CHAPTER 11.

PROJECT FACILITY PLAN

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11.1 Basic Plan of Project Facility

11.1.1 Required Project Facility

(1) Water Diversion Plan in the Project

In accordance with the project water diversion plan mentioned in Chapter 8, the basic concept for the project facility plan has been established under the following manner;

- Maximum Design Discharge of the Project Facility
  140 cu.m/sec between the Kok and Ing rivers
  175 cu.m/sec between the Ing and the Huai Nam Yot, a tributary of the Nan
- The water diversion from the Kok and Ing basins to the Nan basin will be carried out only in the wet season from the June to December when there is sufficient surplus water in the both Kok and Ing basins. The rich flood water in the wet season in the Ing river will be taken firstly with a maximum capacity of 175 cu.m/sec and whatever the deficit occur, it will be supplemented from the Kok water within the maximum capacity of 140 cu.m/sec. The dry season water in the Kok and Ing rivers shall not be allowed to divert to the Nan basin but could be used for the beneficial area within the respective basin.
- The water conveyance will be carried out with the gravity system, without pumping and pressure system.
- Part of the diversion water could be used for the irrigated agriculture and fish culture in the beneficial area along the water diversion route.

(2) Major Project Facility

In order to divert the Kok and Ing water to the Nan, the diversion route with a long distance of more than 150 km crossing the Kok and Ing plains and the high mountainous ranges between the Ing and Nan basins is required. Major project facility to be required along the route and its function are summarized as follows;

- The existing Chiang Rai Weir, which is at present operated and maintained by DEDP will be incorporated into the Project together with the intake at the Kok river to take the Kok water of 140 cu.m/sec at the maximum.
- Kok-Ing diversion canal with the length of 54.6 km crossing the Kok, Tak and Ing basin to convey the Kok water of 140 cu.m/sec to the Ing diversion weir.
- Ing diversion weir at the Ing river including the intake to divert the Kok and Ing water of 175 cu.m/sec to the Ing-Yot tunnel.
- Ing-Yot diversion canal with the length of 13.5 km from the Ing weir to the inlet of the Ing-Yot long tunnel to divert the water of 175 cu.m/sec.

- Ing-Yot long tunnel with the length of 50.9 km underneath the high and steep mountainous area between the Ing-Lao and Nan basin to convey the water of 175 cu.m/sec to the Yot river, a tributary of the Nan.
- Yao flood control dam at the upstream of the Yao river to control the flood at the Yao river and the diversion water of 175 cu.m/sec and to supply the dry season water to the downstream beneficial area in the upper Nan basin.
- Yao river training along the river with the length of 41.9 km for safe release of the diversion water in the river.

(3) Outline of Project Facility

The outline of the project facility from the Kok Weir to the Yao River Training is summarized in the attached Table 11.1.1.

1.1.2 Overall Topographical and Geological Conditions

(1) Preparation of Map and Geological Data

(a) Topographical Survey by Thai Side and JICA

During the conceptual planning stage, the basic site and alignment of the diversion route were studied on the topographical maps with scale of 1:50,000, covering the Kok and Ing basins and a part of the Nan basin where the route passes. In the feasibility stage, the following survey work were carried.

- Aerophoto map with scale of 1:10,000 covering the Kok and Ing basins, the area along the tunnel route and the Yao basin, prepared by RID. (Total 81 sheets)
- Profile and cross section survey map along the Kok, Ing and the tributaries by Thai side, 63 sheets in total and 77 sheets in total by JICA.
- Profile survey along the Kok-Ing and Ing-Lao Diversion Canals by Thai side, 20 sheets in total.
- Plain survey map at the proposed diversion weir sites and the Yao flood control damsite, 33 sheets by Thai side and JICA side.

These survey maps and drawings are used for preliminary design and as shown in the Database Maps.

Table 11.1.1 Outline of Project Facility

Name of Facilities	Item	Dimension	Remarks
(1) Kok Existing Weir	Existing Chiang Rai Weir		by DEDP
(2) Kok Intake (3.3 km upstream the above weir)	- Intake Capacity - Retention Water Level - Intake Bay (Sediment Pond) - Type of Gate - No's., Width and Height	140 cu.m/sec RWL.388.00 m 180w x 400L x 4H Sluice Gate 1 x 12 x 8+7 x10 x 2+2 x 5 x 2(nos. x w x h)	Intake Mouth : V=0.5 m/s Crest EL.393.41 m Sediment Pond : V<0.2m/s Intake Gate : V=0.8 m/s
(3) Kok-Ing Diversion Canal	- Total Canal Length - Open Canal - Culvert and Siphon - No.1 and No.2 Tunnel (A Inner Sec.:61.8)	- 54.4 km - 38.4 km - 7.5 km - 8.5 km	Turnout : 14 nos. Check Gate : 4 nos. Overchute : 46 Bridge : 6(H/W)+27(P/R)+30(New) Inner Radius : 5.00 m
(4) Ing Diversion Weir	- Flood Water Level - Type of Gate - No's., Length and Height	FWL.368.9 m 2 Rubber Gate + 1 Sluice 2 x 32 x 4.8 + 1 x 5 x 3.5m	Crest EL.370.4 m Gate Sill El.358.7 m Fish Way
(5) Ing Intake	- Intake Capacity - Retention Water Level - Type of Gate - No's., Width and Height	175 cu.m./sec RWL.363.50 m Sluice Gate (77.5m) 1x12 x 2+9 x 10 x 2+2 x 5 x 2(nos. x w x h)	Intake Mouth : V=0.5 m/s Sediment Pond : V<0.2m/s 230w x 350L x 4H Intake Gate : V=0.8 m/s
(6) Ing-Yot Diversion Canal	- Total Canal Length - Open Canal - Culvert and Siphon - Ing-Yot No.1 Tunnel (A Inner Sec.:73.4)	- 13.1 km - 1.5 km - 9.6 km - 2.0 km	Inner Radius : 5.45 m
(7) Ing-Yot No.2 Tunnel	- Tunnel Length (A Inner Sec.:73.4) - Construction Divisions - Inclined Adits	- 50.9 k - 9 Divisions - 7 Places, 17.4 km	Inner Radius : 5.45 m Inner Radius : 3.7 m
(8) Yao Flood Control Dam	- Dam Type - Reservoir Capacity - Full Water Level - Dam Crest Length and Height	Rock Fill Type (Random Zone) 32 MCM FWL.320.0 m L : 300 m, H : 57 m	Reservoir surface area:2.93km^2 Outlet Capacity : 200 cu.m./sec LWL.298.5 m Dam Crest El.325.0 m
(9) Yao River Training	- River Length	- 41.9 km	Bridge : 11 (existing) + 3 (New)

(b) Geological Investigation by Thai Side and JICA

Prior to the study of engineering geological analysis for each project facility, the following published geological maps, aerial photographs, and geological investigation reports which are mainly composed of drilling, seismic survey and a variety of in-situ test results including laboratory test results and so on were collected. The above geological investigation reports include the results of deep drilling and electromagnetic prospecting survey performed by JICA. Details of the above maps and geological reports are compiled in the Database Report of Geological Investigation.

(2) Hydraulic Conditions of Three Rivers

(a) Kok River

The Kok river, a tributary of the Mekong river, has a length of 157 km and a catchment area of 10,875 km^2. The average riverbed slope is 1/2,770 in the river stretch between the confluence of the Mekong river and the existing Chiang Rai weir located at 67 km upstream from the confluence. While it steepen at 1/1,250 in the upstream reaches of the weir.

The river width is 80 m to 100 m at the riverbed and 100 m to 150 m between both riverbanks. There is flood dyke on the left and right banks, provided for the downstream reaches with 12 km from the existing Chiang Rai weir.

The backwater of the Mekong river in the wet season comes to the upstream reaches of about 30 km of the confluence, judging from the riverbed elevation of the Kok river and the estimated probable flood water level of 367 m with a return period of 100 years at Sop Kok.

The existing Chiang Rai weir, which is constructed for irrigation development by the DEDP in 1994. The DEDP schedules to complete the construction of irrigation system in 1999. In the upstream and downstream reaches of the Chiang Rai weir, 13 private companies are taking river sand material by installing their dredgers in the Kok river throughout a year.

(b) Ing River

The Ing river, a tributary of the Mekong river, has a length of 300 km and a catchment area of 7,120 km^2. Through the river reaches of the Ing river, it remarkably meanders with a width of 500 m to 2 km.

The average riverbed slope of the Ing river is 1/8,350 in the river reaches of about 100 km from the confluence with the Mekong river, while it slightly changes to 1/6,170 from the upstream of Amphoe Thoeng.

The Mekong river largely affects water level of the Ing river. According to the recorded maximum water level at Chiang Khong, the probable flood water level at the confluence with the Ing river is estimated at EL. 352.7 m which is corresponding to the riverbed elevation at 110 km upstream from the confluence. While, during the dry season, the water level in the lower reaches of about 10 km is influenced by the water level of the Mekong river.

The Ing river with a very gentle riverbed slope, remarkable meandering channel and the backwater effect of the Mekong river results in forming wide flood prone areas along the river course. Especially, the river reaches of about 37 km between Ban Pang Mot Daeng and Amphoe

Thoeng has a bottle-neck at the existing bridge of the road with a route number 1020.

While, three tributaries of the Lao, Loi and Chae joins in this river stretch which forms a wide inundation area of about 5 km^2, where is categorized into bush area in terms of land use, and inundation depth of about 1 m to 2 m even during normal wet season.

(c) Yao River

The Yao river, a tributary of the Nan river, has a length of about 70 km and a catchment area of 883 km^2. The average riverbed slope of the Yao river is 1/1,070 in the river reaches of about 14 km from the confluence with the Nan river, and it steepen to 1/500 in the upstream reaches for Ban Pang Puk. The average riverbed slope in further upstream is gentle as 1/1,100 to the proposed flood control dam. The upstream river reaches planned to be a reservoir by the proposed flood control dam have rather steep slope of 1/270.

The Yot river, which is planned to connect with the Ing-Yot tunnel by the proposed channel, joins the Yao river at 47.5 km upstream from the confluence with the Nan river and has a steep slope of 1/210.

There are many villages being suffered from flooding under the present condition, they are; 1) Song Khwae, 2) Hang Thung, 3) Pang Puk, 4) Sop Pet, 5) Nam Mong, 6) Pang Sa, 7) Wang Phang, 8) Haen, 9) Tut, 10) Na Nun and Son, and 11) Sop Yao. These villages have been developed in the narrow area along the river course of the Yao river in order to cultivate dry season crops and vegetables for their lives.

In most of these village areas, significant flood damages were caused in 1996, which is the largest flood in their memory. Especially, in Ban Na Nun, village people had to evacuate to neighbouring elementary school for three (3) weeks during flooding. Also, the flood with high flow velocity in 1996 washed out several houses in Ban Song Khwae and Ban Hang Thung along the upstream reaches.

(3) Topographical Condition along Route and Site

(a) Kok Intake Site

The Kok alluvial plain is widely distributed over the banks along the Kok river generally ranging from 380 to 390 m in elevation and sloping down gently to the northeastward. On the right-side bank of the Kok river, the plain is also extended to the distance ranging from 5 to 7 km in width till the foot hills of the mountain area. The Kok river nearby the proposed Kok intake flows from the west to the east and from the southwest to the northeast direction having confluence with the Kon, Lao, and Sakoen rivers.

(b) Kok-Ing Diversion Canal Route

The Kok-Ing diversion canal route is planned to pass through the Kok alluvial plain, the mountainous areas located between Kok and Ing alluvial plains, and the Ing alluvial plain. The mountainous areas are composed of two mountain ranges which run in parallel from the northeast to the southwest. The small alluvial plains exist also along the Tak river between two mountain ranges. In addition, several limestone mountains remain isolated in this alluvial plain and the low hilly areas

exist along the foot of mountains.

The diversion canal route at the Kok alluvial plain is aligned through a nearly level plain except for crossing the Lao river, several small rivers and the existing canals. There are marshy grounds and swamps on the upper stream of the Sakoen river, such as the Nong Luang marsh, so that the diversion canal route has to be planned away from these marshy areas.

At the mountain area, since the topographical conditions of two mountain ranges appeared that the feature at the eastern side (the highest mountain with the elevation about 500 m) is almost steep and widespread in comparison with that of the western side (the highest mountain with the elevation about 650 m), three alternative diversion canal routes have been proposed for study. The three alternative routes are A, B and B-J, respectively. The proposed diversion route is planned to have a combination route, i.e. the Kok-Ing No.1 tunnel belongs to the B-J route and the Kok-Ing No.2 tunnel belongs to the B route. Accordingly, this new route is called as the New B-J route.

The alluvial plain around the Ing river has an elevation ranging from 365 to 370 m and is accompanied with small mountains with an elevation of about 500 m located beside the proposed Ing diversion weir. The diversion canal route at the Ing alluvial plain is aligned through a nearly level plain and small hilly areas at the foot of mountain.

(c) Ing Weir Site

The Ing diversion weir is proposed on the Ing river at the foot of Mon Kong Khao hill and is located at about 2.2 km upstream of the Thoeng bridge. The headwater of the Ing river is composed of a number of small tributaries which flow into the Phayao Lake in the high land area. The Ing river flows mainly to the north or north-northeast direction in the alluvial plain and finally empties into the Mekong river. The Ing river has a numerous tributaries such as Huai Rong Khui, Rong Chaung and Nam at the middle reach and after passing the existing rubber weir for irrigation which is located near Ban San Makha, it becomes a meandered river with wide flood plain area.

At the downstream of the proposed Ing diversion weir, the Lao river, which is one of the large tributaries of Ing river and is composed of a number of small tributaries in the steep mountainous area surrounding the Chiang Kham basin, flows into the Ing river. After the confluence of the Ing and Lao rivers, the Ing river becomes largely meandered with wide flood plain and is characterized by the existence of a numerous crescent-shaped lakes around the river. The Ing river around the proposed diversion dam runs from the south to the north with complicated meandering river course.

The proposed diversion weir is located on the Ing alluvial plain which has an elevation of 365 to 370 m at the site and the width of 9 to 11 km.

(d) Ing-Yot Diversion Canal Route

The Ing-Yot diversion canal route starts off at the Ing diversion weir and reaches to the inlet of the Ing-Yot No.2 long tunnel. The proposed diversion canal route is located on the southern mountain area of Amphoe Thoeng and lower hilly areas which are sporadically distributed along the Lao river.

This mountain area is divided into two mountain blocks of Doi Wiang (EL.506 m) and Doi Tha (EL.858 m) and both blocks are bordered by valley features which have possibility of faulting between the elevation of about 390 to 395 m. The Lao river is characterized by complicated

meandering and heavy erosion of both banks and is being vigorously deepened at present. Both abutments of the river consist of alluvial deposits. Moreover, the lower hilly areas which have an elevation of 380 to 400 m at each peak are inferred to be formed by such a way that the mountain is progressively destroyed leaving only a series of peaks at approximately the same height.

(c) Ing-Yot No.2 Tunnel Route

The proposed Ing-Yot No.2 tunnel route is planned with the length of about 51 km passing through high and steep mountainous area along the national borderline between Thailand and Laos. These mountains are dividing the river basins of Ing and Nan, and of Ing and Yom respectively. At the both northern and southern parts around the Chiang Kham basin, there are low hills and small mountains with an elevation of 500 to 600 m wherein three alternative tunnel routes of A, B, C and Lower B have been proposed for study.

The tunnel route A passes through the northern part of Chiang Kham basin area where is a large alluvial plain having an elevation of 400 to 500 m and is connected with main part of the tunnel route B. The tunnel route B is located at the above high mountain area situated at the northward and the eastward of the Chiang Kham basin with an elevation of 600 to 1,000 m or more. The tunnel route C passes through low hills and small mountainous area located at the southward of Chiang Kham basin. This route is called as "proposed south route of Kok-Ing No.2 tunnel". However, this route was evaluated as not feasible route at the conceptual plan study. As for the Lower B route, the starting point will be located on the Ban Huai Pong at the foot of the mountain which is extended at the right-side bank of the Ing river. The tunnel route traverses the Nam Muang river which is one of the large tributaries flowing into the Lao river and is connected to the main part of the tunnel route B at the T.P.22, which corresponds to the third turning point of the tunnel route B.

As for the proposed tunnel route, the tunnel route B was selected as the most suitable plan on the basis of alternative studies in detail.

Topographical conditions around the proposed tunnel route are different in each section which are briefly summarized as follows.

Tunnel inlet – 3 km section

For the section from the proposed tunnel inlet to about 3 km, the tunnel route passes through underneath of the lower hills and the lower mountain area has an elevation of 390 to 420 m.

3 km – 8 km section

At this section, the tunnel route passes through mountainous areas which are accompanied by several large scale valleys. It is inferred that these valleys were formed by erosion along the shear zone of fault origin.

28 km – 30 km section

The tunnel route passes through underneath of the high and unique shaped mountain called Doi Pha Dam (EL.1,000 to 1,300 class in elevation), which are made up of limestone. The existence of several limestone caves and doline topography involving water flow are confirmed at this section.

30 km – 45 km section

At this section, the tunnel route passes through highly steep mountainous areas, such as Doi Yot Huai Nam Lao (EL.1,600 m) and Doi Pha Chang (EL.1,562 m). The gorges in this area are formed by an extremely V-shaped valley which is being vigorously deepened at present.

45 km – Tunnel outlet section

The tunnel route passes through underneath of the two limestone mountains and hilly areas and reaches to the tunnel outlet. The limestone mountains have also unique shape, however, the scale is small in comparison with the mountain of 28 km- 30 km section.

(f) Yao Flood Control Damsite

The Yao flood control dam is planned at the Yao river beside the King Amphoe Song Khwae. This damsite is located at the distance about 3.5 km of the southeastward from the confluence point of the Yot river. The Yao river flows almost southeastward from its confluence point except the large meandering at approximately 0.8 km upstream from the damsite.

Topographical condition of this damsite and surrounding area shows gentle mountains and hills, with the elevation generally ranging from 350 to 400 m. At the damsite, the right side abutment is rather steep gradient in comparison with that of the left side. Furthermore, at the abutment of the left side, several isolated hilly shapes exist along the crest of the mountain ridge.

(g) Yao River Training Course

The headwater of the Yao river is located in the steep mountainous area nearby the national borderline between Thailand and Laos. The Yao river flows southward with complex meandering as a whole and reaches to the confluence point with the Yot river at about 3.8 km northwestward of the proposed Yao flood control dam, and the Yao river at this point turns southeastward. Furthermore, near the King Amphoe Song Khwae, about 1.5 km apart from the proposed Yao flood control dam, the Yao river turns the direction for second time to the south-southeastward and the Yao river flows about 40 km with small-scale meandering and reaches to the confluence point with the Nan river.

In the downstream of the proposed Yao flood control dam, three major tributaries namely; the Mong, the Rak and the Ki rivers join from right-side bank, but on the contrarily, no major tributary joins from the left-side bank.

Topographical condition along the Yao river shows an extremely V-shaped valley in general which is being vigorously deepened at present and is accompanied in part with small-scale terrace deposit up to about 10 km in a straight line upstream direction. Then the valley is widened after passing this point and a small scale flat plain is formed till the confluence point with the Nan river.

(4) Geological Condition along Route

The general geological condition of the project area is mainly composed of upper Paleozoic to Mesozoic sedimentary rocks and a variety of igneous rocks. And at the plain area, these basement rocks are overlain by thick alluvial deposits. The summary of geological formation and rock facies of this area is shown in Table 11.1.2.(4). The difference of geological formation name between the existing geological maps (1/250,000 in scale) by DMR and the geological maps which are used

principally in various studies for project facilities and along the tunnel route is also compared and shown in Table 11.1.2.(4).

(a) Geological Condition along Water Diversion Canal between Kok Intake and Ing Weir

The geological condition at the proposed Kok intake, including that along the Kok river and the Lao river, is composed of thick alluvial deposit. This alluvial deposit is mostly made up of poorly graded sand except for top soil layer.

The geological condition along the diversion canal route is composed of alluvial deposit. This alluvial deposit is mostly made up of CH (high-plasticity clay), CL (lean clay), SM (silty sand) and SC (clayey sand) except for top soil layer.

* Soil classification is based on USCS (Unified Soil Classification System)

For the diversion canal route between the Kok intake and the Ing weir, it is characterized by the existence of poor ground condition at the deeper depth as a whole. On the occasion of study for facility design, much attention should be paid to the potential problems to be encountered by the poor ground condition. Furthermore, at the construction stage during rainy season, especially for excavation works, special attention should be paid to the ground condition because of the soil having a high-plasticity characteristic.

(b) Geological Condition along the Kok-Ing No.1 Tunnel

The Kok-Ing No.1 tunnel is planned to pass through the area of the geological conditions with weathered shale, slate sandstone and tuff of Permian-Triassic age about 700 m length from tunnel inlet and 1.3 km length from tunnel outlet, and with the rhyolite and tuff of the variety of igneous rocks of same age at central portion about 1 km length.

The section about 400 m from tunnel inlet shows gentle slope at the ground surface and is underlain by loose sand and gravel, and/or highly to completely weathered shale, sandstone and tuff of the Permian-Triassic age. In this section, the existence of fault may be supposed along topographical change point. A remarkable fault is also supposed to be at about STA.1+265 section.

Furthermore, the section between STA.2+500 and tunnel outlet shows shallow overburden condition consisting of soft and loose, completely weathered rock and alluvial deposit.

In this section, including that near tunnel inlet and outlet sections, tunnel type at the shallow overburden area should apply E2 tunnel type at least, as a matter of course.

Table 11.1.2.(4) Summary of Geological Formation

Geological Age		Formation Name	Acronym of map	Rock Facies	Geological map (S=1/250,000)
Quaternary	Holocene	Alluvial deposit	(Qa)	Unconsolidated sand, silt & gravel	Qa
	Pleistocene	Terrace deposit	(Qt)	Unconsolidated red soil, sand, silt Gravel	Qt
Tertiary	Tertiary	Huai Sieo	(Ths)	Semi-consolidated clay, silt with Sandstone	Ng
Mesozoic	Jurassic	Mae Tam	(Jmt)	Shale, sandstone	ms 5
		ms 5-3	(ms 5-3)	Tuff, shale and sandstone	Ms 5-3
		Phu Kham	(Jpk)	Quartzitic sandstone, shale	ms 4
		ms 3-5	(ms 3-5)	Sandstone, shale, tuff	Ms 3-5
		Na Ngan	(Jnn)	Sandstone, shale, conglomerate	ms 3
		Ms 3	(ms 3)	Conglomerate, sandstone	ms 1
	Middle-Upper Triassic	Doi Pong Nok	(TRpn)	Sandstone, shale, tuff, lapilly tuff	ms 1
		Pa Lae	(TRpl)	Limestone	h, p 2-1
		Huai Fak	(TRhf)	Sandstone, tuff interbedded with Shale	t-p
	Permian-Triassic	PTR	(PTR)	Sandstone, shale, tuff	t-p
Paleozoic	Permian	P3	(P 3)	Sandstone, shale, slate, tuff, Limestone	t-p
		P2	(P 2)	Limestone	P 2-1
	Carboni-ferous-Permian	Huai Krai	(CPhk)	Metasandstone interbedded with Slate	p-h
		Nam Bong	(CPnb)	Slate, quartzite, interbedded with Sandstone foliated	p-h
		Doi Mun	(CPdm)	Schist, phyllite, slate & metasandstone	p-h

< Igneous rock series >

Tertiary	Tertiary	Basalt	(Bs)	Basalt	B-ng
Mesozoic	Jurassic	Tuff	(Jv, Msv)	Rhyolite, tuff	Lms 2
		Andesite	(an)	Andesite	Lip
	Permian-Triassic	PTRv	(PTRv)	Andesite, rhyolite, dacite, tuff and Agglomerate	Lms 2
Paleozoic		Granite	(PTRgr)	Granite, granodiorite, porphyry	Gt

Note : The outlines of distribution and characteristic of each formation are shown in the Supporting Report and Data-base Maps.

(c) Geological Condition along the Kok-Ing No.2 Tunnel

The first 680 m section from the inlet shows shallow overburden condition and consists of loose and permeable sand, gravel or completely weathered rock of the Permian age. At this section, taking the topographical and geological features such as the shallow overburden area into consideration, final determination of the most suitable connection point for tunnel and culvert facilities requires to carry out further tests in the supplemental investigation.

At next section, especially between STA.0+730 and STA.0+950, geological condition is composed of fractured limestone confirmed by drilling hole and accompanying with fault zone at the rim part of limestone. As for the tunnel, it is necessary to pay much attention to the first 1 km section from the tunnel inlet because the potential difficult geological conditions, for example, shallow overburden, intensely fractured and permeable limestone, and groundwater discharge from limestone etc., are known to be existing.

Geological condition between STA.1+000 and STA.3+550 is composed of shale (slate), sandstone and tuff of the Permian age in the fresh rock under thick overburden. Furthermore, in this section, it is inferred the existence of total five faults on the basis of the results of field reconnaissance survey. This formation is overlain by the basalt lava which indicates about 50 m in thickness confirmed by TEM investigation, and shows many fissured and jointed rock facies. In this case, it is judged that the bottom of basalt lava is located at higher than the tunnel top (tunnel crown) so that tunnel route can pass through Permian age except for the potential existence of basalt dike intruded into the P3 formation.

At the section between STA.3+550 and STA.4+500, there is a possibility of basalt dike intrusion along the fault supposed to be at/around STA.3+550 point. At the section between STA.3+550 and STA.4+550, geological condition is composed of shale (slate), sandstone and tuff of the Permian-Triassic age.

The section between STA.4+500 and tunnel outlet shows shallow overburden condition consisting of soft and loose, completely weathered rock and alluvial deposit in certain distance of the section. In this section, including around tunnel inlet, tunnel at the shallow overburden area should adopt E2 tunnel type at least, as a matter of course.

(d) Geological Condition along the Ing Diversion Weir

Geological condition of the Ing diversion weir site is composed of alluvial deposit which is divided into 2 layers except for top soil. Furthermore, along the Ing weir, existence of sandy materials could be expected.

(e) Geological Condition along the Ing-Yot Diversion Canal Route

Ing-Yot No.1 tunnel has about 2,008 m in length but overburden is shallow (30 m to 130 m). Geological condition along tunnel route is mainly composed of conglomerate and sandstone of Jurassic age, and at/around tunnel inlet, geological condition may change to greenish gray to purple lapilly tuff and tuff breccia of TRpn formation in Middle-Upper Triassic. Rock conditions indicate moderately to highly weathered, medium hard to hard, intensely fractured in one place.

Ing-Yot diversion canal passes through the sporadic flat land in lower hilly area after flowing out Ing-Yot No.1 tunnel. In this area, taking topographical and geological condition into

consideration, it is inferred that the thickness of overburden deposits is considerably shallow. According to the drilling data which is obtained at around the inlet of Ing-Yot No.2 tunnel and is located on alluvial plain, the geological condition is characterized by the existence of CL (lean clay) and SC (cleyey sand) up to about 10 m in depth. And at the deeper depth further, basement rocks, shale and tuff are found out. N values of this borehole show a wide range of scattering from 4 to 19 up to about 7 m in depth, and at the deeper depth from 8 m, N values indicate 40 or more. From these data, it is inferred that the thickness of alluvial deposit along the Ing-Yot diversion canal route may have only 7 to 8 m approximately. In other words, excavation of thick stiff layer (weathered rock) or hard rock may be necessary depending on the invert elevation of the canal facilities.

(f) Geological Condition along the Ing-Yot No.2 Tunnel

Ing-Yot No.2 tunnel route is located on the northern and eastern high mountain area from Chiang Kahm. The geological condition of this route is mainly composed of hard sedimentary rock in spite of accompanying with fault zone in part. It is judged that this route is superior to the other routes on the basis of the results of comparative studies in detail. The geological conditions along the tunnel route can be summarized as follows.

Geological condition of the section from the tunnel inlet to STA.0+800 is composed of weathered shale and sandstone which is soft and intensely fractured rock facies of the TRpn formation in Middle-Upper Triassic. The overburden condition shows remarkably shallow with 30 to 105 m in thickness. Furthermore, according to the refraction survey results, at/around the tunnel inlet, analysis profile shows 3 layer structures with wide variety of Vp (P wave velocity) 2.0 to 4.0 km/s in maximum.

Geological condition of the section from STA.0+800 to STA.1+500 is underlain by medium hard to hard tuff and lapilly tuff of the PTRv formation in Permian-Triassic which is accompanied by porphyry (granite porphyry) intrusion. In this case, according to the results of drilling, porphyry intrusion has a scale of 40 m or more in thickness. The rock facies of the section is medium hard to hard and relatively massive.

Geological condition of the section from STA.1+500 to STA.3+140 is composed of shale, sandstone and tuff of the TRhf formation in Middle-Upper Triassic age. It is inferred that rock facies along the tunnel invert level show hard class excluding nearby presumed fracture zone.

As for the section from STA.3+140 to STA.3+250, the existence of a remarkable large scale fault valley is identified from the aerial photograph and satellite image, and the results of drilling hole also revealed the existence of fractured and altered rock features along the fault zone and existence of limestone simultaneously. Moreover, the results of seismic reflection prospecting SB0-Main line) and TEM prospecting (electromagnetic prospecting survey, TMB3.1 line) indicates also the existence of clear structural feature and broad low resistivity zone respectively. For these it is inferred that fractured zone caused by faulting exists at this area. These information are quite conformable with the evidence obtained from the other investigation.

In this case, special attention should be paid for the presence of fractured rock and fault clay and to the removal of groundwater on this section.

Geological condition of the section from STA.3+250 to STA.6+950 consists of the CPhk formation in Carboniferous-Permian age characterized by brown to dark gray metasandstone interbedded with slate. This section has a relatively thick overburden condition, 150 to 280 m in

thickness. Rock conditions along the tunnel invert level indicate stable facies excluding those around fractured zone caused by faulting.

The section from STA.6+950 to STA.7+050 corresponds to a remarkable thrust fault along tectonic valley, which is clearly described on the published geological map of "Amphoe Chiang Kham, 50,000 in scale" by DMR. According to the drilling data, it shows intensely fractured and altered clayey rock feature (D to CL class) as a whole. Moreover, the results of seismic reflection prospecting (SB8-RFL1 line) and TEM prospecting (TMB 8.1 line) indicate the existence of clear structural feature and broad low resistivity zone respectively. From which it is inferred that fractured zone caused by faulting exists at this area. In this case, special attention should be paid for the presence of fractured rock and fault clay and to the removal of groundwater on this section.

Geological condition of the section from STA.7+050 to STA.10+000 consists of the CPnb formation in Carboniferous-Permian age which is characterized by foliated dark gray slate interbedded with sandstone. Overburden condition shows 120 to 340 m in thickness and rock facies indicate medium hard to hard but somewhat breakable along bedding plain of the slate.

The section from STA.10+000 to STA.11+200 is located on the northern part of the heated groundwater area (Phu Sang spring area). Geological condition of the section consists of the CPnb formation characterized by foliated dark gray slate interbedded with sandstone. According to the drilling data, the geological condition shows sandstone and slate. This spring has 27.5° C (river water is 24.5° C) water temperature and 498 micro-s/cm in conductivity. The results of TEM prospecting reveal the existence of extremely low resistivity (5 to 10 ohm-m or less) from which it is inferred that cracks of basement rock at this area may be partly filled up by the above heated water. These resistivity values may support the idea that geological condition of this area is derived from marine sediments. Furthermore, their thermal origin is presumed to be related to the igneous rocks (granite or porphyry), which is continued for a great depth at a deeper portion, and some faults located around this section may be regarded as a passage of the heated groundwater. In addition, this heated groundwater is characterized by rich in calcium according to the results of water quality analysis. In accordance with the water pressure test at the drilling hole No.DHB5, the result shows the very low permeability from 1.3 to 1.5 Lugeon Value, so that leakage of water during tunnel excavation will be judged to be small.

Taking the whole geological information into consideration, it is inferred that tunnel alignment which passes around drilling hole No.DHB5 location is situated on the outer area of the zone strongly affected by heated groundwater because that is located on the outside of remarkably low resistivity area. However, as for adit No.2 alignment, adit construction must be taken potential hazards into account because the location is presumed to be situated on the above remarkably low velocity area. Furthermore, clear identification and solution of these problems should be carried out further in detail based on the additional investigation from the hydrogeological viewpoint, for example drilling investigation, physical survey including detailed groundwater quality tests etc. In addition, it is required to pay attention to possible influence to the quality and quantity of spring water during the tunnel construction stage.

This long section between STA.11+200 and STA.25+900 is underlain by the CPnb formation in Carboniferous-Permian age which is mainly composed of slate interbedded with sandstone and quartzite. The rock mass along the tunnel invert level shows CM, CH and B class as a whole excluding fractured zone caused by faulting. Overburden of this section reaches 200 to 700 m in thickness.

Geological condition of the section between STA.25+900 and STA.28+550 is composed of PTRv formation in Permian-Triassic age which consists of grayish green tuff interbedded with andesite, rhyolite and dacite, and overburden reaches 440 to 680 m in thickness. According to the rock feature of deep drilling of DHBJ-26.0 performed by JICA, rock mass along the tunnel invert level shows hard and massive in spite of somewhat breakable along latent crack and totally indicates CH to B class. In this case, it is judged that rock condition of this formation corresponds to the most excellent one as for the rock mechanical property on the basis of drilling core condition and the results of logging etc.

Furthermore, drilling of DHBJ-26.0 revealed the existence of excellent confined aquifers at the deeper depth from 276 m, which is reported as 78 litters/minute in maximum quantities at the top of casing. In addition, the confined aquifers are characterized by rich in sodium according to the results of water quality test. In this case, special attention should be paid to the occurrence of unexpected groundwater discharge during the tunnel construction.

At the section between STA.28+550 and STA.30+100, tunnel line passes under high limestone mountains. This limestone is called as TRpl formation in Middle-Upper Triassic and is inferred to be elevated in fault by contact with the CPnb formation. Furthermore, this fault line is clearly described on the geological map "Chiang Kham (50,000 in scale)" by DMR. Rock mass of limestone shows CH class as a whole except for those around the fault zone.

At the surface of this limestone mountain, many dolines are observed, and surface water flows into them and flows out from the caves which is located nearby the Yuan river. Moreover, according to the results of TDEM survey, this limestone is widespread and having a great depth and shows high resistivity (5,500 to 10,000 ohm-m or more) as a whole, however, on this analyzed section of TDEM prospecting, low velocity zone (about 1,000 ohm-m) could be locally found out. In this case, there is a possibility that this low resistivity zone signifies to accompany with groundwater flow in the limestone cave. However, despite the results of this TDEM prospecting which has only one survey line in this limestone mountain area, it is insufficient to draw any definite conclusion as for the mechanism of groundwater flow, therefore, it should be further studied in detail by using additional investigation result.

Moreover, on the occasion of tunnel construction in this section, the most significant problem is removal of groundwater deriving from potential limestone cave and special attention should be paid to this issue.

The section from STA.30+100 to STA.38+000 is overlain by stable rocks belonging to the TRhf formation in Middle-Upper Triassic age which consists of greenish gray sandstone and tuff interbedded with thin shale (slate). Overburden of the section reaches 230 to 600 m in thickness. And rock mass shows CH to B class except for the fault zone.

At this section, the existence of fault zone is confirmed by the results of TEM prospecting and seismic reflection prospecting. Especially, the results of TEM prospecting (TMB 30 line) reveal the excellent fractured zone or fault zone extending at the southward of the tunnel line on the basis of confirmed reversal transient phenomena. Moreover, the results of TEM survey clarified the existence of fault by confirmed structural discontinuities from STA.35+600 to STA.35+750 nearby the Yuan river. The existence of this fault is also confirmed by observation of aerial photograph. In this case, special attention should be paid for the presence of fractured rock and fault clay and to the removal of groundwater at this fault zone area.

At the section from STA.38+000 to STA.46+100, the tunnel passes under the highest mountain (about 1,600 m in elevation) in Kok-Ing No.2 tunnel. The geological condition along the tunnel invert level consists of the TRhf formation in Middle-Upper Triassic age which is continued from the former section. Furthermore, the summit area of mountain range is covered by the ms5-3 formation in Jurassic age which is composed of tuff, shale and sandstone. Overburden of the tunnel is thick and reaches 600 to 1,240 m in elevation.

At the section between STA.46+100 and STA.47+200, tunnel line passes under a limestone mountain which is in the fault contact with alternation of sandstone, tuff and shale belonging to the TRhf formation at STA.46+100. This limestone can be observed on the drillings DHB-7 and DHB46SP and is accompanied by thin shale layer. In addition, the existence of limestone cave which is filled by loose quaternary sediment is found by drilling. Overburden shows ranging from 160 to 300 m.

Moreover, on the occasion of tunnel construction at this section, the most significant problem is removal of groundwater from potential limestone cave as well as the section between STA.28+550 and STA.30+100, and special attention should be paid to this matter.

The section from STA.47+200 to STA.49+900 is underlain by dark gray tuff, sandstone interbedded with shale which belongs to the TRhf formation in Middle-Upper Triassic age. Fresh rocks are characterized by partly silicified and hard facies. Overburden shows the thickness ranging from 85 to 410 m.

The tunnel line of this section between STA.49+900 and STA.50+400 passes through small limestone mountain which is in the fault contact with the TRhf formation. Overburden shows 60 to 200 m in thickness. Furthermore, limestone cave is found in the limestone mountain, therefore, special attention should be paid to removal of groundwater on the occasion of tunnel construction.

The geological condition of this section from STA.50+400 to the tunnel outlet consists also of the TRhf formation, however, overburden is shallow and rock mass shows highly weathered facies.

(g) Geological Condition of the Yao Flood Control Dam

Geological condition of the Yao flood control dam is composed of sedimentary rocks (shale, sandstone and tuff etc.) of the TRhf formation in Middle-Upper Triassic age. According to the "Geological Map of Northern Thailand, sheet 1 (Nan), 250,000 in scale" by DMR, geological condition around damsite is reported as t-p formation in Permian-Triassic age and that of the greater part of reservoir area is marked as ms5-3 formation in Jurassic age. As for these geological formation names around the damsite, the TRhf formation is adopted for having a consistent formation name at the Ing-Yot No. 2 tunnel area.

Total 6 boreholes and 3 lines of seismic refraction prospecting were performed at damsite. The results of drilling investigation revealed that core condition of the drilling holes along the dam axis is hard and dense, however, all of these contain entirely a large quantity of crack up to a deeper portion, except drilling hole (DH-1) at the right abutment. Especially core condition of the drilling hole (DH-4), which is located nearby the original spillway alignment at the left abutment, is characterized by the existence of thick strongly weathered rock zone and weathered rock zone, which show about 10.0 m in thickness including top soil layer and about 24.0 m in thickness respectively. As for this geological condition, the reason of accompanying thick overburden is not apparent. However, there is a possibility that the left abutment of damsite is located on the elongated

part of fault zone which is confirmed as a parallel fault at the northeastward of the damsite on the "Geological Map of Northern Thailand, sheet 1 (Nan), 250,000 in scale" by DMR. Moreover, core condition of drilling holes of DH-5 and DH-6 is also similar to that along the dam axis.

(h) Geological Condition at the Proposed Borrow Area

At the proposed borrow area, which is located on about 500 m upstream direction from the damsite, geological investigations (total 25 test pits and total 57 augerholes) were carried out for the purpose of confirmation of available quality for dam embankment materials and clarification of soil characteristics. The results of investigation revealed abundant existence of ML (SM and CL, locally), therefore, it is judged that this area can be used as proposed borrow area for impervious and semi-pervious materials for dam embankment.

Furthermore, the results of soil test (sieving test) also revealed simultaneously that use of these materials for dam embankment can possibly be accepted, though the graims size is rather rich in fine particles.

On the contrary, the results of field reconnaissance survey also revealed that pervious materials (rock material and filter material) which are always used as dam embankment materials, can not be found at around/near the dam site. In this case, the pervious materials will have to be supplied from the tunnel excavation materials (tunnel muck), especially from tunnel section between adit No.7 and outlet which can be used also as the construction materials of dam. This tunnel muck is composed of tuff and limestone which show stiff and massive characteristics. On the other hand, there is a large possibility that filter materials (sand and gravel material) need to be hauled from the Nan area (river deposits of the Nan river) which is dredged as sand and aggregate materials at present.

(i) Geological Condition along the Yao River Training Route

Geological condition of both abutments along the Yao river is mainly composed of sedimentary rocks. Geological formations at this area are lithologically divided into "the lower Triassic to upper Permian t-p series" and "the middle Triassic t series" in ascending order. (The above series name is based on the data from the "Geological Map of Northern Thailand (sheet No.1), Hannover (DMR), 1975)

In this case, the former is mainly distributed at the area of left-side bank of the Yao river and is composed of conglomerate, shale, sandstone, limestone and chert. On the other hand, the latter extends at the area of right-side bank and mainly consists of tuff and sandstone which are characterized by hard and stiff rock facies as compared with former rock facies. Distribution of the above in major tributaries is inferred to be reflected as different durability of both geological formations.

Furthermore, alluvial deposit on a large scale around the confluence point of the Yao and Nan rivers forms flat plain, which slopes gently south-southeastwardly, with sand and gravel.

Taking the above geological condition and the results of field reconnaissance survey into consideration, at the Yao river training area, it is judged that most of the sites have no problem as for engineering geological sense, except the hazard of erosion on a small scale at the condition of rising and descending of river water, especially at the condition of a rapid increase and decrease of river water.

11.1.3 Overall Environmental Conditions

As the proposed Project facility consists of the long water diversion length of about 170 km and the various kinds of large scale structures such as canals, culverts, tunnels, a weir, a dam and river training works, the Project facility will bring about various environmental impacts for natural conditions, ecological conditions and human life at the area along the water diversion route. Accordingly JICA team has surveyed and studied the following overall environmental impact by the Project facility in cooperation with the local consultant J.V. prior to the preliminary design work for the facility.

(1) Existing Chiang Rai Weir and Kok Intake

The existing Chiang Rai weir is proposed to be used for the weir to divert the Kok water in the Project. The flow condition is as follows;

- Mean annual runoff ; 3,500 MCM (corresponding to the annual mean discharge of 110 cu.m/sec)
- Wet and dry season runoff ; 2,750 MCM (175 cu.m/sec) and 750 MCM (35 cu.m/sec)
- Maximum and minimum discharge ; 950 cu.m/sec and 8 cu.m/sec

(a) Weir

Since the fixed type weir is constructed with the crest elevation of 385.79 m, which is 1.2 m higher than the original river bed elevation, the scouring at the river bed at the weir downstream will be accelerated in future by flood energy, while the flood water level of the Kok river at the Chiang Rai urban area located at 6 km upstream of the weir will be slightly risen up.

The Chiang Rai weir has not fishway to migrate from the Mekong river to the upstream of the Kok river.

Several weirs also are constructed in the Kok-Lao river which joins at the downstream of the Chiang Rai weir but have no provision of fishway. The following mitigation measures for the above environmental impact will be required;

- River bed reinforcement at the downstream of the Chiang Rai weir to prevent the scoring.
- Provision of fishway which will be proposed at the route from the Lao river mouth connecting with the Kok river at the downstream of Chiang Rai weir to the right bank of the weir. This proposed route is the original course of the Kok river before construction of the weir. Fishes being obstructed by the existing weirs in the Lao river could mitigate to the Kok upstream from the Mekong river through the above route.
- The existing intake water level of 389 m at Chiang Rai weir is mainly designed to divert the Kok water in the dry season to the people irrigation area. If the water level of 389 m is maintained in the flood season, its back water will bring about inundation problem at the upstream Chiang Rai area. The operation water level at the weir in the flood season shall be carefully reviewed.

(b) Kok Intake

The Kok intake is proposed at 3.5 km upstream right bank of the Chiang Rai weir. As the Kok

river has a possibility at the proposed intake site to rise up the flood water level and to bring about a large sediment materials, so that the following mitigation measures will be required.

- The Kok intake water level will be set up below 389 m to avoid the inundation problem at the upstream area.
- Flood protection dike with elevation of more than 389 m will be necessary at the Kok intake site.
- A large sediment pond with area of more than 2.0 ha shall be provided in front of the Kok intake structure.
- The sediment materials deposited in the pond shall be handed over to the private dredging company having a license to get the materials because the sediment materials are mostly fine sands which have been dredged and used for construction materials at present by many companies along the Kok river.
- The intake site including a large sediment area will be selected at the site under the public land without land acquisition cost, if possible.

(2) Kok-Ing Diversion Canal Route

The water diverted from the Kok river at the Kok intake is conveyed to the Ing basin through the Kok and Tak basins. These basins are formed with the flat alluvial plain with the elevation of 390 to 360 m. M.S.L where the wet season paddy cultivation has been dominant. The people irrigation system is existing also in the Kok, Tak and Ing basins. The mountains with the low elevation of 500 to 600 m. M.S.L are lying between the Kok-Tak and Tak-Ing. These mountains do not belong to the national park and the reserved forest IA, so that No.1 and No.2 tunnels could be proposed there without any environmental impact and mitigation measures. Following are the environmental issues incorporated in the basic plan for the Project facilities.

- Resettlement, land acquisition and compensation along the canal route
- Sufficient number of bridges to cross the diversion canal is necessary in order to facilitate the smooth communication between villages along the canal route.
- Proper crossing structures at the open canal route such as siphons, culverts, overchutes, aqueducts etc. to maintain the existing flow in the rivers, people irrigation canals and drainage canals.
- Possibility of irrigation and fishpond water supply from the diversion open canal to the beneficiaries at the project site.
- Safety measures for deep excavation at the culvert construction site.
- Spoil bank for excavation materials and borrow area for fill materials taking into account the place, volume and treatment method.
- Operation and maintenance road along the diversion canal route, which will have sufficient road width and could be used for tourism.
- Prevention for slope and land sliding at the canal construction site with deep excavation depth.

(a) Kok-Tak Route

This reach from the Kok intake to the Tak basin consists of open canal and siphons. South and north area routes will be proposed mainly based on the location of the intake and No.1 tunnel which have the following environmental differences.

South area route

- Existing DEDP Chiang Rai weir could be used without extra construction cost.
- The area having ground elevation of 390 m. M.S.L is good residential area and some area development works including village extension are progressing. Land acquisition cost is expensive and the negotiation with the landowners will take long time to settle.
- The canal route will be forced to cross Kon and Lao rivers by siphons.
- The length of culvert should be increased due to high elevation area and close distance to the village area.
- Culvert gives high construction cost but less environmental impact after completion.
- In case of deep open canal, overchute type structures are applied for existing people irrigation system.
- The mountain range between Kok and Tak basins is low and short at southern area. However, the canal route to cross Nong Luang area, shall be cancelled because the Nong Luang areas will be designated as important wetland for birds and fishes in near future.
- There are few swamps and wasteland areas for spoil bank at the upstream reaches.
- In case of parallel bank with the DEDP canal, landscape obstacles and barrier image for villagers will be less.

North Area Route

- Diversion weir at Kok river shall be newly constructed. New environmental impacts such as deposited sand, checked-up water level, flood condition, plants and animal ecology etc. will appear.
- As the route shall cross the long village along the provincial road near intake, resettlement and long temporally bypass road are required.
- The route will pass through paddy field with elevation of lower than 388 m. M.S.L which is same water level as diversion canal. People irrigation system can not cross over diversion canal by overchute type structure.
- The route does not meet Kon and Lao rivers. Construction cost of siphons and head loss will be saved.
- The route crosses DEDP project area and high bank gives disorder of irrigation and drainage system and separation image of area.
- Length and geological condition of Kok-Tak tunnel will be longer and poorer with the north direction alignment.

(b) Tak Route

This reach from the outlet of No.1 tunnel to the inlet of No.2 tunnel consists of open canal and culvert. South and north routes will be proposed mainly based on the location of No.1 and No.2 tunnel which have the following environmental differences.

South area route

- The area having a ground elevation of 390 to 400 m. M.S.L is proposed with a long culvert due to high ground elevation.
- Culvert gives high construction cost and big impact to the farmer/farmland because of big construction scale and long construction period. However culvert gives less environmental impact to natural and social facilities after completion.
- Deep open canal and long construction work of culvert may affect groundwater level and flowing condition.
- There are two reservoirs located at upstream of the Tak river and eastside of the Doi Pha Bom.
- The mountain between Tak and Ing basins has good geological condition and distance of tunnel becomes shorter than that in the southern route.
- Narrow construction site and few swamp/wasteland areas for spoil bank in the area.

North area route

- The route shall make detour route to pass the isolated limestone hills called as Pha Kiu Klai with Wat, Doi Pha Bom standing in the paddy field.
- Villages extending along highway No.1152 at about 500 m intervals are existing. Large land acquisition and resettlement for many villages will be required along the route.
- The route will pass through paddy field with elevation of 380 to 385 m.M.S.L which is the same water level in the diversion canal. People irrigation system can not cross over diversion canal by overchute type structure.
- Water supply to the Tak river if necessary, will be easily achieved by gravity without long canal.
- Geological condition of Tak-Ing tunnel will be poorer as compared with south direction alignment and the length becomes longer.

(c) Ing Route

The Ing canal route from outlet of No.2 tunnel to Roi river, which is a tributary of Ing river, consists of open canal and culvert. The route passing through paddy field to the south is proposed to create Ing regulating reservoir at Amphoe Thoeng.

- The route will pass through Ing alluvial plain between Tak-Ing mountain and Ing river. Low land area will be inundated by Ing river flood.
- The water level at the outlet of No.2 tunnel shows about 375 m.M.L.S, which is higher than the Ing flood plain level with elevation of 370 to 365 m.M.S.L. This excess water

head will make use of the gravity irrigation available.

- Two routes to cross the Ban Huai Kang area extending along the highway are proposed, one with deep excavation which will pass through the village by culvert at the west part and the other will pass by open canal with high embankment due to low paddy field elevation at the north part.
- Some small rivers flow down from the west mountains to the Ing river. Most of these streams will cross under the diversion canal by drainage culvert due to ground elevation.
- The area after crossing the highway No.1120 has an isolated village, poor road conditions and Ing flood basin at the end point.
- River training work of the Roi river is required.

(3) Ing River

The Ing weir is proposed at 2.8 km upstream of the Thoeng Bridge on the provincial road with the code No.1020. At the weir site, the Ing river has a catchment area of 4,440 km^2 and the annual runoff amount of 1,830 MCM.

The river flow during the wet season changes from 30 cu.m/sec in June to 100 cu.m/sec in August to September in the peak wet season on an average. Since the flow discharges during the wet season in the Ing river is insufficient to satisfy the design discharge of 175 cu.m/sec, the diversion water from the Kok river is necessary to supplement it.

The lowland with an area of 500 ha spreads widely at the Ing weir site and in the upstream reaches. The elevation of the lowlands ranges between EL. 362.0 m and EL. 363.5 m.

This area is covered with bush or reed and there are no villages developed in this lowland. There are no important or endangered species of fauna and flora in this area.

There, however, are many kinds of migrant fishes from the Mekong river to the upstream of the Ing river.

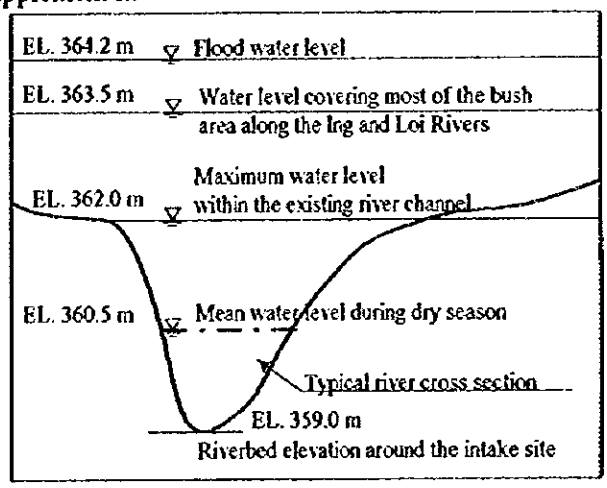


Figure 11.1.3 (3)-2 Water Level and River Cross Section at the Ing Weir Site

Taking into account that there are no sufficient river water or water body during the dry season, it is worthy to provide water for migrant fishes for creating better water environmental situation during the dry season. It also is required to provide fish-way at the proposed Ing diversion weir so as to make migrant fishes passing the proposed weir.

The wide flood prone areas spread along the Ing river from the downstream of the proposed weir site to the confluence with the Mekong river. These areas have suffered from the inundation with a long duration through the wet season due to insufficient flow capacity and the back-water effect of the Mekong river. There is a high possibility that the diversion of river water in the Ing river during the peak wet season will reduce the flood water level significantly in the river reaches.

While, during the dry season, the Ing river has no significant water for cultivating the

aforesaid flood prone areas located along the downstream reaches of the Ing river. The Project may be able to contribute development of land resources along the downstream river reaches.

The Lao river with a catchment area of 1,260 km^2, the largest tributary of the Ing river, joins at the just downstream of the proposed weir site. Flood discharge in the Lao river comes into the wide lowland area and spreads widely there.

The mean annual runoff of the Lao river is about 640 MCM comprised of 570 MCM in the wet season and 70 MCM in the dry season. The mentioned river water has been utilized in the downstream area as a water source for irrigation and drinking water, especially in the dry season. Therefore, the runoff in the Lao river is planned not to be diverted to the Nan river.

(4) Ing-Yot Diversion Canal Route

The Ing-Yot diversion canal is proposed to convey the water regulated in the Ing reservoir from the intake in the Ing weir to the inlet of Ing-Yot No.2 tunnel. The canal however shall pass through the very complicated and difficult area for construction such as the Ing flood plain, the area near village and temple, right bank mountain with poor geological condition, the Lao river with meandering shape, the high land at the right bank of the Lao river, etc.

The following environmental impact shall be carefully studied;

(a) Canal Route from Ing Intake to Ing-Yot No.1 Tunnel

The canal shall pass through at first the Ing flood plain with the open canal. Since the flood water level in the Ing basin is largely changed from 363 m to 367 m, the open canal with design water level of 363.5 m shall be protected by the flood protection dike with the crest elevation of more than 367 m. The canal shall cross the existing provincial road by culvert structure before connection with the Ing-Yot No.1 tunnel.

(b) Ing-Yot No.1 Tunnel

The canal shall cross the right bank mountain with the Ing-Yot No.1 tunnel to convey the water released from the culvert. The tunnel route shall be selected avoiding the existing village and temple and so as to access easily to the Lao river where the canal shall cross with the siphon. The particular care shall be paid for the poor geological condition in the tunnel route.

(c) Alternative Route instead of Tunnel Route

In order to avoid the tunnel construction at the mountain with the poor geological condition, the alternative route to access the Lao river by the open canal and culvert along the existing provincial road will be studied. It will be necessary however to get the concent of village peoples to select this alternative route because the route requires a large farmland acquisition and variation of the Lao river course, where the river water have been used for irrigation by village peoples.

(d) Crossing Siphon at Yao River

The diversion canal shall cross the Yao river by siphon to convey the water released from the Ing-Yot No.1 tunnel. The water level of the diversion canal at the river crossing point is mostly same as the river bed elevation of the Lao. Accordingly temporary works to change the river course during construction period will be carefully studied taking into account the impact for the water use of

village peoples, farmland acquisition for the river course to be changed, flood capacity, etc.

(e) Culvert Canal between Lao Siphon and Inlet of Ing-Yot No.2

The route between the Lao siphon and the inlet of the Ing-Yot No.2 tunnel passes through hilly area being covered with bushes and paddy field without any resettlement. The culvert structure will be required for this canal route because hilly area is formed with high elevation of 370 to 380 m against the water level of 360 m in the culvert canal.

The culvert reach between the highway No.1121 and the inlet of No.2 tunnel is formed with paddy field with the high elevation of 380 to 390 m so that the particular measure for environment impact by the deep excavation such as drainage method, land sliding protection method, etc. in the culvert shall be studied. The compensation of paddy area by the culvert construction also shall be considered.

(5) Tunnel

The No.1 and No.2 tunnels at the water diversion route between the Kok and Ing basin is designed with the discharge capacity of 140 cu.m/s, while the No.1 and No.2 tunnels between the Ing and Yot basin with the discharge of 175 cu.m/s.

Although the Kok-Ing No.1 and No.2, and the Ing-Yot No.1 tunnels are proposed at the mountainous area out of the national park and reserved forest area 1A, while the Ing-Yot No.2 long tunnel passes through the high mountain area with the elevation of 600 to 1,600 m which is belonging to the national park and the reserved forest 1A.

Accordingly the tunnel shall be planned and designed taking into account the following safety and mitigation measures for the environment impact along the tunnel route.

- Tunnel alignment shall consist of the consolidated rock formation, where tunnel construction could be safely carried out.
- The tunnel inlet and outlet, adit portals as well as muck disposal area are selected at the locations outside the national park and watershed conservation area 1A and 1B.
- And the tunnel route is designed at the location more than 100 m deeper from the ground surface in order to avoid any impact on the forest area of the national park and watershed conservation area 1A and 1B.
- Countermeasures to prevent the leakage through poor geological formation at the inlet and outlet of the tunnel as well as the inlet of adits in order to preserve the existing forest area above the entrance of the tunnel and adits.
- Safety measures for the tunnel construction such as electrical, lighting, ventilating, drainage and water supply inside tunnel.
- Treatment facility and proper operation for the polluted drainage water brought from tunnel.
- Tunnel construction method using tunnel excavation machine instead of dynamite blasting method is adopted after due consideration given to the environmental conditions in mountain area.
- Spoil bank of the tunnel excavation materials taking into account quantity and quality of

the materials, spoil bank area, treatment method of the materials using method of the spoil are, etc.

(6) Flood Control Dam Site

The flood control dam is proposed at 1.5 km upstream of the village named as King Amphoe Song Khwae. The dam site has a catchment area of 372 km^2 and the mean annual runoff of 175 MCM. The flow runoff during the wet season occupies 85 % of the annual runoff.

In the upstream of the mentioned dam site, there are several village areas along the Yao river; namely, 1) Ban Sop Phang, 2) Ban Wang Sao, 3) Ban Huai Lao, and 4) Ban Nam Pan. Among these villages, the lowest riverbed elevation at the village area is about EL. 320 m in Ban Huai Lao. Therefore, the maximum reservoir water level is possible to be set at the above mentioned elevation.

Applying the reservoir water level of EL. 320 m, there is no villages, national park and reserved areas in the reservoir area, though there exists farm area of 520 rai, or equivalent to 83 ha in the reservoir area, which requires land acquisition.

(7) Yao River

According to hearing survey about flooding in the past to village people, lowland of Ban Na Nung and Song has suffered from flood damage every year due to backwater effect of the Nan river. Downstream part of Ban Songkhwae has damaged four times in 1989, 1994, 1995 and 1996 by the flood in the last decade. In other villages, they have not experienced flooding, excluding in 1995 and 1996. Significant flood damages were caused in 1996. Especially, in Ban Na Nun and Song, village people had to evacuate to neighboring elementary school for three (3) weeks during flooding. Also, the flood with high flow velocity in 1996 washed out several houses in Ban Songkhwae and Ban Hang Thung.

The Project will convey the large amount of water during the wet season to the Yao river, which has flood problems even under the present flow condition. It is necessary to carefully study the impacts on hydraulic and hydrological change and to identify appropriate measures, as well as to mitigate flood damages along the Yao river.

11.1.4 Alternative Water Diversion Plan

(1) Overall Hydraulic Study

(a) Basic Design Dimensions

Basic hydraulic design dimensions are described as follows:

Maximum design discharge of Kok-Ing diversion canal	140.0 cu.m/s
Maximum design discharge of Ing-Yot diversion canal	175.0 cu.m/s
Kok intake water level in case of Route A	385.0 m
Kok intake water level in case of Route B (Proposed)	388.0 m
Outlet water level at Ing river side	367.6 m
Ing intake water level for Ing-Yot diversion canal	363.5 m
High water level at Yao flood control dam	320.0 m

(b) Hydraulic Design Criteria

Manning's formula is applied in diversion canal;

Flow condition	Uniform flow
Discharge formula	Manning's formula

(c) Checking of Hydraulic Energy

As mean hydraulic gradients of Kok and Ing is 1 to 2,500, while Ing weir to Yao dam is 1 to 1,700, the hydraulic heads are sufficient enough for the diversion canal, because the gradient of the canal are designed with 1/5,000 for open canal and 1/2,500 for culvert and tunnel.

(2) Kok Weir Site

There have been two (2) alternative weir sites. One is effective use of the existing Chiang Rai weir constructed by the DEDP in 1994 for irrigation water use with an area of 78,000 rai and the other is provision of a new weir at the 3.3 km downstream of the said existing weir in Ban Farm, Muang District, Chiang Rai Province.

The Thai Consultants J/V and the JICA Study Team have made comparative study in the Phase I of the Study. Through the Study, the former alternative has advantage on no additional environmental adverse effects and on reduction of the Project cost, but it requires careful monitoring about flooding in the Chiang Rai city due to operation of the existing weir during the wet season.

Whilst, the later alternative could use the water resources not only in the Kok river Basin but also the Lao river which is one of the tributary of the Kok river and joins just downstream of the existing Chiang Rai weir. However, since it is required to align a diversion canal through a new irrigation area of the DEDP and people's irrigation system, it is possible to induce social problems due to crossing the existing canals in these irrigation areas and acquiring developed agricultural land for construction of canal. From the technical viewpoints, this alternative has a disadvantage on the Project cost due to lower water head between the Chaing Rai weir and Ing weir sites.

Through the above mentioned, the alternative using the existing Chiang Rai weir has been selected as the proposed diversion weir of the Project.

(3) Diversion Canal Route in Kok Basin

(a) Route Selection

Route selection for the diversion canal consisting of open canal and siphons will be carried out with consideration of technical, economical and environmental conditions as follows.

- Diversion canal route will be given priority to the farmland away from the villages including village extension area, public infrastructures and natural/social properties. Farms are an important farmer's life basis. High cost or new lands shall be paid for land acquisition or compensation in case it becomes necessary.
- The route will be selected with the shortest distance to reduce land acquisition area and environmental impact, and be also considered of distance not to give the villagers some noise, vibration, traffic problems and other influence during construction.
- Culvert type canal will be employed at the route with deep excavation and village area

and to reduce construction cost and/or to mitigate environmental impact.

- Bridges shall be provided at the open canal which cross the existing highway, provincial road and other roads. New bridges also shall be required by request of the people.
- People irrigation system shall cross over the diversion canal by overchute type structure. Diversion canal will cross under the big rivers with siphon to keep the river function.
- Swamp area, and wasteland area will be used for spoil bank area.

(b) Proposed Diversion Route

Three alternatives which are consisting of Route A, B and B-J have been studied based on the Kok river water level, topographical and environmental conditions. As the result, B-J route is finally proposed because of shortest length of canal, most economic route, no resettlement problem and not crossing DEDP project area. Details are described and shown in the Supporting Report and in the Database Map in 1.1.4 (3). Outline of the routes in Kok basin is shown in Table 11.1.4 (3)-1

Route A North route from existing Chiang Rai Weir

The route is passing through the Kok alluvial plain with elevation of 386 to 382 m.M.S.L from new Kok weir planned at 3.3 km downstream of the existing Chiang Rai weir to No.1 tunnel located at the Kok-Tak mountain and reaches to Pha Klai area at Tak basin. The route crosses village extended along provincial road at 2.5 km downstream of new intake. Geological condition of No.1 tunnel is very poor being covered with shallow overburden and many zones. In addition, length of the tunnel shall be designed with the long distance of 5.8 km and construction cost per meter is much higher comparing with the other route tunnel.

Route B South route from existing Chiang Rai Weir

The route will pass through the Kok alluvial plain of rather high ground level with elevation of 390 to 400 m.M.S.L from the Kok existing weir to Nong Luang swamp area by open canal and culvert. No.1 tunnel is not required in this route but a culvert with a long distance and deep excavation is required due to the route passing through high ground elevation of more than 400 m. Some area of this route is under development for urban area and the route needs to cross one village extending along the highway No.1252. Land acquisition cost is more expensive than the other route. The route shall cross an important wetland "Nong Luang" area and will bring about a large environmental impact.

Route B-J Mid Route of Route A and B

This route will pass through the Kok alluvial plain with the shortest distance from the Kok existing weir to the No.1 tunnel located at the Kok-Tak mountain and after passing through the No.1 tunnel, the route reaches to the Doi Pha Bom area at the Tak basin. This route runs in parallel with DEDP main canal in the Kok basin with elevation of 390 to 382 m. M.S.L at the north of Wiang Chai town by open canal. Geological condition of the No.1 tunnel is poor but the length of the No.1 tunnel could be only 3.1 km which is shorter than the length of the route A tunnel.

Table 11.1.4 (3)-1 Outline of Routes from Kok Intake to Outlet of Kok-Ing No.1 Tunnel

Item	Route A	Route B	Route B-J	Advantage
Diversion Weir	New	Existing	Existing	B,B-J
Total canal length(m)	26,300	35,000	29,100	B-J
Open canal length	12,600	12,800	16,900	A
Culvert length	700	16,800	1,300	A
Tunnel(No.1)	5,800	--	3,100	B
Tunnel(No.2)	7,200	5,400	5,400	B
Construction cost(MB)	6,200	7,800	5,200	B-J
Environmental impact				
Land acquisition (ha)	140	150	180	A
Resettlement	Existing a little	Existing a little	No existing	B-J
Existing canal	Drainage Culvert	Overchute type	Overchute type	B,B-J
DEDP project area	Crossing	No crossing	No crossing	B,B-J
Kok new diversion weir	Necessary	--	--	B,B-J
Major canal type	Open canal	Culvert	Open canal	A
Tunnel geology	Poor	Good	Medium	B

(4) Diversion Canal Route from Tak to Ing

The route of Tak basin has been studied for the north route (B-J) and the south route (New B-J) which is newly proposed after geological survey by JICA and the Thai side. New B-J route is finally selected by the length and geological conditions of the culvert and tunnel. The route of Ing basin has no alternative route because of restricted topographic and environmental conditions. Details are described and shown in the Supporting Report and in the Database Map.

Outline of the routes from Tak basin to the outlet of Tak-Ing tunnel No.2 is shown in Table 11.1.4 (4)-1.

B-J route

The diversion canal route crosses the Tak basin with the shortest distance by open canal based on the topographic condition and crosses the Tak-Ing mountain by the No.2 tunnel with poor geological condition and a length of 7.8 km. Agriculture development is under going at the villages along the highway No.1152.

New B-J route

The route runs to south from Doi Pha Bom and reaches the No.2 tunnel. The proposed route shall pass through high ground area with elevation of 385 to 400 m. M.S.L by deep and long culvert. Geological condition of the No.2 tunnel with a length of 5.45 km is better than the B-J No.2 tunnel.

Table 11.1.4 (4)-1 Outline of Routes from Tak Basin to Outlet of Kok-Ing No.2 Tunnel

Item	Route B-J	New Route B-J	Remarks(Advantage)
Total canal length(m)	14,000	16,300	B-J(Short)
Open canal length	4,900	5,400	B-J(Short)
Culvert length	1,300	5,500	B-J(Short)
Tunnel No.2	7,800	5,400	New B-J(Short)
Construction cost (from Kok Intake To outlet of No.2 tunnel)	5.2 M.Baht	5.5 M.Baht	B-J(Cheep)
Environmental impact			
Land Acquisition (ha)	180	200	B-J(Less)
Land acquisition	Difficult	Medium	New B-J(Easy)
Resettlement	Nothing	Nothing	
Crossing of Tak River	Over the canal	Under canal	New B-J (Safety for flood)
Existing canal	Drainage culvert	Overchute type	New B-J(Good for O/M)
Major canal type	Open canal	Culvert	B-J(Cost & construction) New B-J(after completion)
Tunnel geology, Length	Poor, long	Good, short	New B-J(Cost & construction)
Spoil bank Volume	1.5 MCM	2.2 MCM	B-J(Less)

(5) Ing Weir Site

Two (2) alternative weir sites have been studied in accordance with the alternative alignment of the Ing-Yot diversion canal and tunnel; namely, 1) lower site which locates at 2.8 km upstream of the Thoeng Bridge; and 2) upper site which is lied out in the Ing river 3.5 km southwest of Ban Huai Luang.

The lower site is set up for the alternative water diversion routes A and B, while the upper site is for the route C. The alternative studies on the weir sites were carried out together with the alternative water diversion routes. As a result, the lower site is selected as a preferable option since the tunnel geology for the route C is rather poor and needs larger amount of the project cost than the other alternative routes A and B.

(6) Ing-Yot Diversion Canal

Three alternative routes from the Ing intake to the Ing-Lao siphon are planned under the condition of Kok intake water level, topographic features and environmental impact. These alternatives routes are consisting of the northern route along the Lao river (A), the southern route with tunnel (C), and mid-route of both (B). From the Ing-Lao river to the inlet of No.2 tunnel, the routes passes through paddy field in rolling hilly area or flat paddy field by culvert. The route C will require rather high construction cost due to the longer tunnel distance of 2.0 km than the other routes but have less environment impact. Details are described and shown in the Supporting Report and in the Database Map.

Outline of each Route at Ing-Lao Diversion Canal is shown in Table 11.1.4 (6)-1.

Route A (Ing-Lao river course)

The route running parallel with the Ing-Lao river or under riverbed may cause many troubles for maintenance of the diversion canal, river course, flood damage and river flow etc. during construction stage. The route passing through the flat paddy field shall cross the highway No.1121 and one village.

Route B (Village crossing and tunnel course)

The route crosses provincial road and the Ing-Lao mountain by culvert and tunnel, though the shortest length is only one (1) km but the geological conditions as poor as confirmed by JICA and/or Thai side geological investigation. The route is forced to cross one village located at the inlet of tunnel.

Route C (Tunnel course)

Location of the tunnel with a length of two (2) km is proposed at the south of village. After passing though the Lao river, the route crosses through paddy field in the rolling hilly area by culvert same as Route B. Environment impact to the villager is less than the other routes.

Table 11.1.4. (6)-1 Outline of each Route at Ing-Yot Diversion Canal

Item	Route A	Route B	Route C	Advantage
Total canal length(m)	12,000	13,500	13,100	
Open canal length	2,000	2,500	1,500	A
Culvert length	10,000	10.000	9,600	C
Tunnel	-	1,000	2,000	A
Construction cost(MB)	3,100	3,400	3,500	A
Environmental impact				
Land Acquisition (ha)	40	50	40	A,C
Resettlement	Existing a little	Existing a little	No existing	C
Lao River work	Difficult	-	-	B,C
Existing canal	Over chute type	Overchute type	Overchute type	B,B-J
Major canal type	Culvert	Culvert	Culvert	
Tunnel geology	-	Poor	Medium	C

(7) Ing-Yot No.2 Tunnel

(a) General Conditions

The Ing-Yot No.2 tunnel is planned with the length of about 51 km passing underneath the high and steep mountainous area along the national borderline between Thailand and Laos. Topographical and geological conditions around the proposed tunnel route are different from each other which are briefly summarized and stated in the Supporting Report.

(b) Selection of Ing-Yot No.2 Tunnel Route

As for the Ing-Yot tunnel to divert the water from the Ing diversion weir to the Yao river, which is the tributary of the Nan river, the following three alternative routes in the Ing-Lao basin are selected for the study at first.

- A tunnel route to cross the large alluvial plain currently under cultivation of paddy in the Ing-Lao basin (located in the direction of north-east from Chiang Kham) with the elevation of about 400 to 500 m and shallow overburden depth of about 50 m and below and consisting of completely weathered rock formation with many crushed zones along the tributaries of the Lao river. This tunnel route is planned with the shortest length of 19 km as compared with the length of about 25 km in B and C routes.
- B tunnel route which is located at the northern mountainous area with the high elevation

of 600 to 1,600 m and being covered with deep overburden depth of 200 to 1,300 m above the tunnel route except the tunnel inlet and fault zone consisting of weathered and crushed rock formation. This tunnel route requires the length of 25 km to pass the mountainous area because the tunnel is planned to have a curve along the high mountain consisting of consolidated rock formation where tunnel construction could be safely carried out.

- C tunnel route which is planned at the southern hilly and mountainous area with the elevation of 400 to 600 m and being covered with field crops and bushes. The beginning portion of the C tunnel route with the length of 19 km shall pass under the low hill, terrace and alluvial plain with the ground elevation of 400 to 450 m, so that the overburden depth above the tunnel route is as shallow as less than 60 m. This tunnel also requires the long length of 25 km and consists of slightly poor geological condition as compared with that of the tunnel B route.

The study for three alternative routes was carefully carried out in the conceptual plan on the reconnaissance level by using the topographical map with scale of 1 to 10,000 prepared by RID and geological map of 1 to 250,000 together with the field survey conducted by the tunnel expert and geologist of the JICA Study Team.

The study result is summarized in the Supporting Report according to the study result, the B tunnel route is selected as the most suitable one.

(8) Flood Control Plan in the Yao River

The flood control plan in the Yao river aims to mitigate flood damages as well as to minimize such hydraulic and hydrological changes by the water diversion of 175 m^3/sec as; 1) increase of flooding, 2) widening of inundation area, 3) prolongation of inundation period, and 4) development of river bank and bed erosion at meandering portions, bridge piers, confluence with tributaries, and so on.

(a) Mitigation and Improvement Measures

The Yot, Yao and finally Nan rivers will receive the large amount of diverted water through the proposed water conveyance system. In order to mitigate flooding problems along the villages, there are several measures; 1) provision of flood control dam; 2) improvement of the existing river channel with several types of river structures; and 3) combination of the above mentioned measures.

It is proposed to establish a flood control plan against probable flood with a probability of once in 25 years corresponding to the recorded maximum flood in the Yao river basin.

(b) Proposed Site of Flood Control Dam in the Yao River

There have been identified three (3) sites in the upstream of Ban Songkhwae. One site is located at 200 m upstream of the existing road bridge, where the riverbed elevation is EL. 276 m. Other upstream two (2) sites are 0.7 km and 2.6 km far from this site, respectively. These sites have an advantage on no resettlement in case that the reservoir water level lower than EL. 320 m is applied, since there are several villages such as Ban Huai Lao and Nam Lu over the altitude of EL. 320 m.

The storage volumes of these possible dams enable to reduce flood peak discharge of

570 cu.m/s to 100 cu.m/s (alternative 1), 120 cu.m/s (alternative 2) and 200 cu.m/s (alternative 3), assuming the constant release from each alternative dam. Whilst, the dam sites of alternatives 2 and 3 are judged to be lied on two fault lines running along the Yao river identified through the geological investigation.

Consequently, the dam site of the alternative 1 is further investigated in the feasibility study stage as the optimum dam site, taking into account the geological condition and effectiveness for flood control.

(c) Yao River Training

The Thai side study has established the planning concept for Yao river training works through the social study and discussion with the inhabitants in the riverine villages.

The concept describes that the present river water level should not be changed even if the river water in the Kok and Ing rivers are diverted by the Project and adverse effects be mitigated. Flooding situation would not be improved by the Project though the diverted water will flow down to the downstream reaches.

Based on the mentioned concept, the Thai side study proposes that the river training comprises provision of drop structures for stabilizing the present riverbed and wide and deep river channel excavation for maintain the water level under the present river as illustrated below:

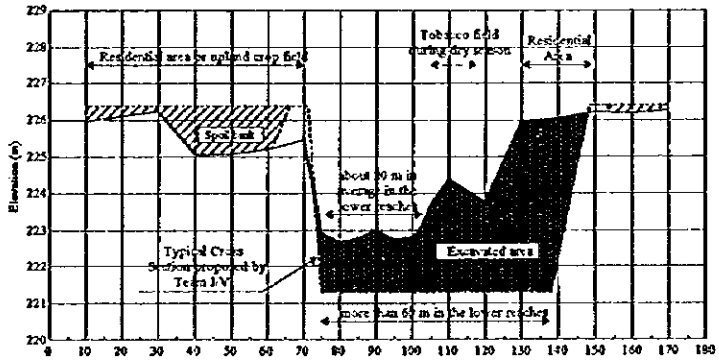


Figure 11.1.4 (8)-3 Typical Cross Section Proposed by Thai side study

It is judged to be necessary to establish an alternative concept on the river training works, which enable to minimize the land loss by the Project and to mitigate the habitual inundation by flooding in the Yao river. From the viewpoints, the study on the river training works is carried out.

(d) Flood Control Plan in the Yao River Basin

Design discharge distribution has been studied by means of unit hydrograph method for generating flood runoff and Mike 11 for converting the estimated flood discharges to water level along the Yao river.

Under the present river condition, the Yot and Yao rivers drain the flood discharge with the peak discharges of 280 m^3/sec and 270 m^3/sec to the proposed reservoir under the probability of once in 25 years. These floods join and form a flood discharge hydrograph with a peak discharge of 570 m^3/sec and duration of 3 days.

Reservoir operation study for regulating the flood peak discharges is made by applying two options; namely, constant release and flexible release.

As a result, the released discharges of 200 m^3/sec consisting of the diverted water (175 cu.m/s) and base flow (25 cu.m/s) during the wet season could be reduced to 100 cu.m/s in the option 1.

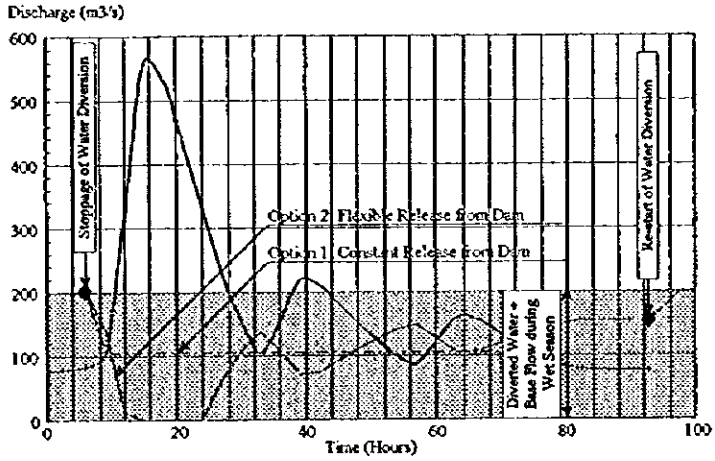
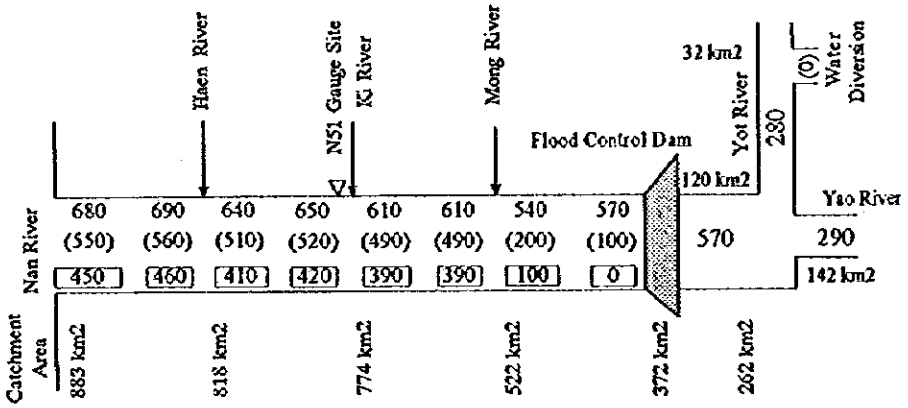


Figure 11.1.4 (8)-5 Concept of Reservoir Operation Method

In the option 2, the aforesaid released discharge of 200 cu.m/s could be decreased by fully closing the outlet gate, taking into account the reservoir storage capacity of about 32 MCM and the deduction rate of 0.6 in the following formula:

[Released Discharge] = [200 m3/s] – [Deduction Rate] x [Inflow Discharge to the Reservoir]

As a result, the following design discharges with a probability of once in 25 years are proposed for flood control plan in the Yao river:



570 Flood peak discharge under present condition

(100) Flood peak discharge under option 1 with the constant release of 100 m3/s during flood

[0] Flood peak discharge under option 2 with the flexible release of 0 m3/s during flood (Proposed)

Figure 11.1.4 (8)-6 Proposed Flood Discharge Distribution

The proposed Yao flood control dam has a capacity for reducing the flood peak discharges under present condition within a extent from 350 cu.m/s in the upstream reaches to 230 cu.m/s in the downstream reaches along the course of the Yao river in case of the option 2. But the option 1 is effective only for the upstream reaches.

Flood control plan under the regulating flood peak discharges under the option 2 is proposed through the above-mentioned study. The proposed work in the plan is; 1) provision of the flood control dam, and 2) river training works along the Yao river, based on the proposed design discharges.