11.2 Preliminary Design

11.2.1 Kok Intake

(1) Design Concept and Criteria

(a) Diversion Weir and Intake Site

It is proposed to utilize the existing Chiang Rai weir of the DEDP as the water diversion weir of the Project. The proposed intake structure locates at about 3 km upstream of the existing Chiang Rai weir.

The existing Chiang Rai weir is planned to be operated at the maximum controlled water level of EL. 389 m even during the wet season to supply supplemental irrigation water to service area.

In this river stretch in the reservoir area created by the weir, there are a few low elevation areas with the altitude of less than 389 m. These areas along the Kok river are uncultivated lands. Some locations are utilized as a temporary ferry terminal for passengers' boats navigating from Chiang Rai city to the border with the Laos during the dry season. The areas along the Kon river, a tributary of the Kok river, have been utilized as a paddy or crop field. Also, the Kon river has drained out discharges from the urban area of Chiang Rai city. Rising the river water level at EL. 389.0 m has a possibility to induce drainage congestion in the city area during the wet season.

Taking into accounts the above-mentioned, the water level of EL. 388.0 m, which is equivalent to the lowest water level during the wet season under full open of the gates at the Chiang Rai weir, is proposed for the Project.

(b) Mitigation Measure of Impact on the Sedimentation in the Existing Reservoir

The de-silting basin with a length of 180 m and the sill elevation of 386 m is designed to trap the river sand in the basin in order to minimise impact on the sediment balance at the existing reservoir.

In the proposed de-silting basin, the current river sand mining is expected to remove the deposited sand in the de-silting basin for maintenance of the intake facility.

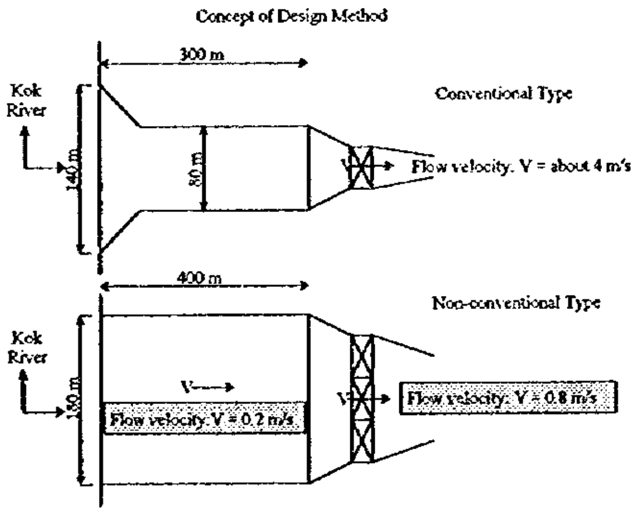


Figure 11.2.1-4 Type of Intake Facility

In order to make the proposed wide de-silting basin more effective, sufficient number of gates are proposed to reduce the flow velocity with more than 0.8 m/sec in order not to convey the significant size of sediment into the proposed diversion canal and tunnel.

(c) Layout and Conditions of Intake Structures

The proposed intake structure comprises; 1) a de-silting basin, 2) an intake tower and gate(s), 3) flood embankment surrounding intake tower, and 4) river structures such as revetment and riverbed protection works.

A de-silting basin is planned to be provided between the Kok river and the proposed Kok intake in order to mitigate the possible change of the sediment flow and to avoid adverse effects on the river sand mining.

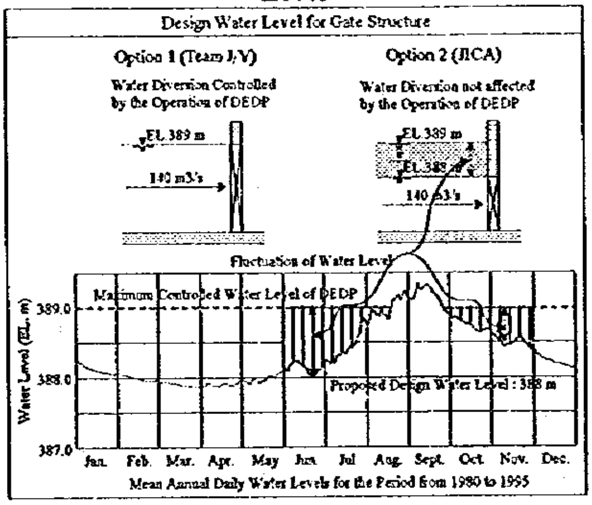
The sill elevation of the proposed intake gate is designed to be higher than the sill level of EL. 385.95 m of the existing gates at the DEDP weir so as not to take the riverbed sand to the diversion canal as possible. Also, its length and width is determined sufficient to deposit the riverbed material conveyed by the diverted water.

The river water stage of the Kok river fluctuates time to time during the wet season, especially from August to October and the proposed gates are required to strictly control the amount of the diverted water according to fluctuating river water level. Therefore, a fixed wheel gate type is selected as intake gate(s) because of advantage on accurate operation comparing with the tender-gate type.

(2) Review of Structural Design Made by the Thai Side Study

Design concept and layout of the intake facilities applied by the Thai side study have been reviewed. The main issues with different approaches from the JICA Study Team are 1) design water level of the intake gates, and 2) consideration of sedimentation in the de-silting basin.

Table 11.2.1-2 Options for Decision of Design Water Level



The Thai side study sets up the design water level of gate structure at EL. 389.0 m on the basis of the planned maximum control level of the DEDP.

However, as described in the section of 11.1.3, the applied water level of EL. 389.0 m by the Thai side study has a high possibility to result in drainage congestion of the Chiang Rai city.

The JICA Study Team concludes that the water level of EL. 388.0 m is appropriate option for design of intake gate so as to avoid the adverse effect of the Project.

In order to finalize the design water level, it is suggested to observe the operation of the existing Chiang Rai weir during the wet season after completion of irrigation system and to review the impacts on drainage congestion in the Chiang Rai city as well as inundation along the Kok river.

Regarding the de-silting basin, it is suggested that it is necessary to carry out further studies for finalizing the applied flow velocity at gate and in the de-silting basin related to sedimentation and make based on the significant investigations and surveys in the next stage of the Project.

(3) Main Features of Kok Intake Designed by JICA Team

The main features of the proposed Kok intake structures are described as follows:

- Catchment area 6,220 km²
- Design flood discharge 1,090 m³/s with a probability of once in 100 years
- Flood water level 391.91 m
- Design water level for intake gate 388.0 m
- Design discharge 140 m³/s
- Width of intake : 114 m
- Width of de-silting basin : 180 m
- Sill elevation : 386.0 m
- Gate type : Fixed wheel gate
- Gate size : 1 no. with 12.0 m (width) and 2.0 m (height)
  7 nos. with 10.0 m (width) and 2.0 m (height)
  2 nos. with 5.0 m (width) and 2.0 m (height)

11.2.2 Kok-Ing Diversion Canal

(1) Design Concept and Criteria

The Kok-Ing diversion canal is designed with the free flow of the maximum discharge capacity of 140 cu.m/sec and at the route from the Kok intake site to the Roi river, which is a tributary flowing into the Ing weir site. The canal passes through three basins of the Kok, Tak and Ing and its total length is 54.4 km consisting of open canals, siphons and tunnels.

The canal also is designed with the following appurtenant structures and its outline is summarized in Table 11.2.2.

Table 11.2.2 Outline of Kok-Ing Diversion Canal

Item	unit	Kok Basin	Tak Basin	Ing Basin	Total
1. Design Discharge Capacity	cu.m/s	140	140	140	140
2. Total Canal Length	km	14.52	16.24	23.63	54.39
Open Canal, Concrete Lining	km	10.75	5.36	19.71	35.82
OpenCanal, Earth Canal	km	-	-	2.58	2.58
Culvert	km	-	5.46	1.34	6.80
Siphon	km	0.73	-	-	0.73
Tunnel	km	3.04	5.42		8.46
3. Appurtenant Facilities					
Bridges for Highway	no.	3	1	2	6
Bridges for Provincial/Other Road	no.	7	2	18	27
Bridges for Farm and O/M	no.	13	5	16	34
Overchutes	no.	29	5	12	46
Drainage Culvert	no.	1	-	12	13
Regulator	no.	-	1	2	3
Turnouts	no.	-	2	6	8
Drops	no.	-	-	2	2

- Bridge for highway, and provincial/other roads crossing the open canal to maintain the existing public communication.
- Bridges for Farm and O/M roads to provide sufficient and smooth communication system among villages and maintain the open canal.
- Overchutes to cross the open canal and supply the irrigation water in the existing people irrigation system.
- Drainage culverts to cross the open canal and drain surplus waters in tributaries, streams and existing drainage canals.
- Regulators and turnouts at the open canal to supply a part of diversion water in the canal to the irrigation canal newly provided at the service areas in the associate projects.
- Drops to dissipate the flow energy in the open canal.

The canal design carried out tentatively by Thai side is reviewed by JICA Team based on site survey along the canal route and discussion for design concept and criteria. As a result, there are no difference in the canal design between Thai Side and JICA Team, except the Kok intake water level of 389 m by Thai Side and 388 m by JICA Team.

As for the canal route, various alternative routes have been studied by the J.V. and JICA Team as explained in the Supporting Report, taking into account topographical, geological and environmental conditions along the canal routes. Finally, B-J route from the Kok to Tak basin which was proposed by JICA Team, new B-J route from the Tak to Ing basin which also was proposed by JICA and changed a little by Thai Side and the route in Ing basin which was proposed by Thai Side were determined.

The detailed routes are described in the Supporting Report and shown in Database Map.

(2) Particular Issues in Canal Design

Particular Issues in canal design based on the reviewing result of Thai Side and supplemental study by JICA Team are summarized as follows;

- The water level at the beginning point of canal and the retention water level of the Ing weir is 387.6 m and 363.5 m. Total hydraulic head of 24.1 m is allocated for the canal length of 54.4 km. Average hydraulic slope is 1 to 2,250.
- The open canal is applied at the place with the excavation depth of less than 15 m, while the culvert canal with the depth of more than 15 m.
- The open canal is designed with trapezoid type with the bottom width of 15 m and side slope of 1 to 1.5 and the concrete lining of 20 cm at the place with excavation depth of more than 5 m and 15 cm at the depth less than 5 m. In the Roi tributary site the canal is designed with the earth canal with the bottom width of 30 m and side slope of 1 to 2.0, because this canal reach will be a part of Ing reservoir.
- The culvert is designed with the standard horse shoe section with inner diameter of 8.70 m taking into account the large overburden pressure of more than 15 m and minimization of excavation volume and compensation area at the culvert construction.
- The siphon is provided at the site where the diversion canal cross the large rivers such as

the Lao, Kon, etc. and designed with rectangular section (width of 3.6 m x 4 units and height of 3.6 m).

- Hydraulic computation is done by the Manning's formula discharge under uniform flow. Allowable maximum velocity is 1.8 m/sec in the concrete lining open canal and 3.0 m/sec in the culvert canal.
- O/M roads along the canal are designed with the road width of 4 to 6 m at the left and right bank respectively.
- Excavated materials are used for fill materials and treated at spoil banks. There are many depressions and wasted land available for spoil banks along the canal route as shown in the Database Map. The spoil bank shall be treated finally so as to be able to use for orchard and vegetable garden or green park for recreation.
- The bridges are designed with the width of 12 to 16 m in the highway and provincial road, and the standard design drawings by P.W.D, which width of other road bridges is 4 to 6 m.
- Regulator to control the water level of diversion water in the canal is designed by two tainter gates with diameter of 5.5 m.

(3) Canal Characteristics in Each Basin

(a) Kok Basin

- The canal passes through the flat paddy area near the Chiang Rai urban area by the open canal with excavation depth of 6 to 8 m. There are no culvert reaches but existing the following four siphons to cross the large rivers.

Name of River	Length of Siphons (m)
Nam Mae Kon	140.5
Nam Mae Lao	218.0
Nam Mae Hang	168.0
Nam Mae Sakoen	198.0
Total	724.5

- 29 overchutes crossing the open canal are installed to supply the irrigation water smoothly to the existing people irrigation area. Some overchute may be chancelled in future when the existing people irrigation area will be fully irrigated by the Chian Rai weir and its canal system.
- Kok-Ing No.1 tunnel is located at the mountain area between the Kok and Tak basins. This tunnel will be excavated at the Tak basin site taking into account a short tunnel length of 3.04 km and suitable spoil bank at the Tak basin.
- Nine (9) spoil banks with total area of 870 rai and spoil volume of about 1.8 million cu.m are proposed at the Kok basin as shown in the Database Map. These spoil banks could cover sufficiently the excavated material in the canal.

(b) Tak Basin

The canal in the Tak basin starts at the No.1 tunnel outlet and reaches the No.2 tunnel inlet and consists of the following open canal and culvert.

Reach	Length of Canal (km)	Remark
No.1 Culvert	1.28	Hilly area at No.1 tunnel outlet
Open Canal	5.36	Paddy area along the Tak river
No.2 Culvert	4.18	Hilly area at No.2 tunnel inlet
Total	10.82	

- As the canal consists of the culvert with the long distance of 5.46 km occupying 50 % of total canal length, the appurtenant structures such as bridges overchutes, etc. are few as compared with those in the Kok and Ing basin.

- A regulator is provided at the beginning point of the open canal to supply the irrigation water from the canal to the Tak river by gravity system. The survice area 7,000 rai along the Tak river could be irrigated by the water diverted at the proposed regulator.

- Five (5) spoil banks sites with the area of 760 rai and depositing volume of 2.1 million cu.m will be identified in the Kok basin to treat the excavated materials of the canal.

(c) Ing Basin

The canal in the Ing basin starts at the No.2 tunnel outlet, runs through the hilly area at the Ing river, crosses the vast paddy area and finally reaches the Roi river, the tributary of the Ing river. The length of open canals and culvert is as follows;

Reach	Length of Canal (km)	Remark
Open Canal (Concrete Lining)	3.96	At the outlet of No.2 tunnel
Culvert	1.34	At hilly area of Ing left bank
Open Canal (Concrete Lining)	15.75	Ing paddy area
Earth canal	2.58	At Roi river
Total	23.63	

- Since the canal in the Ing basin shall cross the existing people irrigation area, a number of bridges, overchutes, drainage culvert, etc. shall be provided.

- Two (2) regulators and six (6) turnouts to supply a part of diversion water to the service area in the existing people irrigation system shall be installed in the canal.

- The earth canal reach to the Roi river will be designed with the water level of 363.5 m, but will be inundated by the flood with the high water level of 367 m in the wet season. Accordingly the both banks of canal is designed with the high embankment canal with the crest elevation of more than 368 m.

- A number of the irrigation canals for the associate irrigation project area branched off from the Ing canal.

- Four (4) spoil banks with the area of 1,780 rai and depositing volume of 3.2 million are proposed in the Ing basin. In addition, the excavated materials will be used for the embank for the flood protection dike along the Ing river.

11.2.3 Ing Weir

(1) Design Concept and Criteria

(a) Diversion Weir and Intake Site

It is proposed that the Ing diversion weir is constructed at the upstream of the confluence with the Lao river, and that an intake structure is provided at 100 m upstream of the proposed weir on the right bank. The diversion weir site and surrounding areas lower than EL. 364 m have about 500 ha which is remained as uncultivated area and have a large retardation effect against flood from the tributaries as well as the Ing river.

(b) Concept of Structural Design

It is required to preserve the current regulating function not only for flood control but also for the existing natural environment. Also, this function is necessary to be effectively utilized for taking water from the Ing river and the diverted water of the Kok river. During the dry season, there are scarce water resources and the farmers have strong desired to have water for irrigation use. Furthermore, it is possible to enhance freshwater fishery by storing river water flow in the reservoir at the end of the wet season.

Based on the above mentioned basic consideration for facilities, the design water level of the gate is studied to enable farmers to use stored water for irrigation in the surrounding area and enhance fishery during the dry season. Also, there will be possible impact on fish migration when the gates are closed. Therefore, it is necessary to design the diversion weir with fish-way.

(d) Design Water Levels for Diversion Weir and Intake Structure

Setting the design water level at EL. 363.5 m, the river water level in the upstream of the Ing diversion weir will inundate the existing bush or reed areas.

The environmental study of the Thai side indicates that there are no rare and endangered animals and species in the wet lands along the Ing river.

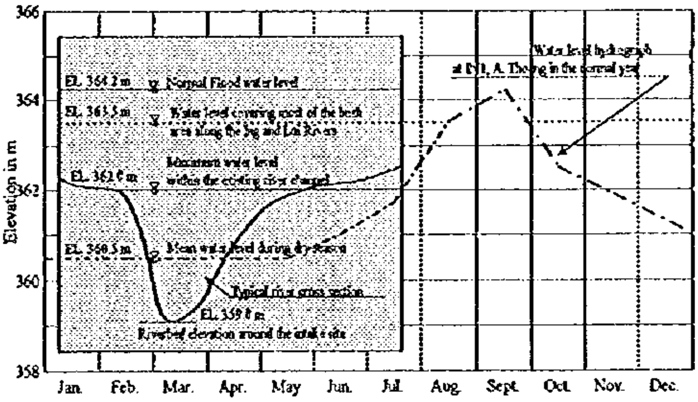


Figure 11.2.3-1 Water Level Hydrograph at Ing Diversion Weir Site

It also reveals that creation of the ponds during the dry season will provide a habitat area for fishes and an opportunity of water use for farmers living in the upstream reaches. Also, the study of the OEPP on the wet lands along the Ing river identified the same environmental situation.

Consequently, the water level of EL. 363.5 m is applied for design of the proposed diversion weir and an intake gates.

(d) Gate type of diversion weir

The Thai study proposed a rubber gate with a span length of 90 m in the Interim Report and afterwards selects the steel slide gates with four (4) leaves in the draft Final Report, since it is identified that the existing rubber gates in Thailand are sometimes broken by the inhabitants due to water allocation problems and that it has difficulty in smooth closing of gates, though the rubber gate have an advantage on cheaper construction cost and simple operation.

The objective of the diversion weir is to control the river water level at EL 363.5 m during the wet and dry season. It is rather impossible that the rubber gate is broken due to water allocation problems, since sufficient water will be provide through the diversion weir taking into account the water uses downstream during the wet season and the river flow during the dry season will pass the weir without any storing of water. The appropriate number of spans will solve the second problems above-mentioned.

(e) Layout and conditions of the diversion weir and intake structures

The proposed diversion weir is designed as a concrete weir with rubber gates of two (2) spans. A unit span length is 32 m and the bridge structure is laid out at the downstream of the rubber gates. Three (3) types of fish-way are provided at the left bank side of weir.

The proposed intake structures consist of a de-silting basin and an intake tower and gate(s). It is planned to construct the de-silting basin between the existing river channel of the Ing and the intake tower, in order to deposit the river sand with a grain size of more than 0.3 mm to be conveyed by the Ing River.

Slide steel gate is selected from the advantage on accurate operation comparing with the tender-gate type, in order to strictly control the diversion water according to the fluctuating river water level.

(2) Review of Structural Design Made by the Thai Side Study

The major differences on design of structures are selection of gate type at the proposed diversion weir and the width of the de-silting basin at the intake structure.

Regarding the gate type of the diversion weir, a rubber type gate has an advantage on construction cost and operation of the gates. Therefore, it strongly recommended furthering study and designing this type of gate in the detailed design stage of the Project.

Whilst, the width of the de-silting basin and flow velocity thereat should be finalized by means of model test about sedimentation based on the result of detailed investigation and topographic survey.

(3) Main Features of the Diversion Weir and Intake Structure Designed by JICA Team

The main features of the structures are given as follows:

Ing Diversion Weir

- Catchment area : 4,400 km^2
- Design flood discharge : 760 m^3/sec with a probability of once in 100 years
- Flood water level : 368.9 m
- Width of weir : 66.0 m
- Sill elevation : 358.7 m
- Crest elevation : 370.4 m
- Gate type : Rubber gate
- Gate size : 2 nos. with 32.0 m (width) and 4.8 m (height)

Ing Intake

- Flood water level : 368.9 m
- Design water level for intake gate : 363.5 m
- Design discharge : 175 m^3/sec
- Width of intake : 77.5 m

- Width of de-silting basin 230 m
- Sill elevation : 360.0 m
- Crest elevation : 370.4 m
- Gate type : Fixed wheel gate
- Gate size : 1 no. with 12.0 m (width) and 2.0 m (height)
  4 nos. with 10.0 m (width) and 2.0 m (height)
  2 nos. with 5.0 m (width) and 2.0 m (height)

11.2.4 Ing-Yot Diversion Canal

The water diverted from the Ing intake is conveyed to the Yao flood control dam through the Ing, Ing-Lao basin and No.2 Ing-Yot tunnel. Ing and Ing-Lao basins are formed with the flat alluvial plain with the elevation of 370 to 400 m M.S.L. The length of Ing-Yot diversion canal with maximum capacity of 175 cu.m/sec is approximately 13.1 km from the Ing intake to the inlet of No.2 Ing-Yot tunnel and diversion canal with free flow type consists of open canal, culvert and tunnel passing through hilly area.

The review and discussions with the Thai side on site survey, route selection and design criteria of diversion canal have been carried out to match the design concept from the Phase 1. Most of them come to the same results including Ing intake water level, except the water level at the beginning point of canal which is 382.80 m M.S.L in Thai side and 383.10 m in JICA side by review of the Intake structure.

After study on the alternative routes based on the topographical survey and environmental survey, diversion canal route consisted of C is adopted. Details are described and shown in the Supporting Repot and in the Data Map.

The diversion canal route is classified into two reaches except tunnel as shown in Table 11.2.4-1.

Table 11.2.4-1 Outline of Ing-Yot Diversion Canal

Reach	Basin	Capacity (cu.m/s)	Length (m)	Remarks
Reach-1			1,835	
Open Canal	Ing basin		1,475	From No.0+724.25 to 2+200.00
No.1 Culvert			360	From No.2+200.00 to 2+560.00
No.1 Tunnel			2,000	From No.2+560.00 to 4+560.00
Reach-2		175.00	9,277	
No.1 Culvert	Lao basin		285	From No.4+560.00 to 4+845.00
Siphon			185	From No.4+845.00 to 5+030.00
No.2 Culvert			8,807	From No.5+030.00 to 13+836.852
Total			13,112	

Hydraulic and structural design for safe and economic facility is carried out based on the following condition with selected route

- Water level at beginning point of canal 363.10 m M.S.L (No.0+724.25)
- Retention water level at Ing reservoir 363.50 m M.S.L

The design criteria applied the same criteria as Kok-Ing canal. The type of canal is composed three types consisting of open canal with concrete lining, siphon and culvert. Open canal with concrete lining and culvert is classified depending on excavation depth with 15 meter more or less considering stability of the structure, economical and environmental conditions.

Safe and economical section of the canal is designed by studying the hydraulic water head, steady flow condition, maximum velocity of lining materials and environmental impact.

Table 11.2.4-2 Ing-Yot Diversion Canal Dimensions

Canal Name Capacity	Canal type	Shape	Depth M	Bed width m	Velocity m/s	Bed slope
Ing-Yot	Open canal	Trapezoid	3.795	20.00	1.789	1/5,000
175.0	Siphon	Circular		D=8.50		
cu.m/s	Culvert	Horse shoe	7.550	D=9.50	2.701	1/2,500

(1) **Design by JICA**

(a) Different Points with Thai Design

The design concept between Thai and JICA sides is almost same except water level at beginning point of the canal. JICA water level is 0.3 m higher than that of the Thai side value. Water levels of JICA and Thai sides as shown in Table 11.2.4-3. Adit and sand trap are planned at inlet of the long culvert and/or tunnel.

Table 11.2.4-3 Ing Intake Water Level of JICA and Thai side

Items	Unit	JICA side	Thai side	Remarks
Ing Intake water level	m.M.L.S	383.50		
Water level at canal	m.M.L.S	383.10	382.80	Review of Intake facility
Station No. of canal B.P	Km	0+724.25	0+373.00	Review of Intake facility

(b) Design Dimensions

Major design dimensions and facilities/structures required are as follows

- Hydraulic conditionsIntake water level 383.500 m M.S.L
- Water level at canal 383.100 m M.S.L
- Canal capacity 175 cu.m/sec
- Canal length 11.112 km (out of tunnel No.1)
- Station No.Beginning point No.0+725.00
- End point No.12+281.12 (Eq=-78.72)
- Component of canal : Open canal, culvert and siphons

(c) Proposed canal type and length

Diversion canal is consisting of open canal and culvert/siphon with a length of 1,475 and 9,637 m respectively. Culvert type is applied for deep excavation portion and/or special area in shallow cases, considering economical and environmental conditions and stability of the canal. Canal type is selected by following criteria.

- Open canal with lining : Excavation depth H< 15m
- Culvert 30m > H > 15m
- Tunnel H > 30m
- Siphon : Crossing point with big river

- Drop : in case of excess water head in diversion canal
- Open canal with earth lining : in case of shallow excavation depth and good soil

11.2.5 Tunnel

(1) Design Concept and Criteria

(a) Design Concepts and Design Features

The design of the tunnel structure is made based on the following concepts;

1) To reduce impact on the current natural and social conditions as much as possible,
2) No resettlement and less compensation to be induced by construction works of the Project,
3) Safety of tunnel structure not only during the construction period but also after completion of the works, and
4) Less project cost, including construction cost and operation and maintenance cost in order to guarantee the engineering viability for the designed structure.

The design features to realize the above mentioned concepts are as follows;

1) To avoid any serious damage to the natural environment and scenery, a fully workout design plan of alignment is to be adopted.
2) When the tunnel entrance, the access road of tunnel and the inclined adit entrances for construction are planned at the locations adjacent to residences, livestock sheds or the similar places, utmost efforts are to be made to avoid negative impact on the environment in the neighboring areas.
3) Tunnel construction method using tunnel excavation machine instead of dynamite blasting is adopted after due consideration given to the environmental conditions and geological conditions in the mountainous area.
4) To build stable tunnel, supporting structures should be designed to suit the given type of ground, in accordance with geological conditions along the tunnel alignment.
5) The main principle of supporting in the mountain tunneling method is to take full advantage of the strength inherent in the excavated ground and keep the tunnel stable by means of interaction between the ground and other supports such as shotcrete and rock bolts, namely, NATM.
6) During the construction, various countermeasures to avoid noise, vibration, water pollution, lowering of groundwater level and surface settlement shall be necessary as mentioned in section 11.1.3 (5).
7) The disposal area is arranged so as to prevent any erosion or collapse by rainfall or river flow and to ensure that the surface quickly blends with the adjacent forest area.
8) Excavated materials from the tunnel can be used to create terrace land on the private lands if local residents agree to it. In such a case, the topsoil of the private lands shall be removed to the sides before dumping the excavated materials and then re-spread as topsoil for use as orchard and/or vegetable garden. Thus once unproductive lands due to rough terrain will become productive, which could certainly benefit the local residents.
9) When terrace lands are created on the public lands utilizing the tunnel excavation materials, these areas could be used as recreation areas or parks. The newly created areas could become objects of eco-tourism benefiting again the local residents.

(b) Concept of Tunnel Construction Method

Construction method commonly used for tunnels include the mountain tunneling, shield tunneling, immersed tunneling, and cut and cover tunneling methods. For Kok-Ing-Nan water diversion tunnel, mainly the mountain tunneling method is to be adopted as the standard method because the sites are located in the mountainous areas.

(c) Inner Cross-Sections of Tunnel

Alternative inner cross-sections for tunnel such as circle, standard horseshoe and widened horseshoe types are studied and the widened horseshoe cross-section is to be applied for the project with the following reasons.

Tunnel designed with circle section is generally applied for the pressure tunnel to ensure the inner water pressure. The standard horseshoe or widened horseshoe section is generally applied for the gravity flow tunnel. If the circle section is applied for the gravity flow tunnel, the circle portion at the tunnel invert shall be filled up with concrete in order to provide the flat area in the invert to haul the tunnel excavation materials and the concrete material during construction and to drive the inspection car during O&M period. Accordingly, tunnel requires the larger hydraulic section area for the circle section than that for widened horseshoe section.

The widened horseshoe cross-section of this diversion tunnel is formed as a 3-center circle, usually with an arched ceiling so that axial force can be delivered smoothly against earth pressure and other loads and bending moment produced can be held at a minimum level.

Further, the widened horseshoe cross-section has the wider invert width that can be used for transportation in the tunnel easily and smoothly.

(d) Hydraulic Gradient of Tunnel

In this study, tunnel was designed with the hydraulic condition such as discharge velocity and tunnel section area by each diversion capacity as follows based on the different hydraulic gradient of 1 to 2,500 and 1 to 4,000 for the Kok-Ing route and Ing-Yot route, respectively.

Table 11.2.5.(1)-1 Hydraulic Tunnel Section for the Kok-Ing Route

Items	Discharge Capacity (cu.m/sec)				
	75	100	125	140	165
1 Gradient of 1 to 4,000					
Radius of Upper Harf (m)	4.35	4.85	5.25	5.45	5.80
Total Height of Inner Section (m)	6.52	7.28	7.88	8.18	8.70
Velocity (m/sec)	1.82	1.95	2.05	2.10	2.19
Inner Section Area (sq.m)	57.20	57.20	68.10	73.43	83.18
2 Gradient of 1 to 2,500					
Radius of upper Half (m)	3.95	4.40	4.80	5.00	5.30
Total Height of Inner Section (m)	5.93	6.60	7.20	7.50	7.95
Velocity (m/sec)	2.15	2.31	2.44	2.51	2.61
Inner Section Area (sq.m)	38.48	47.79	56.90	61.77	69.43

Table 11.2.5.(1)-2 Hydraulic Tunnel Section for the Ing-Yot Route

Items	Discharge Capacity cu.m/sec				
	110	135	160	175	200
1 Gradient of 1 to 4,000					
Radius of Upper Harf (m)	5.00	5.40	5.75	5.95	6.25
Total Height of Inner Section (m)	7.50	8.10	8.63	8.93	9.38
Velocity (m/sec)	1.99	2.09	2.18	2.23	2.30
Inner Section Area (sq.m)	61.77	72.08	81.75	87.55	96.60
2 Gradient of 1 to 2,500					
Radius of upper Half (m)	4.60	4.95	5.25	5.45	5.75
Total Height of Inner Section (m)	6.90	7.43	7.88	8.18	8.63
Velocity (m/sec)	2.38	2.49	2.59	2.66	2.75
Inner Section Area (sq.m)	52.25	60.54	68.12	73.40	81.80

As is clear in the above table, the tunnel inner section area by the gradient of 1 to 2,500 is about 20 percent smaller than that of 1 to 4,000. As a result the tunnel construction cost is naturally reduced. In this study, accordingly design of tunnel longitudinal section with the gradient of 1 to 2,500 has been adopted both for the Kok-Ing and Ing-Yot tunnels.

Needless to say, size of the cross-section is determined in consideration of economy and stability.

(2) Review of Thai Design

(a) Tunnel Alignment

In accordance with the Thai study for the Kok-Ing and Ing-Yot tunnels, some alternative routes are proposed in the Phase 1 study period, as mentioned in 11.1.4. In case of Ing-Yot tunnel, one is the northern (A and B route) and the other is the southern route (C route). The southern tunnel route, however, has no viability to implement because of some negative reasons as the result of further study in this Feasibility Study stage. The proposed northern tunnel route (A and B) by the Thai Study is generally suitable in accordance with the geological and engineering aspect reviewed by the JICA Study Team and decided that the route B as an end result in the Phase 1.

Only the location of tunnel outlet has been slightly changed taking into account the social and environmental impact for Yot Village located nearby the original tunnel route and for provincial road to be relocated.

The northern B route tunnel is planned to pass through mostly the consolidated and firm rock formation with the high overburden of 100 to 1,000 m above tunnel except the inlet section and fault zone section.

The northern B route tunnel, however, requires construction divisions by the tunnel inlet and outlet and as many as 7 inclined adits.

Therefore, a reconnaissance survey has been made on the above mentioned northern B route decided in the Phase 1 study including the above mentioned 7 inclined adits with careful consideration to various conditions inclusive of the topographic features of wide range of areas surrounding the planned route, geological conditions, environment, village location and road condition for using as access road for construction.

During the reconnaissance survey and the initial TDEM survey, following significant points have been found out at the area of two places named Phu Sang Park and Doi Pha Dam, respectively.

The proposed tunnel route passes through several limestone areas, wherein, it is important to confirm the position of limestone bottom. These details are also studied using the results of TDEM survey. Moreover, it is noted that the most significant factor in tunneling at the limestone area is removal of groundwater, however, owing the lack of the hydrogeological data (hydrogeological characteristics of limestone), a definite conclusion must be reserved at this stage, leaving to be further studied in detail in the detail design stage.

As for the spring at the Phu Sang waterfall (located at 10.7 km on the tunnel route), hydrogeological mechanism has been studied based on the results of TDEM survey, including its influence on the boundary for the proposed tunnel route.

Tunnel route passes through underneath the high and unique shape mountains called Doi Pha Dam (EL.1, 000 to 1,300 class in elevation), which are made up of limestone of Triassic in age. The existence of several limestone caves and doline topography involving with water flow (located at 28.7 km on the tunnel route) are known at this area, therefore, the most significant problem when crossing limestone may be removal of groundwater. In this connection, it is inferred that these limestone formations are underlain by sedimentary rocks of the Permo-Carboniferous in age, however, the bottom of limestone has not been confirmed at present, and it will be clarified by using the results of geological analysis (TDEM method) in detail design stage.

(b) Tunnel Entrance

The site selection of tunnel entrance is very important factor. Functionally, the portal is regarded as a sort of retaining wall to protect not only an inlet and outlet of the water diversion main tunnel but also all adits to access the construction of main tunnel.

The commonly employed method in building portals avoids making cuts near the entrance as much as possible, so as to limit the loosening of ground to a minimum. In some cases, entrances have to be built in unfavorable positions that are threatened by the possibility of landslide or slope failure, or are under uneven earth pressure or poor ground bearing capacity. Dealing with these construction problems is another important points to be further studied.

The location of inlet for the Ing-Yot No.2 tunnel is selected at the same place in the stage of Phase 1, namely, at gently slope hills covered with a bamboo thicket about 200 m far from the closest residence of the village named Ban Donchai.

Only the location of tunnel outlet has been changed by about 1 km far to the northern direction in the stage of Phase 1, taking into account the social and environmental impact on Ban Phalak where is located nearby the original tunnel route and for provincial road to be relocated.

The site of entrance of the tunnel are selected and summarized as follows.

Kok-Ing No.1 Tunnel

Inlet :

Coordinates	2,198,120.00-N, 601,450.00-E
Station No.	KM. 12+281.120
Grand elevation	GL.391.3 m
Invert elevation	EL.375.06 m
Land use conditions	old banana plants and bamboo thicket
Slope gradient	gentle slope

Overburden	8 m.
Geological condition	Upper section: talus, loose sand and clay Bottom section: fractured PTR formation
Distance from village	1 km. from Ban Don Mun and Ban Yok Charoen
Turning Point (T.P.):	
Coordinates	2,197,270.00-N, 603,670.00-E
Distance from Inlet	2,377.16 m.
Outlet:	
Coordinates	2,196,785.00-N, 604,132.00-E
Station No.	KM. 15+320.80
Grand elevation	GL.394.4 m
Invert elevation	EL.373.84 m
Land use conditions	paddy field
Slope gradient	very gentle slope
Overburden	12 m.
Geological condition	Full section: alluvium loose sand and clay
Distance from village	3 km from Ban San Ngon Thai 3.5 km from Ban Chong Lom (Route 1152)
Distance from T.P.	669.83 m.
Total Length of No.1 tunnel	3,046.99 m. with one (1) turning point

Kok-Ing No.2 Tunnel

Inlet:	
Coordinates	2,190,180.00-N, 609,330.00-E
Station No.	KM. 26+139.777
Grand elevation	GL.398.7 m
Invert elevation	EL.369.37 m
Land use conditions	old banana plants and bamboo thicket
Slope gradient	gentle slope
Overburden	24 m.
Geological condition	Full section: weathered shale/sandstone
Distance from village	0.5 km. from Ban Huai Luk and Ban Thung Khong
Outlet:	
Coordinates	2,188,360.00-N, 614,430.00-E
Station No.	KM. 31+557.254
Grand elevation	GL.388.0 m
Invert elevation	EL.367.20 m
Land use conditions	orchard for mango, lichee and longan
Slope gradient	very gentle slope
Overburden	12 m.
Geological condition	Upper section: talus, loose sand and clay Bottom section: weathered black shale Distance from village4.5 km. from Ban Huai Kang Rat
Total Length of No.2 tunnel	5,415.02 m. without turning point

Ing-Yot No.1 Tunnel

Inlet:

Coordinates	2,174,143.057-N, 626,502.420-E
Station No.	KM. 2+560.00
Grand elevation	GL.376.8 m
Invert elevation	EL.353.37 m
Land use conditions	bamboo and bush thicket
Slope gradient	gentle slope
Overburden	14 m.
Geological condition	Lapilly tuff to tuff breccia
Distance from village	0.6 km. from Ban Thung Khan Chai
Distance from Wat	0.3 km. from Wat Thung Khan Chai

Turning Point (T.P.):

Coordinates	2,174,384.992-N, 626,024.666-E
Distance from Inlet	679.032 m.

Outlet:

Coordinates	2,174,296.886-N, 628,357.781-E
Station No.	KM. 4+560.000
Grand elevation	GL.394.4 m
Invert elevation	EL.352.58 m
Land use conditions	broad-leaved trees and bamboo thicket
Slope gradient	slightly sharp slope
Overburden	12 m.
Geological condition	lapilly tuff to tuff breccia
Distance from village	3 km. from Ban Pa Chi
Distance from river	0.5 km. from Lao river
Distance from T.P.	1,338.181 m.

Total Length of No.1 tunnel — 2,008.21 m. with one (1) turning point

Ing-Yot No.2 Tunnel

Inlet:

Coordinates	2,174,211.071-N, 635,713.745
Station No.	KM. 13+836.952
Ground elevation	GL.365 m.
Land use conditions	bamboo and bush thicket
Slope gradient	very gentle slope
Overburden	20 m.
Geological conditions	weathered shale, sandstone and tuff alternation
Distance from village	200 m. from Ban Don Chai

Outlet:

Coordinates	2,144,860.00-N, 669,170.00-E
Station No.	KM. 64+711.952
Ground elevation	GL.335 m.
Land use conditions	bush thicket
Slope gradient	very gentle slope

Overburden	10 m.
Geological conditions	highly weathered sandy tuff, tuffaceous shale alternation
Distance from village	1.7 km. from Ban Phalak
Total Length of No.2 tunnel	50,875 m. with six (6) turning points

(3) Design of JICA

(a) Design Criteria of Standard Support Pattern for Tunnel Structure Type

The principle of supporting in the mountain tunneling method is to take full advantage of the strength inherent in the excavated ground and keep the tunnel stable by means of interaction between the ground and other supports such as shotcrete and rock bolts.

Taking the past actual construction achievements into account, this study classifies ground conditions by grouping of geology for rock mass classification as for tunnel construction, and tunnel classification by ground condition as shown in the following section (b), which is associated with the selection of excavation methods and dimension of supports in design stage on the basis of the results of prior geological survey.

The tunnel geology is classified based on the standard of Ministry of Construction in Japan, which includes evaluations on strength of intact rock material, spacing, and conditions of disconnecting, etc. as described in the following section (b).

The conditions of ground water, evaluation on RQD, information of faults, etc. are added to the tunnel rock classification of tunnel type along the alignment. In addition to the above information, the discriminations of different sound by actual keen hearing of the sound with patting rock piece by rock hammer, and confirmation of bedding, jointing and seam by actual patting rock piece are also very useful information to apply the grade of ground.

To build stable tunnel, supporting structures should be designed to be suitable for a given type of ground. As shown in Table 11.2.5. (3)-1, this study has set standard support patterns for initial design corresponding to the classification of ground conditions.

The standard support pattern for tunnel type such as rock bolting, steel supporting, shotcreting, concrete lining, etc. is classified into seven (7) types as B, C1, C2, D1, D2, E1 and E2 in accordance with geological condition along the tunnel alignment. The outline of excavation and concrete lining for each tunnel type is described as follows;

- B and C1 types to be applied for rather favorable geological conditions are excavated by the top heading and long bench method and reinforced with only rock bolt with 4.0 m length but without steel support. Un-reinforced concrete lining thickness is 30 cm for arch and sidewall and 40 cm for invert.

- C2 type is to be excavated by the top heading and long/short bench method with auxiliary bench and reinforced with rock bolt with 3.0 m and steel support of H-125 with 1.2 m interval for upper half only. Thickness of shotcrete is 10 cm and concrete lining thickness is 30 cm in arch and sidewall, 40 cm in invert.

- D1 and D2 type are excavated by the top heading and short bench method and reinforced with rock bolt with 4.0 m length and steel support of H-125 for D1 type and H-150 for D2 type with 1.0 m interval each. Thickness of shotcrete is 15 cm for D1 and 20 cm for

D2 type. Un reinforced concrete lining is available for D1 and reinforced concrete lining is required for D2 type and the thickness are 40 cm in arch and side wall and 50 cm in invert.

- E1 and E2 type are excavated by the top heading and mini bench method and reinforced with rock bolt with 4.0 m length and specially forepiling with 3.0 m length for E2 type and strong steel support of H-200 with 1.0 m or less interval. Reinforced concrete lining is required and its thickness is 50 cm in arch and sidewall and 60 cm in invert.

In the actual construction work, the support pattern needs to be changed appropriately on the basis of observation of cutting faces, measurement of convergence, the axial force of rock bolts and so forth as to make the support structure fit each type of the ground. Figure 11.2.5. (3)-1 is a flow chart of the design and construction of the mountain tunneling method.

For the design of shotcrete and rock bolts, their standard dimensions are set according to the grades of grounds as shown in Table 11.2.5. (3)-1 "Standard Support Patterns". For actual works, these designs are modified on the basis of the results of observation of the face, measurements, etc., to select a suitable support pattern.

(b) Proposed Grade of Ground for Standard Support Patterns

The grade of ground is proposed/decided on the basis of the following factors which are composed of the geological feature and rock mass classification by observation of drilling core, including RQD (rock quality designation) values and core length, in combination with the rock piece test and in-situ test using borehole etc. Furthermore, the purpose of this grading the ground is to present a basic guide for tunnel design, especially in determining tunnels supporting type. Factors for determination of grade of tunnel are summarized as follows.

Geological feature;

The following geological conditions are considered as the items for geological features; weathering, hardness, spacing and condition of bedding or cracks, thickness of overburden, fault and water discharge.

Rock mass classification by observation of drilling core, RQD and core length;

Rock mass classification by drilling core observation is the most basic factor, including RQD and core length.

Laboratory test results;

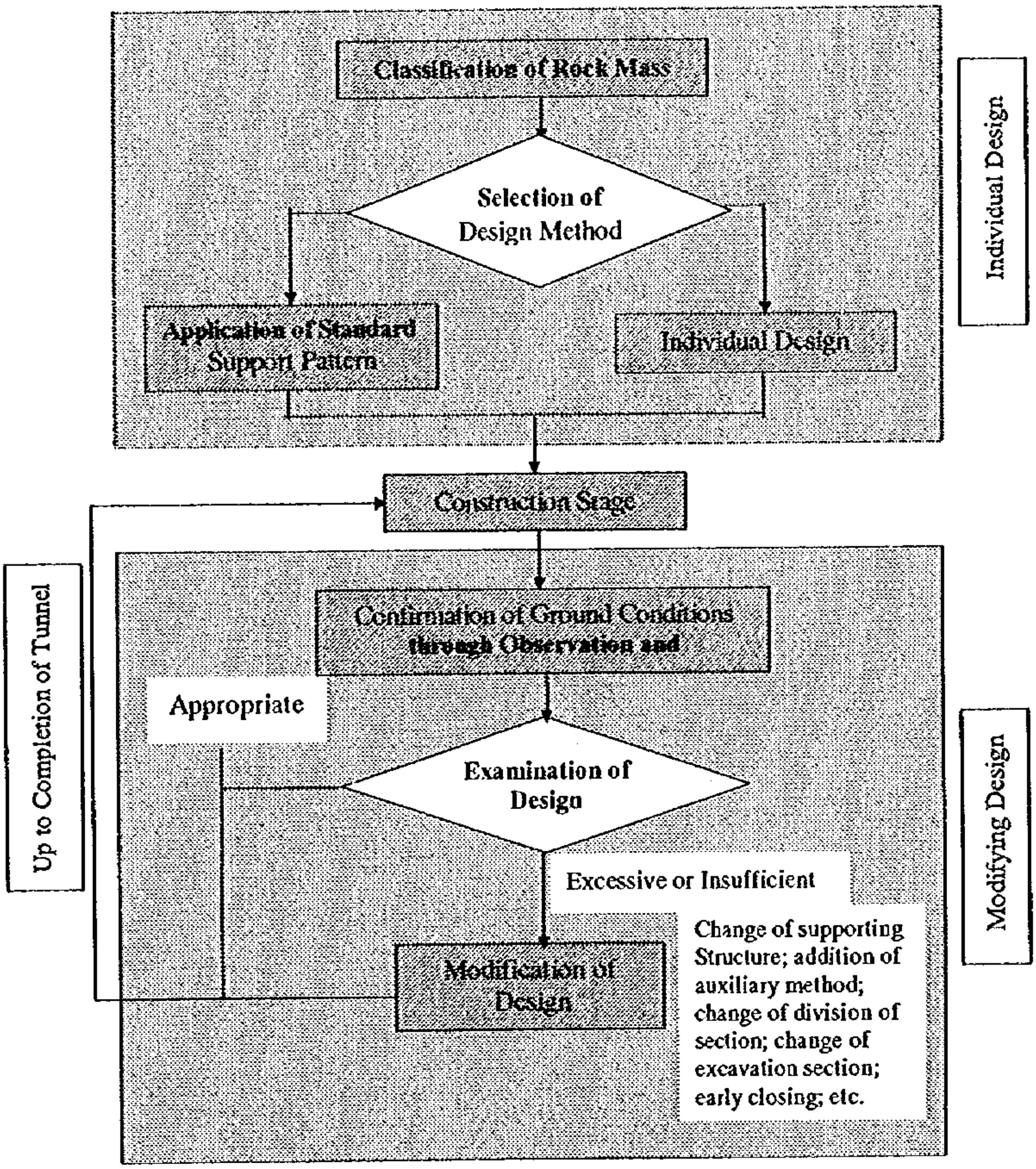
Results of laboratory test are effective application for deciding the grade of ground. The main items of laboratory test are as follows,

Uniaxial compressive strength (qu) by rock pieces

Unit weight by rock pieces

P-wave and S-wave velocity (supersonic wave velocity) by rock piece

Figure 11.2.5.(3)-1 Flow Chart of Design and Construction of Mountain Tunneling Method



In-situ test results;

Results of in-situ test, which means logging test using borehole, are also effective application for deciding the grade of ground. The main items of in-situ test are as follows,

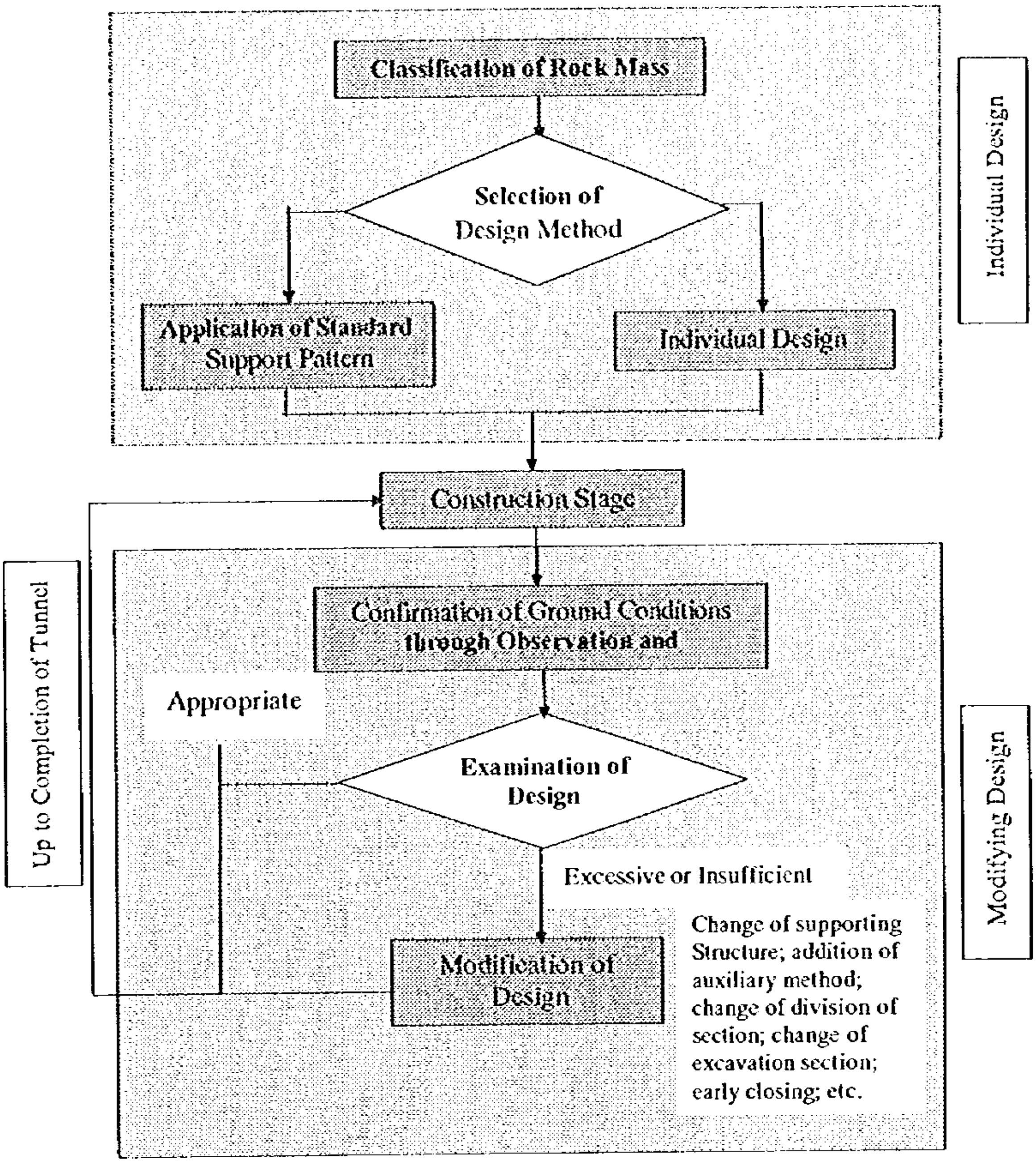
P-wave and S-wave velocity by full wave form logging

Resistivity by resistivity logging

Results of seismic prospecting survey and electromagnetic prospecting survey;

P-wave velocity by seismic prospecting survey (seismic refraction prospecting and seismic

Figure 11.2.5.(3)-1 Flow Chart of Design and Construction of Mountain Tunneling Method



In-situ test results;

Results of in-situ test, which means logging test using borehole, are also effective application for deciding the grade of ground. The main items of in-situ test are as follows,

P-wave and S-wave velocity by full wave form logging

Resistivity by resistivity logging

Results of seismic prospecting survey and electromagnetic prospecting survey;

P-wave velocity by seismic prospecting survey (seismic refraction prospecting and seismic reflection prospecting) is used as reference data because layer structure on the analyzed section contains various rock classes. Moreover, the results of electromagnetic prospecting survey are also used as reference data.

Proposed grade of ground for the tunnel design is summarized as follow. (Refer to Table 11.2.5. (3)-2 to Table 11.2.5. (3)-5)

Table 11.2.5.(3)-1 Standard Support Patterns for Kok-Ing-Nan Water Diversion Tunnels

Grade Of Ground	Excavation Method	Standard round length (upper half) (m)	Rock bolt			Steel arch supporting			Shotcrete thickness (cm)	Welded metal net		Lining			Progress (Excavation Per/Mon.)
			Length (m)	Installation pitch		Upper half	Lower half	Standard pitch (m)		Upper half	Lower half	thickness (cm)		Rein-force-ment	
				Circu.mfer-ential (m)	Longitudinal (m)							Arch and side wall	Invert		
B	Bench Cut Method	2.0	3.0	1.5 (upper half only)	2.0	None	None	-	5	-	-	30	40	-	80
C I	Bench Cut Method	1.5	3.0	1.5	1.5	None	None	-	10	-	-	30	40	-	85-95
C II	Bench Cut Method	1.2	3.0	1.5	1.2	H-125	None	1.2	10	-	-	30	40	-	80-90
D I	Bench Cut Method	1.0	4.0	1.2	1.0	H-125	H-125	1.0	15	○	-	40	50	-	65-70
D II	Bench Cut Method	1.0	4.0	1.2	1.0	H-150	H-150	1.0	20	○	○	40	50	○	65-70
E I	Bench Cut Method	1.0	4.0	1.2	1.0	H-200	H-200	1.0	20	○	○	50	60	○	65-70
E II	Bench Cut Method	1.0 or less	forepiling 3.0	0.6	1.0	H-200	H-200	1.0	25	○	○	50	60	○	60~65
			4	1.2	1.0										

Table11.2.5. (3)-2 Rock Mass Classification by Drilling Core Observation

Rock Class	Description	
	Rock Group Affected by Weathering	Rock Group not Affected by Weathering
A	The rock mass is very fresh, and the rock forming minerals and grains undergo neither weathering nor alteration. Joints are extremely tight and their surface has no visible sign of weathering. Sound by hammer blow is clear.	
B	The rock mass is fresh, solid and massive. There is no open crack (even of 1mm) but latent cracks are formed. Part of the rock forming minerals and grains undergo slight alteration. Rock blocks can be separated by ordinary to firm hammer blow along bedding plains and/or slaty cleavages. Sound by hammer blow is clear.	
CH	The rock mass is relatively solid. The rock forming minerals and grains undergo weathering except quartz along cracks. The cohesion of joints and cracks is slightly decreased and rock blocks can be separated by ordinary to firm hammer blow along joints. Clay minerals remain on the separation surface. Sound by hammer is a little dim.	The rock mass is almost fresh and solid. Rock forming minerals and grains undergo a little alteration. There is no open crack but latent cracks formed mainly along bedding plane or slaty cleavages. The cohesion of latent cracks is slightly decreased and rock blocks can be separated by ordinary to firm hammer blow along latent crack. Core length ranges from 10 cm to 50 cm Sound by hammer is a little dim.
CM	The rock mass is somewhat soft. The rock forming minerals and grains are somewhat softened by weathering except quartz. The cohesion of joints and cracks is somewhat decreased and rock blocks can be separated by ordinary hammer blow along the joints. Clay minerals remain on the separation surface. Sound by hammer is somewhat dim.	The rock mass is relatively solid. Rock forming minerals and grains undergo a little alteration. The cohesion of latent cracks is decreased. Rock blocks can be separated by ordinary hammer blow along latent crack. Core length ranges from 5 cm to 10 cm Sound by hammer is somewhat dim.
CL	The rock mass is soft. The rock forming minerals and grains are softened by weathering. The cohesion of joints and cracks is decreased and rock blocks can be separated by soft hammer blow along the joints. Clay minerals remain on the separation surface. Sound by hammer is dim.	The rock mass is somewhat soft. Rock forming minerals and grains are softened by alteration. The cohesion of latent cracks is remarkably decreased. Rock blocks can be separated by soft hammer blow along the latent joints with remarkable slicken side. Core length is less than 5 cm Sound by hammer is dim.
D	The rock mass is remarkably soft. The rock forming minerals and grains are softened by weathering. The cohesion of joints and cracks is almost absent and rock blocks collapses by light hammer blow. Clay materials remain on the separation surface. Sound by hammer blow is remarkably dim.	The rock mass is soft and/or sheared. The rock forming minerals and grains are softened by alteration and shearing. The cohesion of joint and latent cracks is almost absent and rock blocks collapses by weak hammer blow or some times by finger press along remarkable slicken side.

Table11.2.5. (3)-3 Grade of Ground (Rock Mass Classification) and Geological Condition

Grade of Ground	Geological Group	Geological feature	Drilling			Rock Test			
			Rock Mass Class	RQD	Core Length (cm)	Compress. Strength (kgf/cm^2)	Unit Weight (g/cm^3)	Vp by Ultrasonic (km/sec)	Vs by Ultrasonic (km/sec)
B	a	Rock is fresh and relatively hard, and contains remarkable bedding or slaty cleavage but they contact tightly. Rock blocks will be separated only along small and narrow faults parallel to bedding. Covered by enough thick overburden (more than 500 m in thickness). Rock mass not becomes inferior by water.	(CH -) B	80 or more	10 – 50	800 or more	2.70 or more	4.5 or more	2.5 or more
	b	Rock is fresh and hard to very hard. Bedding plane contacts tightly. Rock blocks will separate along small faults. Formation covered by enough thick overburden (more than 500 m in thickness). Rock mass not becomes inferior by water.	CH - B	90 or more	10 – 30	1,000 or more	2.70 or more	5.0 or more	2.9 or more
CI	a	Rock is fresh. Relatively hard. Bedding and slaty cleavage is remarkable and tends to easily cleave along those. Space of narrow width, small faults is relatively wide Rock mass not becomes inferior by water.	CH (- B)	50 - 80	5 - 50	200 - 800	2.70 or more	3.5 or more	2.3 or more
	b	Rock is fresh or slightly weathered along cracks. Relatively hard. Rock is fresh, but rock blocks may be cleaved along latent joints, while rock is weathered, rock blocks may be separated along crack. Bedding plane contacts relatively tight.	CH (- B)	60 - 90	5 - 30	500 - 1,000 or more	2.65 or more	4.0 or more	2.5 or more

Table11.2.5 (3)-4 Grade of Ground (Rock Mass Classification) and Geological Condition

Grade of Ground	Geological Group	Geological feature	Drilling			Rock Test			
			Rock Mass Class	RQD	Core Length (cm)	Compress. Strength (kgf/cm2)	Unit Weight (g/cm3)	Vp by Ultrasonic (km/sec)	Vs by Ultrasonic (km/sec)
CII	a	Rock is fresh or slightly to moderately weathered. Relatively hard or somewhat soft. Rock blocks may cleave very easily along bedding planes or slaty cleavage and small narrow fault and tends to crack along bedding.	CM (-CH)	10 - 50	5 - 30	100 - 400	2.65 or more	3.0 or more	2.0 or more
	b	Rock is fresh or moderately weathered along cracks. Relatively hard. Rock blocks may cleave along latent joints or bedding and may separate along cracks. Bedding plane contacts are not so tight.	CM (- CH)	10 - 60	5 - 10	200 - 1,000	2.60 or more	4.0 or more	2.5 or more
DI	a	(1) Considerably weathered rock mass. Some part of rock mass is highly weathered and has been altered to brown clay remaining highly fractured hard rock. (2) Fault and crushed rock with considerable width and under considerable thick overburden. Some parts of rock mass have been altered to firm clay minerals and rocks can be crushed easily along bedding or cracks with slicken side. (3) Discharge of groundwater is not so serious.	CL - CM	10 or less	5 or less	100 or less	2.65 or more	---	---
	b					200 or less	2.60 or more		
DII	A, b		CL			--	---		
EI, EII	A, b	(1) Formation covered by very shallow overburden near inlet and outlet. (2) Highly weathered rock, which has been altered to clay. (3) Fault and crushed zone with considerable width in which action of considerable eccentric earth pressure is assumed. Groundwater discharge is serious. (4) Limestone cave filled with loose sediment and water discharge is predicted. (5) Talus and Pediment.	D	---	--	---	---	---	---

Table 11.2.5. (3)-5 Grade of Ground (Rock Mass Classification) and Geological Condition

Grade of Ground	Geological Group	Rock Mass Class	Borehole Logging				
			Full Wave Sonic Logging		Electric Logging (Resistivity ohm-m)		
			Vp (km/sec)	Vs (km/sec)	P3 formation	CPnb formation	PTRv, TRhf formation
B	A	(CH -) B	4.0 or more	2.5 or more	---	10 or more	---
	B	CH - B	4.5 or more	2.8 or more	---	5 or more	1,000 or more
CI	A	CH (- B)	3.5 or more	2.2 or more	---	10 or more	---
	B	CH (- B)	4.0 or more	2.5 or more	---	5 or more	500 or more
CII	A	CM (- CH)	3.0 or more	2.0 or more	600 or more	10 or more	---
	B	CM (- CH)	4.0 or more	2.5 or more	250 or more	5 or more	400 or more
DI	A	CL - CM	3.0 or more	1.9 or more	100 or more	10 or more	---
	B	CL - CM	3.0 or more	2.3 or more	100 or more	5 or more	400 or more
DII	A	CL	3.0 or more	1.9 or more	100 or more	10 or more	---
	B	CL	3.0 or more	2.3 or more	100 or more	5 or more	400 or more
EI	a, b	D	---	---	---	---	---
EII	a, b	D	---	---	---	---	---

(c) Proposed Quality Standard of Shotcrete

For shotcrete in grade D ground, a metal net (150x150x5m/m) is used to reinforce shotcrete. If it is squeezing ground, steel fiber shotcrete may be used at actual works. The quality standard for shotcrete is shown in Table 11.2.5. (3)-6.

Table 11.2.5. (3)-6 Quality Standard of Shotcrete

Compressive strength of one day age (N/mm2)	Compressive strength of 28 days age (N/mm2)	Maximum size of coarse aggregate (mm)	Type of Cement
5	18	15	Ordinary Portland Cement

In general, fully bonded rock bolts are used and materials of high workability and economy are selected to match the grade of the ground. Twist bolts and deformed reinforcing bars are commonly used as rock bolt materials and set accelerator added mortar is in wide use as bond materials. Rock bolts designed with a diameter of about 25 mm and to be endurable against at least 10tf pulling force after three (3) days as guideline.

(d) Standard Sectional Sizes of Concrete Lining

Thickness of lining for the Kok-Ing-Nan water diversion tunnel is planned as shown in Table 11.2.5(3)-7. The most characteristic point of view for this standard of concrete lining is used to make an invert lining for all extend over even rather good geological condition such as type B on the grade of ground because of the reason for water diversion tunnel. The standards were established after comprehensive study of past construction works, as well as by experiment works on full-size models, and so forth.

To prevent water leaks into the tunnels and cracks in lining, waterproof works comprising a waterproof sheet at least 0.8 to 1.0 mm thick and a back buffer textile is provided between shotcrete and lining. Cast-in-place unreinforced concrete are used for B, C1, C2 and D1 types of the grade of ground as the materials for lining though reinforced concrete are employed in places for D2, E1 and E2 types of the grade of ground under high earth pressure or close to the portals.

Table 11.2.5. (3)-7 Sectional Sizes of Lining Concrete

Grade of Ground		B	C1	C2	D1	D2	E1	E2
Thickness of lining (cm)	Arch and Side Wall	30			40		50	
	Invert	40			50		60	
Kind of Concrete		Unreinforced Concrete				Reinforced Concrete		
Compressive Strength of 28 days age (N/mm^2)		18				21		

Table 11.2.5. (3)-8 shows the material composition of concrete for lining and the standard design strength.

Table 11.2.5. (3)-8 Quality Standard for Lining Concrete

Compressive strength of 28 days age (N/mm²)	Maximum size of coarse aggregate (mm	Slump (cm)	Air content (%)	Type of Cement	Minimum amount of cement (kgf/m³)
18	40	15	4.5	Ordinary Portland Cement	270
21	25				280

Notes : Allowance for slump: ±2.5 cm

Allowance for air content: ±1.5 %m

(e) Classifications of the Grade of Grand

The final assumption of classifications for the grade of ground for Kok-Ing-Nan tunnel are as following tables and figures of "Geological Profile of each Tunnel".

Table 11.2.5. (3)-9 Assumption of Grade of Ground for Kok-Ing No.1 Tunnel

Grade of Ground	Length (m)	Ratio (%)
B	0	0
C1	50.0	1.6
C2	440.0	14.4
D1	460.0	15.1
D2	560.0	18.4
E1	530.0	17.4
E2	1,006.99	33.1
Total	3,046.99	100

Table 11.2.5. (3)-10 Assumption of Grade of Ground for Kok-Ing No.2 Tunnel

Grade of Ground	Length (m)	Ratio (%)
B	0	0
C1	480.0	8.9
C2	790.0	14.6
D1	620.0	11.4
D2	660.0	12.2
E1	750.0	13.9
E2	2,115.02	39.0
Total	5,415.02	100

Table 11.2.5. (3)-11 Presumption of Grade of Ground for Ing-Yot No.1 Tunnel

Grade of Ground	Length (m)	Ratio (%)
B	0	0
C1	0	0
C2	100.0	5.0
D1	400.0	19.9
D2	850.0	42.3
E1	350.0	17.4
E2	308.21	15.4
Total	2,008.21	100

Table 11.2.5. (3)-12 Presumption of Grade of Ground for Ing-Yot No.2 Tunnel

Grade of Ground	Grade of Ground	Ratio (%)
B	2,830.0	5.6
C1	10,540.0	20.7
C2	17,880.0	35.1
D1	9,110.0	17.9
D2	6,470.0	12.7
E1	2,430.0	4.8
E2	1,604.6	3.2
Total	50,874.6	100

(f) Adit of Ing-Yot No.2 Tunnel

Necessity of Inclined Shaft

Ing-Yot No.2 tunnel is an ultra long tunnel of 50,895 m in length. Accordingly, it takes about thirty (30) years to construct if excavation is done from both sides of the tunnel, i.e., the inlet and outlet. The Ing-Yot No.2 tunnel, hence, requires an optimum number of supplementary construction tunnel intending to minimize total construction period and cost. There are three (3) kinds of supplementary construction tunnel for the purpose, horizontal adit, inclined shaft and vertical shaft. These supplementary construction tunnels are selected by topographical conditions and elevation difference between designed main tunnel and portal elevation of supplementary construction tunnel. Horizontal adit is adopted if they are at almost the same elevation. Vertical shaft is adopted if the difference between bottom elevation of main tunnel and ground surface is less then 100 m.

The inclined shaft is adopted when neither of the horizontal nor vertical shaft can be adopted. Topographical conditions and elevation difference between the designed main tunnel and portal elevation at proposed site is more than 100 m and the conditions of access road to the proposed portal site is fairly easy in the Ing-Yot No.2 tunnel. The inclined shaft is called the "adit" in this report.

Selection of Numbers of Adit of Inclined Shaft

The adit itself is used as the supplementary construction tunnel for the construction work of the main tunnel. The construction cost of the adit should be minimized. Total numbers of adit should also be minimum. The tunnel construction period for excavation work is planned to be (6) years. Hence, seven (7) adits are selected in total, after carefully trial study of each construction period calculated on the cycle time for the presumed grade of ground.

Selection of Portal Site and Alignment of Adit

The final routes for the adits were selected site by site with careful consideration to total comparative study such as various conditions inclusive of the topographic feature of wide range of the areas surrounding the planned route, geological conditions and environment.

Finally, seven (7) inclined adits will be constructed to avail access to the construction of the main tunnel. The adit locations were selected outside of 1A areas as shown in the Route Map and the outline of the adits is as follows;

Table 11.2.5. (3)-13 The Outline of the Adit

Adit No.	Distance Remark (m)	Invert Elevation at Crossing Point (m)	Portal Elevation of Adit (m)	Difference Height (m)	Length of Adit (m)	Gradient of Adit (%)
(Inlet)	0	(348.2)				
1	5,727	345.9	457.5	111.6	1,982	5.6
2	10,919	343.8	460.0	116.2	1,785	6.5
3	18,442	340.8	506.0	165.2	2,194	7.6
4	25,510	338.0	510.0	172.0	3,171	5.4
5	31,958	335.4	508.0	172.6	2,476	7.0
6	38,156	332.9	570.0	237.1	3,339	7.1
7	44,870	315.0	430.0	115.0	2,432	4.7
(Outlet)	50,875	(327.9)				
Total	50,875				17,379	

Selection of Inner Shape and Size of Adit

The type of shape of adit inner cross section to be applied will be decided based on the judgment or evaluation for geology and construction machines passing through the adit, tunneling workability, cost of construction and method of tunnel construction. The applied horseshoe shape cross-section has a wider invert width that can be used for easy and smooth transport in the tunnel not only during construction but also for operation and maintenance. The NATM with widened horseshoe shape are chosen as the standard adit type for Ing-Yot's seven (7) adits. Radius of the upper half is selected as 3.75 m for the purpose of easy smooth and safe transportation in the adit and from the economical point of view.

Classification of the Grade of Ground for Adit

Seven (7) inclined shaft are planned as the adits for the construction of Ing-Yot No.2 tunnel and the grade of ground for each adit is classified by the geological conditions along each of the adit alignment. The final presumption of classifications for grade of ground for seven (7) adits is shown in the following Table 11.2.5. (3)-14 and figures of "Geological Profile of Adit for Ing-Yot No.2 Tunnel".

Table 11.2.5. (3)-14 Presumption of Grade of Ground for Seven (7) Adits

Grade Of Ground	No.1 Adit		No.2 Adit		No.3 Adit		No.4 Adit		No.5 Adit		No.6 Adit		No.7 Adit		Total	
	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%
B	0	0	0	0	600	27.4	541	17.1	330	13.3	1,109	33.2	692	28.5	3,272	18.8
C1	490	24.7	110	6.2	784	35.7	1,550	48.9	656	26.5	1,060	31.7	980	40.3	5,630	32.4
C2	260	13.1	535	30.0	150	6.8	540	17.0	510	20.6	820	24.6	460	18.9	3,275	18.8
D1	452	22.8	550	30.8	170	7.7	130	4.1	350	14.1	80	2.4	170	7.0	1,902	10.9
D2	80	4.0	150	8.4	160	7.3	130	4.1	270	10.9	90	2.7	70	2.9	950	5.5
E1	150	7.6	170	9.5	150	6.8	130	4.1	280	11.3	90	2.7	30	1.2	1,000	5.8
E2	550	27.7	270	15.1	180	8.2	150	4.7	80	3.2	90	2.7	30	1.2	1,350	7.8
Total	1,982	100	1,785	100	2,194	100	3,171	100	2,476	100	3,339	100	2,432	100	17,379	100

11.2.6 Yao Flood Control Dam

(1) Design Concept and Criteria

(a) Geographical Condition at Dam Site

The Yao flood control dam is planned at the Yao river beside King Amphoe Song Khwae. The dam site is located at about 3.5 km southeast direction from the confluence of the Yot and Yao rivers.

The gentle mountains and hills surround the proposed dam site with an altitude of 350 m to 400 m. The abutment of the dam on the right bank side has somewhat steep gradient in comparison with that on left bank side which is located on the isolated hill lying along the mountain ridge.

(b) Layout Plan

The Yao flood control dam comprises; 1) connection channel between the Ing-Yot tunnel and the Yot river, 2) a reservoir, 3) a main dam, 4) a spillway, 5) river diversion tunnel and river outlet, 6) relocation of the existing road and bridge.

Connection channel between the Ing-Yot tunnel and Yot River

The Ing-Yot tunnel has the outlet at the small stream joining the Yot river at 7 km upstream of the confluence with the Yao river. The connection channel is laid out along this small stream. The connection channel with a total length of 1,470 m has a bottom width of 15 m, riverbed slope of 1 to 1,000, drop structures of about 1 m height at seven (7) locations. The channel section is designed with flow velocity of 2.0 m for the design discharge of 175 cu.m/s.

Yao Reservoir

The proposed reservoir with the design water level of 320 m have an area of 293 ha and the gross storage volume of 32.8 MCM. The upstream end of the reservoir along the Yao river locates just downstream of Ban Huai Lao according to the river cross section survey made by the JICA

Study Team. Also, it along the Phang river, a tributary of the Yao river, reaches about 1.5 km upstream from the confluence of the Yao and Phang rivers.

Main Dam

Taking into accounts rapid draw-down of reservoir water level for releasing stored flood discharges, of which the rate is assumed to be 20 m for two days in the minimum. In order to maintain the safety of dam against the rapid draw-down, applicability of rock-fill type dam is proposed by using rock materials to be excavated for construction of the Ing-Yot tunnel.

The up- and downstream embankment slopes are set at 1 to 3 and 1 to 2.5 respectively. It is noted that any mechanical tests have not been executed for embankment materials by the Study and suggested that it will be done in the next stage of the Project.

The proposed dam comprises the embankment, drainage and filter zones. It is suggested that upstream surface be protected by means of rip raping and that the counter weight is provided at the downstream toe of dam embankment.

Spillway

A spillway is proposed to locate on the hill on the left bank side. Design flood discharge is suggested to be diverted from the Yao reservoir to the Ma-up river, since the geologically poor layer exists on the left abutment of the dam where the spillway is most likely to be laid out. Spillway comprises non-gated overflow weir and chute way and has the design flood discharge of 1,000 m^3/sec with a return period of 1000 years.

River diversion tunnel and river outlet for release of diverted water

It is proposed to provide a river diversion tunnel with a length of about 300 m and a diameter of 6.5 m at about 200m upstream from the dam axis on the left bank. The flow capacity of the diversion tunnel is designed at 200 cu.m/sec, assumed that tunnel work be carried out during a dry season and that the upstream coffer dam and reservoir will regulate the peak discharge of 570 cu.m/sec in 25-year probable flood to 200 cu.m/sec.

The river outlet consists of a bell mouth entrance structure, inclined gate and transition section which is connected to a pressure tunnel, using as diversion tunnel. The entrance structure is planned to be equipped with fixed trash racks.

(2) Review of Design Made by the Thai Side Study

One of the major different issues is selection of the dam type. The Thai side proposes earth-fill type dam, using random materials available at the dam sites. The JICA Study Team suggests rock-fill type dam, using excavated materials at the proposed Ing-Yot tunnel. Also, JICA Study Team recommends to effectively utilizing excavated soil material for construction of flood dyke and embankment behind the proposed dyke.

In addition to the above-mentioned, the layout of spillway is subject to discussion based on verification of geological condition along the spillway channel. The Thai side proposes to excavate the geologically poor layer and replace it by concrete material. The JICA Study Team provides an alternative layout, since the geological investigation carried out by the Thai side could not clarify the extent of such a poor layer and the construction cost of the proposed alternative layout is judged to be cheaper.

In order to finalize design of the Yao flood control dam, further geotechnical investigation at the dam site, and material survey and testing are indispensable for clarifying the extent and characteristics of geologically poor portion on the left abutment, verifying availability of excavated materials for dam construction and so on. Furthermore, availability of appropriate spoil bank for the excavated materials especially in the proposal of the Thai side, is one of the significant issues for finalization of the design.

(3) Design of JICA Study Team

The main features of the proposed structures are described as follows:

1) Reservoir		
Catchment area	:	327 km^2
High water level	:	EL. 320.0 m
Low water level	:	EL. 298.5 m
Reservoir surface area	:	2.93 km^2
Gross storage volume	:	32.8 MCM
Effective storage volume	:	30.3 MCM
2) Dam		
Type	:	
Crest elevation	:	EL. 325.0 m
Dam height	:	58 m
Crest length	:	250 m
Upstream slope	:	1 to 3.0
Downstream slope	:	1 to 2.5
3) Spillway		
Type	:	Side channel (non-gated type)
Flow capacity	:	1,000 cu.m/s at the flood water level
Length of overflow section	:	100 m
Spillway channel width	:	20 m to 50 m
4) River outlet and diversion tunnel		
Type	:	Vertical inlet
Gate type	:	Roller gate
Gate size	:	1 no. with 6.5 m (width) and 7.0 m (height)
Tunnel type	:	Horse-shoe section
Length	:	300 m
Diameter	:	6.5 m
5) Connection channel of tunnel with reservoir		
Length	:	1,470 m
Channel type	:	Trapezoid channel type with a bottom width of 15 m
Channel Slope	:	1 to 1,000 with drop structures (7 nos.)

11.2.7 Yao River Training

(1) Design Concept and Criteria

River training works are comprised of; 1) improvement of riverbed profile, 2) re-forming river channel with enough flow capacity, 3) construction of consolidation sill, 4) provision of groundsill, 5) revetment for river bank protection, and 6) other related works such as replacement of the existing bridges and provision of new bridges.

(a) Riverbed profile

Riverbed profile along the Yao and Yot rivers are designed on the basis of the average riverbed slope of the current river channel so as not to induce large adverse effect on riverbed movement.

Providing same consideration to the river stretches with a comparatively steep slope, it is designed to form moderate riverbed slope by means of provision of consolidation sill with a height of less than 2.5 m.

It, also, is planned to provide the groundsills at the existing and proposed bridge sites in the river improvement stretches in order to protect the bridge piers from the assumed riverbed degradation.

The main features of the protection works for riverbed profiles are described as follows:

Table 11.2.7-1 Main Features of the Proposed River Training Works

River Stretches to be improved	River Length	Design Riverbed Slope	Proposed Improvement Works
Yao River			
0.0 km to 13.5 km	13.5 km	1: 1,070	Riverbed excavation
13.5 km to 19.0 km	5.5 km	(1:600 to 1 to 1,200)	Provision of consolidation sill 15.0 km : 1 no. and 2.5 m height 18.0 km : 1 no. and 1.8 m height
19.0 km to 23.8 km	4.8 km	1 : 400 to 1 : 550	Riverbed excavation, and Provision of groundsill (2 nos.: 20.5 km and 22.0 km)
23.8 km to 30.5 km	6.7 km	(1: 1,100)	Provision of consolidation sill 24.5 km : 1 no. and 2.0 m height 26.7 km : 1 no. and 2.0 m height
30.5 km to 41.8 km	11.3 km	1: 550 to 1: 1,100	Riverbed excavation, and Provision of groundsill (3 nos.: 32.0 km, 40.3 km and 41.8 km)
41.8 km to 56.0 km	14.2 km	(1 : 300)	Construction of flood control dam and reservoir with a height of about 50 m and gross storage volume of 30 MCM.
Yot River			
0. 0 km to 7.1 km	7.1 km	(1: 300 to 1: 380)	4 nos. of consolidation sills with a height of 2.5 m

Note: Riverbed slope in parenthesis indicates the average one.

(b) River cross section

The existing river channel has a bottom width of about 10 m to 20 m in the river improvement stretches. While, the river training plan established by the Thai Side Study is currently proposed to widen the bottom width to 20 m to 60 m. A designed typical cross section is illustrated as follows:

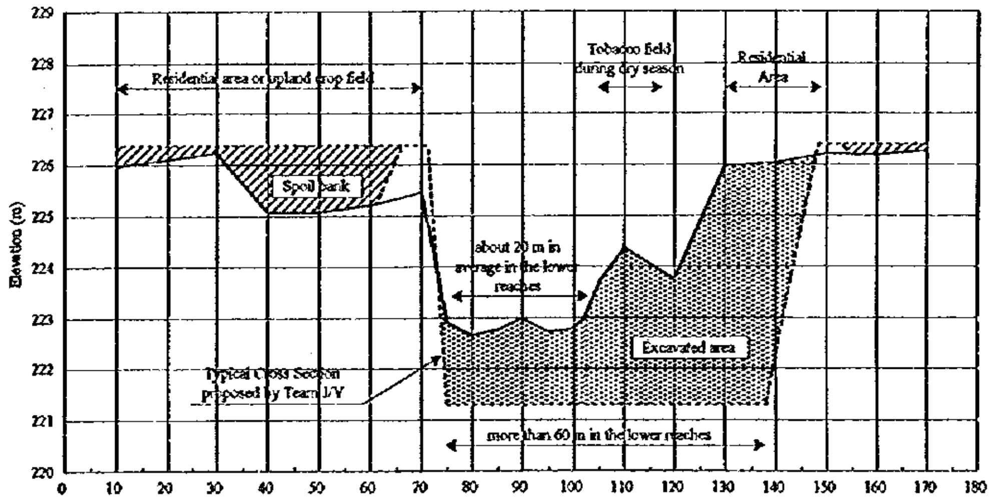


Figure 11.2.7-3 Typical River Cross Section Designed by the Thai Side Study

The proposed excavation work will have a large loss of land with a width of about 40 m, where the village people uses as residential area or upland crop field. This typical cross section is based on the assumption that the water level profile formed by the mean monthly flow discharge would not be changed even after passing the diverted water of 175 cu.m/s.

In order to reduce land loss, the following design concept is proposed as one of the alternative options:

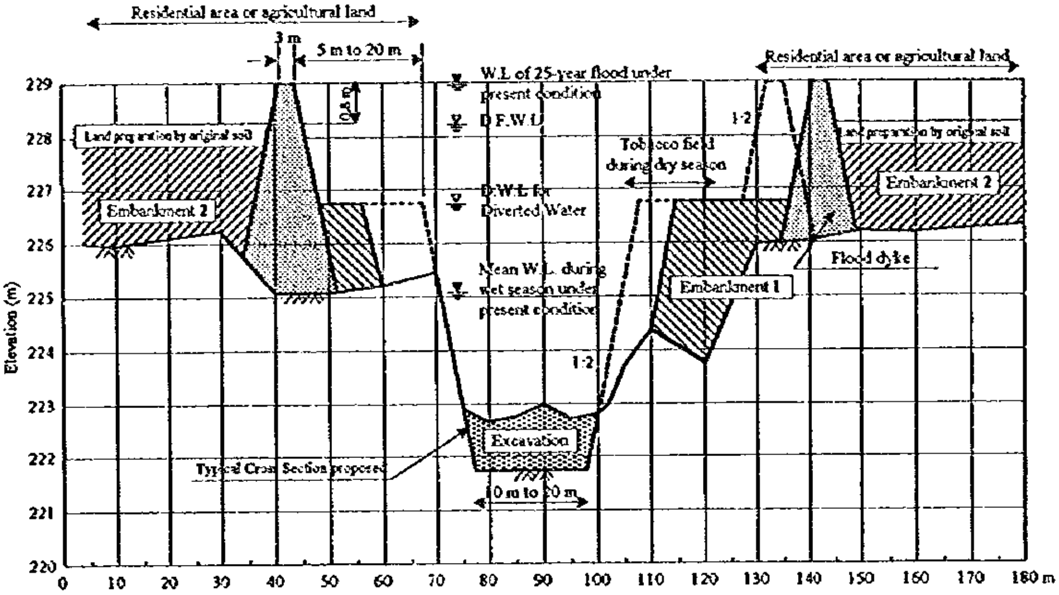


Figure 11.2.7-4 Alternative Typical River Cross Section

Land elevation of riverside area from the flood dyke, where the flood water inundate several times a year and is utilized as agricultural land during dry season, is proposed to be heightened in accordance with the needs of inhabitants (embankment 1 in the Figure).

Land elevation of the protection area, also, is heightened to avoid drainage (embankment 2 in the Figure). A side-ditch is provided at the toe of flood dyke. Especially, it is necessary for use of residence or agricultural land to provide land preparation by utilizing the existing surface soil.

Assuming that the embankment 1 and 2 is possible to use after construction works, the land loss is probably reduced about 40 % comparing with the aforesaid proposal by the Thai Side Study.

(c) Consolidation sills, ground sill and revetment works

It is proposed to provide a series of consolidation sill at the river channel with a riverbed slope steeper than 1 to 500, groundsill and revetment works at new and existing bridge sites. It is suggested to provide revetment works at meandering part, river channel along residential area in the river improvement stretches, up-and downstream of the bridges and groundsills. Location of the propose sites for providing these structures is described as follows:

Table 11.2.7-2 Location and Features of the Proposed Consolidation Sill, Groundsill and Revetment Work

Construction works	Location	Features
Consolidation sill	Distance from the Confluence with the Nan River	
	No. 1 : 15.0 km	Height: 2.5 m Riverbed Elevation: 236.2 m
	No. 2 : 18.0 km	1.8 m 240.5 m
	No. 3 : 24.5 km	2.0 m 255.2 m
	No. 4 : 26.7 km	2.0 m 259.2 m
	Distance from the Confluence with the Yao River	
	No. 5 : 2.2 km	2.5 m 301.0 m
	No. 6 : 3.2 km	2.5 m 306.0 m
	No. 7 : 4.1 km	2.5 m 311.0 m
	No. 8 : 5.1 km	2.5 m 316.0 m
Groundsill	Distance from the Confluence with the Nan River	Crest Elevation (design riverbed elevation):
	No. 1 : 20.5 km	244.9 m
	No. 2 : 22.0 km	248.7 m
	No. 3 : 32.0 km	266.8 m
	No. 4 : 40.3 km	274.4 m
	No. 5 : 41.8 km	276.0 m
Revetment works	0.0 km to 13.5 km	16 locations : 4,550 m
	19.0 km to 23.8 km	3 locations : 2,100 m
	30.5 km to 41.8 km	9 locations : 3,810 m
	Total	28 locations : 10,460 m

(d) Replacement of the Existing Bridges and Provision of New Bridges

There is no structural data on the existing bridges constructed by the Highway Department, excluding their girder elevation and span length. In the Study, replacement of the existing bridges is assumed for design of structures and estimate of project cost.

The proposed bridges are listed as follows:

Table 11.2.7-3 Location of Proposed Bridges

Location	Required Span Length	Lowest Elevation of Bridge Girder
No. 1 : 3.4 km (New)	85 m	EL. 229.3 m
No. 2 : 3.9 km (Existing)	85 m	EL. 229.8 m
No. 3 : 10.9 km (Existing)	85 m	EL. 236.1 m
No. 4 : 13.3 km (New)	60 m	EL. 238.6 m
No. 5 : 20.6 km (Existing)	50 m	EL. 251.0 m
No. 6 : 31.8 km (Existing)	40 m	EL. 272.2 m
No. 7 : 37.0 (New)	40 m	EL. 278.2 m
No. 8 : 39.5 (New)	40 m	EL. 280.5 m
No. 9 : 40.3 (Existing)	40 m	EL. 281.2 m
No. 10 : 42.4 (Existing)	40 m	EL. 282.6 m
No. 11 : Spillway bridge	60 m	

Note: The required span length are based on typical cross section and will be finalized on the basis of the river cross section surveyed by the Thai side and JICA.

In addition to the above bridges, it is identified that additional bridges be provided for communication of village peoples, since the village peoples cross the shallow river at several places by foot even during the wet season and the proposed water diversion affects such activities. Most of such places are planned to provide the new bridges, but the following places are still required to construct new bridges; 1) 1.9 km from the confluence of the Nan River, 2) 20.3 km, and 3) 40.7 km.

(2) Review of Designs Made by the Thai Side Study

The Thai Side Study was planned the river cross section with a dyke system. However, the consultation with the village peoples indicated that they would not like to provide such the dyke system, since they were anxious about sudden failure of the dyke and damages and drainage congestion due to insufficiency of the capacity and closure of the current drainage direction.

Through the result of consultation with the village peoples, the Thai Side Study has proposed the excavated river cross section with the double or triple riverbed width of the existing river channel and without any dyke system.

The JICA Study Team has studied the river channel improvement with a dyke section, since the anxiety of village peoples about technical points could be solved and provision of additional consideration to the dyke system envisaged by the Thai Side Study would give incentive to the village peoples by the dyke system concept.

From the viewpoints mentioned, the JICA Study Team has made comparative study that is given as follows:

Table 11.2.7-4 Evaluation of Flood Dyke and Excavated Channel Concepts

Issues		Flood Dyke Concept	Excavated Channel Concept
Engineering	Advantage	• Excavated soil to be produced by the proposed dam construction can be used for dyke and embankment and will not require the wide spoil bank for dam construction works.	• No drainage congestion, but rise of safety level against flood is envisaged in the channel design. • More safety than the Flood Dyke Concept, against flood with a magnitude lather than planned because of no sudden failure of dyke. • Excess flood will spread village area gradually.
	Disadvantage	• Inland drainage system should be provided, but not completely drained out, when the river water level is higher than inland elevation. • Excess flood larger than planned one (25-year flood) will break the dyke suddenly and cause damage in the village areas.	• Large amount of excavated material (4 MCM) will require wide spoil bank along the river course.
Social Impacts	Advantage	• Existing agricultural land along the riverbank could be used as present, excluding alignment of dyke area. • Embankment 1 could provide agricultural land during the normal wet season (inundation once in 2 or 3 years). • Less land acquisition and land loss	• Inhabitants will not be anxious about failure of flood dyke during the wet season and drainage congestion.
	Dis-advantage	• Approach to the river will not be better than the present, even providing approach way and steps to river.	• Land loss will be larger than Flood Dyke Concept.

Table 11.2.7-4 Evaluation of Flood Dyke and Excavated Channel Concepts

Issues		Flood Dyke Concept	Excavated Channel Concept
Natural Environment	Advantage	• Least excavation of riverbed could not change the present environmental situation significantly.	
	Disadvantage	• Less impact than Excavated Channel	• Excavated river channel will have a width of double of the existing one in the upstream and triple in the downstream and will make flat bed, which possibly give large impact on ecology and fishes due to change of water depth. • It is necessary to provide counter-measures for such impact.

Most important issues are the public acceptance, for which the Thai Side Study has intensively made public consultation and participation in the planning stage. Through these activities, the village peoples select the currently proposed excavated channel with river structures. The JICA Study Team evaluates that the proposed excavated channel plan is applicable option for passing the diverted water through the river channel of the Yao river, taking into account the village people's intention.

Whilst, the spoil banks for the excavated materials of 4 MCM will require the wide areas along the river reaches to be improved. It is recommended that further consultation is made in the next stage of the Project and that a combined concept heightening of ground elevation in the low land areas might provide one of the solutions for requirement of spoil bank.

(3) Design of JICA Team

The main features of the project facilities are summarized as follows:

1) Flood dike	Length of flood dyke	
	Left bank	: 15.1 km
	Right bank	: 11.5 km
	Total	: 26.6 km
	Average height	
	Left bank	: 2.6 m
	Right bank	: 2.4 m
	Embankment volume	: 578 thousand m^3
	Excavation volume	: 646 thousand m^3
2) Heightening of ground elevation behind the flood dike	Embankment volume	: 1,082 thousand m^3
3) Revetment	Locations	: 28
	Length	: 10,460 m
4) Drainage sluice	54 nos. (diameter 1.5 m and pipe length 10m)	
5) Consolidation sill	8 nos.	
6) Groundsill	5 nos.	
7) Bridge structure	Road bridge	: 11 nos.
	Communication bridge	: 3 nos.

11.2.8 Water Management System

The water management of Project facility will be carried out with the operation and maintenance office for the Project and with the following water management system.

(1) Operation and Maintenance Office

- The existing Chaing Rai provincial office of RID will be used as the main office of O/M of the Project.
- New branch offices will be provided at three sites of the Kok intake, the Ing weir and the Yao dam.

(2) Hydrological Monitoring Station and Work

The hydrological monitoring stations to monitor river flow variation, peak flood discharge, and sediment transport, etc. are installed as follows;

River	No. of Stations	Location
Kok	2	Upstream of Kok and Kok-Lao
	2	Kok intake site and Kok river mouth
Ing	2	Upstream of Ing
	2	Upstream of Ing-Lao and Lao river mouth
	1	Ing Weir Site
	3	Downstream of Ing
Yao	1	Upstream of Yao
	1	Yao damsite
	8	Downstream of Yao river (40km)
Total	22	

Monitoring data at stations are transmitted to main office and analyzed and evaluated. Some important data shall be transmitted from the main office to the Bangkok head office of RID and DEDP.

(3) Water Operation Management at each Facility

(a) Existing Chiang Rai Weir

The existing Chiang Rai Weir will be operated by DEDP in cooperation with RID and taking into account the following items.

- Since the Kok discharge changes largely in the wet season, the weir gates shall be operated so as to release the flood and surplus discharge while maintaining the water level of 388 m, which is the designed retention level at the Kok intake.
- The dry season discharge at the weir will be diverted to DEDP irrigation area and released to the downstream for river maintenance as priority. Surplus dry season water will be diverted to the Kok canal at the Kok intake.

(b) Kok Intake

- A large sediment depositing pond is provided in front of the Kok intake in order to prevent invasion of sediment-transport to the Kok canal. The water diversion at the pond will be carried out with the low flow velocity of 30 to 40 cm/sec.
- The water diversion at the Kok intake in the wet season shall be carried out based on the request and information from the Ing branch office, because the Kok diversion water is supplemental one to the discharge of the Ing river which does not reach the design

diversion water of 175 cu.m/sec. When a large flood appears in the Ing river and the Yao river, the Kok water diversion operation will be suspended.

- The dry season water will be carefully diverted taking into account diversion water to DEDP irrigation area and river maintenance water to the downstream. It is necessary to set up the diversion water rate for the discharge at the Kok weir.
- The water diversion amount at the Kok intake shall be measured on daily basis and reported to the O/M main office.
- Accumulated sediment-deposits shall be removed by dredging boat during the dry season and will be used construction materials.

(c) Open Canal

- The canal water shall be operated with the constant water level at the regulator point in order to divert irrigation water accurately to the irrigation beneficial area at the Kok, Tak and Ing basins through turnouts provided at the open canal.
- It is not necessary to take care the variation of diversion water in the open canal, because the diversion water is the surplus water after using for irrigation at the donor basins.

(d) Ing Weir Site

Water at the Ing Weir Site shall be operated taking into account the following rule and manner;

- In the flood season, the Ing discharge shall be firstly diverted to the Ing-Yot tunnel in order to mitigate the inundation problem by flood at the lower Ing basin. When the Ing river has discharge more than 175 cu.m/sec, the water diversion from the Kok river shall be suspended.
- Since the water level at the flood season between August to September is estimated at 365 to 370 m which is higher than the designed retention level of 363.5 m, the diversion water operation at the intake of Ing weir will be carried out by adjusting opening degree of the intake gate under the high water level so as to divert the maximum discharge of 175 cu.m/sec.
- When reservoir water level at the weir site is lower than the retention water level due to less inflow at the weir, the water diversion operation shall be carried out by maintaining the retention water level by the rubber weir.
- Since the reservoir provided at the river channel by the weir has the functions to regulate the Ing flow and diverted water from the Kok river, and to divert the regulated water to the Ing-Yot tunnel, the fluctuation of reservoir water level shall be always monitored at the weir site.
- Some river maintenance water shall be released through fish ladder installed at the weir. The Ing-Lao water which joins to the Ing mainstream at 2 km downstream of the weir site shall not be diverted to the Nan basin but used for the river maintenance and irrigation purpose at the lower Ing river. However the flow condition of the Ing-Lao river shall be monitored.

- The farm area along both banks of the reservoir could use the reservoir water for irrigation by installing pumps at reservoir. This water use shall be carefully controlled by the monitored the diversion water from the Kok river, the inflow of Ing river, the released water to the downstream and variation of reservoir water level.
- The diversion water amount to Ing-Yot tunnel and released water to the downstream river shall be measured on daily basis and reported to the O/M main office.

(4) Yao Dam

The Yao dam has two functions to control the peak flood in August to September and to supply irrigation water in the dry season.

- The reservoir shall be operated under empty condition during August to September to control the peak flood. Namely, the diverted water of 175 cu.m/sec at the Ing-Yot tunnel outlet shall be released by the low reservoir water level to the downstream river without any storage and control at the reservoir.
- When the peak flood appears in the reservoir, the discharge over 200 cu.m/sec shall be stored in the reservoir. Namely, the reservoir shall be operated in such a way to release 200 cu.m/sec through the dam outlet and storing remaining part of flood. If the large flood appears at the downstream basin of the Yao river, the above outflow of 200 cu.m/sec during flood season shall be stopped. Namely the diversion water operation shall be suspended by closing the intake gate at the Ing weir site.
- Flood alarm system shall be provided along the Yao river to inform the flood or large outflow released from the Yao dam to the village people living along the river.
- The reservoir with a capacity of 30 MCM shall be filled-up at the end of November by diversion water and the Yao river flow from October to November. This reservoir water will be used for the dry season irrigation at the area along the Yao and upper Nan river. Since the reservoir outflow for irrigation is small as 2 to 3 cu.m/sec, the outflow control will be carried out with small jet flow valve.

(5) Yao River

The flow condition of the Yao river will be remarkably changed daily and monthly depending on the released water from the Yao dam. It will be necessary to set up the gaging stations to measure variation of water level at representative villages and to monitor and evaluate the impact by the river flow variation to the river channel and villages.

11.3 Construction Plan

11.3.1 Basic Plan

(1) Construction Divisions

The construction of the Project facility will be carried out with the following 11 construction divisions taking into account the working quantity, construction period, construction cost, tunnel construction period, etc. in each division.

(1) Kok intake and Kok diversion canal including Kok-Ing No.1 tunnel.

(2) Tak-Ing diversion canal including the Tak culvert.

(3) Kok-Ing No.2 Tunnel.

(4) Ing diversion canal and Ing weir.

(5) Ing-Yot diversion canal consisting of Ing open canal, Ing-Yot No.1 tunnel, siphon crossing the Lao river and the culvert in Lao right bank.

(6) Ing-Yot No.2 tunnel dividing into 5 construction divisions.

(7) Yao flood control dam and Yao river training works.

(2) Construction Conditions

The south and north basins of the Ing weir site holds the large farm area which could be developed by the diversion water from the Kok river in the Project. In order to supply the irrigation and fishery water to the above area firstly, the construction of the Kok-Ing diversion canal system including the Kok intake and the Ing diversion weir will be commenced and completed at first. The construction of the Yao flood control dam and the Yao river training works also be commenced at the earlier stage in order to give the benefit to the Yao and upper Nan beneficial areas by the flood control and irrigation. The construction for the Ing-Yot diversion canal and the Ing-Yot No.2 tunnel will be commenced one or two years later than the above Kok-Ing canal works and Yao dam works and will be completed with a long period of 7 to 8 years. The canal works are to be carried out with 12^{hrs}/day (net operating hour 10^{hrs}), because of the large volume of the earth works while the tunnel works will be carried out with two shifts (24 hr) a day. The dam and river training works however will be carried out 8 hrs./day.

The construction plan for each project facility is studied as follows based on the working quantity and construction method to be applied.

11.3.2 Kok Intake, Diversion Canal and Ing Weir

(1) Quantity of the Works

Quantity of the works for the Kok intake, the Kok-Ing diversion canal, the Ing weir and the Ing-Yot diversion canal excluding tunnel, dam and river training works are summarized in Table 11.3.2.(1)-1.

Table 11.3.2.(1)-1 Quantity of Kok Intake, Kok-Ing Diversion Canal, Ing Weir and Ing-Yot Diversion Canal

Item	Unit	Kok Intake	Kok Canal	Tak Canal	Ing Canal	Ing Weir	Ing-Yot Canal
1 Total Length		400	11,711	10,819	23,647	-	11,548
Open Canal	km	400	11,711	5,360	22,300	-	2,096
Culvert	km	-	-	5,459	1,347	-	9,452
2 Earth Works							
Stripping	10^3m^3	65	193	279	452	29	341
Excavation (Open/Earth)	10^3m^3	500	1,916	1,581	3,780	1,110	441
Excava. (Culvert/Earth)	10^3m^3	-	-	3,099	400	-	6,537
Excava (Culvert/Soft Rock)	10^3m^3	-	-	770	100	-	1,630
Excava. (Culvert/Rock)	10^3m^3	-	-	203	26	-	430
Fill at Canal	10^3m^3	173	274	155	1,041	120	351
Backfill at Culvert	10^3m^3	-	-	3,568	412	-	7,566
Spoil of Excavated Material	10^3m^3	392	1,835	2,209	3,305	1,019	1,462
3 Concrete Works							
Canal Lining Concrete	m^3	36,000	53,260	31,400	99,520	-	10,880
Culvert Concrete	m^3	-	-	169,580	36,000	-	327,300
Structured Concrete	m^3	18,000	15,980	-	-	45,000	9,640
4 Appurtenant Works							
Overchute	no.	-	29	5	12	-	-
Highway Bridge	no.	-	3	1	2	-	-
Feeder Road Bridge	no.	-	7	2	18	-	-
Drainage Culvert	no.	-	1	-	13	-	-
Drops	no.	-	-	-	2	-	-
Concrete Pile ϕ600	m	4,500	-	-	-	3,200	-

The large earth and concrete volumes will be involved in the diversion canal construction. Especially the culvert construction in the Tak basin and the Ing-Yot canal require the large working volume as mentioned in Table 11.3.2.(1)-2.

Table 11.3.2.(1)-2 Working Volume of Tak and Ing-Yot Culvert

Item	Excavation (m^3)	Backfill (m^3)	Concrete (m^3)
Tak Culvert	4,232,000	3,658,000	169,600
Ing-Yot Culvert	8,875,000	7,566,000	327,300

(2) Earth Works

(a) Operation Month

The open canal at the Kok, Tak and Ing basins passes through the paddy field where the works in the wet season are very difficult due to requirement of the large scale drainage works during construction period. The open canal construction is planned with 9 months from October to June excluding heavy rainy season from July to September. The construction for the culvert could be carried out through the year because the culvert route is placed mostly at the hilly area and high land.

(b) Spoil Bank and Temporary Stock Yard

The spoil bank and temporary stock yard of the excavated materials will be provided at the depression and swamp areas as well as the lower land in the tributaries. Those areas could be converted to the farm land by filling-up with the excavated material and will be allocated to the farmers who will lose their farm lands due to land acquisition along the canal route. The spoil and temporary stockyards are as shown in the canal design drawings and summarized as follows;

Table 11.3.2.(2)-1 Spoil Bank and Temporary Stock-Yard

Diversion Canal	Places	Total Area (ha)	Spoil Volume (10^3m^3)
Kok Basin	9	139	1,530
Tak Basin	6	119	2,100
Ing Basin	4	187	1,680
Ing-Yot Canal	9	98	1,290
Total	28	543	6,600

(c) Construction Equipment and Their Outputs

The construction equipment and their outputs for the earth and concrete works are prepared as shown in Table 11.3.2.(2)-2.

(d) Working Party and Schedule

The construction period for the works is planned approximately with four years consisting of temporary works of 0.5 year, the excavation works of 2.5 years concrete works of 3.0 years and other works of 0.5 years. The excavation works can be carried out simultaneously with the concrete works. The working party and work schedule are studied based on the working quantity in Table 11.3.2.(1)-2 and equipment output in Table 11.3.2.(2)-2 and summarized in Table 11.3.2.(2)-3.

(e) Excavation Method of Open Canal

Since the excavation depth of the open canal is 7 to 10 m from the ground surface, the excavation works will be carried out with three steps as shown in the following figure.

Figure 11.3.2.(2) Procedure of Excavation Works of Open Canal

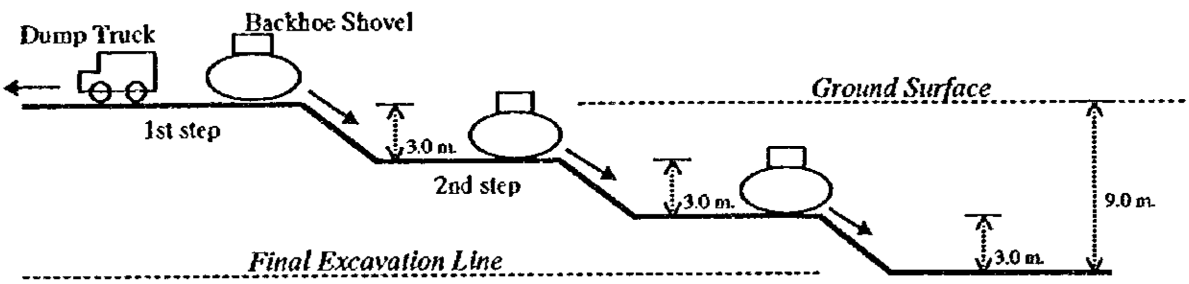


Table 11.3.2.(2)-2 Construction Equipment and Output in Diversion Canal

Kind of the Works and Construction Equipment	Output Estimation/Month	Monthly Output (m^3)
1 Stripping Wheel loaded 2.0 m^3 x 2 units Bulldozer 21 ton x 3 units Dump truck 15 ton x 6 units	130 m^3/hr x 10 hr x 25 days x 2 units (2 units at site and 1 unit at spoil) (Distance of 5 km to spoil)	65,000
2 Canal Excavation Backhoe Shovel 2.0 m^3 x 2 units Bulldozer 21 ton x 2 units Dump truck 15 ton x 6 units	125 m^3/hr x 10 hr x 25 days x 2 units (1 unit at site and 1 unit at spoil) (Distance of 5 km to spoil)	60,000
Remarks: Excavation works includes canal slop trimming and some excavation under water		
3 Culvert Excavation Backhoe Shovel 2.0 m^3 x 2 units Bulldozer 21 ton x 2 units Dump truck 15 ton x 4 units	150 m^3/hr x 10 hr x 25 days x 2 units (1 unit at site and 1 unit at stock yard) (Distance of less than 1 km)	75,000
Remarks: Excavation is carried out at the high land without drainage problem and its material is used for backfill.		
4 Culvert Excavation (Wearthered Rock) Ripper bulldozer 32 ton x 4 units Backhoe Shovel 2.0 m^3 x 2 units Bulldozer 21 ton x 2 units Dump truck 15 ton x 4 units	60 m^3/hr x 10 hr x 25 days x 4 units 120 m^3/hr x 10 hr x 25 days x 2 units (1 unit at site and 1 unit at stock yard) (Distance of less than 1 km)	60,000 60,000
5 Culvert Excavation (Rock) Rock blasting Backhoe Shovel 2.0 m^3 x 1 units Bulldozer 21 ton x 2 units Dump truck 15 ton x 2 units	80 m^3/hr x 10 hr x 25 days x 1 unit 80 m^3/hr x 10 hr x 25 days x 1 units (1 unit at site and 1 unit at stock yard) (Distance of less than 1 km)	20,000 20,000
6 Fill and Backfill Wheel loaded 2.0 m^3 x 2 units Bulldozer 21 ton x 2 units Dump truck 15 ton x 6 units	120 m^3/hr x 10 hr x 25 days x 2 units (1 unit at stock yard and 1 unit at site) (Distance of 5 km to site)	60,000
7 Concrete Mixing and Transport 7.1 Large Capacity Mixing plant 1.0 m^3 x 2 units Agitator car 4.5 m^3 x 8 units	30 m^3/hr x 10 hr x 20 days x 2 units 4.0 m^3/hr x 10 hr x 20 days x 8 units	6,000 6,400
7.2 Large Capacity Mixing plant 1.0 m^3 x 2 units Agitator car 4.5 m^3 x 6 units	25 m^3/hr x 10 hr x 20 days x 2 units 4.0 m^3/hr x 10 hr x 20 days x 8 units	5,000 4,800

Table 11.3.2.(2)-3 Construction Schedule of Kok-Ing Diversion and Ing Weir (1)

Item	Unit	Quantity	1st year				2nd year				3rd year				4th year				Remarks
			3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	(M Month)
1. Kok Intake, Kok Canal and No.1 Tunnel																			
(1) Temporary Work	L.S.																		
(2) Kok Intake																			
Stripping & Canal Ex.	m^3	565,000																	565,000 ÷ 21 m.= 26,900/m.
Fill & Backfill	m^3	173,000																	173,000 ÷ 12 m.= 14,400/m.
Canal Slope Concrete	m^3	36,000																	36,000 ÷ 15 m.= 2,400/m.
Structure Concrete	m^3	18,000																	18,000 ÷ 12 m.= 1,500/m.
Intake Gate	L.S.																		
(3) Kok Canal																			
Stripping & Canal Ex.	m^3	2,109,000																	2,109,000 ÷ 27 m.= 78,100/m.
Fill & Backfill	m^3	274,000																	274,000 ÷ 21 m.= 13,000/m.
Canal Lining Concrete	m^3	53,300																	53,300 ÷ 24 m.= 2,200/m.
Structure Concrete	m^3	16,000																	16,000 ÷ 12 m.= 1,400/m.
(4) Appurtenant Works	L.S.																		
(5) Kok-Tak No.1 Tunnel																			
2. Tak Canal & No.2 Tunnel																			
(1) Temporary Works	L.S.																		
(2) Tak Open Canal																			
Stripping & Common Ex.	m^3	1,700,000																	1,700,000 ÷ 24 m.= 70,800/m.
Fill & Backfill	m^3	155,000																	155,000 ÷ 15 m.= 10,300/m.
Canal Lining Crete	m^3	31,400																	31,400 ÷ 15 m.= 2,100/m.
(3) Tak Culvert Canal																			
Stripping & Common Ex.	m^3	3,259,000																	3,259,000 ÷ 33 m.= 100,000/m.
Weathered Rock Ex.	m^3	770,000																	770,000 ÷ 32 m.= 24,000/m.
Rock Ex.	m^3	203,000																	203,000 ÷ 32 m.= 6,300/m.
Backfill	m^3	3,568,000																	3,568,000 ÷ 30 m.= 119,000/m.
Culvert Concrete	m^3	169,600																	169,600 ÷ 30 m.= 5,700/m.
(4) Appurtenant Works	L.S.																		
3. Kok-Ing No.2 Tunnel																			

Table 11.3.2.(2)-3 Construction Schedule of Kok-Ing Diversion and Ing Weir (2)

Item	Unit	Quantity	1st year				2nd year				3rd year				4th year				Remarks
			3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	(M Month)
4. Ing Canal & Ing Weir																			
(1) Temporary Works																			
(2) Ing Open Canal																			
Stripping & Canal Ex.	m^3	4,205,000																	4,205,000 ÷ 27 m.= 155,700/m.
Fill & Backfill	m^3	1,040,800																	1,040,800 ÷ 24 m.= 43,400/m.
Lining Concrete	m^3	99,500																	99,500 ÷ 24 m.= 4,100/m.
(3) Ing Culvert Canal																			
Stripping & Common Ex.	m^3	427,000																	427,000 ÷ 18 m.= 23,700/m.
Weathered Rock Ex.	m^3	100,000																	100,000 ÷ 18 m.= 5,600/m.
Rock Ex.	m^3	26,000																	26,000 ÷ 15 m.= 1,700/m.
Backfill	m^3	412,000																	412,000 ÷ 18 m.= 22,900/m.
Culvert Concrete	m^3	36,000																	36,000 ÷ 18 m.= 2,000/m.
(4) Ing Weir																			
Stripping & Common Ex.	m^3	139,000																	139,000 ÷ 9 m.= 15,400/m.
River Training Ex.	m^3	1,000,000																	1,000,000 ÷ 24 m.= 42,000/m.
Fill & Backfill	m^3	120,000																	120,000 ÷ 12 m.= 10,000/m.
Weir Concrete	m^3	45,000																	45,000 ÷ 15 m.= 3,000/m.
Rubber Gate	L.S.																		
(5) Ing Intake																			
Stripping & Common Ex.	m^3	668,000																	668,000 ÷ 21 m.= 31,800/m.
Fill & Backfill	m^3	360,000																	360,000 ÷ 15 m.= 24,000/m.
Structural Concrete	m^3	62,000																	62,000 ÷ 18 m.= 3,400/m.
Intake Gate																			
(6) Main O/M Office																			
Control House	m^2	300																	
Main Office	m^2	2,000																	
Repair & Store Shop	m^2	3,000																	
Residencial Quarter	m^2	3,000																	

(f) Culvert construction Method

Since the culvert excavation is carried out with a depth of 15 to 20 m., the excavation works will be carried out with five to six steps in the above figure. In order to transport the excavated materials directly to the backfill site after completion of the culvert concrete and to minimize the transportation cost and land compensation cost, the construction method as shown in the following table will be applied.

Table 11.3.2.(2)-4 Construction Method of Culvert

First Reach	Excava. 450,000 m^3	6 month Excavation → Spoil
L= 500 m.	Concrete 17,000 m^3	4 month Concrete
	Backfill 400,000 m^3	6 month Backfill
2nd Reach	Excava. 450,000 m^3	Excavation → Backfill at First
L= 500 m.	Concrete 17,000 m^3	Concrete
	Backfill 400,000 m^3	Backfill
3rd Reach	Excava 450,000 m^3	Excavation → Backfill
L= 500 m.	Concrete 17,000 m^3	Concrete
	Backfill 400,000 m^3	Backfill

(g) Concrete Works

Concrete mixing plant will be provided at the following sites and the concrete is transported from the plant to the placing site by agitator cars. The concrete placing will be carried out mostly by using truck crane and concrete pump.

Table 11.3.2.(2)-5 Concrete Plant

Basin	Concrete Plant	Plant Site
Kok	0.75 m^3 x 2 units	Middle point of the Kok Canal
Tak	0.75 m^3 x 2 units	Near No.2 tunnel Inlet
Ing	0.75 m^3 x 2 units	Middle point of the Ing Canal
Ing-Yot Canal	1.0 m^3 x 2 units	Culvert working site

(h) Construction Schedule

The construction schedule is set up as shown in Table.11.3.2.(2)-6.

The canal and weir works will be completed within 4 years.

Table 11.3.2.(2)-6 Construction Schedule of Ing-Yot Diversion Canal

Item	Unit	Quantity	1st year				2nd year				3rd year				4th year				5th year				Remarks
			3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	
(1) Temporary Works																							
(2) Open Canal																							
Stripping & Common Ex.	m^3	438,200																					438,200 ÷ 12 m.= 36,500/m.
Fill & Backfill	m^3	264,900																					264,900 ÷ 9 m.= 29,400/m.
Lining Concrete	m^3	10,900																					10,900 ÷ 9 m.= 1,200/m.
(3) Culvert Canal																							
Stripping & Common Ex.	m^3	6,815,000																					6,815,000 ÷ 45 m.= 151,000/m.
Weathered Rock Ex.	m^3	1,630,000																					1,630,000 ÷ 45 m.= 36,000/m.
Rock Ex.	m^3	430,000																					430,000 ÷ 45 m.= 9,600/m.
Backfill	m^3	7,566,000																					7,566,000 ÷ 45 m.= 168,000/m.
Culvert Concrete	m^3	327,300																					327,300 ÷ 45 m.= 7,300/m.
(4) Appurtenant Works																							
(5) Ing-Yot No.1 Tunnel																							

11.3.3 Tunnel

The tunnel construction in the Project is carried out at the following four tunnel sites.

Name of Tunnel	Discharge Capacity	Tunnel Length
Kok-Ing No.1 Tunnel	140 cu.m/sec	3,047 m
Kok-Ing No.2 Tunnel	140 cu.m/sec	5,415 m
Ing-Yot No.1 Tunnel	175 cu.m/sec	2,008 m
Ing-Yot No.2 Tunnel	175 cu.m/sec	50,875 m

Construction plans for the tunnel are planned as follows:

(1) Standard Driving System for Tunnel

Construction methods commonly used for tunnels include the mountain tunneling, shield tunneling, immersed tunneling, and cut and cover tunneling methods.

For Kok-Ing-Nan water diversion tunnel, mainly the mountain tunneling method (conventional method) is to be adopted as the standard method because the sites are located in the mountainous area.

The following three (3) driving systems are compared in order to selected the most applicable method for the tunnels of the Project.

- Conventional tunnel driving method is consisted of drilling, blasting and hauling the excavated materials, and if necessary, tunnel supporting works including rock bolts, steel rib supports, sprayed concrete (shotcrete) for primary lining, etc. Main advantage is that this conventional method is flexible and can be adapted easily to most of the geological conditions along the tunnel alignment.

  NATM (New Austrian Tunneling Method) construction technique uses rock bolting and sprayed concrete to prevent the rock from falling down from the original place and NATM has succeeded in applying to many kinds of the character of rock formation.

- Partial face tunneller uses mechanical cutter mounted on load header and is applicable not only for rather soft or medium hard rock formation but also for hard rock formation due to the recent highly advanced in technology of cutter bits materials. The boom of a crawler or loader equips cutter. This method is effective for NATM construction.

- On the other hand, TBM (Tunnel Boring Machine) is applicable only for circular shape tunnel with full face, and/or use for advancing drift for large scale cross-section tunnel recently. The choice of TBM depends on the rock characteristic, strength and size of tunnel. TBM used to be good for soft rocks but becomes applicable for hard rock due to recent advance in cutter bits. TBM might have problems when different rock characteristic are encountered or rock fracture pattern is not favorable. TBM is able to excavate at a remarkable faster rate and will save time and construction cost when the geological conditions are suitable for the TBM.

  TBM as the full face method shall be studied and discussed in more detail up to final design stage. At this stage the geological data and information are insufficient to decide the application of the full face method. Only TBM has a higher possibility to be adopted for advancing drift as pilot tunnel. Nevertheless, the possibility of adopting conventional drill or blast tunneling method can be ruled out at present and shall be studied again at the time of detailed design when more geological data and information become available.

NATM will be adopted with partial cutting machine such as the road header, as it is applicable for most kinds and conditions of rocks, for standard tunnel section of the Kok-Ing-Nan diversion tunnel.

The hauling of tunnel muck will be done by 20 tons dump trucks from the cutter face to out the of portal site. The lining concrete will be firstly placed at invert and then arch and side walls will be lined by concrete.

The standard tunnel excavation methods of the Project are the mechanical (partial-face-cutter) excavation method by top and lower heading-attack with bench cut. Figure 11.3.3.(1) is a work flow chart of the tunnel for the Project.

(2) Construction Division

The Kok-Ing and Ing-Yot tunnels are constructed in the following divisions.

Item	Kok-Ing Tunnel		Ing-Yot Tunnel	
	No.1(BJ-1)	No.2(B)	No.1	No.2
Tunnel Length (km)	3,047	5,415	2,008	50,875
Construction Division (s)	1	2	1	9
Driving Site	Outlet	Both Sides	Inlet	9 site

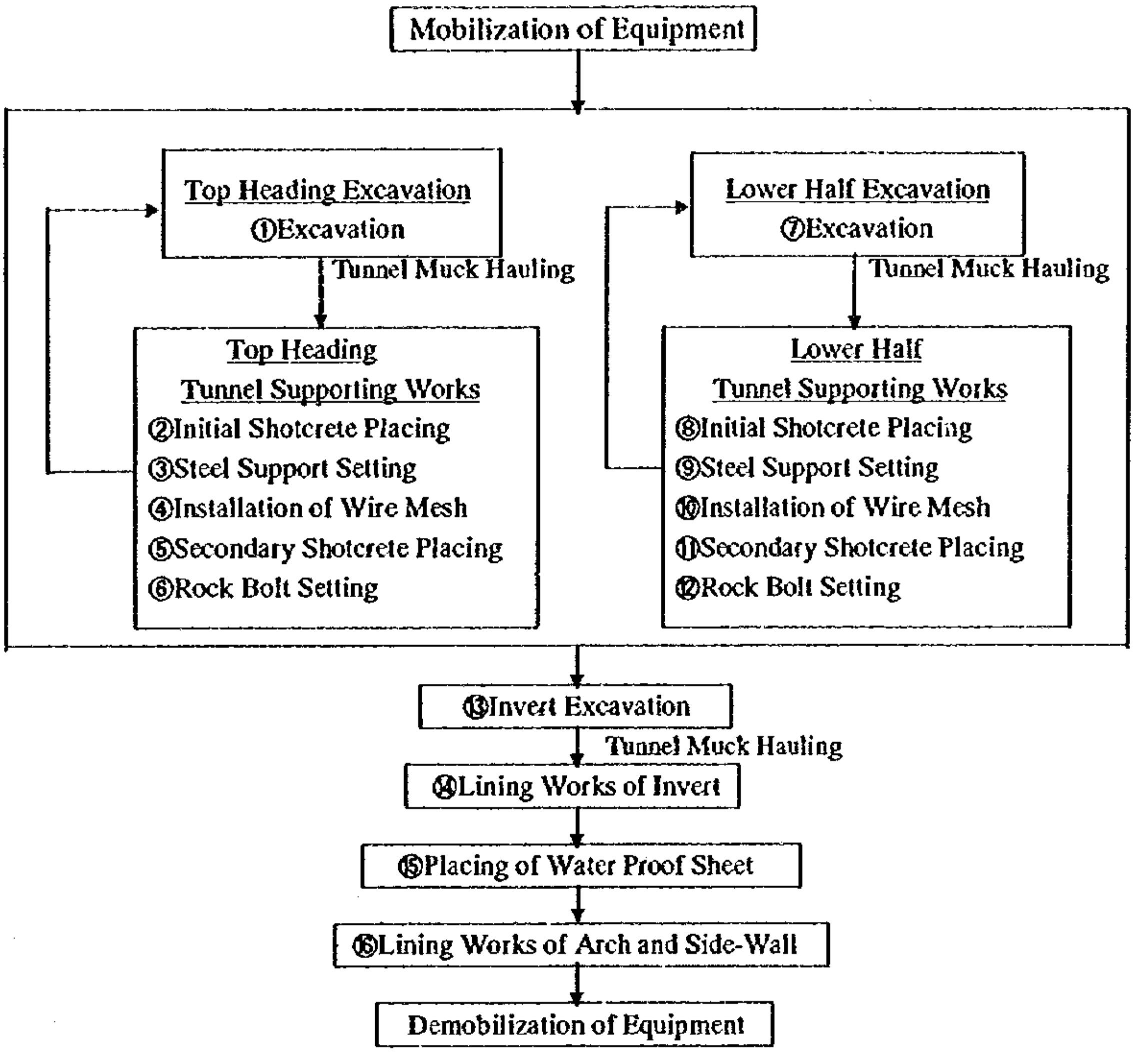
No.1 tunnel with a length of 3.1 km of the Kok-Ing tunnel will be driven at the outlet site taking into account the short distance, tunnel slope to drain the ground water inflow in the tunnel under construction by gravity, spoil bank access road, etc.

However, Kok-Ing No.2 will be driven with two construction divisions from the inlet and outlet in order to shorten the construction period, and minimize construction cost for the temporary works for construction.

Ing-Yot No.1 tunnel will be driven at the inlet site taking into account the access road. Seven (7) inclined adits are planned for construction of Ing-Yot No.2 tunnel with total length of 50,875 m, and total of nine (9) construction divisions are planned and shown in Table 11.3.3.(2).

Figure 11.3.3.(1) Work Flow for Tunnel Construction by NATM

Mechanical (Partial-Face-Cutter) Excavation Method by Top and Lower Heading-Attack
with Bench Cut Method
(Short Bench and Mini Bench Method)



Remark : Top heading and lower half is divided by the spring line. Excavation procedure are shown in Database Map.

Table 11.3.3.(2) Construction Division for Ing-Yot No.2 Tunnel

Construction Division	Length of Inclined Adit (m)	Length of Main Tunnel To Upstream (m)	To Downstream (m)	Subtotal of Main (m)	Total Length (m)
1	-	-	4,910.00	4,910	4,910
2	1,982	816.71	3,733.29	4,550	6,532
3	1,785	1,458.56	3,976.44	5,435	7,220
4	2,194	3,691.30	3,523.70	7,215	9,409
5	3,171	3,399.20	3,040.80	6,440	9,611
6	2,476	3,408.00	2,992.00	6,400	8,876
7	3,339	3,205.80	2,854.20	6,060	9,399
8	2,432	3,859.80	1,090.20	4,950	7,382
9	-	4,914.60	-	4,914.6	4,914.6
Total	17,379	24,753.97	26,120.63	50,874.6	68,253.6

Adits are planned to provide multiple construction headings in order to minimize construction costs and construction time. Some of adits might be possible to cancel if TBM becomes adaptable construction method.

(3) Quantity for Tunnel Construction

Quantity for excavation, shotcrete, rock bolt, steel support, concrete lining, etc. per meter for Kok-Ing-Nan tunnel are estimated as follows ;

Table 11.3.3.(3) Quantity per meter for Kok-Ing-Nan Tunnel

Item		Quantity per meter by each Grade of Ground					
Kok-Ing Tunnel		C I	C II	D I	D II	E I	E II
1 Tunnel Excavation (m^3/m)		77.18	77.18	81.49	82.57	85.90	87.01
2 Shotcrete (m^2/m)		20.47	20.47	20.79	20.79	21.10	21.10
3 Rock Bolt (Nos./cycle)		15	15	18	18	18	8/19.5 Forepiling
4 Steel Arch Supporting (ton/cycle)		-	0.39	0.49	0.65	1.05	1.06
5 Tunnel Lining (m^3/m)		12.29	12.29	15.46	15.46	18.70	18.70
6 Reinforcement (ton/m)		-	-	-	0.70	0.84	1.07
Ing-Yot Main Tunnel	B	C I	C II	D I	D II	E I	E II
1 Tunnel Excavation (m^3/m)	89.00	90.13	90.13	94.79	95.95	99.54	100.73
2 Shotcrete (m^2/m)	22.09	22.09	22.09	22.40	22.40	22.71	22.71
3 Rock Bolt (Nos./cycle)	12	16	16	19	19	19	8/22 Forepiling
4 Steel Arch Supporting (t/cycle)	-	-	0.43	0.53	0.71	1.13	1.14
5 Tunnel Lining (m^3/m)	13.55	13.55	13.55	16.99	16.99	20.51	20.51
6 Reinforcement (ton/m)	-	-	-	-	0.77	0.92	1.17
Ing-Yot Adit Tunnel	B	C I	C II	D I	D II	E I	E II
1 Tunnel Excavation (m^3/m)	46.92	47.82	47.82	59.33	59.33	59.33	59.33
2 Shotcrete (m^2/m)	17.45	17.45	17.45	17.60	17.60	17.60	17.60
3 Rock Bolt (Nos./cycle)	8	12	12	15	15	15	8/15 Forepiling
4 Steel Arch Supporting (t/cycle)	-	-	0.29	0.89	0.89	0.89	0.89
5 Tunnel Lining (m^3/m)	6.68	6.68	6.68	11.79	11.79	11.79	11.79
6 Reinforcement (ton/m)	-	-	-	-	0.53	0.53	0.74

(4) Major Tunnel Construction Machine and Equipment

The major construction equipment by NATM is listed up as shown in Table 11.3.3.(4).

Table 11.3.3.(4) Major Construction Machines for Kok-Ing-Nan Tunnel

Operations		Items	Description	Unit	No's	Remarks
Excavation & Mucking	Upper Half Excavation	Partial Face Tunneller	Mechanical Cutter Bits Mounted on Loadheader	set	1	qu<50N/mm²:200kw qu<100N/mm²:300kw
		Tractor Shovel	Wheel Type/Side Dump 2.3 m³	set	1	Muck Loading countermeasure for fume
	Down Half Excavation	Giant Breaker	Wheel Type/Hydraulic 1,300 kg	set	1	countermeasure for fume
		Back Hoe	Crawler Type/ Hydraulic		1	countermeasure for fume
	Mucking (Transportation)	Dump Truck	Diesel 20 ton (Adit : Diesel 10 ton)	set	4~2 (5-3)	countermeasure for fume
Supporting, Shocrete and Rock Bolt	Rock Bolt	Hydraulic Jambo(3boom)	Wheel Type / Oil-Pressure 150 kg	set	1	countermeasure for fume
		Hydraulic Breaker	Oil Pressure:600-800 class	set	1	
		Grouting Mixer	Vertical Type/5.5kw	set	1	
		Grouting Pump	Horizontal Type/15-30m³/min	set	1	
	Shotcrete	Shotcrete-Robot	Shotcrete Range:8m class	set	1	
		Shotcrete-Machine	10-15 m³/hr	set	1	
		Shotcrete-Plant	Fixed Type/Mixer:25 m³/hr	set	1	Cement
		Mortar Pump Mixer	5.5 kw	set	1	Silo:30ton/day
		Mixed-Concrete Car	4.4-4.5 m³class	set	1	
		Back Hoe	Crawer Type/Oil Pressure 0.4	set	1	Base Machine for Robot
	Common	Air Compressor	Screw Type:12m³/m,7kg/cm²,75kw	set	2	Per 1.2 km
		Truck	Diesel 4 ton/crane 2.9 ton	set	1	
		Lift Car		set	1	for Steel Supporting
Sheeting and Concrete Lining		Concrete Pump Car	Pressed Pipe, 55 m³/hr	set	1	
		Concrete Vibrator	Electrical Stick Type	set	2	
		Sliding Form	L=10.5m	set	1	Per / 1 face
		Working Frame	Frame Range:4-6m,L=4.5m	set	1	for Sheeting

(5) Construction Progress

(a) Cycle Time of Excavation

The cycle time of tunnel excavation (m/day) is different in accordance with the tunnel type based on geological condition as shown in the Table 11.3.3.(5)-1.

Table 11.3.3.(5)-1 Cycle Time of Excavation for Kok-Ing-Nan Tunnel

Grade of Ground \ Name of Tunnel	Kok-Ing Tunnel	Ing-Yot Tunnel	
		Adit	Main Tunnel
B	-	5.21	3.54
C1	4.14	5.98	3.69
C2	3.86	5.10	3.51
D1	3.03	3.76	2.83
D2	3.07	3.78	2.88
E1	3.04	3.75	2.84
E2	2.70	3.30	2.52

The progress rate of Kok-Ing and Ing-Yot main tunnel construction will be about 80 to 100 m/month for the sections with good geological conditions and about 60 to 70 m/month for poor geological conditions, and in case of adit tunnel, it will be about 140 m/month for the grade with good conditions and about 80 to 100 m/month for the grade with poor geological conditions.

(b) Tunnel Construction Period

Tunnel construction period is estimated by the above cycle time for excavation and tunnel length consisting of the various tunnel type and shown in Table 11.3.3.(5)-2.

As shown in Table 11.3.3.(5)-2, the construction period of the excavation works at each division in the Ing-Yot tunnel is about 6 years.

Accordingly total construction period of the tunnel including the tunnel lining works will be planned to be 7 years.

(6) Access Road and High Tension Power Line

(a) Access Road

An access road is planned from the existing asphalt-paved national or provincial road to each of the tunnel portal. The width of access road is six (6) meters and paved by asphalt. The length of access road to each tunnel portal is as follows.

Table 11.3.3.(6)-1 Access Road of Proposed Tunnel

No. of Tunnel	Tunnel Portal	Nearest of Village (Ban)	Distance from Main Road	
Kok-Ing No.1	Outlet Site	Mai-Chaimongko	Laterite road	: 3.0 km
Kok-Ing No.2	Inlet Site	Thung Khong	Laterite road	: 2.6 km
Kok-Ing No.2	Outlet Site	Sang Khong	Laterite road	: 3.7 km
Ing-Yot No.1	Inlet Site	Thung Khan Chai	New road	: 0.5 km
Ing-Yot No.2	Inlet Site	Donchai	Laterite road	: 1.5 km
-ditto-	Adit No.1	Pharad Luang	Laterite & New	: 1.3 km
-ditto-	Adit No.2	Nong Lao	Laterite road	: 2.7 km
-ditto-	Adit No.3	Hua Na Kaoy	Laterite road	: 1.4 km
-ditto-	Adit No.4	Huai Pum	Laterite road	: 6.5 km
-ditto-	Adit No.5	Pang Thum	Laterite road	: 10.8 km
-ditto-	Adit No.6	Pang Thum	New road	: 3.3 km
-ditto-	Adit No.7	Yod	Laterite road	: 1.8 km
-ditto-	Outlet Site	Phalak	Laterite & New	: 2.8 km

Table 11.3.3.(5)-2 Outline of Proposed Tunnel

Name of Tunnel			Inner Diameter (m)	Total Length (m)	Classification of Tunnel Type (m)							Name of Rock	Excavation Period (Years)	
					B	C1	C2	D1	D2	E1	E2			
Kok-Ing	No.1		10.0	3,047	-	50	440	460	560	530	1,007	rhyolite & tuff, shale, sandstone and tuff	3.6	
	No.2		10.0	5,415	-	480	790	620	660	750	2,115	limestone, shale, sandstone and basalt	3.2	
Ing-Yot No.1			10.9	2,008	-	-	100	400	850	350	308	sandstone	2.4	
Ing-Yot No.2	Div. 1		10.9	4,910	-	220	1,780	440	1,130	620	720	shale, sandstone, tuff and slate	5.8	
	Div. 2	Adit 1		1,982	-	490	260	452	80	150	550	metasandstone with cal-careous shale (slate)	1.7	5.8
		Main T.		4,550	-	1,350	1,460	1,020	570	150	-	metasandstone, slate, thrust fault	4.1	
	Div. 3	Adit 2		1,785	-	110	535	550	150	170	270	metasandstone with calcareous shale (slate)	1.6	5.8
		Main T.		5,435	300	1,460	1,045	1,190	930	330	180	Phu Sang Park, slate, sandstone and quartzite	4.2	
	Div. 4	Adit 3		2,194	600	784	150	170	160	150	180	slate and sandstone	1.6	5.8
		Main T.		7,215	470	1,210	2,555	1,750	1,090	140	-	slate, sandstone and quartzite	4.2	
	Div. 5	Adit 4		3,171	541	1,550	540	130	130	130	150	slate and sandstone	2.2	5.8
		Main T.		6,440	580	990	3,240	1,360	260	10	-	slate, sandstone and quartzite	3.6	
	Div. 6	Adit 5		2,476	330	656	510	350	270	280	80	sandstone, tuff and shale	1.9	5.8
		Main T.		6,400	420	1,040	2,370	1,190	970	400	10	tuff, andesite, rhyolite, dacite and limestone	3.9	
	Div. 7	Adit 6		3,339	1,109	1,060	820	80	90	90	90	tuff, shale	2.3	5.7
		Main T.		6,060	560	2,250	1,880	940	430	-	-	sandstone, tuff, shale and slate	3.4	
	Div. 8	Adit 7		2,432	692	980	460	170	70	30	30	sandstone, shale	1.7	5.7
		Main T.		4,950	500	1,400	2,180	570	300	-	-	sandstone, tuff, shale and slate	4.0	
	Div.9			4,915	-	620	1,370	650	790	780	705	limestone, sandstone and shale	5.8	
	Total	Adit		17,379	3,272	5,630	3,275	1,902	950	1,000	1,350			
		Main T.		50,875	2,830	10,540	17,880	9,110	6,470	2,430	1,605			

(b) High Tension Power Line

The total electric power is required between 1,400 and 3,700 kVA (kilovolt-ampere) at each portal site throughout the tunnel construction period. The extension of power line has been discussed with the DEDP and planned from the existing high voltage electricity cable line to each tunnel portal site in Table 11.3.4.(6)-2.

Table 11.3.3.(6)-2 Extension of Power Line to each Tunnel Portal Site

No. of Tunnel	Tunnel Portal	Existing High Voltage Electricity Cable Area(Ban)	Approximately Cable Length (km)
Kok-Ing No.1	Outlet Site	Bang Chong Lom	3.75
Kok-Ing No.2	Inlet Site	Ban San Muang Kham	7.62
Kok-Ing No.2	Outlet Site	Ban San Muang Kham	7.62
Ing-Yot No.1	Inlet Site	Ban Thung Chai	0.50
Ing-Yot No.2	Inlet Site	Ban Don Chai	1.00
-ditto-	Adit No.1	Ban Pa Lat Luang	1.40
-ditto-	Adit No.2	Ban Huak	5.90
-ditto-	Adit No.3	Ban Thung Kluai	6.05
-ditto-	Adit No.4	Main Road of Pang Tham	1.60
-ditto-	Adit No.5	Pang Tham Road	1.00
-ditto-	Adit No.6	Ban Thon Phung	1.55
-ditto-	Adit No.7	Ban Sakoen	7.00
-ditto-	Outlet	Ban Sakoen-Adit No.7	5.25

(7) Temporary Work Area at each Tunnel Mouth

Temporary work area at each tunnel mouth is approximately 25 rai which is required for temporary offices and workshops, shotcrete plant, equipment deposit, temporary stock area of tunnel muck, etc. The existing conditions for temporary area at each portal are as follows.

Table 11.3.3.(7) Existing Conditions of Temporary Areas at each Portal Site

No. of Tunnel	Tunnel Portal	Cropping in Wet season	Cropping in Dry Season
Kok-Ing No.1	Outlet Site	Paddy field	Non
Kok-Ing No.2	Inlet Site	Paddy field, Orchard	Non
Kok-Ing No.2	Outlet Site	Paddy field, Orchard	Maize, Nut
Ing-Yot No.1	Inlet Site	Non	Non
Ing-Yot No.2	Inlet Site	Paddy field	Nut
-ditto-	Adit No.1	Paddy field	Orchard
-ditto-	Adit No.2	Orchard	Maize
-ditto-	Adit No.3	Paddy field, Orchard	Non
-ditto-	Adit No.4	Orchard	Maize
-ditto-	Adit No.5	Orchard	Maize
-ditto-	Adit No.6	Orchard	Maize
-ditto-	Adit No.7	Paddy field, Orchard	Nut
-ditto-	Outlet	Orchard	Maize

In addition to the above conditions, temporary work area at the inlet site of No.2 tunnel is to be made to avoid nagative impact to be environment to the neighboring village areas.

(8) Tunnel Muck Disposal Area

A particular attention is given for identification of suitable disposal area for excavation materials from the tunnel. The disposal area as well as access road to the disposal area should be sited to avoid adverse environmental impacts, and at the same time it must be close to the tunnel portal in order to minimize the construction cost. The disposal area shall be so arranged as to prevent any erosion or corruption by rainfall or river flow and to ensure that the surface can quickly blend into the adjacent forest area. The tunnel muck from the Kok-Ing tunnel will be fragments or dust of sedimentary rocks, shale and sandstone, therefore, no oxidation problem will be expected. It is planned that all disposal area of tunnel muck will be created as terrace land to be covered by proper thickness of top-soil so as to develop as the orchard garden if local villagers agree so. Some amount of muck is utilized for embankment for roads and dikes at low-land areas.

The quantities of muck from each tunnel are summarized in Table 11.3.3.(8), and the location with access road and spoil banking plan of each tunnel is shown in Database Map.

Table 11.3.3.(8) Quantities of Muck from each Tunnel

Tunnel Portal	Excavation Volume (m^3)	Muck Volume(*1.4) (m^3)	Distance to Disposal area (km)
Outlet of Kok-Ing No.1	254,700	356,600	1.5
Inlet of Kok-Ing No.2	227,800	318,900	1.5
Outlet of Kok-Ing No.2	223,700	313,200	1.5
Inlet of Ing-Yot No.1	194,400	272,200	1.5
Inlet of Ing-Yot No.2	464,600	650,400	0.8
Adit No.1	528,000	739,200	1.5
Adit No.2	584,800	818,700	1.5
Adit No.3	777,200	1,088,100	0.8
Adit No.4	744,900	1,042,900	1.4
Adit No.5	720,000	1,008,000	1.5
Adit No.6	715,000	1,001,000	1.6
Adit No.7	568,700	796,200	1.6
Outlet of Ing Yot No.2	465,400	651,600	1.5
Total	6,469,200	(9,057,000)	

(9) Environmental Considerations During Construction Period

The construction works at each tunnel entrance are planned almost in hills and mountainous areas except the inlet of the Ing-Yot No.2 tunnel which is located adjacent to a village named Ban Donchai. When tunnel entrance is planned in such locations adjacent to residence, livestock sheds or the like, utmost efforts are to be made to avoid negative impact on the environment in neighboring areas. During the construction, it shall be necessary to take various counter measures as follows.

Noise

Noise caused by tunnel construction such as machine, and equipment operation, etc. shall be mitigated by providing the insulation door at tunnel entrance.

As for operations outside the tunnel, for example, concrete plants with soundproof devices and a low-noise compressor shall be used. To reduce vehicle noise, a construction road for exclusive use is to be built so as to avoid densely inhabited section/areas.

Vibration

Vibration associated with tunnel construction is mainly caused by blasting. 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.

Water Pollution

The polluted drainage water in tunnel shall be treated and controlled pH and SS (suspended solid) by suitable equipment such as chemical plant (PAC= polyaluminum chloride= $[Al_2(OH)_nCl_{6-n}]_m$) before releasing to the local river.

Lowering of Groundwater Level
Tunnel construction under the unconsolidated layer at the surface may lower the groundwater level. To secure the lowering at the minimum level, some method like grouting works be applied in case of groundwater level lowering occurred during construction.

Surface Settlement
In tunnel with shallow and loose overburden which remains uncemented or in cracky ground, the crown or the face often collapses during excavation or before supporting and surface settlement may occur during construction. To cope with such cases, type E2 using of forepoling bolts is planned already. In order to prevent settlement, long pre-supporting such as pipe roofing and chemical grouting will be required.

(10) Effect of the Earthquake on Tunnels

In view of the fact that underground tunnels suffered almost no damage in comparison to the tremendous damage on the surface by the effect of the great Hansin-Earthquake in Japan occurred on January 17, 1995. It can be said that it has reconfirmed the fact that underground tunnels are superior in terms of resistance to earthquake damage.

11.3.4 Yao Dam and Yao River Training Works

In the Yao dam construction, the large excavation volume with 1.6 million cu.m. is carried out at the dam foundation and spillway. Out of the excavation materials, about 500,000 cu.m could be used for the dam embankment of random and rock zones. Since the large spoil bank to treat the surplus materials of 1.1 million cu.m. is not existing at the reservoir area and the downstream of damsite, the surplus materials shall be used for the Yao river training works which requires the fill materials of about 1.0 million cu.m. in the flood protection dike and the heightening works of the river banks.

Accordingly the Yao dam and Yao river training works shall be carried out together by the same contractor.

(1) Quantity of the Works

Quantity of the Yao dam and Yao river training works is shown in Table 11.3.4.(1).

(2) Yao Dam Construction Plan

(a) Utilization Plan of Excavated Material

The utilization plan of the excavated materials at the damsite is studied taking into consideration the kinds of excavated materials, work schedule of excavation, dam embankment volume and period and fill works and period at the Yao river training. The study result is shown in Table 11.3.4.(2)-1 and summarized as follows;

- The excavation at the intake, outlet, cofferdam and main dam will be carried out at the beginning stage of the dam construction and its material could not be used directly for the dam embankment but deposited at the stock yard.

- The excavated material at the spillway could be transported directly and used for the random and rock embankment zone.
- Stocked material will be used for the fill materials of the Yao training works.

The excavated material of the Yao dam will be used or wasted as follows ;

- Earth and weathered rock of 760,000 m^3 at the stockyard will be used for the fill material of the Yao river training works.
- Hard rock of 39,000 m^3 at the stockyard will be for the gabion material in the Yao river.
- Earth and weathered rock of 304,000 m^3 at spillway will be for the random zone of dam embankment.
- Hard rock of 190,000 m^3 will be for the rock zone of dam embankment.
- The excavated material of about 300,000 cu.m. consisting of stripping and unsuitable materials for fill and dam embankment is wasted to the spoil bank.

The core and filter materials are transported from the nominated borrow area, while the deficit rock material for the dam embankment and the gabion in the Yao river will be supplied from the excavation material of the Ing-Yot No.2 tunnel, Divisions 8 and 9.

(b) Construction Equipment and Its Output

The construction equipment and its output for the earth works are studied as shown in Table 11.3.4.(2)-2.

(c) Diversion Tunnel

The diversion tunnel with a length of 270 m and diameter of 6.5 m is constructed through the mountain at the left bank. Tunnel is excavated by the ordinary tunnel construction method and will be completed within 8 months. Since the tunnel shall release the large discharge capacity of 200 cu.m./sec with high velocity, the tunnel is to be lined with the steel liner. The steel liner could be used for the form of concrete works.

The consolidation grout shall be carried out through the tunnel length after completion of tunnel concrete works in order to fill the gaps between tunnel excavated surface and placing concrete.

(d) Intake and Outlet

The open channel reaches at the intake and outlet which connects to the diversion tunnel shall be constructed at the early stage and used for river diversion. The excavation works for the channel will be carried out with three to four months and their materials will be deposited at the stock yard. Various gates and valves are installed at the intake and outlet. The concrete works will be completed prior to gate installation works.

The concrete mixing plant of 0.75 m^3 x 2 units is provided at the downstream site of the spillway taking into account damsite topographical condition and the large concrete volume for spillway.

Table 11.3.4.(1) Quantity of Yao Dam and River Training

Item	Unit	Quantity	Item	Unit	Quantity
1. Yao Dam			Embankment, Riprap	m^3	25,000
(1) River Diversion Tunnel			(6) Spillway		
Tunnel Excavation	m^3	15,000	Stripping	m^3	28,000
Steel Support	ton	220	Excavation, Common	m^3	475,000
Tunnel Concrete	m^3	4,000	Excavation, Weathered Rock	m^3	285,000
Plug Concrete	m^3	1,500	Excavation, Rock	m^3	190,000
Grouting Works	m	2,200	Fill & Backfill	m^3	21,000
(2) Intake			Concrete	m^3	79,000
Stripping	m^3	6,000	Curtain Grout	m	6,800
Excavation, Common	m^3	17,000	(7) Control House Yard		
Excavation, Weathered Rock	m^3	23,000	Stripping	m^3	15,000
Excavation, Rock	m^3	29,000	Excavation, Common	m^3	144,000
Backfill	m^3	6,000	Excavation, Weathered Rock	m^3	110,000
Concrete	m^3	21,500	Fill & Backfill	m^3	2,000
(3) Outlet			Concrete	m^3	1,500
Stripping	m^3	10,000			
Excavation, Common	m^3	34,000	2. Yao River Training		
Excavation, Weathered Rock	m^3	14,000	(1) Flood Protection Dike		
Concrete	m^3	13,800	Stripping	m^3	156,000
(4) Coffer Dam			Embankment	m^3	578,000
Stripping	m^3	6,000	(2) River Channel Expansion		
Excavation, Common	m^3	29,000	Excavation, Common	m^3	646,000
Excavation, Weathered Rock	m^3	12,000	(3) Heightening of Ground Elevation		
Embankment, Core	m^3	39,000	Stripping	m^3	534,000
Embankment, Filter	m^3	36,000	Embankment	m^3	1,082,000
Embankment, Rock	m^3	150,000	(4) River Crossing Structure		
Embankment, Riprap	m^3	20,000	Gabion Mattres	m^3	178,000
(5) Main Dam			Consolidation Sill	No	8
Stripping	m^3	31,000	(Rubble Concrete)	(m^3)	(4,400)
Excavation, Common	m^3	84,000	(Gabion)	(m^3)	(1,600)
Excavation, Weathered Rock	m^3	36,000	Bridges	No	14
Blanket Grouting	m	4,500			
Curtain Grouting	m	18,000	3. Yot River Training		
Embankment, Core	m^3	95,000	Excavation, Common	m^3	729,000
Embankment, Filter	m^3	85,000	Excavation, Weathered Rock	m^3	238,000
Embankment, Random	m^3	260,000	Concrete	m^3	4,000
Embankment, Rock	m^3	250,000			

Table 11.3.4.(2)-1 Utilizing Plan of Excavated Materiel in Yao Dam.

Excavation Item	Quantity	Stock Yard		Dam Embankment		Spoil Bank
		Earth & Weathered Rock	Hard Rock	Earth & Weathered Rock	Hard Rock	
1 Tunnel Rock	15,000	5,000	10,000	-	-	-
2 Intake						
Stripping	6,000	-	-	-	-	6,000
Common	17,000	13,600	-	-	-	3,400
Weathered Rock	23,000	20,700	-	-	-	2,300
Rock	29,000	-	29,000	-	-	-
3 Outlet						
Stripping	10,000	-	-	-	-	10,000
Common	34,000	27,200	-	-	-	6,800
Weathered Rock	14,000	12,600	-	-	-	1,400
4 Coffer Dam						
Stripping	6,000	-	-	-	-	6,000
Common	29,000	23,200	-	-	-	5,800
Weathered Rock	12,000	10,800	-	-	-	1,200
5 Main Dam						
Stripping	31,000	-	-	-	-	31,000
Common	84,000	67,200	-	-	-	16,800
Weathered Rock	36,000	32,400	-	-	-	3,600
6 Spillway						
Stripping	28,000	-	-	-	-	28,000
Common	475,000	333,000	-	47,000	-	95,000
Weathered Rock	285,000	-	-	257,000	-	28,000
Rock	190,000	-	-	-	190,000	-
7 Control House Yard						
Stripping	15,000	-	-	-	-	15,000
Common	144,000	115,200	-	-	-	28,800
Weathered Rock	110,000	99,000		-	-	11,000
Total	1,593,000	759,900	39,000	304,000	190,000	300,100

Remarks ; (1) 20% of common and 10% of weathered rock is planned to be wasted at the spoil bank.
(2) Excavated materials at the stock yard are used for the embankment material in the Yao river training works.

Table 11.3.4.(2)-2 Dam Construction Equipment and Output (1)

Kinds of Works and Construction Equipment	Output Estimation	Monthly Output (m^3)
1 Stripping at Damsite		
Wheel Loader 1.5 m^3 x 1 unit	80 m^3/hr x 10 hr x 25 days	20,000
Bulldozer 21 ton x 1 unit	0.5 unit at damsite & spoil	
Dump Truck 11 ton x 3 units	Distance of less than 1.0 km.	
2 Excavation at Intake, Outlet and Damsite		
(1) Common Ex.		
Backhoe Shovel 1.2 m^3 x 1 unit	90 m^3/h x 10 h x 25 days	22,500
Bulldozer 21 ton x 1 unit	0.5 unit at damsite & spoil	
Dump Truck 11 ton x 3 units	Distance of 500 m. to stock	
(2) Weathered Rock, Ex.		
Backhoe shovel 1.2 m^3 x 1 unit	80 m^3/h x 10 h x 25 days	20,000
Ripper Bulldozer 21 ton x 2 units	40 m^3/h x 10 h x 25 days x 2 units	
Bulldozer 21 ton x 1 unit	0.5 unit at site and stock	
Dump Truck 11 ton x 3 units	Distance of 500 m. to stock	
(3) Rock Ex.		
Backhoe Shovel 1.2 m^3 x 1 unit	70 m^3/h x 10 h x 25 days	17,500
Bulldozer 21 ton x 1 unit	0.5 unit at site and stock	
Dump Truck 11 ton x 3 units	Distance of 500 m. to stock	
3 Excavation at Spillway and Control House Yard		
(1) Common Ex.		
Backhoe Shovel 1.2 m^3 x 1 unit	90 m^3/h x 10 h x 25 days	22,500
Bulldozer 21 ton x 1 unit	Push dozer at site	
Dump Truck 11 ton x 4 units	Distance of 1.0 to 2.0 km. to embankment site	
(2) Weathered Rock Ex.		
Same as common Ex.	80 m^3/h x 10 h x 25 days	20,000
Ripper Bulldozer 21 ton x 2 units	40 m^3/h x 10 h x 25 days x 2 units	
(3) Rock Ex.		
Same as Common Ex.	70 m^3/h x 10 h x 25 days	17,500
4 Core Embankment at Coffer		
(1) Material Transportation		
Backhoe Shovel 1.2 m^3 x 1 unit	80 m^3/h x 7 h x 25 days	14,000
Bulldozer 15 ton x 1 unit	At Borrow Area	
Dump Truck 11 ton x 3 units	Distance of less than 500 m.	

Table 11.3.4.(2)-2 Dam Construction Equipment and Output (2)

Kinds of Works and Construction Equipment	Output Estimation	Monthly Output (m^3)
(2) Spreading & Compaction		
Bulldozer 15 ton x 1 unit	Pulling of Tamping Roller	
Tamping Roller 20 ton x 1 unit	80 m^3/h x 7 h x 25 days	14,000
Bulldozer 21 ton x 0.5 unit	Material Spreading	
Water Lorry 5.0 m^3 x 1 unit		
5 Filter Embankment at Coffer and Main Dam		
(1) Material Transport		
Wheel Loader 1.2 m^3 x 1 unit	60 m^3/h x 7 h x 25 days	10,500
Bulldozer 15 ton x 1 unit	Assist of Loader	
Dump Truck 11 ton x 4 units	2 Times/day for 60 km	
(2) Spreading & Compaction		
Vibrating Roller 5 ton	140 m^3/h x 7 h x 25 days	24,500
Bulldozer 21 ton x 0.5	Material Spreading	
6 Rock Embankment at Coffer Dam from Tunnel Excavation		
(1) Material Transport		
Wheel Loader 2.0 m^3 x 1 unit	100 m^3/h (Bank) x 7 h x 25 days	17,500
Bulldozer 21 ton x 0.5 unit	At spoil bank of tunnel muck	
Dump Truck 11 ton x 5 units	Distance of 10 km	
(2) Material Compaction		
Bulldozer 21 ton x 0.5 unit		
7 Random at Main Dam		
(1) Transport by Spillway	-	
(2) Compaction		
Bulldozer 21 ton x 1 unit	Material Spreading	
Tire Roller 20 ton	200 m^3/hr x 7 hr x 25 day	35,000
8 Rock at Main Dam		
(1) Transport by Spillway		
(2) Spreading		
Bulldozer 21 ton x 1 unit	170 m^3/hr x 7 hr x 25 days	30,000
9 Fill & Backfill		
(1) Material Transport		
Wheel Loader 2.0 m^3	120 m^3/hr x 7 hr x 25 days	21,000
Bulldozer 15 ton x 1 unit	Collection of Material	
Dump Truck 11 ton x 3 units	Distance of 1.0 km.	
(2) Compaction		
Compaction by Bulldozer 21 ton	120 m^3/h x 7 h x 25 days	21,000

(e) Coffer Dam

The coffer dam works are consisting of the embankment of core, filter and rock and will be commenced immediate after completion of the river diversion works. The core material is collected at the borrow area in the reservoir area and the filter materials from the Nan river with transportation distance of 50 to 60 km. Rock materials are transported from the stock yard. The coffer dam works will be completed by the end of 2nd year.

(f) Main Dam

The main dam excavation is carried out in parallel with the coffer dam embankment. The curtain and blanket grouting works of 22,500 cu.m will be carried out at the core trench after completion of excavation. The dam embankment will be commenced at the beginning month of the third year and completed at the middle of 4th year. The core and filter materials are collected from the same borrow area as proposed in the coffer dam but the random and rock materials are transported from the spillway excavation site. Some rock materials will be transported from the Ing-Yot No.2 tunnel, Division 9.

(g) Spillway

The excavation works of spillway will be carried out in parallel with the dam embankment, because the excavated materials at spillway are directly transported to the dam embankment site. The concrete works at spillway will be commenced at the side channel portion and then continued to the chute and stilling basin site.

(h) Construction Schedule

The construction will be completed within 4 years and the detailed construction schedule is as shown in Table 11.3.4.(2)-3.

Table 11.3.4.(2)-3 Construction Schedule of Yao Dam and Yot Yao River Training Works (1)

Item	Unit	Quantity	1st year				2nd year				3rd year				4th year				Remarks
			3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	
1. Yao Dam																			
(1) Temporary Works																			
(2) River Diversion Works																			
Tunnel Excavation	m.	270																	270 m ÷ 8 m.= 34 m/m.
Tunnel Concrete	m.	270																	270 m ÷ 6 m.= 45 m/m.
Steel Liner	m.	230																	230 m ÷ 6 m.= 39 m/m.
Plug Concrete	m^3	1,500																	1,500 ÷ 3 m.= 500/m.
Tunnel Grouting	m.	2,200																	2,200 ÷ 5 m.= 440/m.
(3) Intake Works																			
Stripping, Common Ex.	m^3	23,000																	23,000 ÷ 3 m.= 7,700/m.
Weathered Rock Ex.	m^3	23,000																	23,000 ÷ 3 m.= 7,700/m.
Rock Ex.	m^3	29,000																	29,000 ÷ 3 m.= 9,700/m.
Fill & Backfill	m^3	6,000																	6,000 ÷ 15 m.= 400/m.
Structure Concrete	m^3	21,500																	21,500 ÷ 15 m.= 1,400/m.
Intake Gate	L.S.																		
(4) Outlet Works																			
Stripping & Common Ex.	m^3	44,000																	44,000 ÷ 4 m.= 11,000/m.
Weathered Rock Ex.	m^3	14,000																	14,000 ÷ 4 m.= 3,500/m.
Structure Concrete	m^3	13,800																	13,800 ÷ 9 m.= 1,500/m.
Roller Gate	L.S.																		
Hollw Jet Valve	L.S.																		
(5) Coffer Dam																			
Stripping & Common Ex.	m^3	35,000																	35,000 ÷ 3 m.= 11,700/m.
Weathered Rock Ex.	m^3	12,000																	12,000 ÷ 3 m.= 4,000/m.
Embankment, Core	m^3	39,000																	39,000 ÷ 4 m.= 10,000/m.
Embankment, Filter	m^3	36,000																	36,000 ÷ 4 m.= 9,000/m.
Embankment, Rock	m^3	170,000																	170,000 ÷ 7 m.= 24,300/m.
(6) Main Dam																			
Stripping & Common Ex.	m^3	115,000																	115,000 ÷ 6 m.= 19,200/m.
Weathered Rock Ex.	m^3	36,000																	36,000 ÷ 6 m.= 6,000/m.
Embankment, Core	m^3	95,000																	95,000 ÷ 18 m.= 5,300/m.
Embankment, Filter	m^3	85,000																	85,000 ÷ 18 m.= 4,700/m.

Table 11.3.4.(2)-3 Construction Schedule of Yao Dam and Yot Yao River Training Works (2)

Item	Unit	Quantity	1st year				2nd year				3rd year				4th year				Remarks
			3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	
Embankment, Random	m^3	260,000																	260,000 ÷ 18 m.= 14,400/m.
Embankment, Rock	m^3	275,000																	275,000 ÷ 18 m.= 15,300/m.
Grout	m	22,500																	22,500 ÷ 15 m.= 1,500/m.
(7) Spillway																			
Stripping & Common Ex.	m^3	503,000																	503,000 ÷ 24 m.= 21,000/m.
Weathered Rock Ex.	m^3	285,000																	285,000 ÷ 18 m.= 16,000/m.
Weathered Rock Ex.	m^3	190,000																	190,000 ÷ 18 m.= 10,500/m.
Backfill	m^3	21,000																	21,000 ÷ 9 m.= 2,300/m.
Structure Concrete	m^3	79,000																	79,000 ÷ 15 m.= 5,300/m.
Curtain Grout	m	6,800																	6,800 ÷ 5 m.= 1,400/m.
(8) Control House Yard																			
Stripping & Common Ex.	m^3	159,000																	159,000 ÷ 12 m.= 13,300/m.
Weathered Rock Ex.	m^3	110,000																	110,000 ÷ 9 m.= 12,200/m.
Backfill	m^3	2,000																	2,000 ÷ 3 m.= 700/m.
Plain Concrete	m^3	1,500																	1,500 ÷ 3 m.= 500/m.
(9) O/M Brench Office																			
Control House	L.S.																		
O/M Branch Office	L.S.																		
Reside Quarter	L.S.																		
2 Yao River Training																			
(1) Temporary Works																			
(2) Flood Protection Dike																			
Stripping	m^3	156,000																	156,000 ÷ 9 m.= 17,300/m.
Fill at Dike	m^3	578,000																	578,000 ÷ 18 m.= 32,000/m.
(3) River Improvement																			
Stripping & Common Ex.	m^3	1,180,000																	1,180,000 ÷ 27 m.= 43,700/m.
Fill	m^3	1,082,000																	1,082,000 ÷ 27 m.= 40,000/m.
Gabion Mattres	m	10,460																	10,460 ÷ 18 m.= 600/m.
Road Bridges	No.	14																	
Other Apputenant Work	L.S.																		

(3) Yao River Training Works

The Yao river training works will be carried out dividing the river length of 49 km into 4 divisions as follows ;

	Division 1	Division 2	Division 3	Division 4	Total
River Reaches	13.5	17.0	11.3	7.1	48.9 km.

Division 1 is the downstream of the river near the conjunction of the Nan river, while Division 4 is the upstream near the Yao damsite.

The following river training works will be carried out.

Table 11.3.4.(3) Yao River Training Works by Divisions

Item	Unit	Division 1	Division 2	Division 3	Division 4	Total
(1) Flood Protection Dike						
Left Bank	km.	9.4	1.4	1.3	-	15.1
Right Bank	km.	8.0	0.8	2.7	-	11.5
Fill at Left Bank	10^3 m^3	198	12	106	-	316
Fill at Right Bank	10^3 m^3	209	8	45	-	262
Total	10^3 m^3	407	20	151	-	578
(2) River Channel Excavation	10^3 m^3	430	140	77	-	646
(3) Heightening of Ground Elevation						
Fill at Left Bank	10^3 m^3	551	10	150	-	711
Fill at Right Bank	10^3 m^3	259	21	92	-	372
Total	10^3 m^3	810	31	242	-	1,083
(4) Gabion Mattress	10^3 m^3	75	28	75	-	178
(5) Road Bridges	No	5	2	7	-	14

As shown in the above table, the river training works are carried out mainly in Division 1 at the downstream of the Yao river.

(a) Earth Works ;

The large fill works of 578,000 cu.m in the flood control dike and 1,083,000 cu.m in the heightening of ground elevation will be required in the river training works, while available fill materials along the river are 646,000 cu.m. in the river channel excavation. Namely the fill materials of about 1.0 million cu.m are deficit and will be provided from the stock yard of dam excavation materials.

The gabion of 178,000 cu.m is required for the protection of both banks and will be transported from the tunnel excavation of Ing-Yot No.2 tunnel, No.9 Division.

As mentioned in the above, the Yao river training works shall use the excavated materials from the dam and tunnel, so that the construction schedule is set up taking into account the schedule of the Yao dam and Ing-Yot No.2 tunnel.