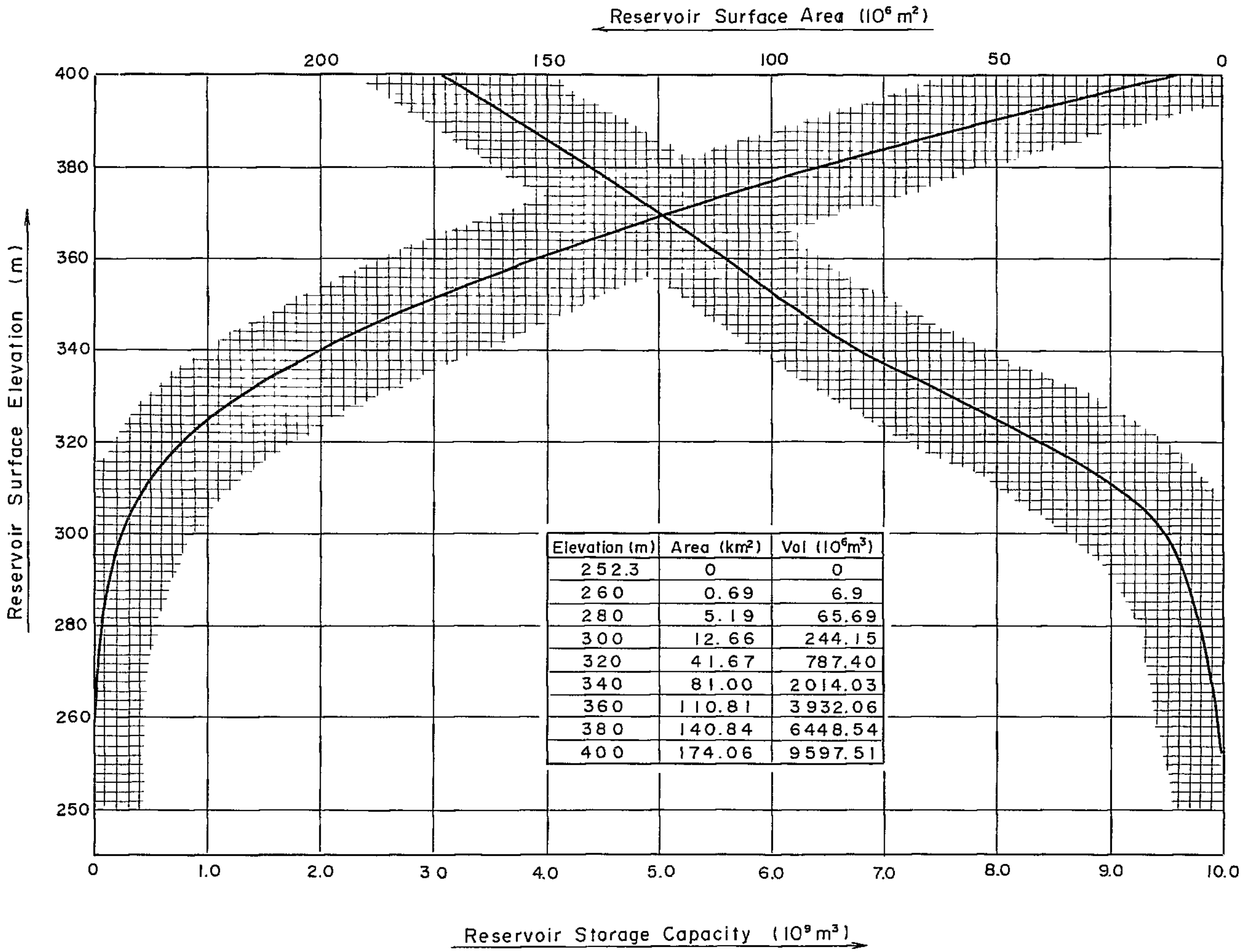


Fig.6- 9 Storage Capacity and Surface Area at No.9A Site




| Elevation (m) | Area (km²) | Vol (10⁶m³) |
|---|---|---|
| 252.3 | 0 | 0 |
| 260 | 0.69 | 6.9 |
| 280 | 5.19 | 65.69 |
| 300 | 12.66 | 244.15 |
| 320 | 41.67 | 787.40 |
| 340 | 81.00 | 2014.03 |
| 360 | 110.81 | 3932.06 |
| 380 | 140.84 | 6448.54 |
| 400 | 174.06 | 9597.51 |

Fig. 6-10 Alternative Location of NO.9A Power Plant

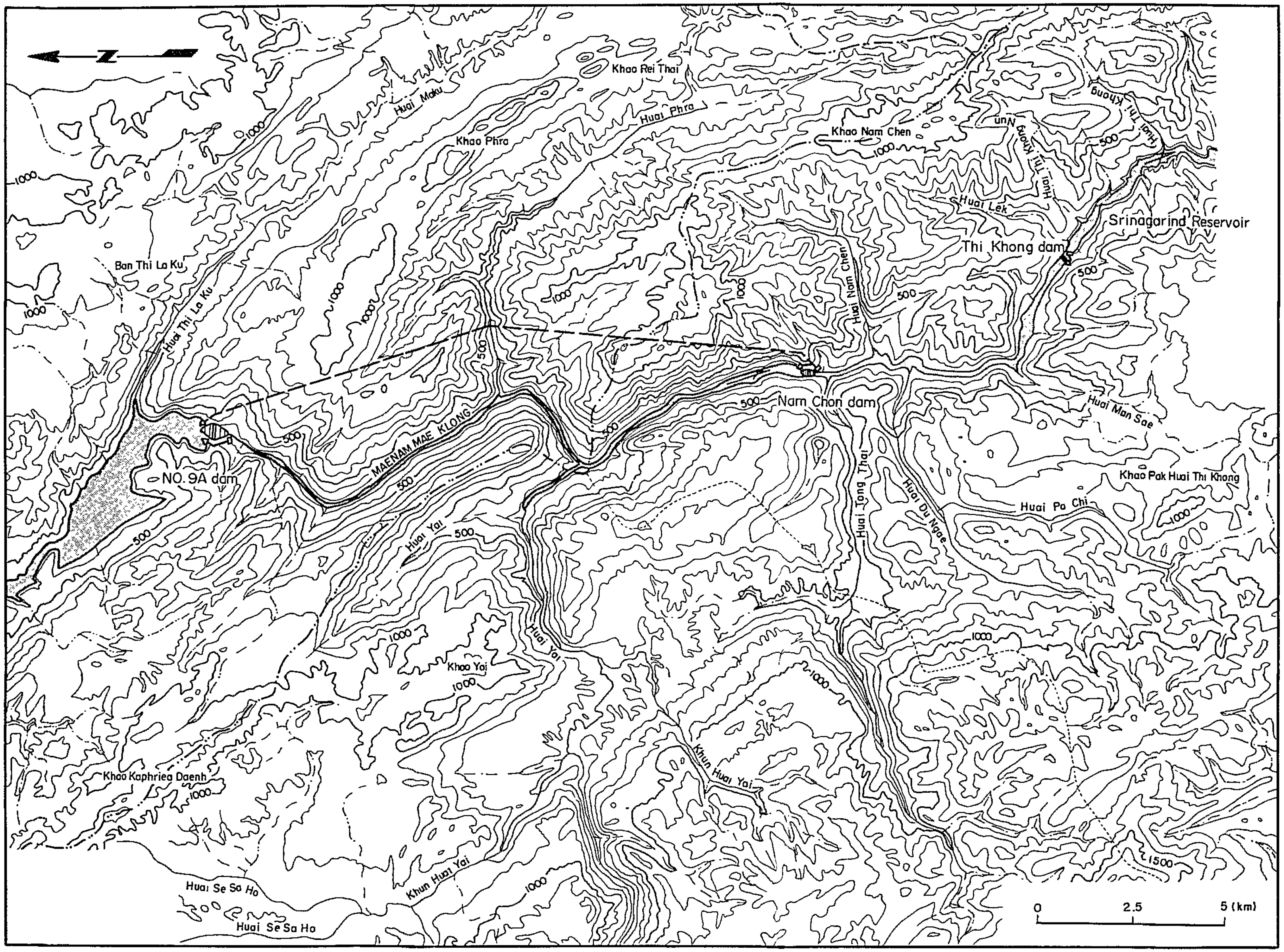
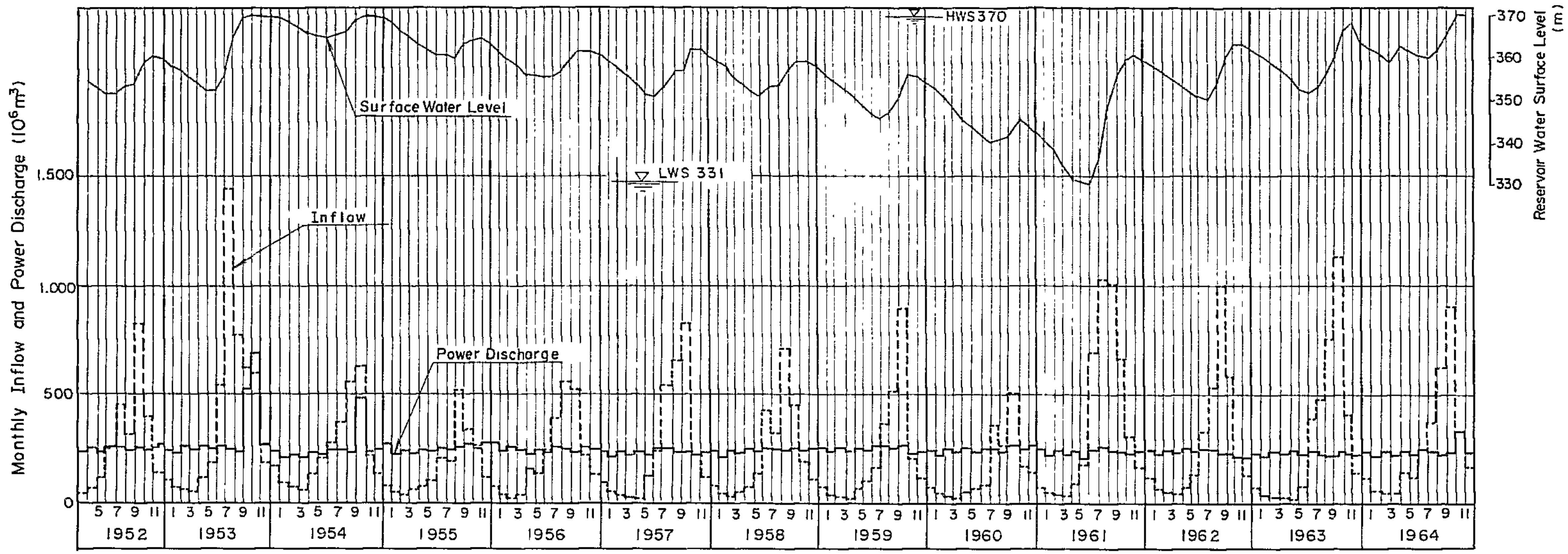


Fig. 6-11 Inflow, Power Discharge and Reservoir Water Surface at Nam Chon Power Station



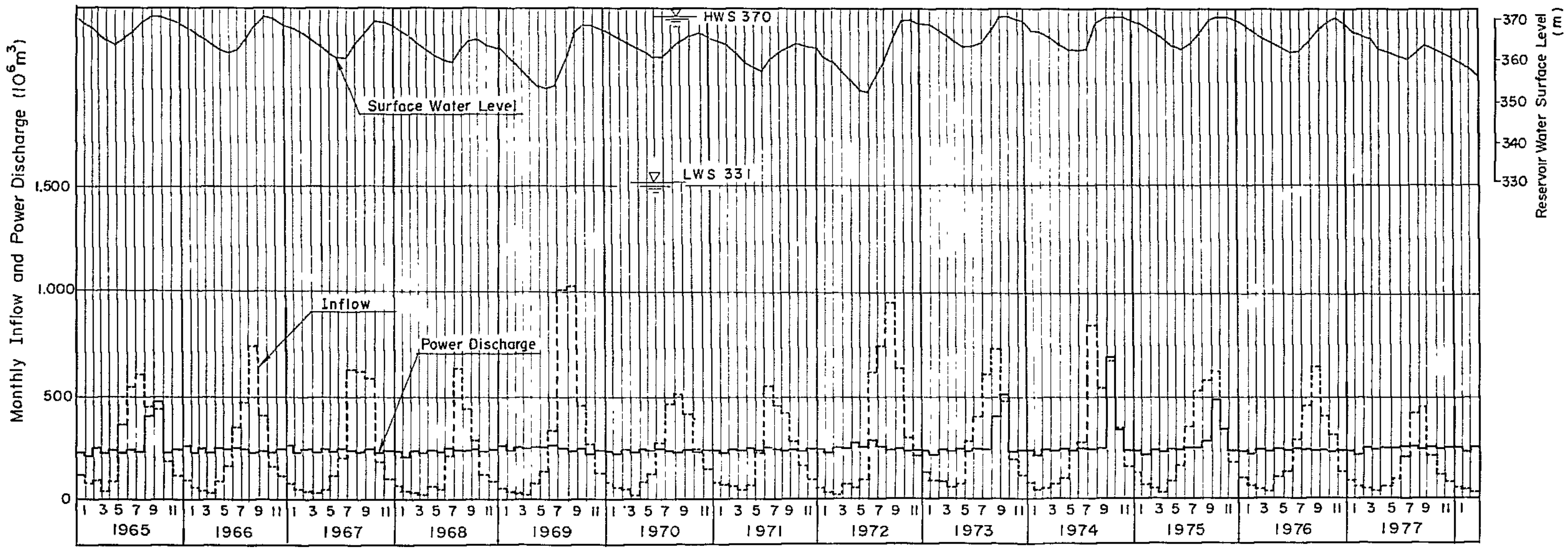
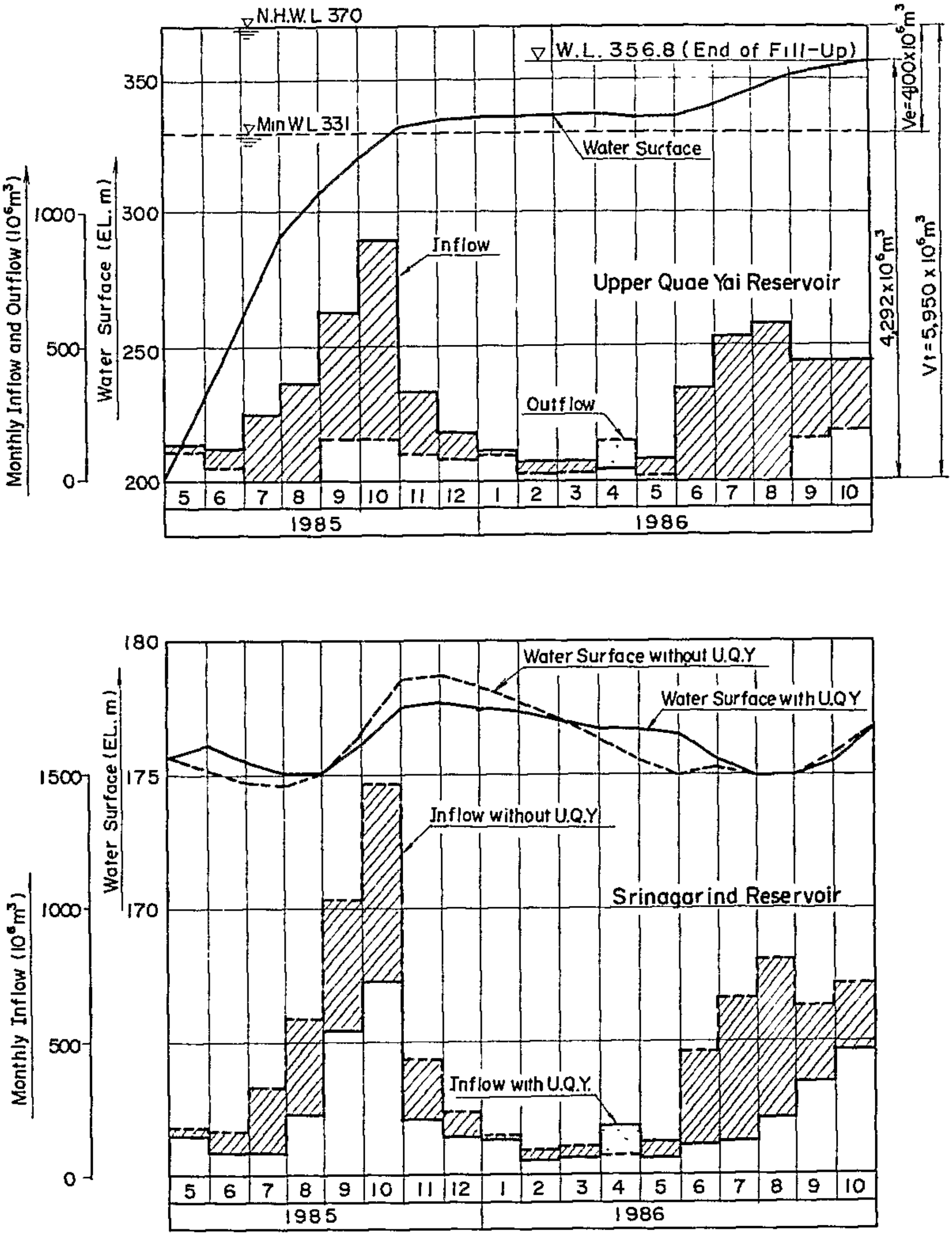



Fig.6-12 Reservoir Simulation during Fill-Up




Note : Inflow of average years (1964~1965) is adopted for the reservoir simulation during fill-up

Table 6-1 Mae Klong Basin Stage of Water Requirements (Vajiralongkorn) ( $10^6 m^3$ )

| Year | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 158.6 | 176.2 | 173.4 | 268.9 | 240.0 | 129.6 | 147.8 | 259.2 | 242.4 | 159.1 | 150.5 | 163.4 | 2,269.1 |
| 1978 | 168.2 | 182.9 | 176.5 | 282.6 | 252.3 | 129.6 | 150.0 | 273.2 | 256.6 | 167.4 | 160.4 | 173.3 | 2,373.0 |
| 1979 | 177.8 | 189.6 | 179.6 | 296.0 | 264.4 | 129.6 | 151.6 | 287.2 | 270.8 | 175.7 | 176.4 | 183.2 | 2,481.9 |
| 1980 | 187.4 | 196.3 | 182.7 | 309.6 | 276.7 | 129.6 | 153.7 | 300.9 | 284.7 | 184.0 | 180.2 | 193.1 | 2,578.9 |
| 1981 | 239.8 | 223.4 | 196.5 | 323 8 | 287.9 | 129.6 | 154.8 | 315.7 | 305.9 | 232.2 | 234.9 | 253.6 | 2,898.1 |
| 1982 | 292.1 | 250.2 | 210.5 | 338.3 | 299.2 | 129.6 | 156.2 | 330.7 | 326.8 | 280.4 | 289.6 | 314.4 | 3,218.0 |
| 1983 | 344.5 | 277.2 | 224.2 | 352.5 | 310.4 | 129.6 | 157.5 | 345.5 | 347.9 | 328.6 | 356.5 | 375.0 | 3,549.4 |
| 1984 | 376.1 | 331.9 | 246.2 | 378.7 | 339.4 | 129.6 | 162.6 | 373.2 | 361.6 | 420.5 | 450.5 | 488.0 | 4,058.3 |
| 1985 | 428.7 | 407.7 | 289.0 | 426.1 | 389.4 | 150.3 | 189.1 | 422.0 | 396.4 | 534.1 | 575.8 | 622.2 | 4,830.8 |
| 1986 | 460.3 | 462.3 | 311.0 | 452.1 | 418.1 | 150.3 | 194.2 | 450.0 | 410.1 | 625.9 | 682.0 | 735.0 | 5,351.3 |
| 1987 | 603.7 | 501.1 | 326.3 | 452.1 | 418.1 | 150.3 | 194.2 | 450.0 | 410.1 | 693.4 | 786.8 | 818.0 | 5,804.1 |
| 1988 | 746.8 | 540.0 | 341.6 | 452.1 | 418.1 | 150.3 | 194.2 | 450.0 | 410.1 | 760.7 | 837.0 | 901.0 | 6,201.9 |
| 1989 | 890.4 | 579.3 | 356.4 | 452.4 | 418.4 | 150.3 | 194.5 | 450.2 | 410.3 | 828.4 | 914.2 | 984.3 | 6,629.1 |
| 1990 ~1994 | 991.2 | 636.1 | 396.3 | 499.3 | 460.1 | 176.3 | 221.2 | 493.3 | 463.1 | 917.4 | 1,008.3 | 1,089.0 | 7,351.6 |
| 1995 ~1999 | 1,027.5 | 673.6 | 432.6 | 536.8 | 497.6 | 212.5 | 258.7 | 529.5 | 500.6 | 954.8 | 1,042.2 | 1,126.5 | 7,792.9 |
| 2000 Onward | 1,063.8 | 711.1 | 468.9 | 574.2 | 535.1 | 248.8 | 296.2 | 565.8 | 538.1 | 992.3 | 1,076.1 | 1,164.0 | 8,234.4 |

Table 6-2 Plan of the Alternative Schemes at Nam Chon Site

| Item | Unit | Ve = 4,100 x $10^6m^3$ | | | | | Ve = 2,940 x $10^6m^3$ | | | | Ve = 1,670 x $10^6m^3$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HWL 360 | HWL 365 | HWL 370 | HWL 375 | HWL 380 | HWL 350 | HWL 360 | HWL 370 | HWL 380 | HWL 350 | HWL 360 | HWL 370 | HWL 380 |
| STREAM FLOW | | | | | | | | | | | | | | |
| Catchment Area | $km^2$ | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 | 4,908 |
| Average Annual Runoff | $10^6m^3$ | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 | 2,975 |
| RESERVOIR | | | | | | | | | | | | | | |
| Normal High Water Level | m | 360 | 365 | 370 | 375 | 380 | 350 | 360 | 370 | 380 | 350 | 360 | 370 | 380 |
| Total Storage Capacity | $10^6m^3$ | 4,684 | 5,260 | 5,950 | 6,700 | 7,439 | 3,550 | 4,684 | 5,950 | 7,439 | 3,550 | 4,684 | 5,950 | 7,439 |
| Minimum Water Level | m | 303 | 320 | 331 | 341 | 348 | 305 | 330 | 345 | 359 | 332 | 345 | 357 | 369 |
| Available Drawdown | m | 57 | 45 | 39 | 34 | 32 | 45 | 30 | 25 | 21 | 18 | 15 | 13 | 11 |
| Inactive Storage Capacity | $10^6m^3$ | 584 | 1,160 | 1,850 | 2,600 | 3,339 | 610 | 1,744 | 3,010 | 4,499 | 1,880 | 3,014 | 4,280 | 5,769 |
| Effective Storage Capacity | $10^6m^3$ | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 | 2,940 | 2,940 | 2,940 | 2,940 | 1,670 | 1,670 | 1,670 | 1,670 |
| DAM | | | | | | | | | | | | | | |
| Type | | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill | Rockfill |
| Height | m | 175 | 180 | 185 | 190 | 195 | 165 | 175 | 185 | 195 | 165 | 175 | 185 | 195 |
| Volume | $10^6m^3$ | 10.7 | 11.8 | 12.7 | 14.1 | 16.1 | 9.0 | 10.7 | 12.7 | 16.1 | 9.0 | 10.7 | 12.7 | 16.1 |
| HEADRACE | | | | | | | | | | | | | | |
| Inner Diameter x Number of Lines | m | 7.9 x 2 | 7.9 x 2 | 7.9 x 2 | 7.9 x 2 | 7.9 x 2 | 7.6 x 2 | 7.6 x 2 | 7.6 x 2 | 7.6 x 2 | 7.2 x 2 | 7.2 x 2 | 7.2 x 2 | 7.2 x 2 |
| Total Length | m | 840 | 830 | 820 | 817 | 815 | 880 | 840 | 820 | 815 | 880 | 840 | 820 | 815 |
| PEN STOCK | | | | | | | | | | | | | | |
| Inner Diameter x Number of Lines | m | 5.0 x 4 | 5.0 x 4 | 5.0 x 4 | 5.0 x 4 | 5.0 x 4 | 4.8 x 4 | 4.8 x 4 | 4.8 x 4 | 4.8 x 4 | 4.6 x 4 | 4.6 x 4 | 4.6 x 4 | 4.6 x 4 |
| Total Length | m | 994 | 1,020 | 1,040 | 1,056 | 1,070 | 952 | 994 | 1,040 | 1,070 | 952 | 994 | 1,040 | 1,070 |
| POWER GENERATING | | | | | | | | | | | | | | |
| Normal Intake Level | m | 341 | 347 | 353 | 360 | 366 | 334 | 347 | 358 | 370 | 342 | 353 | 364 | 375 |
| Tailwater Level | m | 200.5 | 200.5 | 200.5 | 200.5 | 200.5 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| Normal Effective Head | m | 134.5 | 140.5 | 146.5 | 153.5 | 159.5 | 128 | 141 | 152 | 164 | 136 | 147 | 158 | 169 |
| Maximum Discharge | $m^3/s$ | 460 | 460 | 460 | 460 | 460 | 430 | 430 | 430 | 430 | 385 | 385 | 385 | 385 |
| Installed Capacity | MW | 530 | 560 | 580 | 610 | 630 | 470 | 520 | 560 | 610 | 450 | 490 | 520 | 560 |
| Number of Units | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

Table 6-3 Economic Evaluation of the Alternative Schemes at Nam Chon Site

| Item | Unit | Ve = 4,100 x $10^6 m^3$ | | | | | Ve = 2,940 x $10^6 m^3$ | | | | Ve = 1,670 x $10^6 m^3$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HWL 360 | HWL 365 | HWL 370 | HWL 375 | HWL 380 | HWL 350 | HWL 360 | HWL 370 | HWL 380 | HWL 350 | HWL 360 | HWL 370 | HWL 380 |
| Dependable Capability | MW | 541(15) | 571(15) | 591(15) | 619(15) | 638(15) | 481(13) | 530(14) | 571(14) | 616(14) | 461(12) | 501(13) | 532(13) | 572(13) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Effective Capability | MW | 522 | 551 | 570 | 597 | 616 | 464 | 511 | 551 | 594 | 445 | 483 | 513 | 552 |
| Value per kW | Ƀ/kW | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 | 1,224 |
| Benefit of kW (B1) | MɃ | 639 | 674 | 698 | 731 | 754 | 568 | 625 | 674 | 727 | 545 | 591 | 628 | 676 |
| Annual Firm Energy | GWH | 975(14) | 1,024(18) | 1,075(23) | 1,124(29) | 1,173(35) | 850(△5) | 945(2) | 1,019(2) | 1,107(8) | 802(△17) | 873(△18) | 928(△20) | 1,001(△19) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Effective Firm Energy | GWH | 941 | 988 | 1,037 | 1,085 | 1,132 | 820 | 912 | 983 | 1,068 | 774 | 842 | 896 | 966 |
| Value per kWH | Ƀ/kWH | | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 | 1.013 |
| Benefit of kWH (B2) | MɃ | 953 | 1,001 | 1,050 | 1,099 | 1,147 | 831 | 924 | 996 | 1,082 | 784 | 853 | 908 | 979 |
| Annual Secondary Energy | GWH | 72(1) | 41(△5) | 33(△10) | 6(△16) | △2(△23) | 142(19) | 113(11) | 109(9) | 85(1) | 206(33) | 196(28) | 209(27) | 221(30) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Effective Secondary Energy | GWH | 69 | 40 | 32 | 6 | △2 | 137 | 109 | 105 | 82 | 199 | 189 | 202 | 213 |
| Value per kWH | Ƀ/kWH | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 | 0.864 |
| Benefit of kWH (B3) | MɃ | 60 | 35 | 28 | 5 | 2 | 118 | 94 | 91 | 71 | 172 | 163 | 175 | 184 |
| Total Annual Benefit (B)<br>(B) = (B1) + (B2) + (B3) | MɃ | 1,652 | 1,710 | 1,776 | 1,835 | 1,899 | 1,517 | 1,643 | 1,761 | 1,880 | 1,501 | 1,607 | 1,711 | 1,839 |
| Construction Cost | MɃ | 10,833 | 10,997 | 11,244 | 11,724 | 12,256 | 10,570 | 10,745 | 11,242 | 12,207 | 10,464 | 10,682 | 11,038 | 12,050 |
| Decreased Energy Cost | " | 803 | 900 | 1,064 | 1,261 | 1,610 | 629 | 846 | 1,124 | 1,689 | 646 | 856 | 1,215 | 1,879 |
| Total Cost | " | 11,636 | 11,897 | 12,308 | 12,985 | 13,866 | 11,199 | 11,591 | 12,366 | 13,896 | 11,110 | 11,538 | 12,253 | 13,929 |
| Annual Cost (C) | " | 1,348 | 1,378 | 1,426 | 1,504 | 1,607 | 1,298 | 1,343 | 1,433 | 1,610 | 1,287 | 1,337 | 1,420 | 1,614 |
| Surplus Benefit (B - C) | MɃ | 304 | 332 | 350 | 331 | 292 | 219 | 300 | 328 | 270 | 214 | 270 | 291 | 225 |
| Benefit - Cost Ratio (B/C) | - | 1.23 | 1.24 | 1.25 | 1.22 | 1.18 | 1.17 | 1.22 | 1.23 | 1.17 | 1.17 | 1.20 | 1.20 | 1.14 |

Note: Values in parenthesis mean increased energy after completion
for the down stream power plant

Table 6-4 Comparative Plan of Nam Chon Power Plant
( study of maximum discharge )

| Item | Unit | 5 hours Peak | 4 hours Peak |
|---|---|---|---|
| STREAM FLOW | | | |
| Catchment Area | $km^2$ | 4,908 | 4,908 |
| Average Annual Runoff | $10^6m^3$ | 2,975 | 2,975 |
| RESERVOIR | | | |
| Normal High Water Level | m | 370 | 370 |
| Total Storage Capacity | $10^6m^3$ | 5,950 | 5,950 |
| Minimum Water Level | m | 331 | 331 |
| Available Drawdown | m | 39 | 39 |
| Inactive Storage Capacity | $10^6m^3$ | 1,850 | 1,850 |
| Effective Storage Capacity | $10^6m^3$ | 4,100 | 4,100 |
| DAM | | | |
| Type | | Rockfill | Rockfill |
| Height | m | 185 | 185 |
| Volume | $10^6m^3$ | 12.7 | 12.7 |
| HEADRACE | | | |
| Inner Diameter x Number of Lines | m | 7.9 x 2 | 8.8 x 2 |
| Total Length | m | 820 | 820 |
| PEN STOCK | | | |
| Inner Diameter x Number of Lines | m | 5.0 x 4 | 5.6 x 4 |
| Total Length | m | 1,040 | 1,040 |
| POWER GENERATING | | | |
| Normal Intake Level | m | 353 | 353 |
| Tailwater Level | m | 200.5 | 201 |
| Normal Effective Head | m | 146.5 | 146 |
| Maximum Discharge | $m^3/s$ | 460 | 575 |
| Installed Capacity | MW | 580 | 730 |
| Number of Units | | 4 | 4 |

Table 6-5 Economic Evaluation of the Comparative Plan
( study of maximum discharge )

| Item | | Unit | 5 Hours Peak | 4 Hours Peak |
|---|---|---|---|---|
| Dependable Capability | | MW | 591 (15) | 737 (15) |
| Loss & Stopping | | % | 3.5 | 3.5 |
| Effective Capability | | MW | 570 | 711 |
| Value per kW | | ฿/kW | 1,224 | 1,224 |
| Benefit of kW | ( B1 ) | M฿ | 698 | 870 |
| Annual Firm Energy | | GWH | 1,075 (23) | 1,078 (23) |
| Loss & Stopping | | % | 3.5 | 3.5 |
| Effective Firm Energy | | GWH | 1,037 | 1,040 |
| Value per kWH | | ฿/kWH | 1.013 | 1.013 |
| Benefit of kWH | ( B2 ) | M฿ | 1,050 | 1,054 |
| Annual Secondary Energy | | GWH | 33 (△10) | 23 (△10) |
| Loss & Stopping | | % | 3.5 | 3.5 |
| Effective Secondary Energy | | GWH | 32 | 22 |
| Value per kWH | | ฿/kWH | 0.864 | 0.864 |
| Benefit of kWH | ( B3 ) | M฿ | 28 | 19 |
| Total Annual Benefit<br>(B) = (B1) + (B2) + (B3) | ( B ) | M฿ | 1,776 | 1,943 |
| Construction Cost | | M฿ | 11,244 | 12,896 |
| Decreased Energy Cost | | " | 1,064 | 1,064 |
| Total Cost | | " | 12,308 | 13,960 |
| Annual Cost | ( C ) | " | 1,426 | 1,617 |
| Surplus Benefit | ( B – C ) | M฿ | 350 | 326 |
| Benefit – Cost Ratio | ( B/C ) | – | 1.25 | 1.20 |

Note: Values in parenthesis mean increased energy after completion for the down stream power plant

Table 6-6 Comparative Plan of the Nam Chon Power Plant (study of power plant location)

| Item | Unit | Dam-Type | | Water Way-Type | |
|---|---|---|---|---|---|
| | | Nam Chon | Thi Khong | (1) | (2) |
| STREAM FLOW | | | | | |
| Catchmen Area | $km^2$ | 4,908 | 5,154 | 4,908 | 4,908 |
| Average Annual Runoff | $10^6m^3$ | 2,975 | 3,090 | 2,975 | 2,975 |
| RESERVOIR | | | | | |
| Normal High Water Level | m | 370 | 197 | 370 | 370 |
| Total Storage Capacity | $10^6m^3$ | 5,950 | 16 | 5,950 | 5,950 |
| Minimum Water Level | m | 331 | 196.8 | 331 | 331 |
| Available Drawdown | m | 39 | 0.2 ( 3.5) | 39 | 39 |
| Inactive Storage Capacity | $10^6m^3$ | 1,850 | 15.7 (11.7) | 1,850 | 1,850 |
| Effective Storage Capacity | $10^6m^3$ | 4,100 | 0.3 ( 4.3) | 4,100 | 4,100 |
| DAM | | | | | |
| Type | | Rockfill | Gravity | Rockfill | Rockfill |
| Height | m | 185 | 32 | 185 | 185 |
| Volume | $10^6m^3$ | 12.7 | 0.046 | 12.7 | 12.7 |
| HEADRACE | | | | | |
| Inner Diameter x Number of Lines | m | 7.9 x 2 | — | 7.9 x 2 | 7.9 x 2 |
| Total Length | m | 820 | — | 14,960 | 12,900 |
| PEN STOCK | | | | | |
| Inner Diameter x Number of Lines | m | 5.0 x 4 | — | 5.0 x 4 | 5.0 x 4 |
| Total Length | m | 1,040 | — | 1,200 | 1,500 |
| POWER GENERATING | | | | | |
| Normal Intake Level | m | 353 | 197 | 353 | 353 |
| Tailwater Level | m | 200.5 | 183.5 | 183.5 | 184.5 |
| Normal Effective Head | m | 146.5 | 12.5 | 153.5 | 154 |
| Maximum Discharge | $m^3/s$ | 460 | 480 | 460 | 460 |
| Installed Capacity | MW | 580 | 51 | 610 | 610 |
| Number of Units | | 4 | 2 | 4 | 4 |

Note: Values in parenthesis mean in the case of urgent need

Table 6-7 Economic Evaluation of the Comparative Plan of Nam Chon Power Plant

( study of power plant location )

| Item | Unit | Dam-Type | | | Water Way-Type | |
|---|---|---|---|---|---|---|
| | | Nam Chon | Thi Khong | Total | (1) | (2) |
| Dependable Capability | MW | 591 (15) | 48 | 639 (15) | 621 (15) | 622 (15) |
| Loss & Stopping | % | 3.5 | 3.5 | — | 3.5 | 3.5 |
| Effective Capability | MW | 570 | 46 | 616 | 599 | 600 |
| Value per kW | Ƀ/kW | 1,224 | 1,224 | — | 1,224 | 1,224 |
| Benefit of kW ( B1 ) | MɃ | 698 | 56 | 754 | 733 | 734 |
| Annual Firm Energy | GWH | 1,075 (23) | 89 | 1,164 (23) | 1,130 (23) | 1,131 (23) |
| Loss & Stopping | % | 3.5 | 3.5 | — | 3.5 | 3.5 |
| Effective Firm Energy | GWH | 1,037 | 86 | 1,123 | 1,090 | 1,091 |
| Value per kWH | Ƀ/kWH | 1.013 | 1.013 | — | 1.013 | 1.013 |
| Benefit of kWH ( B2 ) | MɃ | 1,050 | 87 | 1,137 | 1,104 | 1,105 |
| Annual Secondary Energy | GWH | 33 (△10) | 4 | 37 (△10) | 37 (△10) | 39 (△10) |
| Loss & Stopping | % | 3.5 | 3.5 | — | 3.5 | 3.5 |
| Effective Secondary Energy | GWH | 32 | 4 | 36 | 36 | 38 |
| Value per kWH | Ƀ/kWH | 0.864 | 0.864 | — | 0.864 | 0.864 |
| Benefit of kWH ( B3 ) | MɃ | 28 | 3 | 31 | 31 | 33 |
| Total Annual Benefit ( B )<br>(B) = (B1) + (B2) + (B3) | MɃ | 1,776 | 146 | 1,922 | 1,868 | 1,872 |
| Construction Cost | MɃ | 11,244 | 1,103 | 12,347 | 15,066 | 14,615 |
| Decreased Energy Cost | " | 1,064 | — | 1,064 | 1,064 | 1,064 |
| Total Cost | " | 12,308 | 1,103 | 13,411 | 16,130 | 15,679 |
| Annual Cost ( C ) | " | 1,426 | 128 | 1,554 | 1,869 | 1,817 |
| Surplus Benefit ( B − C ) | MɃ | 350 | 18 | 368 | △1 | 55 |
| Benefit − Cost Ratio ( B/C ) | — | 1.25 | 1.14 | 1.24 | 1.00 | 1.03 |

Note: Values in parenthesis mean increased energy after completion for the down stream power plant

Table 6-8 Plan of the Alternative Schemes at No. 9A Site

| Item | Unit | HWL 370 | HWL 380 | HWL 390 |
|---|---|---|---|---|
| STREAM FLOW | | | | |
| Catchment Area | $km^2$ | 4,524 | 4,524 | 4,524 |
| Average Annual Runoff | $10^6m^3$ | 2,802 | 2,802 | 2,802 |
| RESERVOIR | | | | |
| Normal High Water Level | m | 370 | 380 | 390 |
| Total Storage Capacity | $10^6m^3$ | 5,100 | 6,449 | 7,970 |
| Minimum Water Level | m | 330 | 347 | 362 |
| Available Drawdown | m | 40 | 33 | 28 |
| Inactive Storage Capacity | $10^6m^3$ | 1,243 | 2,592 | 4,113 |
| Effective Storage Capacity | $10^6m^3$ | 3,857 | 3,857 | 3,857 |
| DAM | | | | |
| Type | | Rockfill | Rockfill | Rockfill |
| Height | m | 125 | 135 | 145 |
| Volume | $10^6m^3$ | 5.3 | 6.7 | 9.0 |
| HEADRACE | | | | |
| Inner Diameter x Number of Lines | m | 7.6 x 2 | 7.6 x 2 | 7.6 x 2 |
| Total Length | m | 635 | 615 | 600 |
| PEN STOCK | | | | |
| Inner Diameter x Number of Lines | m | 4.8 x 4 | 4.8 x 4 | 4.8 x 4 |
| Total Length | m | 1,520 | 1,600 | 1,680 |
| POWER GENERATING | | | | |
| Normal Intake Level | m | 353 | 365 | 337 |
| Tailwater Level | m | 257 | 257 | 257 |
| Normal Effective Head | m | 90 | 101 | 114 |
| Maximum Discharge | $m^3/s$ | 430 | 430 | 430 |
| Installed Capacity | MW | 330 | 380 | 420 |
| Number of Units | | 4 | 4 | 4 |

Table 6-9 Economic Evaluation of the Alternative Schemes at No. 9A Site

| Item | Unit | HWL 370 | HWL 380 | HWL 390 |
|---|---|---|---|---|
| Dependable Capability | MW | 344 (15) | 392 (15) | 430 (13) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 |
| Effective Capability | MW | 332 | 378 | 415 |
| Value per kW | ฿/kW | 1,224 | 1,224 | 1,224 |
| Benefit of kW ( B1 ) | M฿ | 406 | 463 | 508 |
| Annual Firm Energy | GWH | 620 (18) | 704 (16) | 758 (△4) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 |
| Effective Firm Energy | GWH | 598 | 679 | 731 |
| Value per kWH | ฿/kWH | 1.013 | 1.013 | 1.013 |
| Benefit of kWH ( B2 ) | M฿ | 606 | 688 | 741 |
| Annual Secondary Energy | GWH | 65 (△11) | 32 (△6) | 41 (9) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 |
| Effective Secondary Energy | GWH | 63 | 31 | 40 |
| Value per kWH | ฿/kWH | 0.864 | 0.864 | 0.864 |
| Benefit of kWH ( B3 ) | M฿ | 54 | 27 | 35 |
| Total Annual Benefit ( B ) (B) = (B1) + (B2) + (B3) | M฿ | 1,066 | 1,178 | 1,284 |
| Construction Cost | M฿ | 8,753 | 9,323 | 10,305 |
| Decreased Energy Cost | " | 918 | 1,314 | 1,989 |
| Total Cost | " | 9,671 | 10,637 | 12,294 |
| Annual Cost ( C ) | " | 1,120 | 1,232 | 1,424 |
| Surplus Benefit ( B − C ) | M฿ | △54 | △54 | △140 |
| Benefit − Cost Ratio ( B/C ) | — | 0.95 | 0.95 | 0.90 |

Note: Values in parenthesis mean increased energy after completion for the down stream power plant.

Table 6-10 Comparative Plan of No. 9A Power Plant (study of power plant location)

| Item | Unit | Dam-Type | | | Water Way-Type | |
|---|---|---|---|---|---|---|
| | | No. 9A | Nam Chon | Thi Khong | No. 9A | Thi Khong |
| STREAM FLOW | | | | | | |
| Catchment Area | $km^2$ | 4,524 | 4,908 | 5,154 | 4,524 | 5,154 |
| Average Annual Runoff | $10^6m^3$ | 2,802 | 2,975 | 3,090 | 2,802 | 3,090 |
| RESERVOIR | | | | | | |
| Normal High Water Level | m | 380 | 252 | 197 | 380 | 197 |
| Total Storage Capacity | $10^6m^3$ | 6,449 | 50 | 16 | 6,449 | 16 |
| Minimum Water Level | m | 347 | 251.9 | 196.5 | 347 | 196.5 |
| Available Drawdown | m | 33 | 0.1 | 0.5 | 33 | 0.5 |
| Inactive Storage Capacity | $10^6m^3$ | 2,592 | 49.6 | 15.3 | 2,592 | 15.3 |
| Effective Storage Capacity | $10^6m^3$ | 3,857 | 0.4 | 0.7 | 3,857 | 0.7 |
| DAM | | | | | | |
| Type | | Rockfill | Rockfill | Gravity | Rockfill | Gravity |
| Height | m | 135 | 62 | 32 | 135 | 32 |
| Volume | $10^6m^3$ | 6.7 | 0.55 | 0.046 | 6.7 | 0.046 |
| HEADRACE | | | | | | |
| Inner Diameter x Number of Lines | m | 7.6 x 2 | 7.9 x 2 | — | 7.6 x 2 | — |
| Total Length | m | 800 | 885 | | 33,760 | |
| PEN STOCK | | | | | | |
| Inner Diameter x Number of Lines | m | 4.8 x 4 | 7.1 x 2 | — | 4.8 x 4 | — |
| Total Length | m | 1,600 | 320 | | 1,600 | — |
| POWER GENERATING | | | | | | |
| Normal Intake Level | m | 365 | 252 | 197 | 365 | 197 |
| Tailwater Level | m | 257 | 200.5 | 184 | 200.5 | 184 |
| Normal Effective Head | m | 102 | 46.5 | 12.5 | 137 | 12.5 |
| Maximum Discharge | $m^3/s$ | 430 | 460 | 480 | 430 | 480 |
| Installed Capacity | MW | 380 | 180 | 51 | 510 | 51 |
| Number of Units | | 4 | 2 | 2 | 4 | 2 |

Table 6-11 Economic Evaluation of the Comparative Plan of No. 9A Power Plant
( study of power plant location )

| Item | Unit | Dam-Type | | | | Water Way-Type | | |
|---|---|---|---|---|---|---|---|---|
| | | No. 9A | Nam Chon | Thi Khong | Total | No 9A | Thi Khong | Total |
| Dependable Capability | MW | 392 (15) | 169 | 48 | 609 (15) | 523 (15) | 47 | 570 (15) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 | | 3.5 | 3.5 | |
| Effective Capability | MW | 378 | 163 | 46 | 587 | 505 | 45 | 550 |
| Value per kW | Ƀ/kW | 1,224 | 1,224 | 1,224 | | 1,224 | 1,224 | |
| Benefit of kW ( B1 ) | MɃ | 463 | 200 | 56 | 719 | 618 | 55 | 673 |
| Annual Firm Energy | GWH | 704 (16) | 309 | 87 | 1,100 (16) | 944 (16) | 87 | 1,031 (16) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 | | 3.5 | 3.5 | |
| Effective Firm Energy | GWH | 679 | 298 | 84 | 1,061 | 911 | 84 | 995 |
| Value per kWH | Ƀ/kWH | 1.013 | 1.013 | 1.013 | | 1.013 | 1.013 | |
| Benefit of kWH ( B2 ) | MɃ | 688 | 302 | 85 | 1,075 | 923 | 85 | 1,008 |
| Annual Secondary Energy | GWH | 32 (△6) | 17 | 5 | 54 (△6) | 61 (△6) | 6 | 67 (△6) |
| Loss & Stopping | % | 3.5 | 3.5 | 3.5 | | 3.5 | 3.5 | |
| Effective Secondary Energy | GWH | 31 | 16 | 5 | 52 | 59 | 6 | 65 |
| Value per kWH | Ƀ/kWH | 0.864 | 0.864 | 0.864 | | 0.864 | 0.864 | |
| Benefit of kWH ( B3 ) | MɃ | 27 | 14 | 4 | 45 | 51 | 5 | 56 |
| Total Annual Benefit ( B )<br>(B) = (B1) + (B2) + (B3) | MɃ | 1,178 | 516 | 145 | 1,839 | 1,592 | 145 | 1,737 |
| Construction Cost | MɃ | 9,323 | 3,355 | 1,103 | 13,781 | 18,101 | 1,103 | 19,204 |
| Decreased Energy Cost | " | 1,314 | — | — | 1,314 | 1,314 | — | 1,314 |
| Total Cost | " | 10,637 | 3,355 | 1,103 | 15,095 | 19,415 | 1,103 | 20,518 |
| Annual Cost ( C ) | " | 1,232 | 389 | 128 | 1,749 | 2,249 | 128 | 2,377 |
| Surplus Benefit ( B − C ) | MɃ | △54 | 127 | 17 | 90 | △657 | 17 | △640 |
| Benefit − Cost Ratio ( B/C ) | — | 0.96 | 1.33 | 1.13 | 1.05 | 0.71 | 1.13 | 0.73 |

Note: Values in parenthesis mean increased energy after completion
for the down stream power plant

Table 6-12 Plan of the Optimum Scheme

| Item | Unit | Nam Chon | Thi Khong |
|---|---|---|---|
| STREAM FLOW | | | |
| Catchment Area | $Km^2$ | 4,908 | 5,154 |
| Average Annual Runoff | $10^6m^3$ | 2,975 | 3,090 |
| RESERVOIR | | | |
| Normal High Water Level | m | 370 | 197 |
| Total Storage Capacity | $10^6m^3$ | 5,950 | 16 |
| Minimum Water Level | m | 331 | 196.8 |
| Available Drawdown | m | 39 | 0.2 ( 3.5) |
| Inactive Storage Capacity | $10^6m^3$ | 1,850 | 15.7 (11.7) |
| Effective Storage Capacity | $10^6m^3$ | 4,100 | 0.3 ( 4.3) |
| DAM | | | |
| Type | | Rock fill | Gravity |
| Height | m | 185 | 32 |
| Volume | $10^6m^3$ | 12.7 | 0.046 |
| HEADRACE | | | |
| Inner Diameter x Number of Lines | m | 7.9 x 2 | — |
| Total Length | m | 820 | — |
| PENSTOCK | | | |
| Inner Diameter x Number of Lines | m | 5.0 x 4 | — |
| Total Length | m | 1,040 | — |
| POWER GENERATING | | | |
| Normal Intake Level | m | 353 | 197 |
| Tailwater Level | m | 200.5 | 183.5 |
| Normal Effective Head | m | 146.5 | 12.5 |
| Maximum Discharge | $m^3/S$ | 460 | 480 |
| Installed Capacity | MW | 580 | 51 |
| Number of Units | | 4 | 2 |

Note: Values in parenthesis mean in the case of urgent need.

Table 6-13 Construction Cost of the Optimum Scheme

| Item | Unit | Nam Chon | Thi Khong | Total |
|---|---|---|---|---|
| Preparation Works | MB̸ | 1,227 | 65 | 1,292 |
| Civil Works | " | 4,507 | 430 | 4,937 |
| Hydraulic Equipment | " | 353 | 77 | 430 |
| Electric Equipment | " | 1,367 | 345 | 1,712 |
| Transmission Line and Telecomunication | " | 1,164 | —— | 1,164 |
| Engineering and Supervision | " | 414 | 47 | 461 |
| Total Direct Cost | " | 9,032 | 964 | 9,996 |
| Escalation Price | " | —— | —— | —— |
| Import Duty and Taxes | " | 450 | 53 | 503 |
| Interest During Construction | " | 2,212 | 139 | 2,351 |
| Grand Total | " | 11,694 | 1,156 | 12,850 |

Remarks: Construction Cost was estimated at the 1980 Price level.

Import duty is

| | | |
|---|---|---|
| Preparation Works | 5 | percent |
| Civil Works | 10 | " |
| Hydraulic Equipment | 20 | " |
| Electric Equipment | 10 | " |
| Transmission and Telecommunication | 10 | " |

Table 6-14 Estimation of Economic Evaluation

| Item | Unit | Nam Chon | Thi Khong | Total |
|---|---|---|---|---|
| Dependable Capability | MW | 591 (15) | 48 | 639 (15) |
| Loss & Stopping | % | 3.5 | 3.5 | — |
| Effective Capability | MW | 570 | 46 | 616 |
| Value per kW | ฿/kW | 1,224 | 1,224 | — |
| Benefit of kW ( B1 ) | M฿ | 698 | 56 | 754 |
| Annual Firm Energy | GWH | 1,075 (23) | 89 | 1,164 (23) |
| Loss & Stopping | % | 3.5 | 3.5 | — |
| Effective Firm Energy | GWH | 1,037 | 86 | 1,123 |
| Value per kWH | ฿/kWH | 1.013 | 1.013 | |
| Benefit of kWH ( B2 ) | M฿ | 1,050 | 87 | 1,137 |
| Annual Secondary Energy | GWH | 33 (▵10) | 4 | 37 (▵10) |
| Loss & Stopping | % | 3.5 | 3.5 | — |
| Effective Secondary Energy | GWH | 32 | 4 | 36 |
| Value per kWH | ฿/kWH | 0.864 | 0.864 | — |
| Benefit of kWH ( B3 ) | M฿ | 28 | 3 | 31 |
| Total Annual Benefit ( B ) (B) = (B1) + (B2) + (B3) | M฿ | 1,776 | 146 | 1,922 |
| Construction Cost | M฿ | 11,244 | 1,103 | 12,347 |
| Decreased Energy Cost | " | 1,064 | — | 1,064 |
| Total Cost | " | 12,308 | 1,103 | 13,411 |
| Annual Cost ( C ) | " | 1,426 | 128 | 1,554 |
| Surplus Benefit ( B − C ) | M฿ | 350 | 18 | 368 |
| Benefit − Cost Ratio ( B/C ) | — | 1.25 | 1.14 | 1.24 |

Note: Values in parenthesis mean increased energy after completion for the down stream power plant.

Construction cost is estimated without import duties and taxes.

# CHAPTER 7

# PRINCIPAL STRUCTURES

# CHAPTER 7 PRINCIPAL STRUCTURES

## 7.1 Nam Chon Project

Selection of Dam Type

As stated in Appendix 3 "Design of Structures", it can be found that a rockfill dam is superior to a concrete dam as Nam Chon dam from the view of technical points, economical points and other all condition to be considered.

Consequently, an impervious core rockfill dam having tunnel spillways at the left bank and a powerhouse at the left bank immediately downstream of the dam as shown in Fig. 7-1 and Fig. 7-2 provides the optimum layout for this Nam Chon site.

(1) Dam

The dam planned for construction at the Nam Chon site is a rockfill dam of dam height of 185 m and crest length of 450 m, having a central impervious core and a total embankment volume of 12,700,000 $m^3$. This height of Nam Chon dam will be in one of the highest in the Asian countries.

As described in Chapter 4, the geological conditions are that the left bank consists of hard and massive calcareous sandstone, while the right bank consists of formations of limestone, dolomite, conglomerate and calcareous sandstone which are cracky as a whole with weathering advanced.

On consideration of the layout of the whole, various comparison studies were made, and the location of the dam was selected in the sense of avoiding as much as possible the limestone distributed at the right bank downstream side which poses problems with regard to the watertightness of the dam.

Providing a water cutoff curtain for the whole foundation will be amply possible through grouting. Besides, blanket grouting is to be done prior to curtain grouting and embankment. The raws, spacings and depths of grouting holes are to be carefully decided upon consideration of the geological conditions of dam foundation.

(2) Spillway

It was judged that spillway, intake and powerhouse should be arranged at the left bank based on the previously described geological conditions, and further, taking into account the topographical conditions of gullies of streams cutting into the left bank at upstream and downstream of the dam axis planned.

Considering economy, the diversion tunnels are to be converted into tunnel spillways.

The required capacity of the spillways was taken to be 2,500 $m^3$/sec based on inflow of PMF 5,900 $m^3$/sec and considering a surcharge of 3.84 m above normal high water level of 370 m.

The spillways consist of two tunnels of 10 m diameters, each having a radial gate of width of 11.5 m and height of 10.5 m.

Fig 7-4 shows the relation between reservoir water level and spill discharge.

It can be said that the arrangement of spillway was determined from the standpoint of economy and safety of dam.

When carrying out detail design, it is thought necessary for hydraulic problems to be solved performing hydraulic model tests. Since these are closely related with the diversion tunnels, it is desirable for the tests to be carried out at an early date considering the timing of development of this Project.

(3) Diversion Tunnel

Considering the 20-year return period flood and past maximum flood, it is thought a design capacity of 1,600 $m^3$/sec will be appropriate for diversion at this Project site.

Two diversion tunnels each of inner diameter of 8.00 m at the upstream half and 10.00 m at the downstream half are to be provided in the left bank which comprises hard bedrock. The downstream halves are to be converted to spillway tunnels.

Tunnel No.1 (length 1,080 m) is to have its inlet portal at El. 205.00 m, and Tunnel No.2 (length 1,150 m) at El. 210.00 m, and if the elevations of the outlets of the two tunnels are made to match the estimated tailrace bay water level of about 200.00 m at maximum power discharge (460 $m^3$/sec), it is thought a height of about 250.00 m is appropriate as the crest height of the cofferdam, taking also economical and technical points into consideration.

(4) Intake, Headrace Tunnel and Penstock

Studies were made with the objective of making the length of the water-way system from the intake to the powerhouse as short as possible and to minimize the quantity of open-cut excavation as much as possible. The intake structure is to be of reinforced concrete with two roller gates each of 8 m width and 10 m height.

The headrace is to consist of two tunnels each of inner diameter of 7.9 m for passage of a maximum 460 $m^3$/sec for power generation. The lengths are to be 370 m and 450 m, and these are to connect to chamber-type surge tanks of 11 m inner diameter each.

The penstocks are to be embedded steel pipes bifurcated at upper parts so that two lines will become four (inner diameter 5.00 m to 4.20 m, length 260 m) to connect to each turbine.

(5) Powerhouse and Switchyard

As stated in (2) of this Chapter, the powerhouse is to be arranged at the left bank, but since the topography at this site is very steeply sloped, with the purpose of minimizing the open-cut excavation for the powerhouse as much as possible, the location was made closer to the middle of the river, in addition to which the part above the tail-race bay was considered for the switchyard to result in the layout shown in Fig. 7-1 and Fig. 7-3.

The powerhouse is to be a surface type of reinforced concrete structure of 110 m in length and 20 m in width.

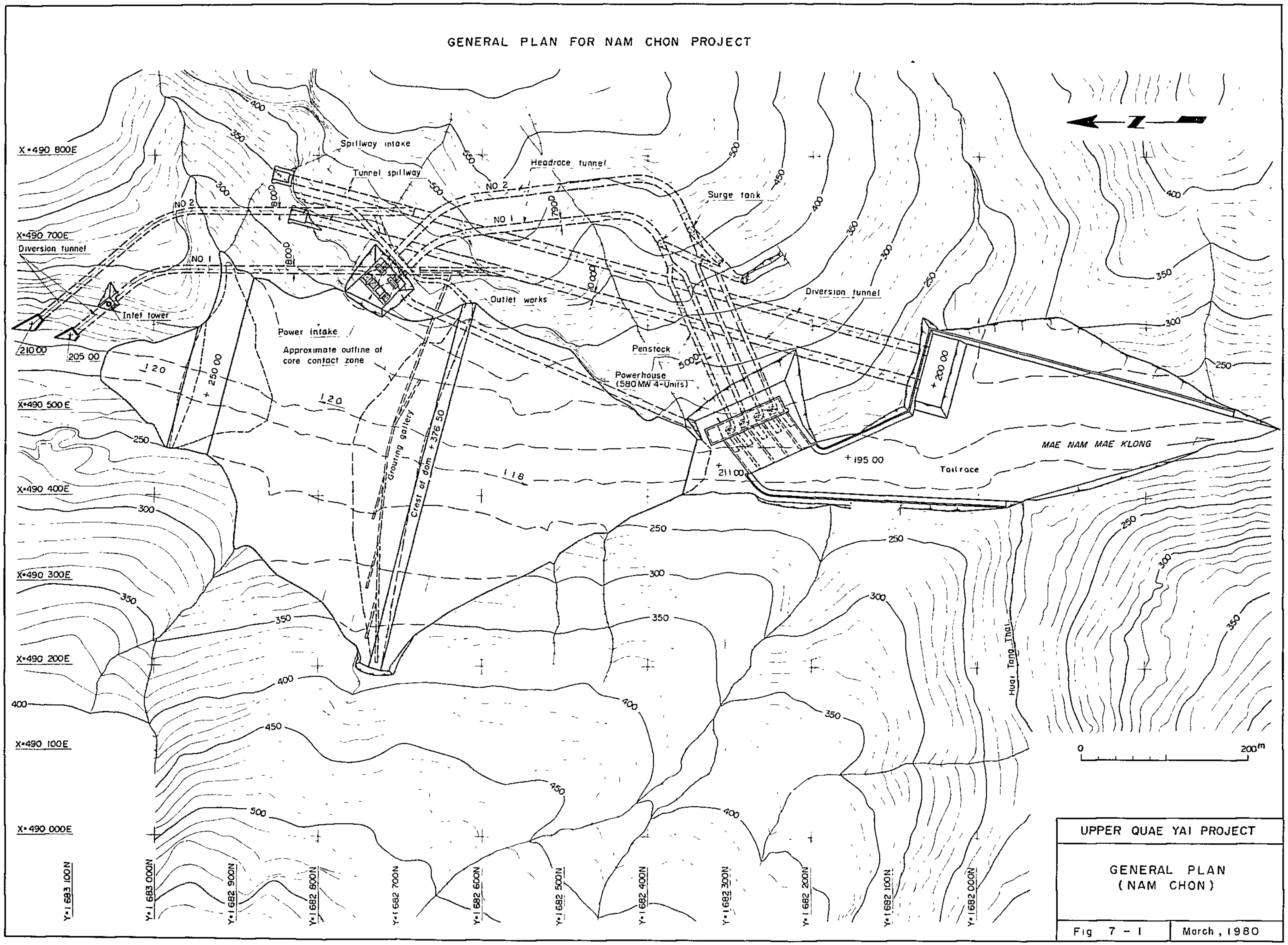
## 7.2 Thi Khong Project

This Project site is located approximately 8 km downstream from the Nam Chon damsite and has slopes of approximately 25° at the right bank side and approximately 30° at the left bank side, but conversely, good foundation rock is reached under approximately 4 m of talus deposit at the right bank and approximately 8 m at the left bank.

Regarding the arrangement of structures, as indicated in Fig. 7-5, the spillway is to be located at the present thalweg to quickly discharge the runoff of approximately 2,800 $m^3$/sec during floods, while it was judged best to locate the powerhouse at the right bank side where the talus deposit is thinner.

The powerhouse is to be a reinforced concrete structure of 65 m in length and 20 m in width. The casing is to be of concrete structure.

The spillway is to be a dam spillway with four roller gates (width 11 m, height 13 - 15 m) including a sand flush gate, for discharge of design flood of 2,800 $m^3$/sec.

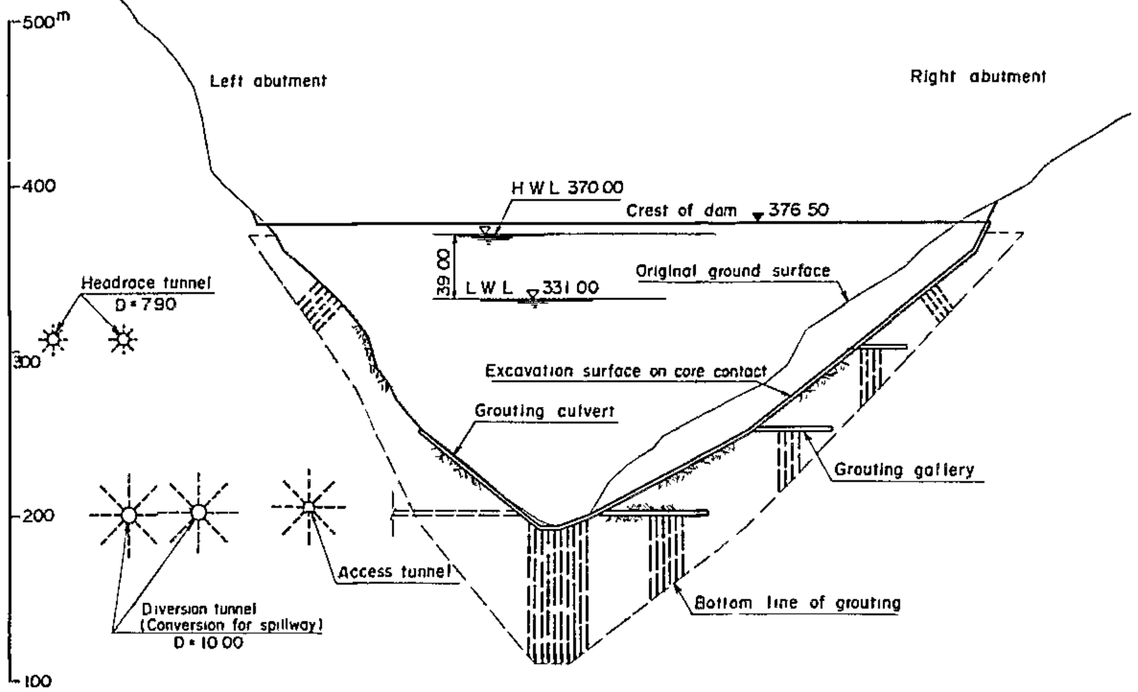



UPPER QUAE YAI PROJECT

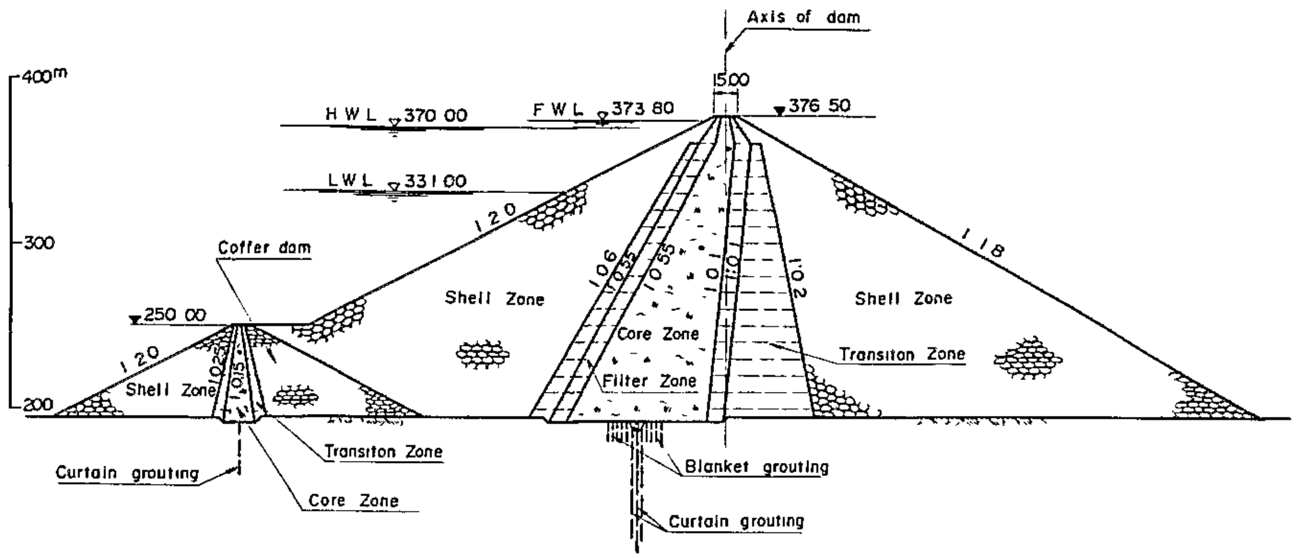
GENERAL PLAN
(NAM CHON)

Fig 7 - 1 | March, 1980

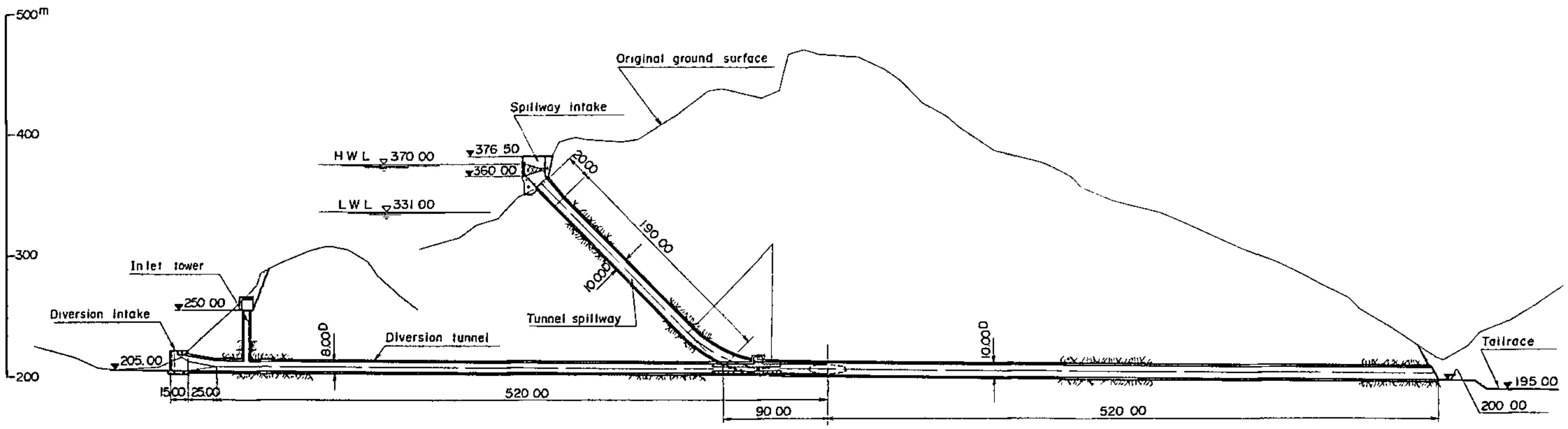
## PROFILE ALONG AXIS OF DAM




## TYPICAL SECTION OF DAM




## PROFILE OF DIVERSION TUNNEL NO.1 AND TUNNEL SPILLWAY NO.1

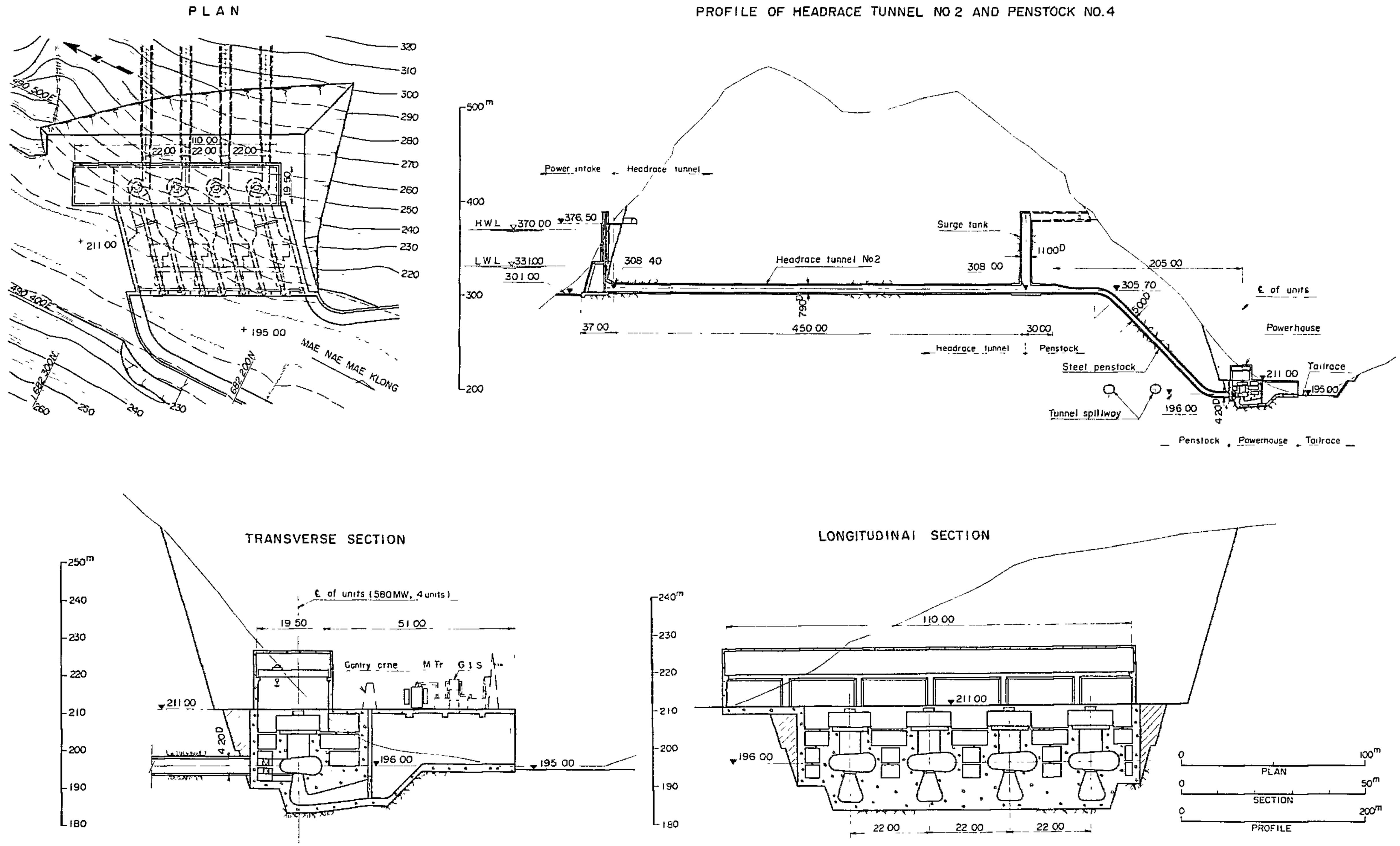




UPPER QUAE YAI PROJECT

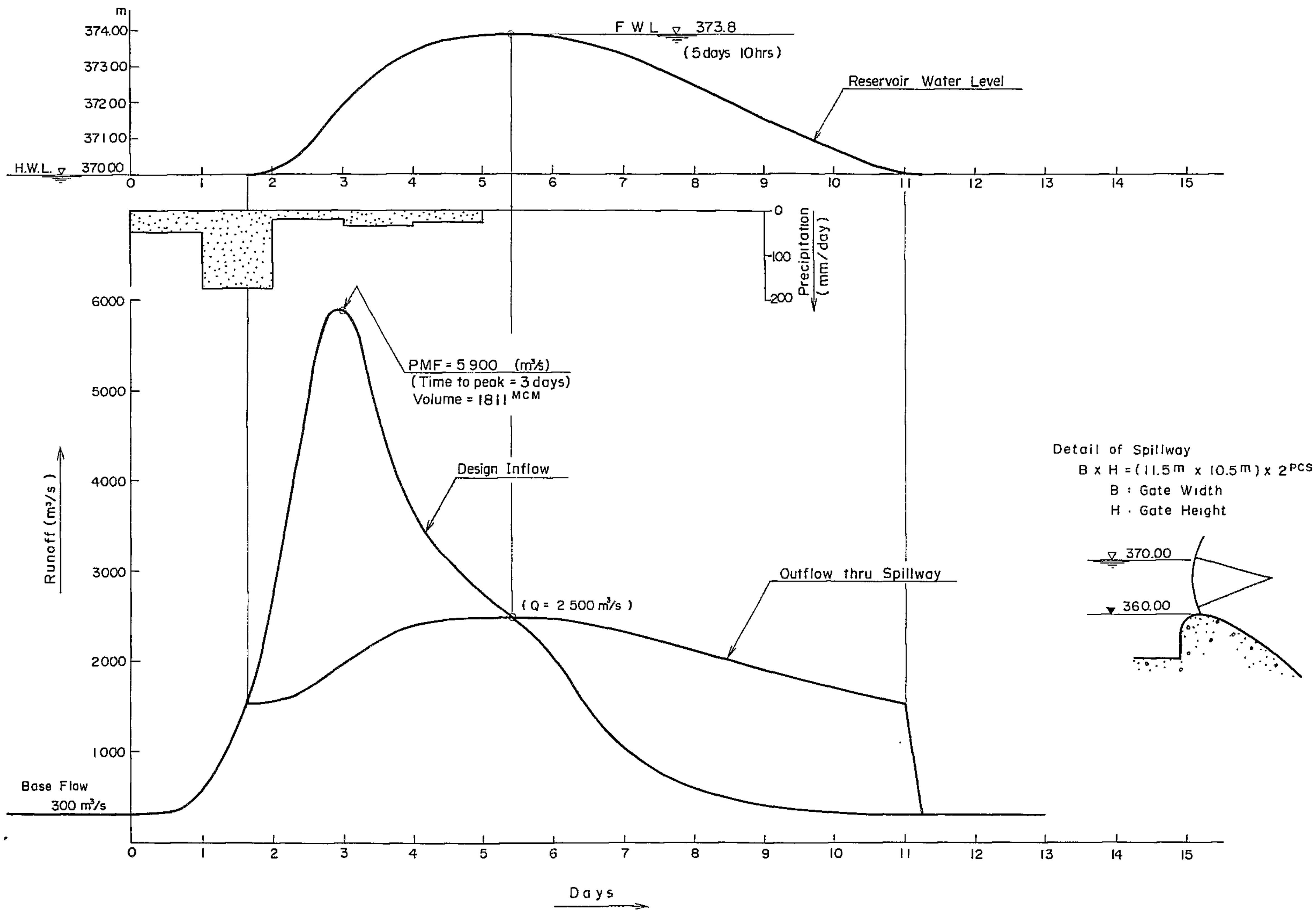
TYPICAL PROFILE & SECTION
PRINCIPAL STRUCTURE
( NAM CHON )

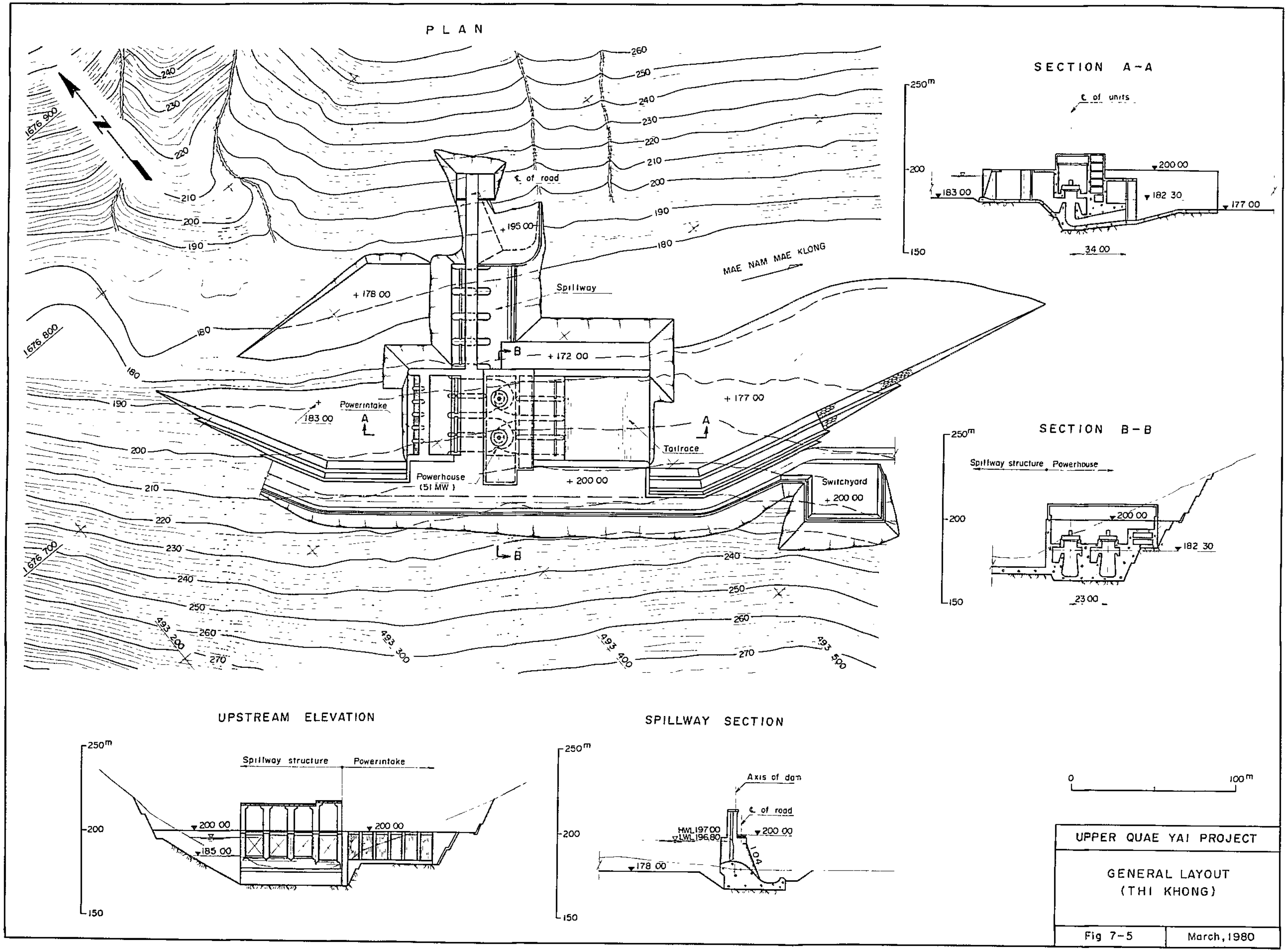
Fig 7 - 2 | March , 1980




| UPPER QUAE YAI PROJECT | |
|---|---|
| PLAN, PROFILE & SECTION<br>POWER INTAKE~POWER HOUSE<br>( NAM CHON ) | |
| Fig 7-3 | March, 1980 |

Fig. 7-4 Nam Chon Reservoir — Flood Routing —




PLAN
SECTION A-A
SECTION B-B
UPSTREAM ELEVATION
SPILLWAY SECTION
℄ of road
Spillway
MAE NAM MAE KLONG
Powerintake
Powerhouse (51 MW)
Tailrace
Switchyard
℄ of units
Spillway structure
Powerintake
Powerhouse
Axis of dam
HWL 197.00
LWL 196.80
UPPER QUAE YAI PROJECT
GENERAL LAYOUT
(THI KHONG)
Fig 7-5
March, 1980

# CHAPTER 8

# ELECTRICAL EQUIPMENT

## CHAPTER 8 ELECTRICAL EQUIPMENT

### 8.1 Nam Chon Power Station

(1) Main Equipment of Power Station

This power station is planned for normal effective head of 146.5 m, maximum available discharge of 460 $m^3$/sec and power plant output of 580 MW.

For this development scale, the number of units is to be four, each unit consisting of a combination of a 150 MW vertical-shaft Francis turbine, 162 MVA synchronous generator and a 162 MVA main transformer.

The unit system where the four generators and main transformers are connected one on one is to be adopted for the main circuits, with the generators and main transformers to be installed outdoors connected by metal enclosed buses.

(2) Switchyard Equipment

Four main transformers and other necessary equipment are to be installed at the outdoor switchyard. The switchyard equipment is planned for nominal voltage of 230 kV and GIS ($SF_6$ gas insulated switchgear) type.

The 230 kV buses are of the double-bus system, and two transmission lines are to be connected.

In adopting GIS types, consideration was given to the fact that it would be difficult to secure a lot with the required area for a conventional type switchyard in the vicinity of this power station.

The outlined specifications of the main equipment at Nam Chon Power Station aggregating the above are as listed below, while the single-line diagram, plan and cross-sectional drawings of the power station are as indicated in Figs. 8-1, 8-2 and 8-3.

Specifications of Main Equipment for Nam Chon Power Station

| | |
|---|---|
| Power Plant Output | 580,000 kW |
| Turbines | |
| Type | Vertical-shaft Francis Turbine |
| Number of units | 4 |
| Normal effective head | 146.5 m |
| Max. discharge | 115 $m^3$/sec |
| Output | 150,000 kW (at normal effective head) |
| Revolving speed | 188 rpm |
| Generators | |
| Type | 3-phase, a.c., synchronous generator |
| Number of units | 4 |
| Capacity | 162,000 kVA (power factor 0.9, lagging) |
| Frequency | 50 Hz |
| Main Transformers | |
| Type | 3-phase, outdoor, oil-immersed |
| Number of units | 4 |
| Capacity | 162,000 kVA |
| Voltage | 230/13.8 kV |
| Switchyard Equipment | |
| Type | Outdoor, $SF_6$ gas insulated switchgear |
| Bus connection system | Double-bus system |
| Number of transmission lines | 2 |

## 8.2 Thi Khong Power Station

### (1) Main Equipment of Power Station

This power station is planned for normal effective head of 12.5 m, maximum available discharge of 480 $m^3$/sec and power plant output of 51 MW.

The number of units of this power station is two, each unit consisting of a combination of a 26.4 MW vertical-shaft Kaplan turbine, a 27 MVA synchronous generator and a 27 MVA main transformer.

A unit system is adopted for the main circuits similarly to Nam Chon Power Station, and the two generators and the two main transformer sets installed outdoors are respectively connected by metal enclosed buses.

### (2) Switchyard Equipment

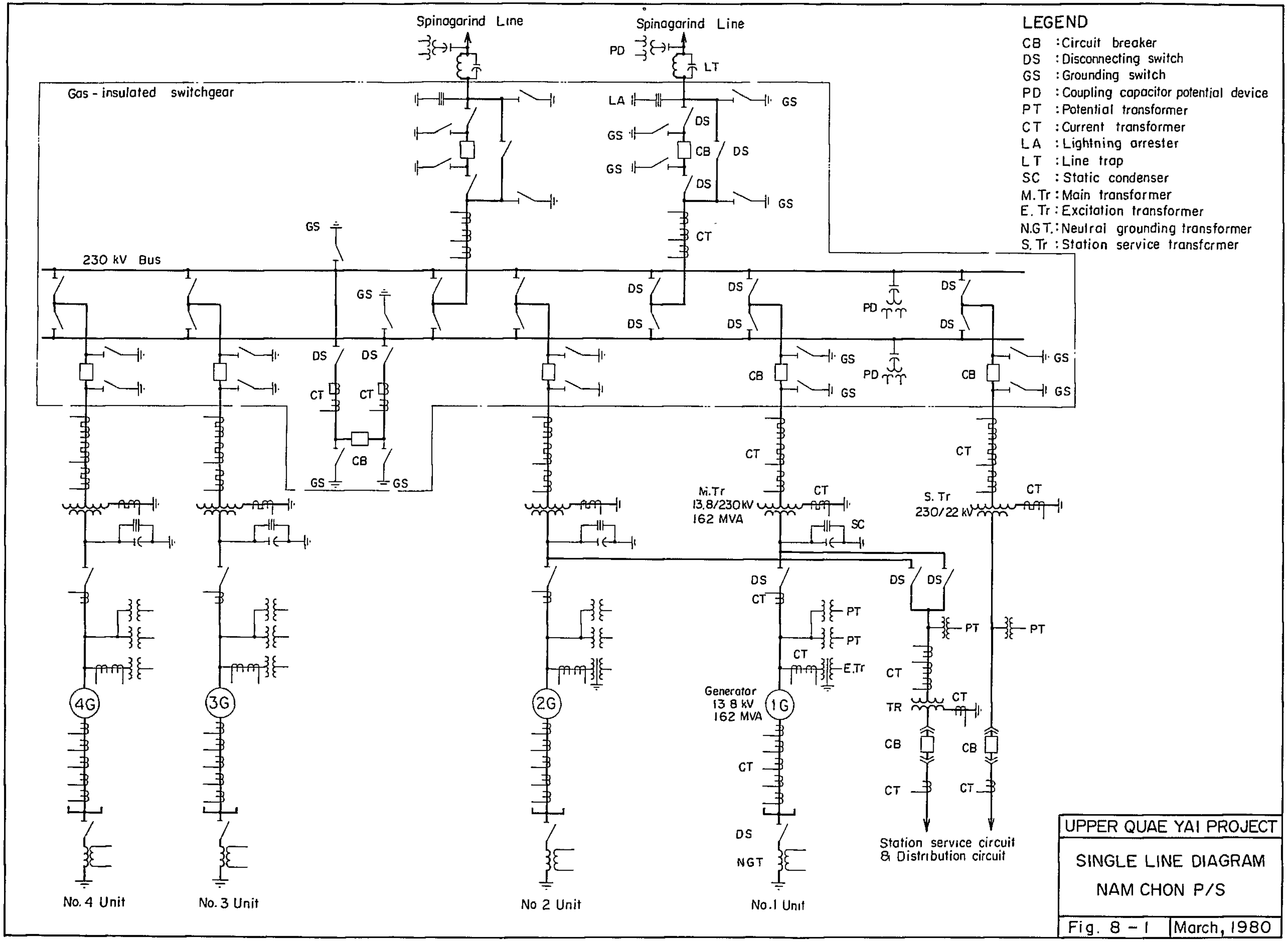
An outdoor switchyard is to be provided at the right bank close to the powerhouse.

The switchyard equipment is planned to be conventional types of nominal voltage of 230 kV, and are to be connected by overhead conductors to the two sets of main transformers installed at the power station side and to the transmission line between Nam Chon Power Station and Srinagarind Switchyard passing a point approximately 5 km distant from the switchyard.

The outlined specifications of the main equipment at Thi Khong Power Station aggregating the above are as listed below, while the single-line diagram, plan and cross-sectional drawings are as indicated in Figs. 8-4 and 8-5.

## Specifications of Main Equipment for Thi Khong Power Station

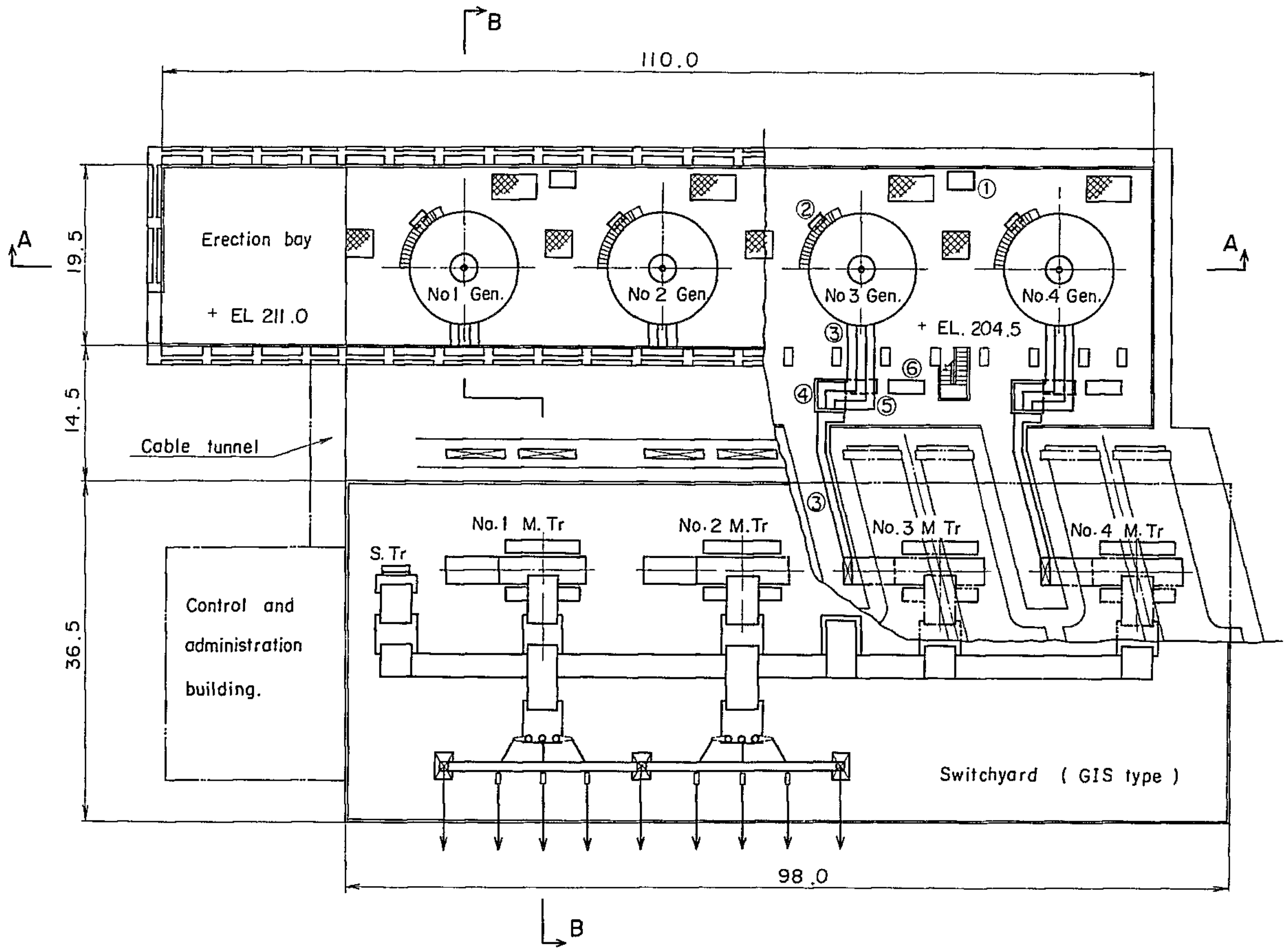
| | |
|---|---|
| Power Plant Output | 51,000 kW |
| **Turbines** | |
| Type | Vertical-shaft Kaplan Turbine |
| Number of units | 2 |
| Normal effective head | 12.5 m |
| Max. discharge | 240 $m^3$/sec |
| Output | 26,400 kW (at normal effective head) |
| Revolving speed | 94 rpm |
| **Generators** | |
| Type | 3-phase, a.c., synchronous generator |
| Number of units | 2 |
| Capacity | 27,000 kVA (power factor 0.95, lagging) |
| Frequency | 50 Hz |
| **Main Transformers** | |
| Type | 3-phase, outdoor, oil-immersed |
| Number of units | 2 |
| Capacity | 27,000 kVA |
| Voltage | 230/138 kV |
| **Switchyard Equipment** | |
| Type | Outdoor, air-insulated |
| Bus connection system | Single-bus system |
| Number of transmission line | 1 |




UPPER QUAE YAI PROJECT

SINGLE LINE DIAGRAM
NAM CHON P/S

Fig. 8 - 1 | March, 1980

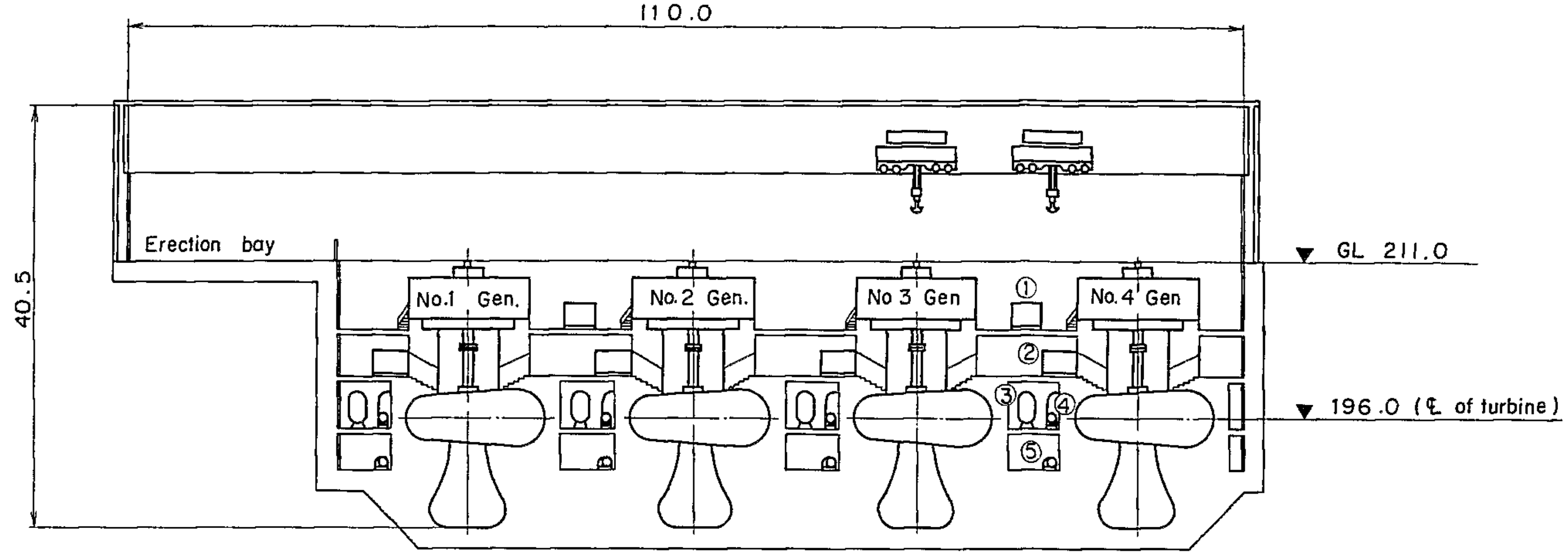



## LEGEND

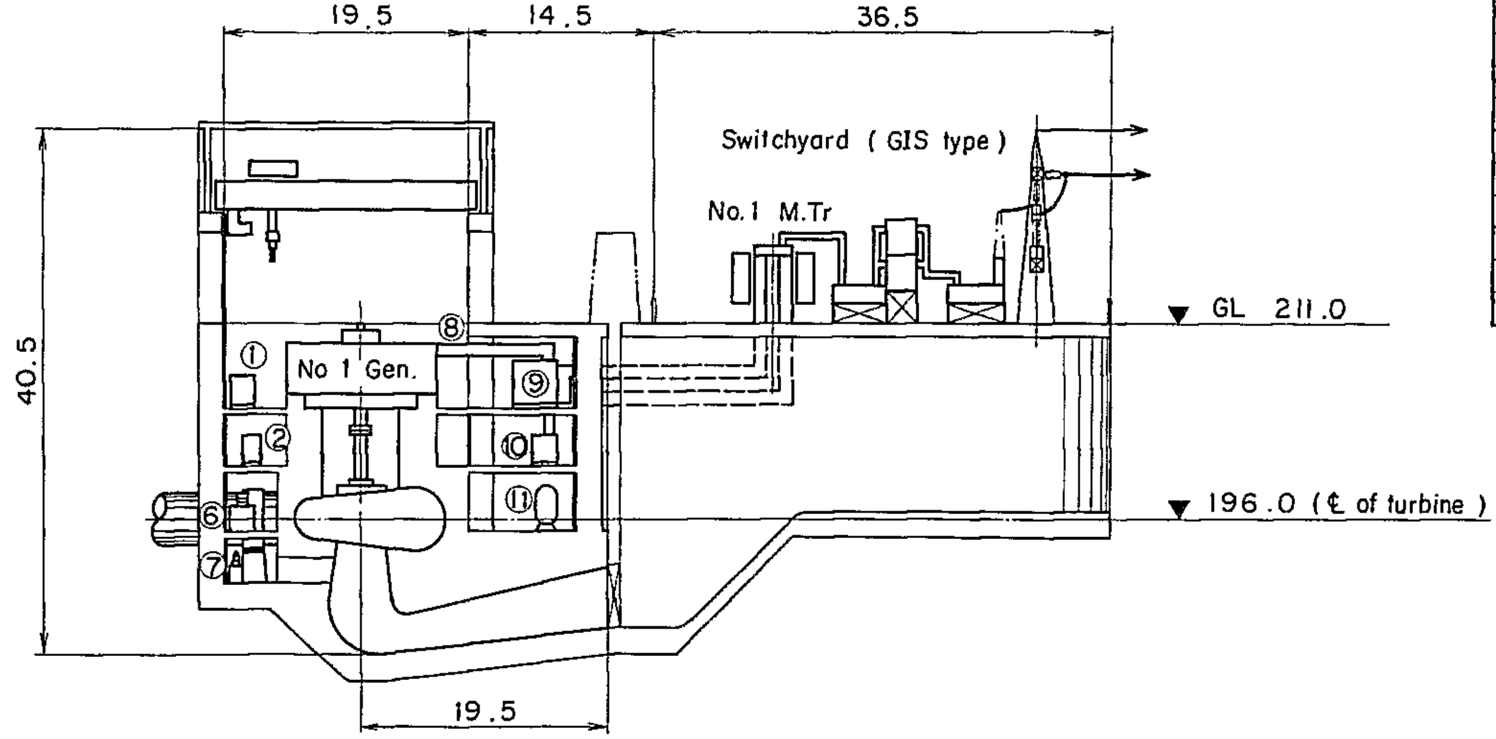
| SIGN | DESCRIPTION |
|---|---|
| ① | Carbon dioxide extinguisher cubicle |
| ② | Neutral grounding transformer cubicle |
| ③ | 15kV metal enclosed bus |
| ④ | 15kV metal enclosed cubicle |
| ⑤ | Excitation transformor cubicle |
| ⑥ | Exciter cubicle |

| UPPER QUAE YAI PROJECT | |
|---|---|
| PIAN<br>NAM CHON P/S | |
| Fig.8-2 | March,1980 |

## SECTION A - A




## SECTION B - B




### LEGEND

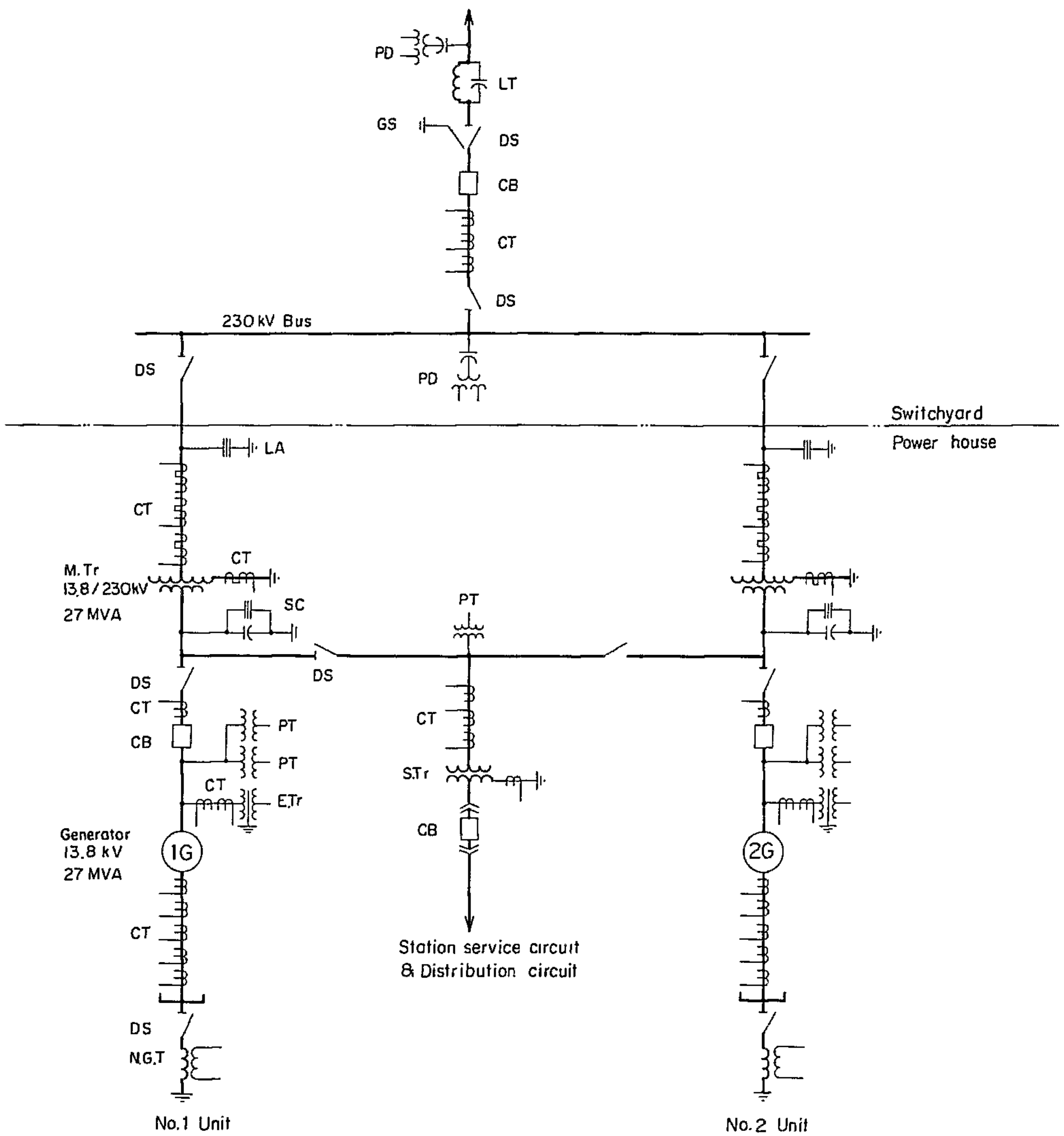
| SIGN | DESCRIPTION |
|---|---|
| ① | Carbon dioxide extinguisher cubicle |
| ② | Governor and turbine control board |
| ③ | Pressure oil tank |
| ④ | Stationary washing strainer |
| ⑤ | Water pump |
| ⑥ | Oil sump tank |
| ⑦ | Leaked oil tank and pump |
| ⑧ | 15kV metal enclosed bus |
| ⑨ | 15kV metal enclosed cubicle |
| ⑩ | 11kV metal enclosed cubicle |
| ⑪ | Main air tank |

UPPER QUAE YAI PROJECT

SECTION

NAM CHON P/S

Fig.8-3 | March, 1980




## LEGEND

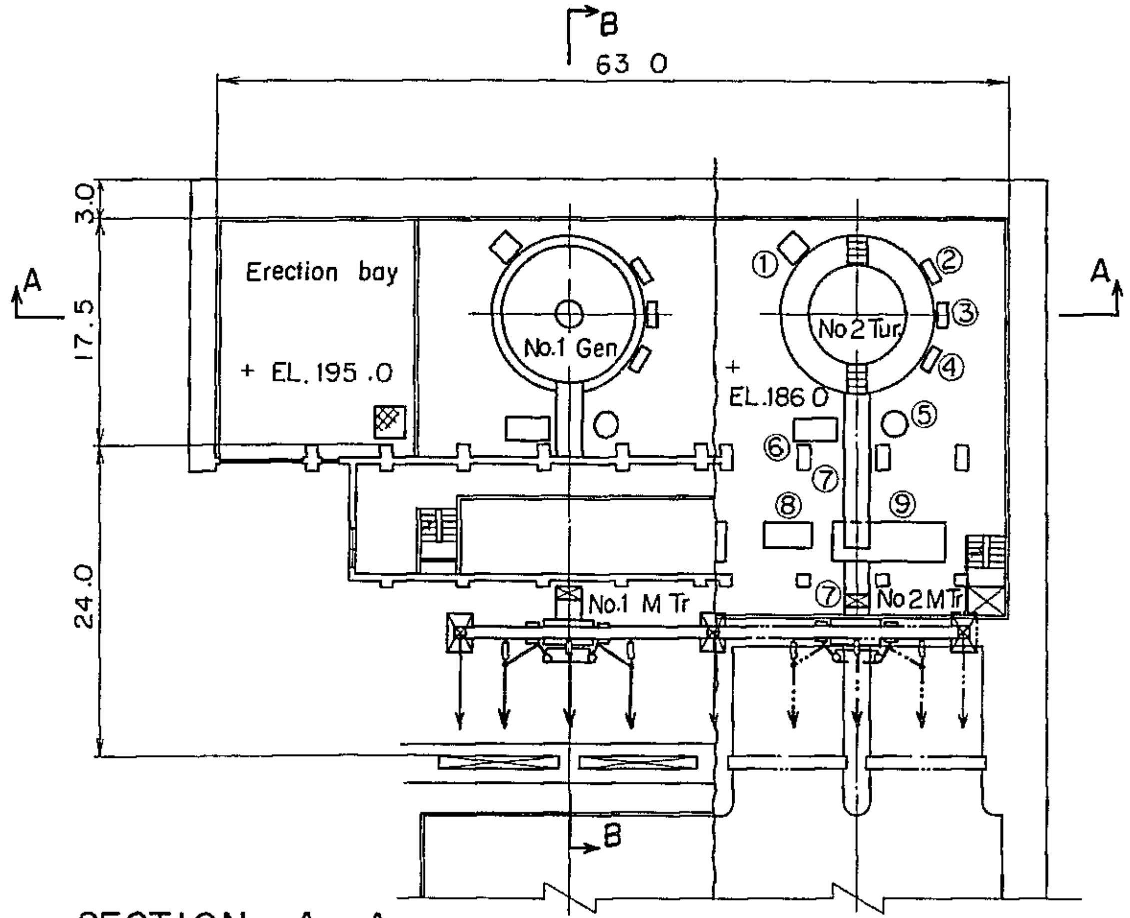
- CB : Circuit breaker
- DS : Disconnecting switch
- GS : Grounding switch
- PD : Coupling capacitor potential device
- PT : Potential transformer
- CT : Current transformer
- LA : Lightning arrester
- LT : Line trap
- SC : Static condenser
- M.Tr : Main transformer
- E.Tr : Excitation transformer
- N.G.T. : Neutral grounding transformer
- S.Tr : Station service transformer

UPPER QUAE YAI PROJECT

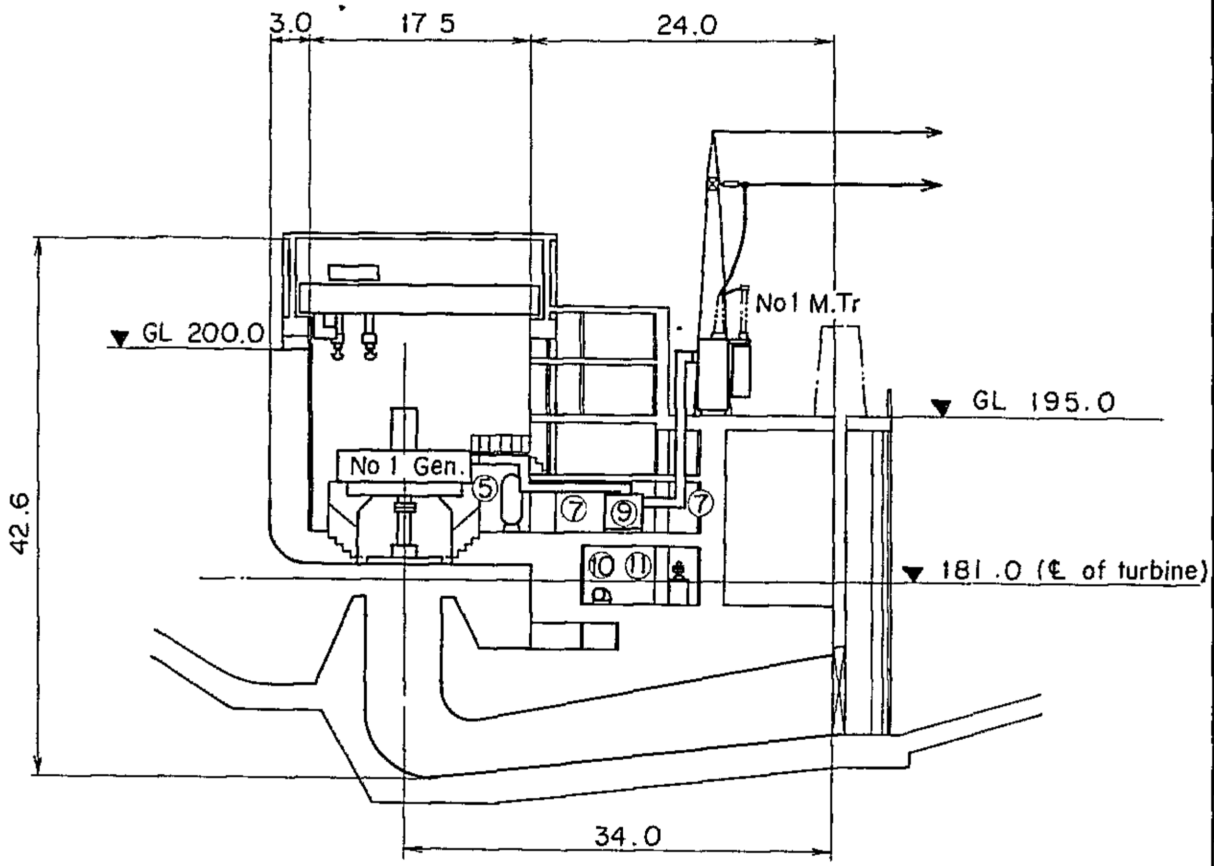
SINGLE LINE DIAGRAM

THI KHONG P/S

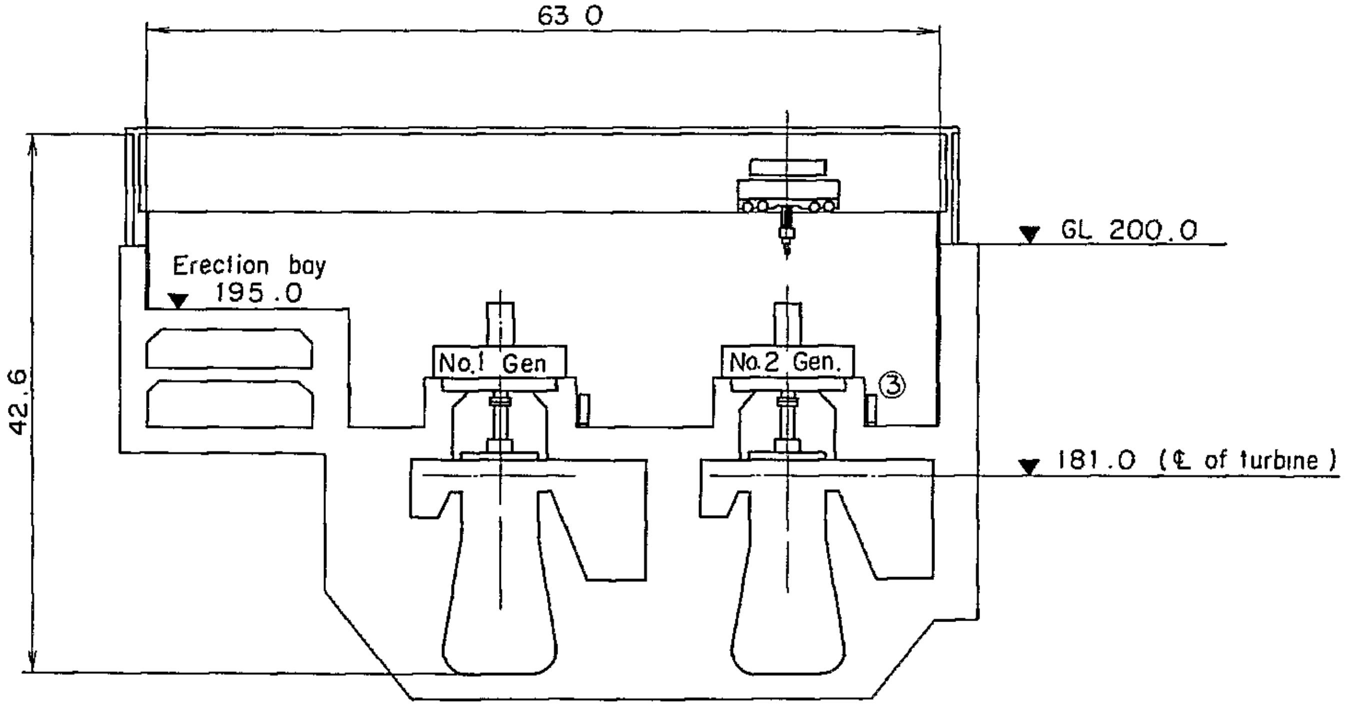
Fig. 8-4 | March, 1980




SECTION B - B




SECTION A - A




LEGEND

| SIGN | DESCRIPTION |
|---|---|
| ① | Neutral grounding transformer cubicle |
| ② | External heat exchanger |
| ③ | Oil lifter cubicle |
| ④ | Grease pump tank |
| ⑤ | Oil pressure tank |
| ⑥ | Governor and turbine control board |
| ⑦ | 15 kV metal enclosed bus |
| ⑧ | Exciter cubicle |
| ⑨ | 15 kV metal enclosed cubicle |
| ⑩ | Water pump |
| ⑪ | Oil sump tank and pump |

UPPER QUAE YAI PROJECT

PLAN & SECTION
THI KHONG P/S

Fig. 8-5 | March , 1980