4.5 Possibility of Pumping Water Diversion from Lower Ing River

The operation studies of the Sirikit reservoir were made on annual basis employing the criteria to control outflow during dry season in connection with the storage volume available in the reservoir at the end of wet season as indicated below, and with and without pumping water diversion from the lower Ing river. Such results of the study are shown in the following tables.

Outflow Control Criteria

End of November Storage (MCM)	Dry Season Outflow Control	
	Rate (%)	Volume (MCM)
Storage > 6,000	105	6,300
5,000 < Storage > 6,000	85	5,100
4,000 < Storage > 5,000	70	4,200
3,000 < Storage > 4,000	60	3,600
3,000 > Storage	50	3,000

- For without pumping case
- For with 50 cu.m/sec of pumping case
- For with 100 cu.m/sec of pumping case

Table 4.5.1 Annual Operation of Sirikit Reservoir

Diversion Capacity:Kok-Ing Diversion Channel=125cu.m/sec,Ing-Nan Diversion Channel=125cu.m/sec

Pumping Capacity = none

Year	Inflow (MCM)			Wet Outflow	Diversion (MCM)			Wet Balance	Nov. Storage	Spill Water	Dry Outflow (MCM)		June Storage	Total Outflow
	Wet 1	Dry 2	Total 3=1+2	4	Channel 5	Pump 6	Total 7	8=1+7-4	9=12+8	10	Rate (%)	Release 11	12	13=4+11
1974	3505	724	4229	1637	2039	0	2039	3907	4907	0	70	4200	1431	5837
1975	7649	925	8574	2456	2306	0	2306	7499	6660	2270	105	6300	1285	8756
1976	5347	976	6323	2394	1921	0	1921	4874	6159	0	105	6300	835	8694
1977	3434	706	4140	1996	2148	0	2148	3586	4421	0	70	4200	927	6196
1978	5793	728	6521	2408	2303	0	2303	5688	6615	0	105	6300	1043	8708
1979	3068	508	3576	1722	1735	0	1735	3081	4124	0	70	4200	432	5922
1980	5735	882	6617	2294	2025	0	2025	5466	5898	0	85	5100	1680	7394
1981	6858	717	7575	2844	2332	0	2332	6346	6660	1366	105	6300	1077	9144
1982	4615	695	5310	1529	2020	0	2020	5106	6183	0	105	6300	578	7829
1983	4592	858	5450	1867	2087	0	2087	4812	5390	0	85	5100	1148	6967
1984	5641	771	6412	2370	2031	0	2031	5302	6450	0	105	6300	921	8670
1985	4517	1170	5687	1879	2171	0	2171	4809	5730	0	85	5100	1800	6979
1986	3593	485	4078	1945	1982	0	1982	3630	5430	0	85	5100	815	7045
1987	2552	685	3237	1530	1800	0	1800	2822	3637	0	60	3600	722	5130
1988	3843	643	4486	1643	2325	0	2325	4525	5247	0	85	5100	790	6743
1989	3316	605	3921	1407	2296	0	2296	4205	4995	0	70	4200	1400	5607
1990	3476	552	4028	1638	2211	0	2211	4049	5449	0	85	5100	901	6738
1991	2862	402	3264	1413	2094	0	2094	3543	4444	0	70	4200	646	5613
1992	2555	563	3118	1382	1700	0	1700	2873	3519	0	60	3600	482	4982
1993	2743	583	3326	1557	2006	0	2006	3192	3674	0	60	3600	657	5157
MEAN	4284	708	4993	1895	2076	0	2076	4465	5279	181		5010	978	6905

Table 4.5.2 Annual Operation of Sirikit Reservoir

Diversion Capacity:Kok-Ing Diversion Channel=125cu.m/sec,Ing-Nan Diversion Channel=125cu.m/sec

Pumping Capacity = 50 cu.m/sec

Year	Inflow (MCM)			Wet Outflow	Diversion (MCM)			Wet Balance	Nov. Storage	Spill Water	Dry Outflow (MCM)		June Storage	Total Outflow
	Wet 1	Dry 2	Total 3=1+2	4	Channel 5	Pump 6	Total 7	8=1+7-4	9=12+8	10	Rate (%)	Release 11	12	13=4+11
1974	3505	724	4229	1637	2039	351	2390	4258	5258	0	85	5100	882	6737
1975	7649	925	8574	2456	2306	198	2504	7697	6660	1919	105	6300	1285	8756
1976	5347	976	6323	2394	1921	375	2296	5249	6534	0	105	6300	1210	8694
1977	3434	706	4140	1996	2148	222	2370	3808	5018	0	85	5100	624	7096
1978	5793	728	6521	2408	2303	95	2398	5783	6407	0	105	6300	835	8708
1979	3068	508	3576	1722	1735	534	2269	3615	4450	0	70	4200	758	5922
1980	5735	882	6617	2294	2025	334	2359	5800	6558	0	105	6300	1140	8594
1981	6858	717	7575	2844	2332	205	2537	6551	6660	1031	105	6300	1077	9144
1982	4615	695	5310	1529	2020	461	2481	5567	6644	0	105	6300	1039	7829
1983	4592	858	5450	1867	2087	254	2341	5066	6105	0	105	6300	663	8167
1984	5641	771	6412	2370	2031	239	2270	5541	6204	0	105	6300	675	8670
1985	4517	1170	5687	1879	2171	254	2425	5063	5738	0	85	5100	1808	6979
1986	3593	485	4078	1945	1982	385	2367	4015	5823	0	85	5100	1208	7045
1987	2552	685	3237	1530	1800	421	2221	3243	4451	0	70	4200	936	5730
1988	3843	643	4486	1643	2325	292	2617	4817	5753	0	85	5100	1296	6743
1989	3316	605	3921	1407	2296	278	2574	4483	5779	0	85	5100	1284	6507
1990	3476	552	4028	1638	2211	323	2534	4372	5656	0	85	5100	1108	6738
1991	2862	402	3264	1413	2094	397	2491	3940	5048	0	85	5100	350	6513
1992	2555	563	3118	1382	1700	564	2264	3437	3787	0	60	3600	750	4982
1993	2743	583	3326	1557	2006	400	2406	3592	4342	0	70	4200	725	5757
MEAN	4284	708	4993	1895	2076	329	2405	4794	5643	147		5370	982	7265

Table 4.5.3 Annual Operation of Sirikit Reservoir

Diversion Capacity:Kok-Ing Diversion Channel=125cu.m/sec,Ing-Nan Diversion Channel=125cu.m/sec

Pumping Capacity = 100 cu.m/sec

Year	Inflow (MCM)			Wet Outflow	Diversion (MCM)			Wet Balance	Nov. Storage	Spill Water	Dry Outflow (MCM)		June Storage	Total Outflow
	Wet 1	Dry 2	Total 3=1+2	4	Channel 5	Pump 6	Total 7	8=1+7-4	9=12+8	10	Rate (%)	Release 11	12	13=4+11
1974	3505	724	4229	1637	2039	601	2640	4508	5508	0	85	5100	1132	6737
1975	7649	925	8574	2456	2306	120	2426	7619	6660	2091	105	6300	1285	8756
1976	5347	976	6323	2394	1921	618	2539	5492	6660	117	105	6300	1336	8694
1977	3434	706	4140	1996	2148	412	2560	3998	5334	0	85	5100	940	7096
1978	5793	728	6521	2408	2303	99	2402	5787	6660	67	105	6300	1088	8708
1979	3068	508	3576	1722	1735	910	2645	3991	5079	0	85	5100	487	6822
1980	5735	882	6617	2294	2025	557	2582	6023	6510	0	105	6300	1092	8594
1981	6858	717	7575	2844	2332	84	2416	6430	6660	862	105	6300	1077	9144
1982	4615	695	5310	1529	2020	663	2683	5769	6660	186	105	6300	1055	7829
1983	4592	858	5450	1867	2087	467	2554	5279	6334	0	105	6300	892	8167
1984	5641	771	6412	2370	2031	324	2355	5626	6518	0	105	6300	989	8670
1985	4517	1170	5687	1879	2171	462	2633	5271	6260	0	105	6300	1130	8179
1986	3593	485	4078	1945	1982	621	2603	4251	5381	0	85	5100	766	7045
1987	2552	685	3237	1530	1800	708	2508	3530	4296	0	70	4200	781	5730
1988	3843	643	4486	1643	2325	409	2734	4934	5715	0	85	5100	1258	6743
1989	3316	605	3921	1407	2296	413	2709	4618	5876	0	85	5100	1381	6507
1990	3476	552	4028	1638	2211	488	2699	4537	5918	0	85	5100	1370	6738
1991	2862	402	3264	1413	2094	612	2706	4155	5525	0	85	5100	827	6513
1992	2555	563	3118	1382	1700	825	2525	3698	4525	0	70	4200	888	5582
1993	2743	583	3326	1557	2006	595	2601	3787	4675	0	70	4200	1058	5757
MEAN	4284	708	4993	1895	2076	499	2576	4965	5837	166		5505	1041	7400

5.2 General Topography and Geology

(1) Geological data

1) Data Collection

a) Geological Map of North Thailand 1/250,000

Sheet 1 (Nan)

Sheet 2 (Chiang Rai)

Sheet 3 (Phayao)

b) Geological Map 1/50,000 (Map & Report = Thai word)

* Ban Waen Klong (5047-1)
* Amphoe Chun Quadrangle (5047-4) = Amphoe Chun
* Chiang Rai(4948-1)
* Ban Mae Pao Luang (5048-4) = Amphoe Phaya Meng Rai
* Amphoe Thoeng (5048-3)
* Amphoe Pong Quadrangle (5047-2)
* Ban Tham Quadrangle (5047-3)
* Amphoe Chiang Kham(5048-2)(1/250,000 Geological map & Report)

2) Drilling & Seismic Survey Report

a) ING-YOM-NAN Diversion Project ING-YOM River Diversion Study Feasibility Report Volume 4 & 5 Geotechnical Investigation

3) Aerial photograph

a) Flight course map (1/50,000)

b) Aerial photograph----- scale 1/30,000.

4) Aerial photographic survey

Stereoscopic vision and analysis of lineation was made along the tunnel alignment A and B route using aerial photograph which was made by RID at 1993.

these analyzed lineament is shown on the 1/50,000 compiled geological map.

5) Geological reconnaissance

Field reconnaissance survey was made to confirm lithological stratigraphical, geological structural feature, weathering of rocks, and rock mechanical characters by observation of major outcrops which was observed in the main river and cuttings made with roads and dam constructions .

As a result of the survey the location of out crops , and dip and strike of bedding is put on topographic map of 1/10,000.

6) Compilation of Geological map

Finally, the geological map of scale 1/250,000 and 1/50,000 was made compiling collected geological maps and referring the information from the aerial photographic survey and field reconnaissance survey. The map of scale 1/250,000 is shown in the Database map (Figure G-1). Some part the compiled map of 1/50,000 is shown in the Database map for Kok-Ing canal route (Figure G-2) and Ing-Yot tunnel alignment (Figure G-3, G-4, G-5) .

(2) Core Drilling

On early stage of field reconnaissance survey ,each geological object , drilling points is shown 1/50,000 map (refer to Database map) and these drilling depth is shown in Table S5.2.1, number of drilling hole are 12 and total drilling depth are 877m. Each core drilling is accompanied with Lugeon test of 3 sections of each interval 5 m (from bottom to upward) and for drilling core uni-axial compression test was carried out.

The purpose of these drilling point are to make clear following geological feature .

1) Depth to intact rock on inlet and outlet of tunnel and driving canal to tunnel from Ink diversion dam.

2) Classification of weathered rock and these rock mechanical feature

Result of drilling is shown on Geological Logging chart in the Database map (Figure G-15, to G-19).

Table S5,2.1

CORE DRILLING POINT ON ING-YOT TUNNEL

ROUTE B (NORTH) CONCEPTUAL STUDY STAGE 1996 RID

DRILLING No	DISTANCE	GROUND HEIGHT	TUNNEL BOTTOM	GH -T BOTTOM	LENGTH	GEOLOGY	CORD
DHB-1	-920	384	352	32	40	Weathered depth of Shale(TRpm)	X= 635,190 Y=2173,920
DHB-2	0	388	352	36	45	Weathered depth of Shale(TRpm)	X= 636,130 Y=2173,920
DHB-3	B1480	400	352	48	55	Weathered depth of Lapilly tuff fault zone	X= 635,710 Y=2175,520
DHB-4	*3218	463	351	112	120	Fault zone of phyllite (CPpr)	X= 638,820 Y=2175,580
DHB-5	9915	460	348	112	120	Fault zone of phyllite (CPpr)	X= 644,940 Y=2174,990
DHB-6	*29500	485	340	145	150	Bottom of Limestone (TRpc) and fault	X= 652,530 Y=2156,850
DHB-7	B49205	383	332	51	60	Depth of Sand & Gravel dep, Limestone(Pbt?)	X= 655,820 Y=2145,430
DHB-8	*49800	378	332	46	50	Weathered depth of sandst. or/& tuff(TRhs)	X= 668,150 Y=2144,010
SUB TOTAL					640		

ROUTE A (NORTH)

DRILLING No	DISTANCE	GROUND HEIGHT	TUNNEL BOTTOM	GH-T BOTTOM	LENGTH	GEOLOGY	CORD
DHA-1	1300	403	349	54	60	Weathered depth of Lapilly tuff (TRmp)	X= 635,050 Y=2177,260
DHA-2	2580	411	349	62	70	Fault zone of Phyllite (CPpr)	X= 636,230 Y=2177,510
SUB TOTAL					130		

ROUTE C (SOUTH)

DRILLING No	DISTANCE	GROUND HEIGHT	TUNNEL BOTTOM	GH-T BOTTOM	LENGTH	GEOLOGY	CORD
DHS-1	2940	386	349	37	42	Weathered depth of shale (TRmp)	X= 628,480 Y=2159,310
DHS-2	9200	410	346	64	65	Depth of Terrace deposit, weathered condition of shale (Jmt)	X= 631,150 Y=2153,150
SUB TOTAL					107		

TOTAL			877	

Remarks ; Distance B=Alingment B of RID Study
*=Projected to Alignment

Geological feature of each drilling hole is as follows

a) **DHB-1, DHB-2**

Shows typical rock feature of Shale of **TRmp** formation which consist of brownish gray shale. Easily breakable along bedding plane, so rock mechanical characteristics can not judge exactly from RQD. It seems that the Shale will be inferior by water.

b) **DHA-1**

Shows typical rock feature of Lapilly tuff of **TRmp** formation which consist of Andesite lapilly and Andesitic tuff. 0-30m is relatively intact. 30m-60m is cracky but Lugeon value is small.

c) **DHB-3**

Shows rock feature of Fault zone of Lapilly tuff in contrast to intact rock of DHB-2. 0m-18m consist of clay and silt of overlain sediment of Quaternary or strongly weathered clayey rock of fault zone. After that, continue cracky Lapilly tuff.

d) **DHA-2**

The drilling point is selected on the fault which divides **CPpr** formation and **TRmp** formation. Drilling core shows strongly weathered and cracky rock feature of broken Phyllite of **CPpr** formation, especially below 35 m is broken strongly.

e) **DHB-4**

The drilling point is selected on the typical fault valley which divides **CPpr** formation and **TRhs** formation. Surface part (to 18m) consist of alluvial sand and gravel. After that underlain by cracky and deeply weathered Sandstone and Phyllite which is altered to talc. Two Limestone bed of thickness 7m and 12 m is interbedded. Open crack which is eroded by water is found in the Limestone.

f) **DHB-5**

Shows typical rock feature of **CPpr** formation which consist of Phyllite and Sandstone fin alternation. Phyllite is dark gray, contain and graphite. Sandstone is hard and each bed is generally thin so in mark of sandstone in the drilling core column means the part in which sandstone layer is relatively dominant. Small scale fault is found along bedding plane accompanied with thin Quartz vein.Intraformation folding is formed. Bedding plane dips generally 30 degree to 45 degree. Drilling core is easily breakable along Phyllite bed.

g) **DHB-6**

The drilling point was selected to confirm boundary between **CPpr** and limestone of **TRpc** formation. But Limestone continue to bottom of drill hole. Surface part (to 23 m) is Talus which consist of sand and gravel. Below that, continue Limestone. To 43 m depth, some cracky part is found, below that generally massive. Very thin (less than 1 mm -5

mm) and slightly muddy limestone is frequently interbedded which dipping generally low angle (10-20 degree).

h) DHB-7

To 19 m, consist of sand and gravel of Quaternary deposit. Below that to 37 m, sand and gravel which include big boulder (diameter more than 1 m), this part with possibility of drilling into limestone cave. Below that, continue Limestone, which is generally massive, but there are found many latent hair crack.

I) DHB-8

To 10 m, consist of clay and sand of Quaternary sediment. To 27 m, is strongly weathered tuffcious sandstone in which almost composed minerals is altered to clay minerals. Below that to 30m, consist of cracky Tuffcious sandstone rock and to 50 m become massive.

j) DHC-1 and DHC-2

These drilling point are selected to confirm geological condition of first half of alignment C under low hill area which underlain by Jurassic sedimentary rocks. Both drilling core consist of Shale and Sandstone which are brownish gray color. Apparently massive but brittle broken by hammer blow. About to 20 m, strongly weathered and is altered to clayey.

(3) Rock Mass Classification for Tunneling

Rock mass classification to be adapted to design tunnel of the project is considered as follow.

Tunnel design is planned in accordance with geological conditions and it is neccessary to make some standard which is integrated with many geological parameter such as hardness, weathering conditions, interval and conditions of crack and joint. this standard generally called " Rock Mass Classification".

As a effective measure, usually elastic wave velocity is used in major standards but seismic prospecting has not been made for the project on conceptual study of Thai side. So a rock mass classification is made in accordance with information of drilling and field geological survey.

Table S5.2.3 shows the druft of Rock Mass Classification.

In this table , type of rocks is classified following groups shown Table S5.2.2.

This standerd should be made complete after get more information such as elastic wave velocity, additional drilling data on feasibility study stage.

Table S5.2.2 Grouping of Geology for Rockmass Classification of Tunneling of Kok-Ing-Nan

Geological Group	Formation	Acronym	Lithofacies
a	Phu Rang Ka	CPpr	alternation of Phyllite,Slate & Sand st.associated Quartzite,Tuff & Calcareous shale
b	p3	p3	Shale, Sandstone, Tuff
	Huai Sarian	TRhs, t-p	fin alternation of Shale and Sand st. associated tuff
	Pha Chik,'Ban Tham	TRpc, Pbt	Limestone.
c	Doi Mon Yao Volcanic	TRv, Lms-2	Rhyolitic & Andesitic tuff, Andesite, Diabase
	Andesite-Rhyolite	L-tp	Andesite,Rhyolite & Tuff
	Granite	Gt	Granite,Granodiorite porphyry
d	Mae Phong	TRmp	Sand st.,Shale, Tuff & Lapilly tuff
e	Talus	Qt	unconsolidated Sand,Silt & Gravel

Table S5.2.3 Rockmass Classification for Tunneling of Kok-Ing-Nan

Rockmass Classification for		Geological Grouping	Overburden	Geological Feature	Drilling Core
A		a b c			
B		a b c	more than 300 m	*Fresh & hard rock, relatively few crack *In strata,stratification or shistosity(group a) is found and breakable along the plane	Core recovery > 90% Show columunar shape (10-20cm) group c; RQD 90-70
C	I	a b c d	100m to 300m	*Relatively hard, some part altered by weathering, crack is found offen *Rock show clear stratification, easily broken (group a.b.d)	Core recovery 70-90% Show short columnar shap 5-10 Group c; RQD 30-70
	II	a b c d	less than 100m	*Altered by weathering and somewhat softened (group b), Rock is relatively hard but easily brakable along bedding plane (group a,d) *Narrow and small fault are sandwiched	Core recovery > 70-50 Show short columnar shap and small pieces group c; RQD 30 >
D	I	a b c d	less than 100m	*Subjected to severe weathering , rock is partially transformed to sand and clay. Soft and brittle with slightly hard portion remaining inside *Joints are so numerous. *Fault zone which has not been altered completly to clay; cohesive soil is mixed with rock fragment containing some hard portion *If rock is softened by water, classified under E	Core recovery < 10 Show small pieces, sometimes sand mixed with breeciated pebles and clay
	II	a b c d			
E	I	a b c d e	less than 50 m	*Fault zone which subjected to severe weathering under sharrow overburden and altered to clay *Limestone cave on fault zone in which groundwater discharge is supposed, rock is crushed also. *talus which consist of loose sand and gravel with clay. *E2 type applied espesially to inlet and outlet.	
	II	a b c d e			

(4) Geological notice for tunneling

<Ing-Yot tunnel>

① Treatment for shallow overburden section from inlet to about 2 km.

Main part of this section is overlain by shale sand stone and lapilly tuff of TRmp formation which become cracky and sheared with a lot of faults, in addition is weathered highly because of shallow overburden. Therefore , it is necessary to study some special treatment of tunneling as Forepiling method etc..

② Investigation for limestone of TRpc of the Doi Pha Deang mountain.

Groundwater discharge when tunnel meet to limestone cave is one of serious problem, so it is necessary to make clear the hydro-geological characteristics of limestone, specially it is important to confirm the altitude of bottom of limestone (impervious boundary) of the Doi Pha Deang mountain. There fore additional investigation on the Feasibility Stage is required.

③ Rock mechanical feature of fault zone

Some drilling core of the conceptual study stage show that the rock facies of fault zone of relatively shallow part (some times shallower than 70 m) become cracky and clayey. There are supposed some fault along river cause, so it is necessary to investigate such fault zone.

④ Influence to spring of Phu Sang water fall

This spring of temperature 33℃ is flow out as the Phu Sang water fall. The hydro-geological mechanism has not been made clear so influence of tunneling cannot estimate. This fall is famous tourist attraction, it is necessary to investigate the mechanism of the spring and to observe influence during implement of tunnel excavation.

⑤ Investigation of higher mountain area

This area is supposed to be underlain by TRhs but there aren't any available road for transportation of survey instruments, so it is difficult to approach and to investigate specially in the rainy season.

⑥ Groundwater discharge of Limestone formation located on Yot valley and nearby Ban Pha Lak village.

There are two Limestone beds between 46 km to the outlet. Especially it is supposed that when the tunnel pass through the Limestone bed located under the Yot river will be meet with groundwater discharge from the Limestone cave or/and fractured zone along fault zone. Therefore it is necessary to investigate rock feature and groundwater of the Limestone bed in the Feasibility Study stage.

⑦ Land slide or collapse of entrance to tunnel (include in case of inclined shaft)

Surface part of the rocks are weathered deeply and completely and became clayey,

and it is observed that many small scale and shallow land slide or collapse occurred after heavy rain on this weathered zone of many kind of formations. So it have to take care to excavate entrance of tunnel and to consider some treatment to inlet and outlet of the tunnel.

⑧ Investigation for inclined adits

Seven (7) inclined adits is planned to approach main tunnel. There inclined adits also are big size and long (1.5-3 km length) tunnel. Therefor it's important to make clear geological conditions of these inclined adits, especially for weathered conditions and rock feature of fault zone to design these adits.

<Kok-Ing tunnel>

Geological notice for proposed three alternative alignment of Kok-Ing tunnel, Route A, Route B and route BJ is as follows.

⑨ To make clear geology of every alignment

The geological survey has not been made yet, so it is necessary to make clear geological condition of every alternatives, such as depth of weathered zone, rock facies of each geological unit.

⑩ Geological feature of route A-1 tunnel

A-1 tunnel passes through lower hills underlain by weak geology which is strongly and deeply weathered and crashed eleven (11) supposed faults. Therefore, it is important to confirm rock feature and geo-technical conditions and groundwater of the alignment.

⑪ Fault zone

Another alternative tunnel alignments also pass through some faults, therefore it is necessarily to investigate rock facies of these fault zone.

⑫ Land slide or collapse of entrance to tunnel

Near inlet and outlet of each alternative tunnels are underlain by more deeply and more strongly weathered rocks than the Ing-Yot Tunnel alignment and Tulles, so it is necessary more carefully to investigate such part.

⑬ Bottom of basalt of tunnel alignment B

The boundary of Basalt lave and t-p and p3 formation will be weak geological condition, so it is necessary to confirm shape of bottom of Basalt.

(5) Proposal of geological investigation of Feasibility Study for Kok-Ing-Nan diversion canals, tunnels, dams and Flood control dam

Following investigation is proposed on the Feasibility Study stage of Thai side to solved the geotechnological problems which has been brought up by result of the Conceptual Study with detail in the Table S5.2.4 - S.2.7. These investigations will be carried out when the feasibility study is started by Thai side.

If the JICA evaluate to progress the project, considering these investigation plan of Thai side, some additional investigation shown as follows and detail in the Table S5.2.8 is necessary on the feasibility study by JICA.

< Investigation with Thai Side >

Investigation with Thai Side consist of seismic prospecting which is necessary to make clear major part along tunnel alignment and adits, and core drilling for shallower part near inlet and outlet ,and adits.

① Seismic prospecting

Seismic prospecting (Refraction method) is proposed to investigation of Kok-Ing Tunnel and Ing-Yot tunnel A1,BJ1, BJ2 and B alignment, its inclined adits and some part of canal route and flood control dam. To main tunnel of Ing-Yot tunnel, this survey is planned specially to whole section under lower hills and lower mountain part of ground height bellow 200 m and some part of which cross supposed fault along river cause and to shaft.

Total number of survey line are 31 and total length are about 63.8 km.

② Core drilling

Core drilling is proposed to Kok-Ing and Ing-Yot tunnel and its adits, Kok intake and new diversion wier, on the canal route of Nong Luan lake, Ing diversion weir, and Yao flood control dam. With drilling , Standard penetration test and Lugeon test is made and also some laboratory test such as unite weight, Point load , Uniaxial compression test , Tensile strength test and P.s wave velocity test.

Some special geo-loggings is proposed also, using the equipment donated with expert dispatch from JICA (refer to Table S5.2.8).

Total drilling point are 38 and total length are 2185 m.

③ Schedule

(a) seismic prospecting

About 5 months with 5 survey party will be required to complete total length 63.8 km.

(b) Drilling

About 4.5 months with 4 survey party will be required to complete total length 2185 m.

2 Investigation required to feasibility study with JICA

Investigation with JICA study consist of TDEM and drilling for deeper part

① TDEM prospecting (Time Domain Electro-Magnetic method)

TDEM is more available than seismic prospecting (refraction method) and electric prospecting for survey to make clear geology of deeper part and especially these part which is overlain by geology shown higher electric receptivity or higher elastic wave velocity. So, TDEM method is proposed to solve following problems.

(1) To confirm shape of basement of Basalt formation on the Kok-Ing tunnel.

(2) To confirm shape of basement of limestone of TRpc on Doi Pha Deang mountain.

(3) To make clear rock feature of some fault zone.

(4) The geological structure near tunnel elevation on which covered with thick overburden about 500m to 1000m , in high mountain area of Ing-Yot tunnel.

(5) To make clear fissures and fault zone nearby the spring of Phu Sang water fall to suppose hydrogeological mechanism of the spring.

Different survey method is applied, one of these is normal one which applied to analyze shallower object such as above mentioned (1), (3) and (5), and another one is special one to analyze deeper object of (2) and (4).

Number of survey line is 8, 6 are normal method and 2 are special method.

Total lengh of survey line are 11.6 km

② Core drilling

It has been difficult to take satisfactory core from fault sheared zone and it seems difficult to drill deeper part (more than 100 m) on the conceptual study stage of Thai side. Therefore , it's necessary to cooperate with technical advice and on the job training of deeper drilling especially on fault zone and on site test which needs higher technique and experiences such as water pressure test, some kind of geo-logging, rock test, X-ray analysis for clay minerals and observation by optical microscope.

Number of drilling point are 6 and total length are 1415 m.

③ Schedule

(a) TDEM

About 3 months is required to complete survey and analysis after started site survey.

(b) Drilling

About 4.5 months with 4 drilling party will be required to complete total length 1300 m.

Table S5.2.4

PROPOSAL FOR GEOLOGICAL INVESTIGATION OF RID F/S STUDY STAGE

	DISTANCE	GROUND HEIGHT	TUNNEL BOTOM	GEOLOGY	DRILLING (m)		SYSMIC PROSPECT (km)			
					No.	Depth	No.	Main	Sub	Total
	-0.4	385	352	Al/WTRmp(Shale)	DHB -0.4	35				0.00
	B-0.1-7.0	400	353	Fault/WTRmp-hs(Shale,Sand st)			SB 0-	7.70	4.70	12.40
ING	B0.6	390	352	Fault/WeatherTRmp(Shale)	DHB-0.6	50				
	B2-(0-3.6)			Al/WTRmp(Shale)			S2B 0-	2.70	1.30	4.00
	B2-0.6	420	352	WTRmp(Shale)	DHB-1SP	80				
	Adi 1(0-1)			CPpr(Phyllite)			SAd 1	1.00	0.50	1.50
YOT	Adi-1(0.11)	482	437	CPpr(Phyllite)	DH1Ad 1	65				
	B8-8.8			CPpr(Phyllite)/Fault			SB 8	0.80	0.50	1.30
	B8	488	348	CPpr(Phyllite)/Fault	DHB-8SP	145				
	B10.5-11.5			Fault/CPpr(Phyllite)			SB 10-	1.50	1.00	2.50
	Adi 2(0-1.7)			Weather/CPpr(Phyllite)			SAd 2	1.50	1.00	2.50
	Adi-2(0.77)	495	410	Weather/CPpr(Phyllite)	DH2Ad 1SP	90				
TUNNEL	B16-18.5			Fault/CPpr(Phyllite)			SB 16-	1.00	1.00	2.00
	Adi 3(0-1)			Fault/CPpr(Phyllite)			SAd 3	1.00	0.50	1.50
	Adi 3(0.2)	530	486	Weather/CPpr(Phyllite)	DH3Ad 1	60				
	B17.5-18.5			Fault/CPpr(Phyllite)			SB 17-	1.00	0.50	1.50
	B20.8-21.0			Fault/CPpr(Phyllite)			SB 21-	1.10	0.80	1.90
	Adi 4(0-1)			Fault/CPpr(Phyllite)			SAd 4	1.40	0.60	2.00
	Adi 4(0.15)	535	478	Weather/CPpr(Phyllite)	DH4Ad 1	65				
	Adi 5(0-1)			Feather/CPpr(Phyllite)			SAd 5	1.10	0.50	1.60
	Adi 5(0.35)	550	490	Weather/Ths(Shale,Sand st)	DH5Ad 1	70				
	B34.7-36.7			Ths(Shale,Sand st)			SB 35-	2.00	1.50	3.50
	Adi 6(0-1)			Ths(Shale,Sand st)			SAd 6	1.40		1.40
	Adi 6(0.3)	660	560	Weather/Ths(Shale,Sand st)	DH6Ad 1SP	120				
	B46.1			Al/Fault/Pb(Limestone)			SB 46	0.80		0.80
	B46	420	331	Al/Fault/Pb(Limestone)	DHB-46SP	100				
	B48.22-49.82			Weather/TRhs(Tuff)			SB 48-	1.60	0.60	2.20
	B49.42	390	332	Weather/TRhs(Tuff)	DHB 49	60				
	B50.38-51.18			Weather/TRhs(Tuff)			SB 49-	0.80	0.60	1.40
	Adi 7(0-1)			Weather/Ths(Shale,Sand st)			SAd 7	1.00	0.50	1.50
	Adi 7(0.1)	460	412	Weather/Ths(Shale,Sans st)	DH7Ad 1	60				
	B50.38	420	330	Weather/Ths(Shale,Sand st Tuff)	DHB 50SP	90				
	sub total				14	1090		29.40	16.10	45.50
	A1-1.1-2.2			t-p(Shale, Sand			SK1A1-1.1	1.20	0.80	2.00
KOK	BJT1-0-			₩. t-			SKIBJ-0	2.00	0.80	2.80
	BJT1-1.4	430	380	₩. Lms2(Tuff)/Fault3	DHKBJT1-1	70				
	BJT1-2.0			₩. Lms2(Tuff)/Fault4. 5			SKIBJ1-2.0	1.20	0.70	1.90
	BJT2-1.0	435	377	₩. p-3(Schale)/L-tp(Tuff)/Fault	DHKBJ2-1.0	65				
	BJT2-0.0-			₩. p3(Shale)/Fault1			SKIBJ2-0	1.20	0.40	1.60
	BJT2-3.3-4.3			₩. t-p(Shale, Sand st)/Fault3			SKIBJ-3.3	1.00	0.40	1.40
	BJT2-3.5	420	375	₩. t-p(Shale, Sand st)/Fault3	DHKBJ2-3.5	55				
ING	B-0-1.5			Talus/Basalt/t-p(Shale)/Fault			SKIB 0.0-1.5	1.50	0.50	2.00
	B-0.01	436	374	Weather/c-p(Shale)	DHKB-0.1	70				
	B-4.0-5.5			Talus/Weather/c-p(Shale)			SKIB-4.0	1.50	0.50	2.00
TUNNEL	B-3.8	426	369	Weather/c-p(Shale)	DHKB-3.8	65				
	sub total				5	325		9.60	4.10	13.70
	total				19	1415		39.00	20.20	59.20

Table S5.2.5

PROPOSAL FOR GEOLOGICAL INVESTIGATION OF RID F/S STUDY STAGE

KOK INTAKE

ALTERNA	DISTAN	GROUN HEIGHT	WEIR BOTOM	GEOLOGY	DRILLING (m) No.	Dept	SYSMIC PROSPECT (km) No.	Main	Sub	Total
B	0			Qa (Sand Gravel)	DHKI-B1	30				
A	0			Qa (Sand Gravel)	DHKI-A1	30				
sub total					2	60				

KOK-ING CANAL

ALTERNA	DISTAN	GROUN HEIGHT	CANA BOTOM	GEOLOGY	DRILLING (m) No.	Dept	SYSMIC PROSPECT (km) No.	Main	Sub	Total
B	3.8	391		Qa (Sand Gravel Clay)	DHKI-B2	30				
B	13.2	395		Qa / Tp (Shale Sand st.)	DHKI-B4	30				
B	17.5	397		Qa / Tp (Shale Sand st.)	DHKI-B5	30				
B	18.8	397		Qa / Tp (Shale Sand st.)	DHKI-B6SP	30				
B	20	397		Qa / Tp (Shale Sand st.)			SKI-B20	1.00	0.30	1.30
B	25.3	397		Qa / Lms2 (Tuff)	DHKI-B7	30				
B	39.3	367		Qa (Sand Gravel)	DHKI-B8	20				
B		372		Qa (Sand Gravel)	DHKI-B9	20				
Total					7	190		1.00	0.30	1.30

KOK-ING DIVERSION

ALTERNA	DISTAN	GROUN HEIGHT	WEIR BOTOM	GEOLOGY	DRILLING (m) No.	Dept	SYSMIC PROSPECT (km) No.	Main	Sub	Total
B		362		Qa (Sand) / Jnn (Sand st. Congl.)	DHBID-1	40				
B		362		Qa (Sand) / Jnn (Sand st. Congl.)	DHBID-2	40				
B		364		Qa (Sand) / Jnn (Sand st. Congl.)	DHBID-3	40				
sub total					3	120				

CANAL(ING DV.-INGYOT TUNNEL)

ALTERNA	DISTAN	GROUN HEIGHT	CANA BOTOM	GEOLOGY	DRILLING (m) No.	Dept	SYSMIC PROSPECT (km) No.	Main	Sub	Total
Tunnel	-0.15-0.85			W. ms3 (Congl) / Fault			SB 0	1.00	0.50	1.50
	0.33	394	350	W. ms3 (Congl) / Fault	DHI-IT-1	50				
Siphon		373	350	W. Lms2 (Tuff)	DHI-IT-2	30				
sub total					2	80		1.00	0.50	1.50

YAO FLOOD CONTROL DAM

ALTERNA	GROUN HEIGHT	DAM BOTOM	GEOLOGY	DRILLING (m) No.	Dept	SYSMIC PROSPECT (km) No.	Main	Sub	Total
DAM 1	320		TRbs (Sand, Tuff, Shale)	DHF1-1	60	SF1-1	0.60	0.00	0.60
	302		TRbs (Sand, Tuff, Shale)	DHF1-2	80	SF1-2	0.40	0.00	0.40
	286		TRbs (Sand, Tuff, Shale)	DHF1-3	60	SF1-3	0.40	0.00	0.40
	320		TRbs (Sand, Tuff, Shale)	DHF1-4	60	SF1-4	0.40	0.00	0.40
	285		TRbs (Sand, Tuff, Shale)	DHF1-5	60				
sub total				5	320		1.80	0.00	1.80
Total				19	770		3.80	0.80	4.60

Table S5.2.6

PROPOSAL FOR GEOLOGICAL INVESTIGATION OF JICA F/S STUDY 2nd STAGE

ING-YOT TUNNEL

DISTANCE	GROUND HEIGHT	TUNNEL BOTTOM	GEOLOGY	DRILLING		T.O.E.M			REMARKS
				No.	Depth	No.	Metho	Length(	
B3.9-4.6			Fault/CPpr(phyllite)			TMB 3.9	N	0.70	DHB 4
B8.1-8.5			Fault/CPpr(phyllite)			TMB 8.1	N	0.40	
B11			Fault/fissure CPpr(phyllite)			TMB 11	N	1.30	Phu Sang
B16.5	530	345	Fault/CPpr(phyllite)	DHB 16.5	200				
B18	550	345	Fault/CPpr(phyllite)	DHB 18	210				
B21.5	544	345	Fault/CPpr(phyllite)	DHB-22.5	200				
B29.4-31.4			Base of limestone			TMB29.4	S	2.00	Doi Phadeang
B26.4	600	342	TRhs(Shale,Sandstone)	DHB-26	270				
B33.2	580	340	Ths(shale/sandstone.)	DHB-33	250				
B33.7-34.4			Fault/CPpr(phyllite)			TMB33		0.70	Riv.Yuan
B35.5-37.5			Fault/TRhs(shale,sandstone)			TMB35	S	2.00	B.Than Pung
B46.3-47.3			Al/Fault/Limestone/TRhs(shale)			TMB46		1.00	
SUB TOTAL				5	1130			8.10	
KOK-ING TUNNEL									
B1.0-2.9			Basalt/c-p(shale)			TMK 1-4.5	N	3.50	
B2.1	546	370	Basalt/c-p(shale)	DHK-3.0	180				
SUB TOTAL				1	180			3.50	
TOTAL				6	1310			11.60	

Table S5.2.7 GEOLOGICAL INVESTIGATION TO SOLVE THE PROBLEMS WITH TUNNELING

Tunnel section from km	to km	Adit		Geological Problems have to be solved	Geological Investigation Thai Side F/S				Geological Investigation proposed to JICA F/S				Remarks
					Sysmic Prospecting		Drilling		Drilling		TDEM		
					No.	Length	No.	Length	No.	Length	No.	Length	
ING-YOT TUNNEL													
Inlet	7		①	Treatment for lower overburden section	SB 0.-	12.40	DHB-0.4	35					
							DHB 0.6	50					
	(B-2		①	Treatment for lower overburden section	S2B O-	4.00							
			①	Treatment for lower overburden section			DHB-1SP	80					
			③	Rock mechanical feature of fault zone							TMB 3.9	0.70	
			③	Rock feature of fault	SB 8	1.30	DHB 8.0	145			TMB 8.1	0.40	
		1	⑦⑧	Land slide of entrance Geology of Adit	SAd 1	1.50	DH1Ad 1	65					
8	11		③	Rock feature of fault	SB 10-	2.50							
			④	Infruence to spring of Phu Sang water fall							TMB 11	1.30	
		2	⑦⑧	Land slide & Geology Adit	SAd 2	2.50	DH2Ad1sp	90					
16	22		③	Rock feature of fault	SB 16	2.00			DHB 16.5	200			
					SB 17	1.50			DHB 18	210			
					SB 21	1.90			DHB 22.5	200			
		3	⑦⑧	Land slide & Geology Adit	SAd 3	1.50	DH3 Ad1	60					
		4			SAd 4	2.00	DH4 Ad1	65	DHB 26	270			
29	32		②	Geology of Limestone Mountain Doi Pha Deang							TMB 29.4	2.00	
33	39		③	Rock feature of fault	SB 35-	3.50			DHB 33	250	TMB 33	0.70	
			⑤	Investigation for higher mountain area of TRhs							TMB 35	2.00	
		5	⑦⑧	Land slide & Geology Adit	SAd 5	1.60	DH5A 1	70					
		6			SAd 6	1.40	DH6A1SP	120					
47	Outlet		⑥③	Depth of Quarternary deposit of Yot vally	SB 46	0.80	DHB 46.6SP	100			TMB 46	1.00	
			③	Rock feature of fault	SB 48-	2.20	DHB 49	60					
			⑦	Land slide & Geology of Outlet	SB 49-	1.40	DHB 50.3SP	90					
		7	⑦⑧	Land slide & Geology Adit	SAd 7	1.50	DH7A 1	60					
SUB-TOTAL						45.5	14	1090	7	1130		8.1	
KOK-ING TUNNEL													
AT1-1-	2.2		⑩	Geological feature of A-1	SKIA1-1	2.00							
BJT1-1			⑨	Geological condition	SKIBJ-0	2.80							
BJT1-1.4			⑨	Geological condition			DHKBJT1-1.4	70					
BJT1-2.0	outlet		⑦	Land slide & Geology Inlet & Outlet	SKIBJ1-2	1.90							
BJT2-1.0			⑪	Rock feature of fault			DHKBJ2-1.0	65					
BJT2-0.0-			⑪	Rock feature of fault	SKIBJ2-0	1.60							
BJT2-3.3	3.4		⑪	Rock feature of fault	SKIBJ-3.3	1.40							
BJT2-3.5			⑪	Rock feature of fault			DHKBJ-3.5	55					
B-0	1.5		⑫	Land slide & Geology Inlet & Outlet	SKIB-0	2.00	DHKB-0.1						
B-0.1			⑦	Land slide & Geology Inlet & Outlet			DHK 0.1	70					
B-4.0	5.5		⑦	Land slide & Geology Inlet & Outlet	SKIB-4.0	2.00							
B-1.0	4.5		⑬	Bottom of Basalt					DHKB-3	180	TMK1-4.5	3.5	
B-3.8			⑦	Land slide & Geology Inlet & Outlet			DHK 3.8	65					
SUB TOTAL						13.70	5	325.00	1	180.00		3.50	
TOTAL						59.20	19	1415.00	8	1310.00		11.60	

Table S5.2.8 **PROPOSAL FOR GEOLOGICAL INVESTIGATION OF RID F/S STUDY**

GEO-LOGGING GROUNDWAER TEST

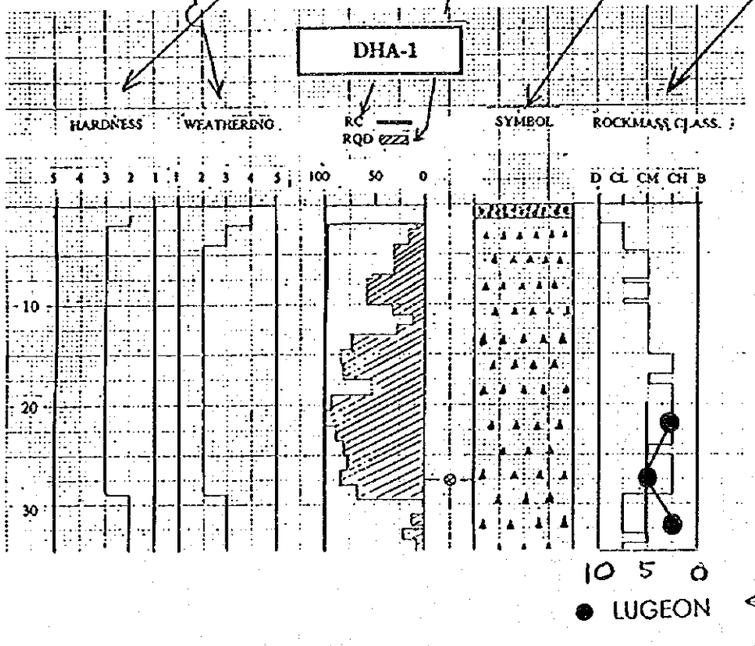
FACITLITIES	DISTANCE	GROUND HEIGHT	RELATED DRILLING	GEOLOGY	SURVEY HOLE (m)		EXAMINATION ITEM				REMARK
					No.	Depth	BGS	PSL	MHT	CONE	
KOK-ING CANAL	0	397	DHKI-B6	qa(Sand Clay) / tp(Shale Sand st	DHKI-B6SP	30	X		X	X	
KOK-ING TUNNEL		430	DHKBJ-1.4	W. Lms2(Tuff) /Fault3	DHKBJT1-1S	70	X	X	4		
ING-YOT		420		W.TRpm(Shale)	DHB-1SP	80	X	X	5		
		488	DHB-8.0	CPpr(Phyllite,Sandstone)	DHB-8SP	145	X	X	6		
		480	DH2Ad 1	Weather/CPpr(Phyllite)	DH2Ad 1SP	90	x	x	4		
		660		TRhs(Sandstone,Shale)	DH6Ad-1SP	120	X	X	X		
		420	DHB-46	Pbt(Limestone)	DHB-46SP	100	X	X	X		
		420	DHB 50.3	Weather/Ths(Shale,Sand st Tuff)	DHB-50SP	90	x	x	4		
sub total					8	725					

* BGS; Borehole Geophysics System(Geologger 3030)
* PSL; Suspension PS Logging System
* MHT; Multi Hydraulic Tester
* CONE; Borehple Geophysics System(McCONE)

Column Section, RQD, Rock Classification, Etc. of Drilling Core

	Weathering		Hardness
1	Very fresh. No weathering of mineral component	5	Very hard. Broken into knifeedged pieces by strong hammer blow.
2	Fresh. Some minerals are weathered slightly. Usually no brown crack	4	Hard. Broken into pieces by strong hammer blow.
3	Fairly fresh. Some minerals are weathered. Cracks sre stained and with weathered material.	3	Brittle. Broken into pieces by medium hammer blow.
4	Weathered. Fresh portions still remain partially	2	Very brittle. Easy broken into pieces by medium hammer blow.
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	1	Soft. Able to dig with hammer.

RC=Core Recovery(%)
RQD=Rock Quality Designation(Core length more than 10 cm)(%)



Symbol

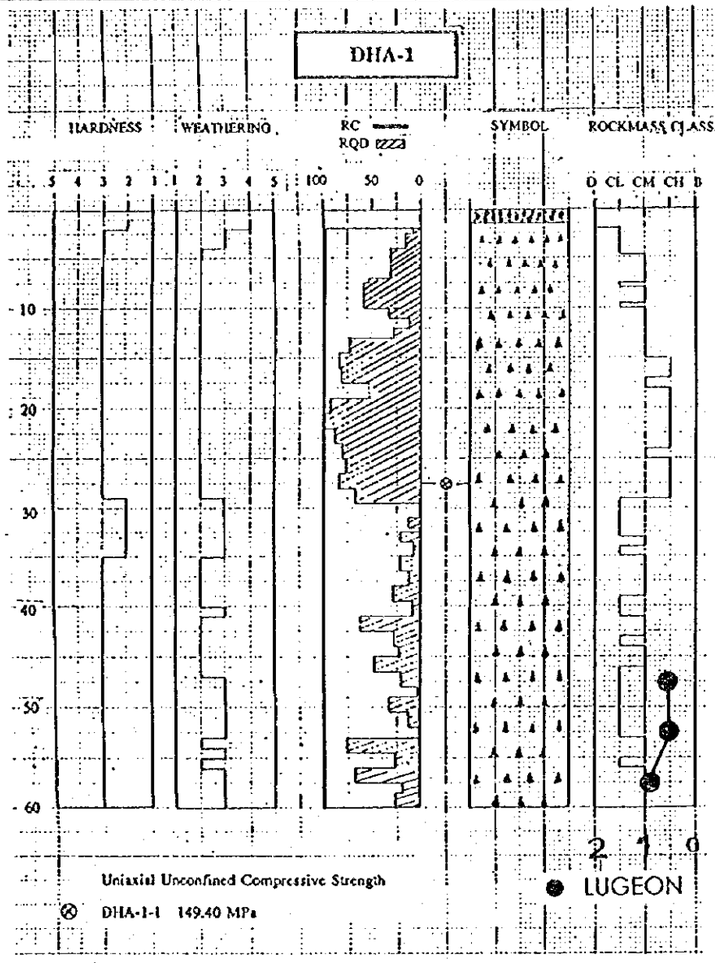
- Clay and gravel
- Clay
- Sand and gravel
- Phyllite and slate
- Fold
- Tuff
- Lapilly tuff
- Shale
- Sandstone
- Limestone
- ⊗ Sample for rock test

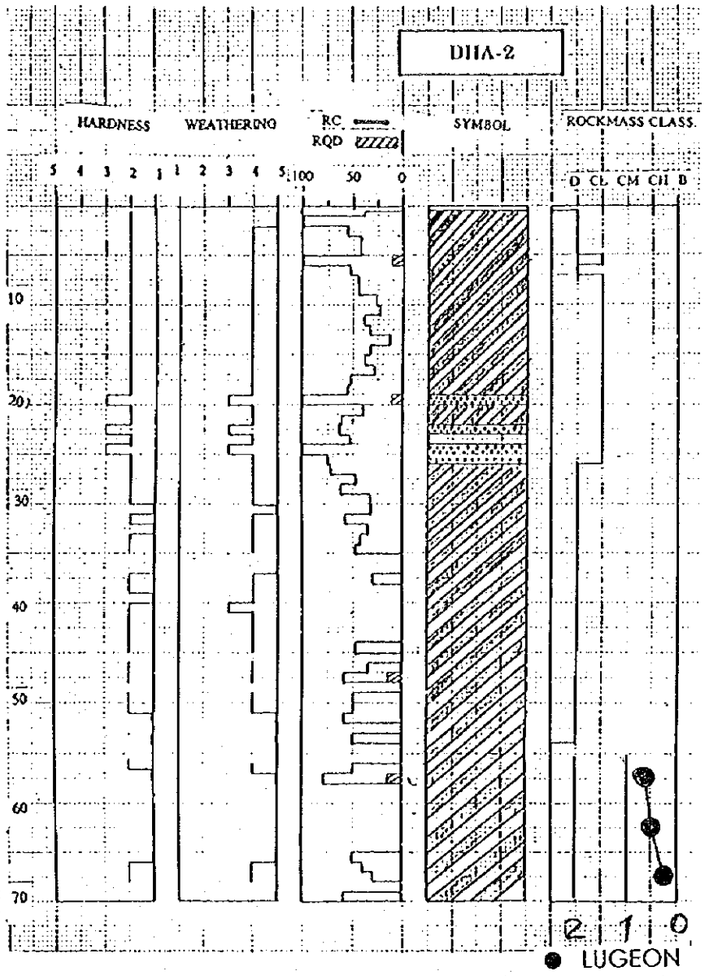
Rock Mass Classification by CRIEPI
(Central Research Institute of Electric Power Industry of Japan)

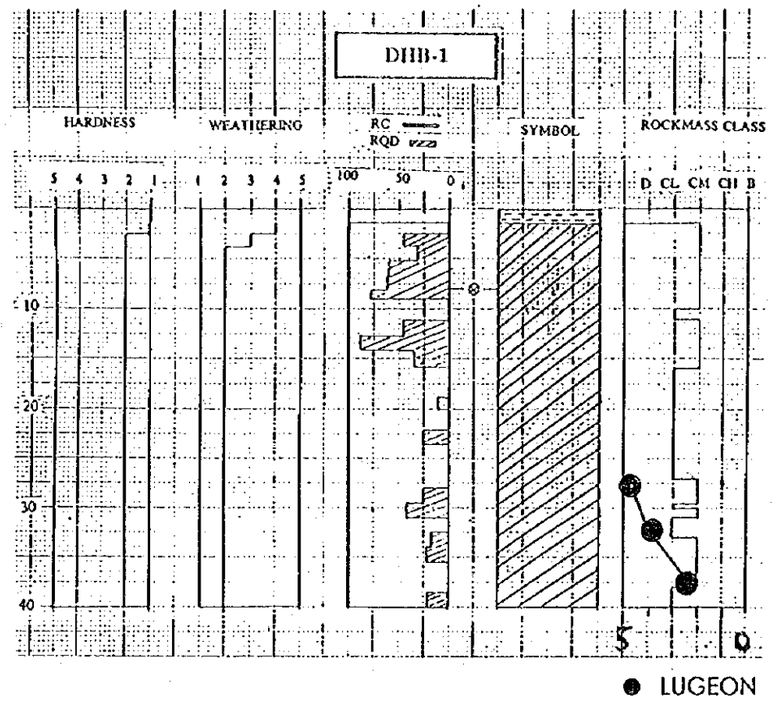
	Description
A	The rock mass is very fresh, and the rock forming minerals and grains undergo neither weathering nor alteration. Joints are extreaely tight and their surfaces have no visible sign of weathering. Sound by hammer blow is clear.
B	The rock mass is solid. There is no opening joint and crack (even of 1 mm). But rock forming minerals and grains undergo a little weathering and alteration in partly. Sound by hammer blow is clear.
C_H	The rock mass is relatively solid. The rock forming minerals and grains undergo weathering except for quartz. The rock is contaminated by limonite, etc. The cohesion of Joints and cracks is slightly decreased and rock blocks are separated by firm hammer blow along joints. Clay minerals remain on the separation surface. Sound by hammer blow is a little dim.
C_M	The rock mass is somewhat soft. The rock forming minerals and grains are somewhat softened by weathering, except for quartz. The cohesion of Joints and cracks is somewhat decreased and rock blocks are separated by ordinary hammer blow along the joints. Clay materials remain on the separation surface. Sound by hammer blow is somewhat dim.
C_L	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 are separated by soft hammer blow along the joints. Clay materials remain on the separation surface. Sound by hammer blow 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. The rock mass collapses by light hammer blow. Clay materials remain on the separation surface. Sound by hammer blow is remarkably dim.

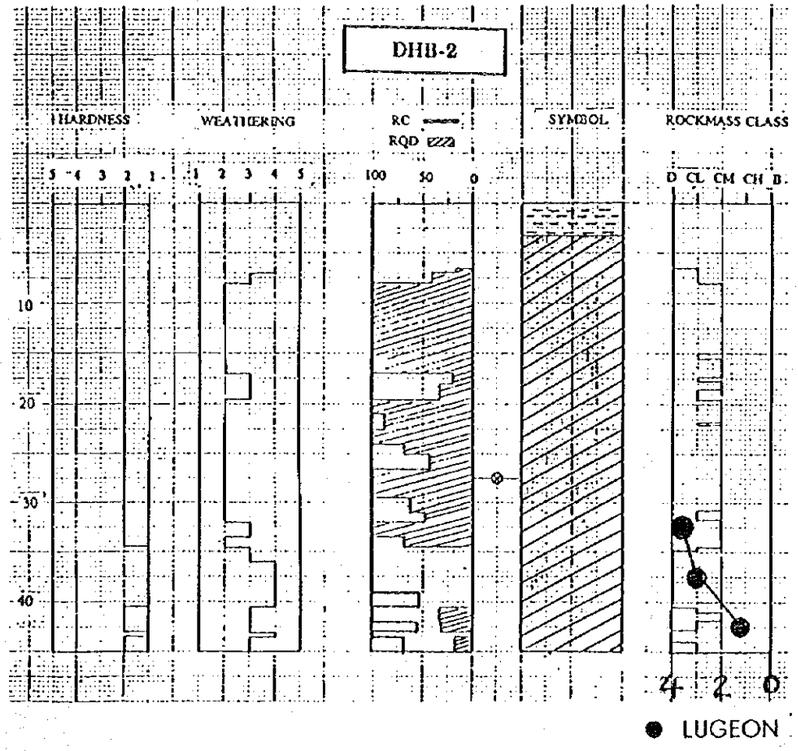
●	LUGEON	Injection quantity of water (Q)(l/min/m) at Injection Pressure (P) =10 kg/cm2

THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
GEOLOGICAL LOGGING FOR DRILLING OF ING-YOT TUNNEL ROUTE (LEGEND)	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) / SANYU CONSULTANTS INC. & NIPPON KOEI CO.,LTD.	Figure G-15

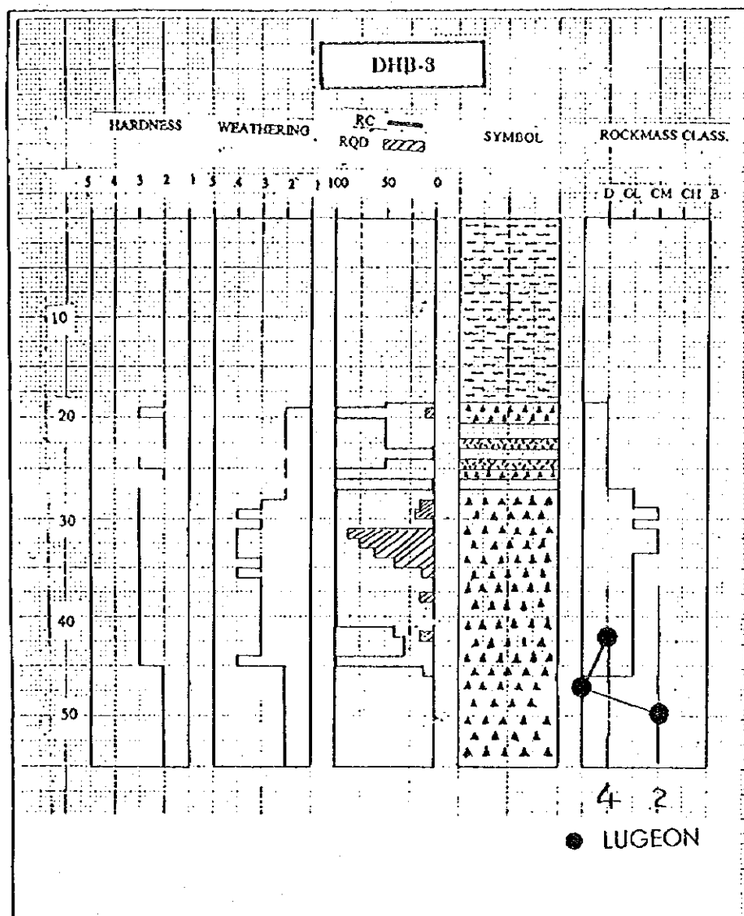


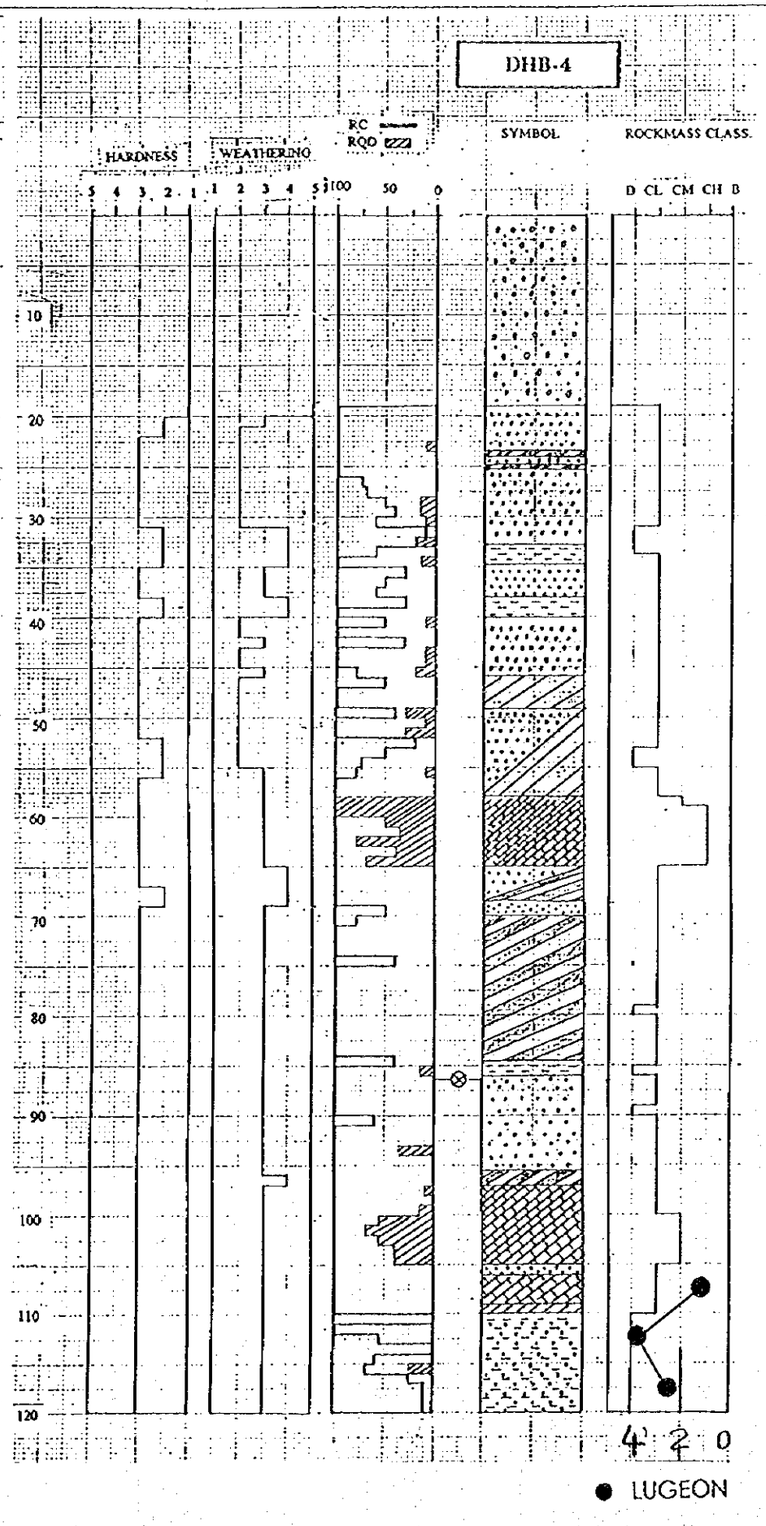


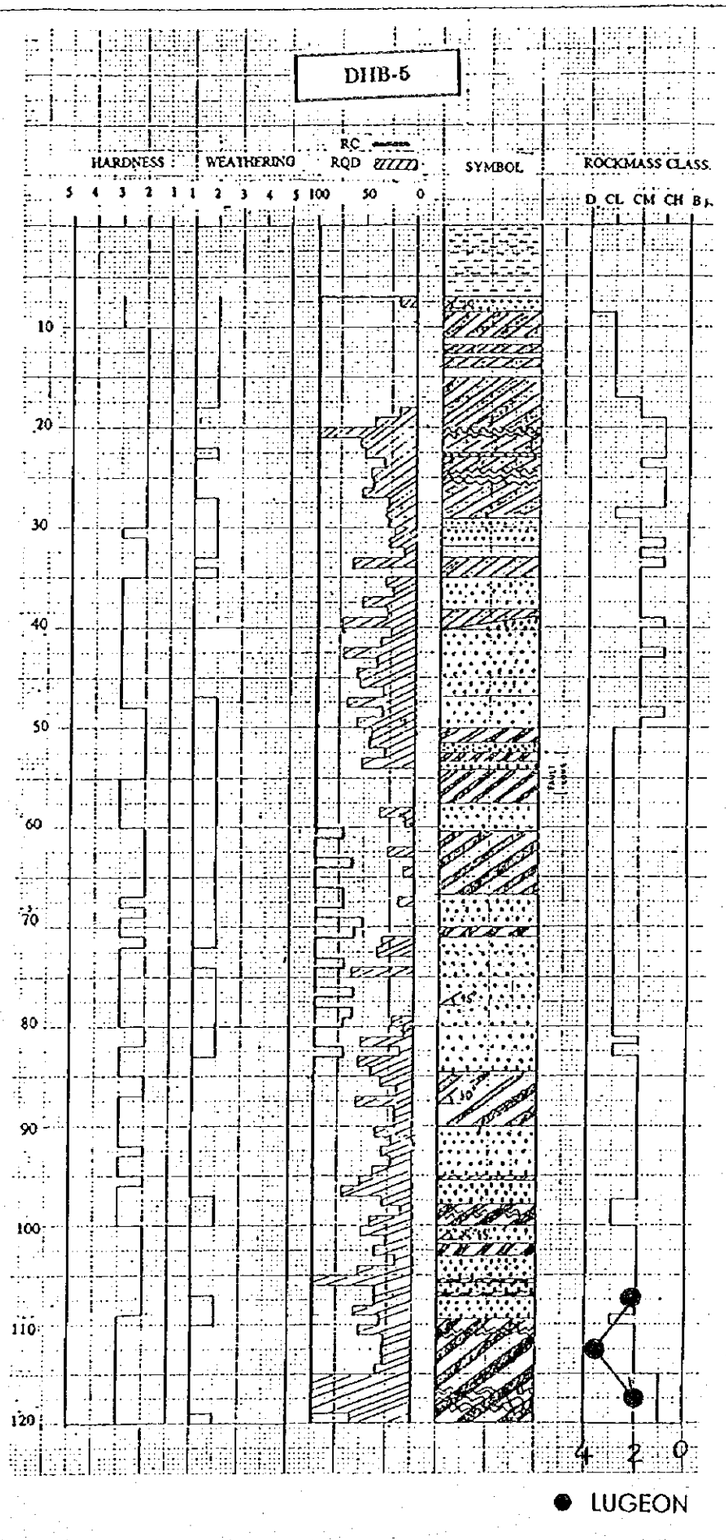




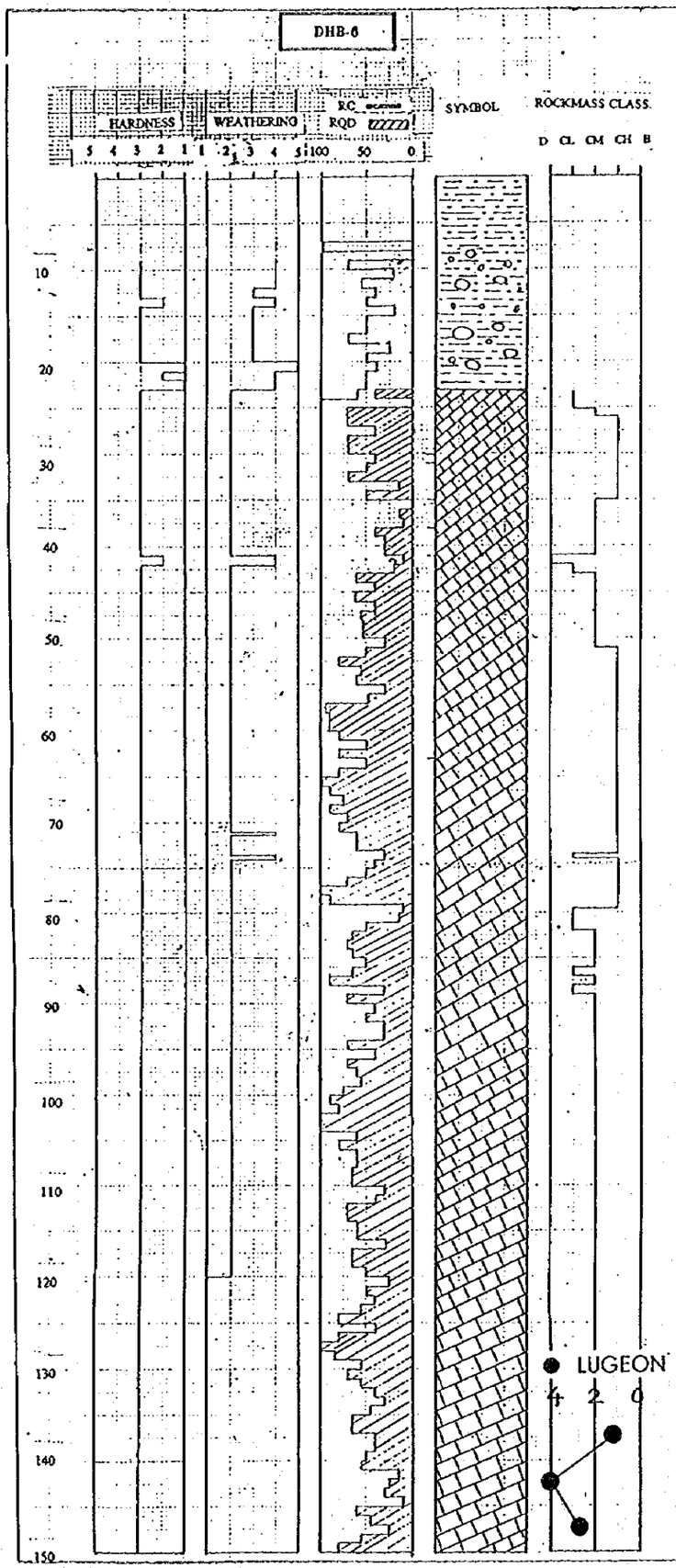
THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
GEOLOGICAL LOGGING FOR DRILLING OF ING-YOT TUNNEL ROUTES (Chart 1)	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	Figure G-16
SANYU CONSULTANTS INC. & NIPPON KOEI CO.,LTD.	

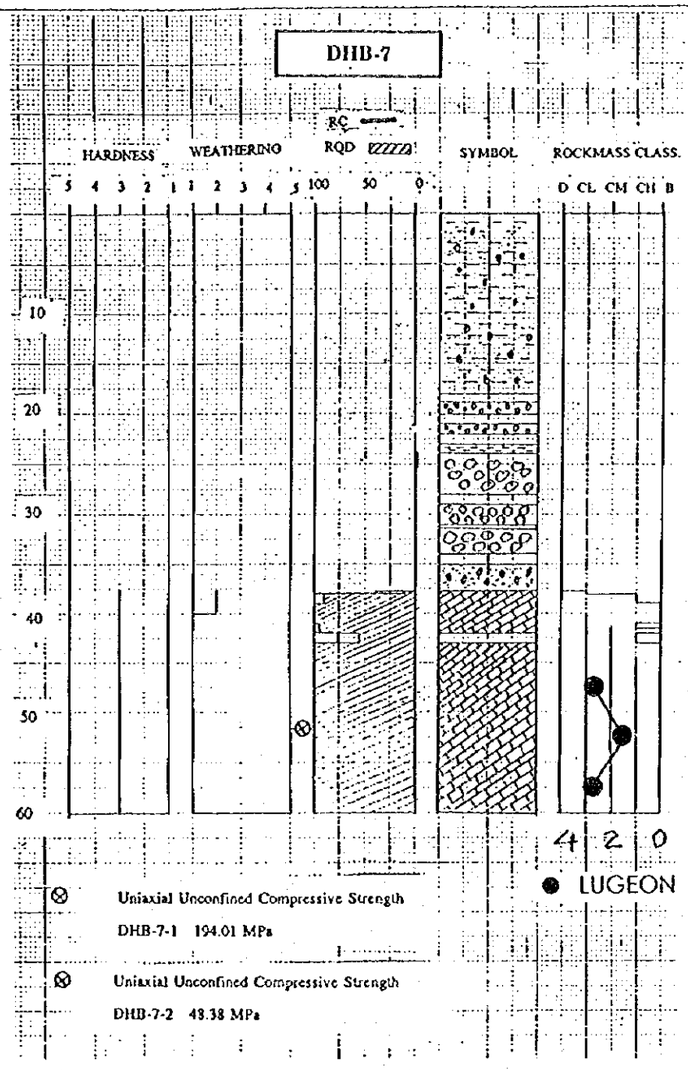


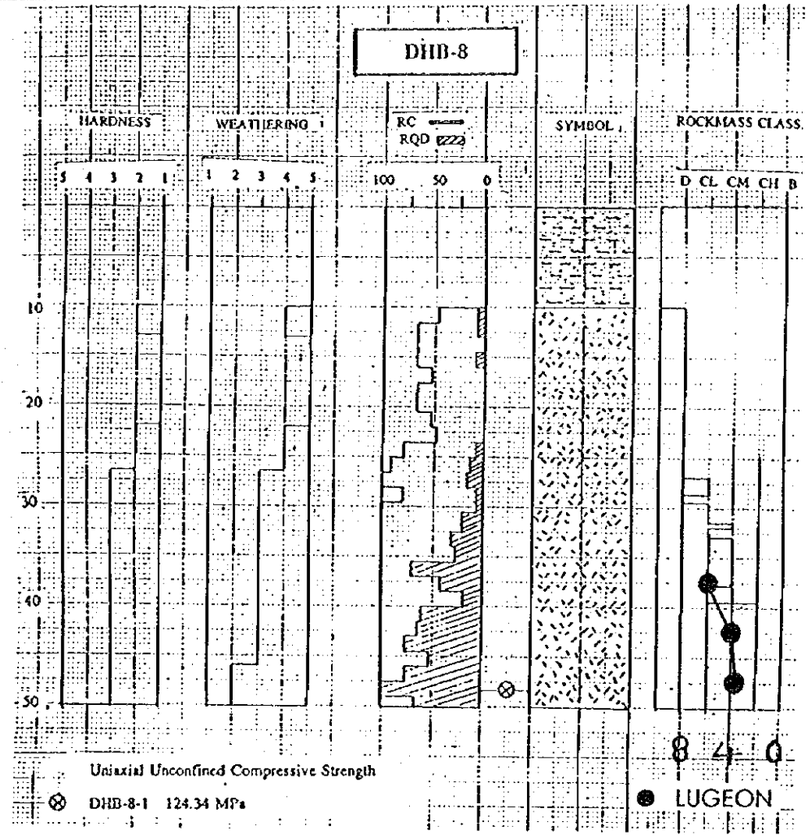




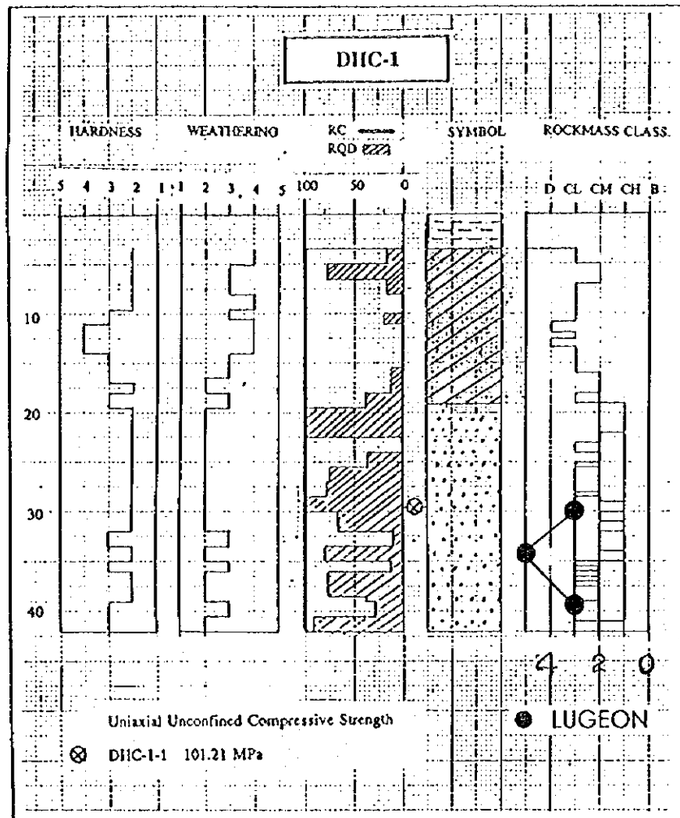
THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
GEOLOGICAL LOGGING FOR DRILLING OF ING-YOT TUNNEL ROUTES (Chart 2)	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	Figure G- 17
SANYU CONSULTANTS INC. & NIPPON KOEI CO.,LTD.	

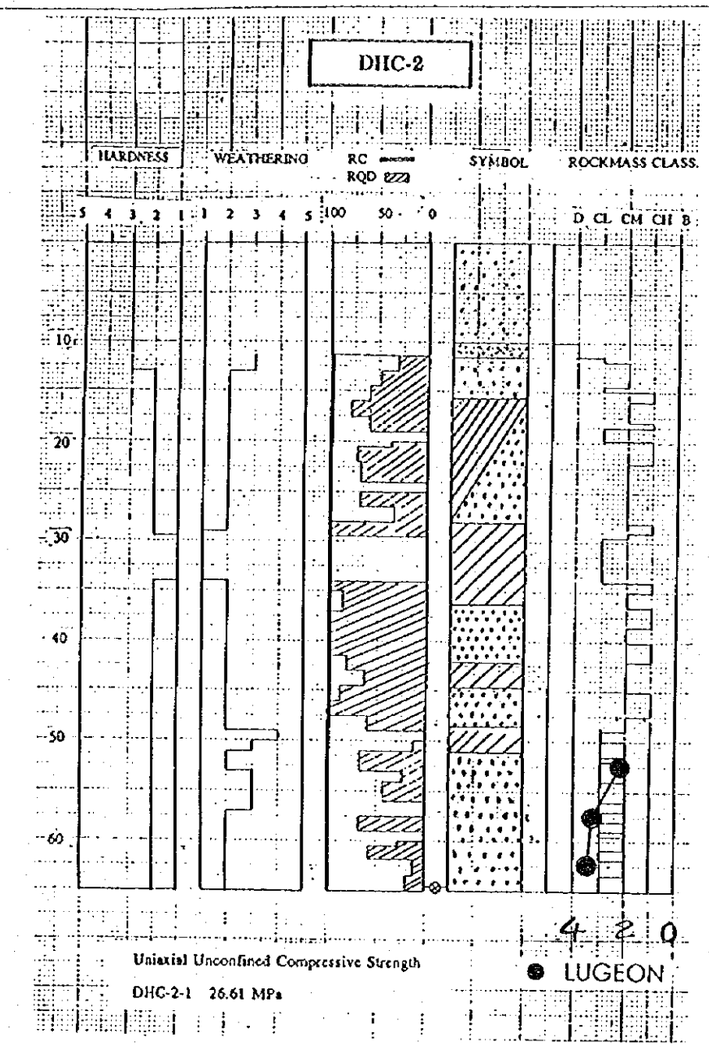






THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
GEOLOGICAL LOGGING FOR DRILLING OF ING-YOT TUNNEL ROUTES (Chart 3)	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	Figure G-18
SANYU CONSULTANTS INC. & NIPPON KOEI CO.,LTD.	





THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
GEOLOGICAL LOGGING FOR DRILLING OF ING-YOT TUNNEL ROUTES (Chart 4)	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) SANYU CONSULTANTS INC. & NIPPON KOEI CO.,LTD.	Figure G- 19

5.3 Kok Diversion Dam

The Kok diversion dam (weir) will regulate water level of the Kok river for the water diversion at the design discharge of 125 m^3/s.

(1) Alternative Study of Diversion Damsite

The Thai side study made the alternative study on Kok diversion dam and set up the following two alternatives.

a) Alternative 1: Existing Chiang Rai Weir

Alternative 1: Existing Chiang Rai Weir was selected in connection with the water diversion rout of alternative "B". The Chiang Rai weir was constructed in 1994 by DEDP for the purposes of irrigation about 78,000 rais, water supply for the Chiang Rai City and water conservation of the Kok river and Korn river, a tributary, for river transportation and tourism. The weir is located on the Kok river at Ban Pa Yang Mon, Amphoe Muang, Chiang Rai Province and it is about 7 km downstream from the Chiang Rai City. The irrigation facilities are under construction at present of November 1996 and the intake facility will be constructed from December 1996 or early 1997.

b) Alternative 2: New Kok Diversion Dam

Alternative 2: New Kok Diversion Dam was selected in connection with the water diversion rout of alternative "A". The new diversion dam is planned at downstream of Ban Farm, Muang District, Chiang Rai Province or about 3 km downstream of the existing Chiang Rai weir.

Principal features of the Alternatives are shown in Table S.5.3.1. The Thai side study recommended the Alternative 1: existing Chiang Rai weir as the Kok diversion dam with the following reason.

(It is desired to select Chiang Rai weir as the diversion dam site because; it was already constructed, and the control water level is high enough for diverting water to a diversion canal. Besides, this can reduce the construction cost of new diversion structures.)

Table 5.3.1 Principal Features of Alternative Diversion Dams

Principal Features	Unit	Alternative 1 Existing Chiang Rai Weir	Alternative 2 New Kok Diversion Dam
Hydrology and Reservoir			
- Catchment area	km^2	6,220	9,330
- Average annual Inflow	MCM	3,645	
- Peak discharge in 100 year return period	m^3/s	890	1,105
- Maximum water level in 100 year return period	m MSL	390.50	386.70
- Backwater level at upstream	m MSL	389.00	386.98
- Control water level	m MSL	389.00	385.00
Length of reservoir		at 389.00 m MSL	at 385.00 m MSL
- Kok river	km	9.1	
- Korn river	km	3.1	
- Surface area of reservoir	km^2	2.77	
- Gross storage	MCM	2.95	
Dam facilities			
- Type of dam		Reinforced concrete dam	Reinforced concrete dam
- Type of gate		Radial gate	Radial gate
- Height of steel gate pane	m	4.0	3.80
- Width of steel gate pane	m	8.0	10.00
- Numbers of steel gate	nos.	11	10
- Cut-off channel bed elevation at upstream and downstream	m MSL	384.75	381.50
- Gate sill elevation	m MSL	385.75	381.50
- Pier top elevation	m MSL	392.00	389.00
Dike			
- Crest level	m MSL	390.50	
- Height	m	0 ~ 3	
- Length	km	10.7	

Source : Thai side study

The JICA Study Team reviewed the Thai side study and prepared the comments as follows:

	Alternative 1 Existing Chiang Rai Weir	Alternative 2 New Kok Diversion Dam
Advantage		
1)	The utilization of the existing weir as the Kok diversion dam does not make additional environmental problem.	The operation would be more simple.
2)	The utilization of the existing weir would save the Project cost.	Water resource of the Kok-Lao river is available.
Disadvantage		
1)	It shall monitor the flood condition in the Chiang Rai city more carefully.	It might make a problem crossing the new irrigation canals.
2)	Joint operation by the both DEDP (mainly in dry season) and RID (wet season) is required.	It might make a problem of land acquisition in the value added paddy field by the new irrigation system.
3)		It might increase the dimension of water diversion facilities due to the lower head between the dam and the Ing diversion dam.

If the above items 1), 2) and 3) in disadvantage of Alternative 2; New Kok Diversion Dam are not serious problem or the cost increase is not so much compared with the total project cost, the new diversion dam might be considerable for the safety of the Chiang Rai city.

The site selection of the Kok diversion dam might not be the major issue to select the optimum route alignment from the technical, environmental and economical point of view. The selection of optimum route will depend on the diversion canal and tunnel alignment since the cost and environmental condition of them will affect to the Project much more. It is recommended to decide the suitable location of the Kok diversion dam based on the optimum route between the Kok river basin and the Nan river basin.

(2) Proposed Intake Water Level at Diversion Site

The Thai side study recommended the control water level at diversion structures in order to define the optimum dimension of head regulator of diversion canal which can operate without any effect on the downstream water requirement. The control water level at diversion structures was recommended as follows:

Control Water Level = 389.00 m. MSL for Alternative 1: Existing Chiang Rai Weir
Control Water Level = 385.00 m. MSL for Alternative 2: New Kok Diversion Dam

The crest length of intake facility will be about 125 m assuming that approach velocity is 0.5 m/s and overflow depth is 2 m in case of the design water diversion discharge at 125 m^3/s.

The rating curve and water level fluctuation in wet season at the Kok diversion damsite are shown in Figures S.5.3.1 to S.5.3.3 respectively. Design intake water level of the Kok diversion dam shall be determined taking into consideration the maintenance flow to the downstream of Kok river, stable water diversion and safety of the Chiang Rai city against floods. Judging from the rating curve and water level fluctuation, the design discharge of 125 m^3/s could be diverted within some drawdown. It is recommended to study the possibility of the intake water level as follows:

Alternative 1: Existing Chiang Rai Weir	Normal High WL = 389.00 m MSL
	Low WL = 388.00 m MSL
Alternative 2: New Kok Diversion Dam	Normal High WL = 385.00 m MSL
	Low WL = 384.50 m MSL

Conceptual layout of the diversion dam is shown in Figures S.5.3.4 and S.5.3.5.

(3) Particular Attention for Water Operation and Flood Releasing

The Thai side study made the preliminary hydrological analysis. Probable flood at the alternative diversion site on the Kok river was estimated as follows:

Probable Flood and Water Level at Kok Diversion Dam

Return Periods (yrs)	Alternative 1 Existing Chiang Rai Weir		Alternative 2 New Kok Diversion Dam	
	Flow (m^3/s)	WL (m MSL)	Flow (m^3/s)	WL (m MSL)
2	486.85	389.25	638.86	385.55
5	595.50	389.52	761.54	385.90
10	673.05	389.92	852.15	386.10
20	741.74	390.10	932.11	386.25
50	828.41	390.35	1,033.25	386.50
100	890.20	390.50	1,105.26	386.70
500	1,043.82	390.75	1,286.32	387.05
1,000	1,109.86	390.85	1,364.29	387.15
10,000	1,330.30	391.25	1,625.09	387.65

Source : Thai side study

As the results of hydrological analysis are used as basic data for the water resources study and for the design of diversion structures, it is recommended to study the hydrological analysis more carefully. The JICA Study Team regard the preliminary hydrological analysis unreliable.

The Thai side study estimated the peak discharge in 100 year return period at the alternative diversion damsites as follows.

Alternative 1: Existing Chiang Rai Weir (catchment area = 6,220 km^2)

Peak discharge in 100 year return period = 890 m^3/s (q = 0.14 $m^3/s/km^2$)

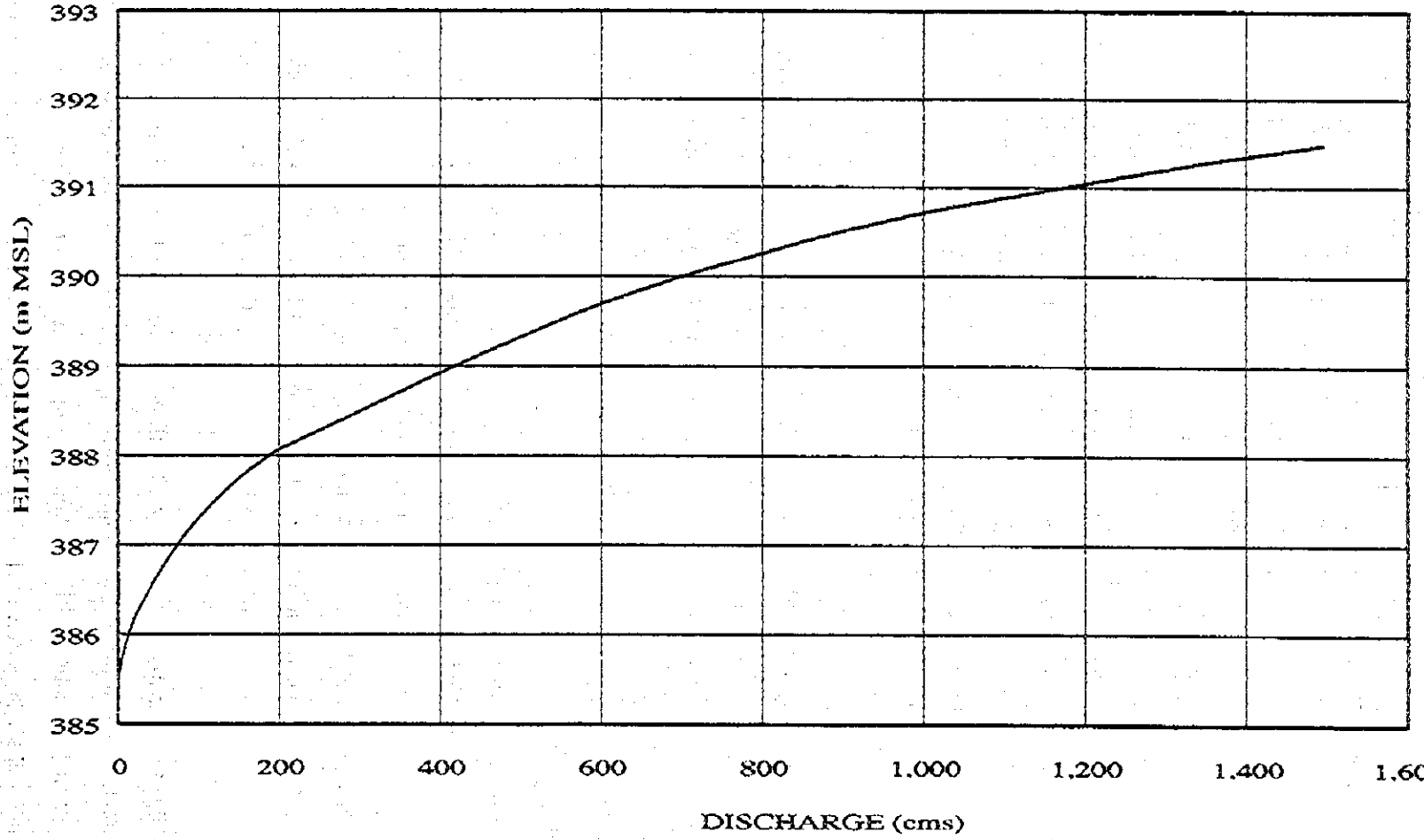
Maximum WL in 100 year return period = 390.5 m MSL

Alternative 2: New Kok Diversion Dam (catchment area = 9,330 km^2)

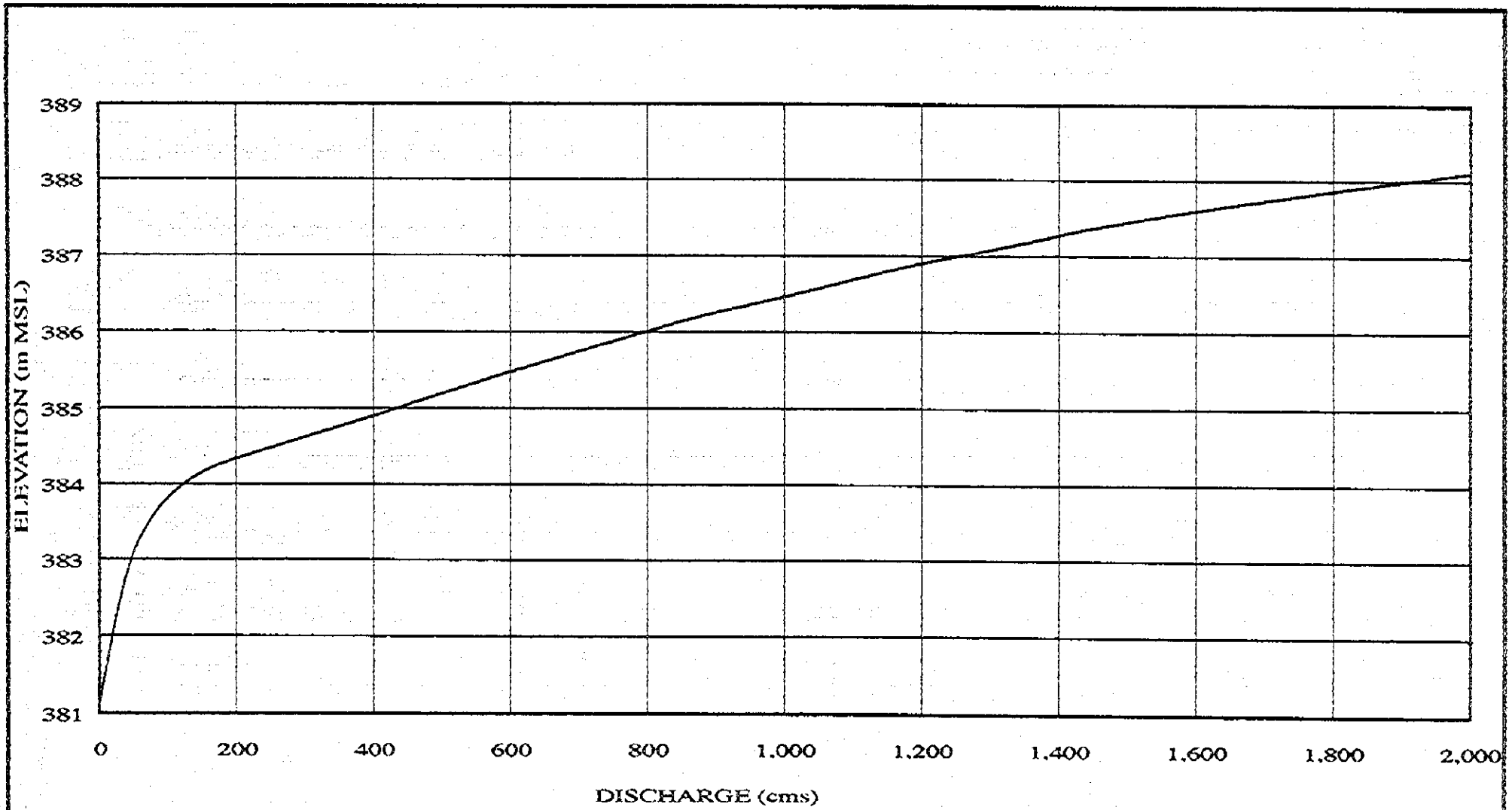
Flood discharge in 100 year return period = 1,100 m^3/s (q = 0.12 $m^3/s/km^2$)

Maximum WL in 100 year return period = 386.7 m MSL

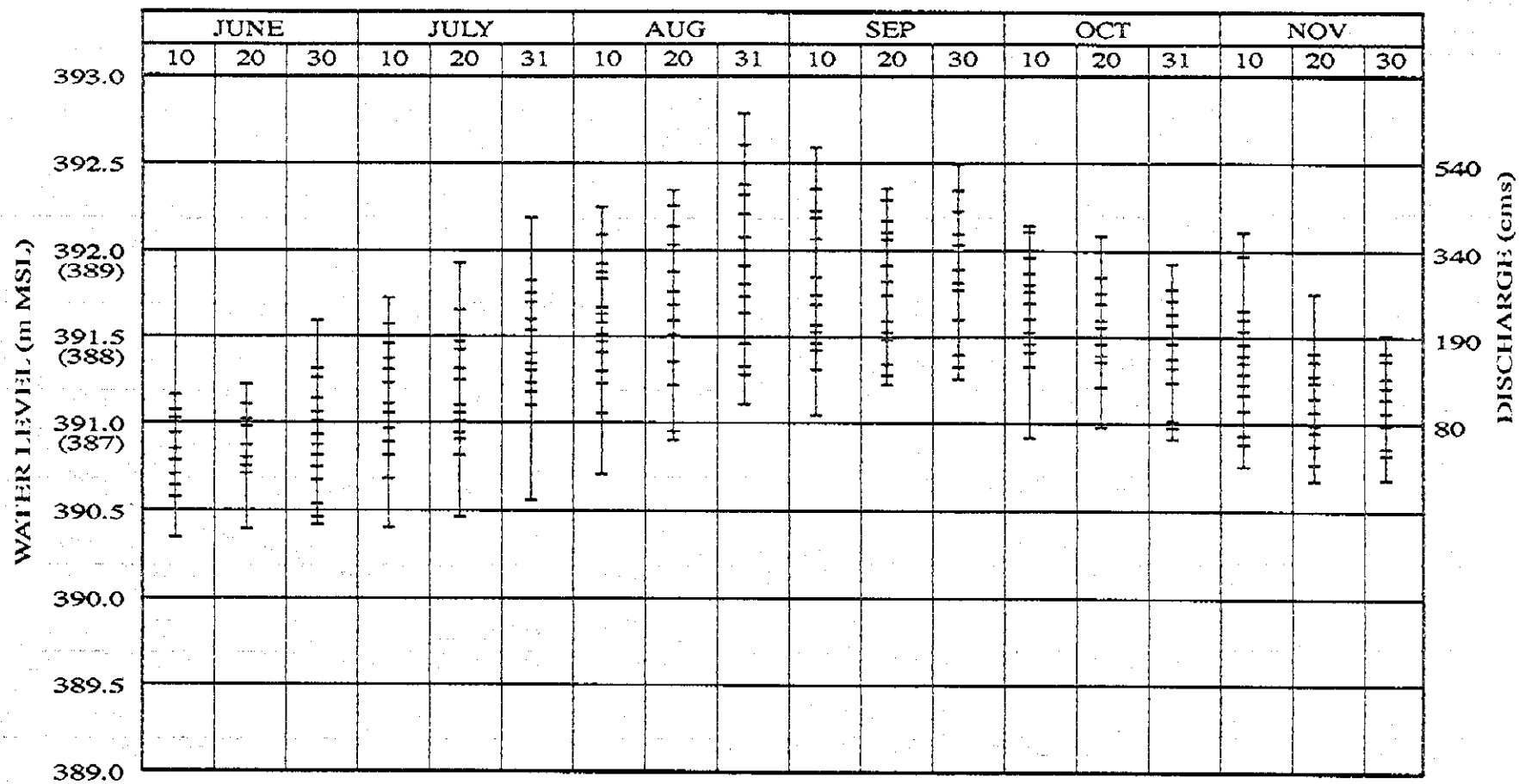
According to the map on a scale of 1/10,000, the elevation of low land area in the Chiang Rai city is about 390.8 m MSL. The Chiang Rai city may be safe against flood from the Kok river. However, it is recommended to establish an operation rule for reliable regulation of the diversion water and for the safety of the Chiang Rai city against flood due to the mistake of gate operation.



THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
Rating Curve at Kok Diversion Damsite (Alternative 1: Existing Chiang Rai Weir)	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
SANYU CONSULTANTS INC. & NIPPON KOEI CO., LTD.	



THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
Rating Curve at Kok Diversion Damsite (Alternative 2: New Kok Diversion Dam)	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
SANYU CONSULTANTS INC. & NIPPON KOEI CO., LTD.	



NOTE: (389) is assumed El. at existing Chiang Rai weir.

THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
Water Level Fluctuation of Kok River at Chiang Rai Gauging Station	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
SANYU CONSULTANTS INC. & NIPPON KOEI CO., LTD.	

5.5 Ing Diversion Dam

The Ing diversion dam will regulate water level of the Ing river for the water diversion to the Nan river basin at the design discharge of 175 m^3/s which consists of diversion water at 125 m^3/s from the Kok river and at 50 m^3/s from the Ing river.

(1) Proposed Damsite

The Thai side study set up the following two damsites in accordance with the alternative diversion route alignment.

a) Lower Site

The lower site plan was prepared for the alternative Ing-Yot diversion alignment "A" and "B". The lower site of Ing diversion weir is located on the Ing river at the foot of Mon Kong Khao hill about 2.8 km upstream of the Thoeng bridge. This site is selected to avoid the rise of flood water level at Thoeng District due to the weir construction.

The design of diversion dam with radial gates is not applicable since the pin bearing elevation 364.00 m MSL will be lower than 367.6 m MSL which is the maximum water level in 100 year probable flood. A rubber weir on a reinforced concrete floor was recommended by the Thai side study.

b) Upper Site

The upper site plan was prepared for the alternative Ing-Yot diversion alignment "C". The upper weir site is located on the Ing river about 3.5 km southwest of Ban Huai Luang. Bank elevation at the weir site is at 366.00 m MSL while low water control level upstream of the weir is at 365.50 m MSL. This weir will also be of rubber type. Since hydrological data at the weir site is still unavailable at present, the weir size will be the same as the lower site.

The alternative Ing-Yot diversion alignment "C" was not recommended by the both Thai side and JICA Study Team, since the Ing-Yot tunnel work might be more dangerous and costly due to the poor geological condition. The lower site is recommended for the time being as the Ing diversion damsite from the technical, environmental and economical point of view.

(2) Regulating Capacity and Design Water Level

The lower site is located on the flood plain and its catchment area is 2,210 km^2. The upstream of the lower site spreads as swamp and paddy field. The diversion water of 125 m^3/s from the Kok river will flow into the Ing river and increase water level at the damsite above 364 m MSL. The rating curve and water level fluctuation in wet season at the Thoeng bridge, about 2.8 km downstream of the diversion damsite, are shown in Figure S.5.5.1.

It is predicted that cultivation lands on this elevation will be inundated continuously in wet season especially from August to October due to the diversion water of 125 m^3/s from the Kok river. In addition, it is required to stop and store the diversion water volume from the Kok-Ing diversion canal (about 3 MCM) in accordance with flood condition in the Nan basin.

The maximum discharge of 784 m^3/s (q = 0.226 m^3/s/km^2), which was equivalent to 100 year probable flood, was recorded at the Thoeng bridge in September 1980 for the recent 20 years. The recent flood in 1995 marked at 367.45 m MSL, 700 m^3/s, which was equivalent to 50 year probable flood. Probable flood at the Thoeng bridge on the Ing river was estimated as follows:

Probable Flood and Water Level at Thoeng Bridge

Return Periods (yrs)	Flow (m^3/s)	WL (m MSL)
2	293.65	365.60
5	413.07	366.60
10	509.50	367.10
20	579.73	367.25
50	700.47	367.50
100	779.89	367.60
500	963.13	367.80
1,000	1,046.46	368.00
10,000	1,311.69	368.20

Source : Thai side study

The extraordinary floods exceeding 50 year and 100 year probable flood occurred for 20 years. The preliminary hydrological analysis by Thai side is questionable. Since the results of hydrological analysis are used as basic data for the design of diversion facilities, it is recommended to study the hydrological analysis more carefully.

The JICA Study Team recommend a flood retention/regulating pond with the Ing diversion dam, taking into consideration that the site area is frequently flooded and that the diversion water of 125 m^3/s will increase water level of the Ing river in wet season. The flood retention/regulating pond has the following functions.

- to store the diversion water volume from the Kok river,
- to regulate the water level fluctuation for the stable water diversion to the Nan river basin and
- to protect paddy field from the ordinary floods.

The regulating pond will be provided by the embankment of polder dike along the boundary of swamp. High water level of the regulating pond will be set at 365 m MSL and low water level at 363.5 m MSL. The storage volume is estimated at 6 MCM at HWL 365 m.

It is also recommended to construct a flood diversion canal from the Lao river into the flood retention/regulating pond for the following purposes.

- to protect downstream of the Lao river from floods and
- to utilize flood excess water for the water diversion to the Nan river basin.

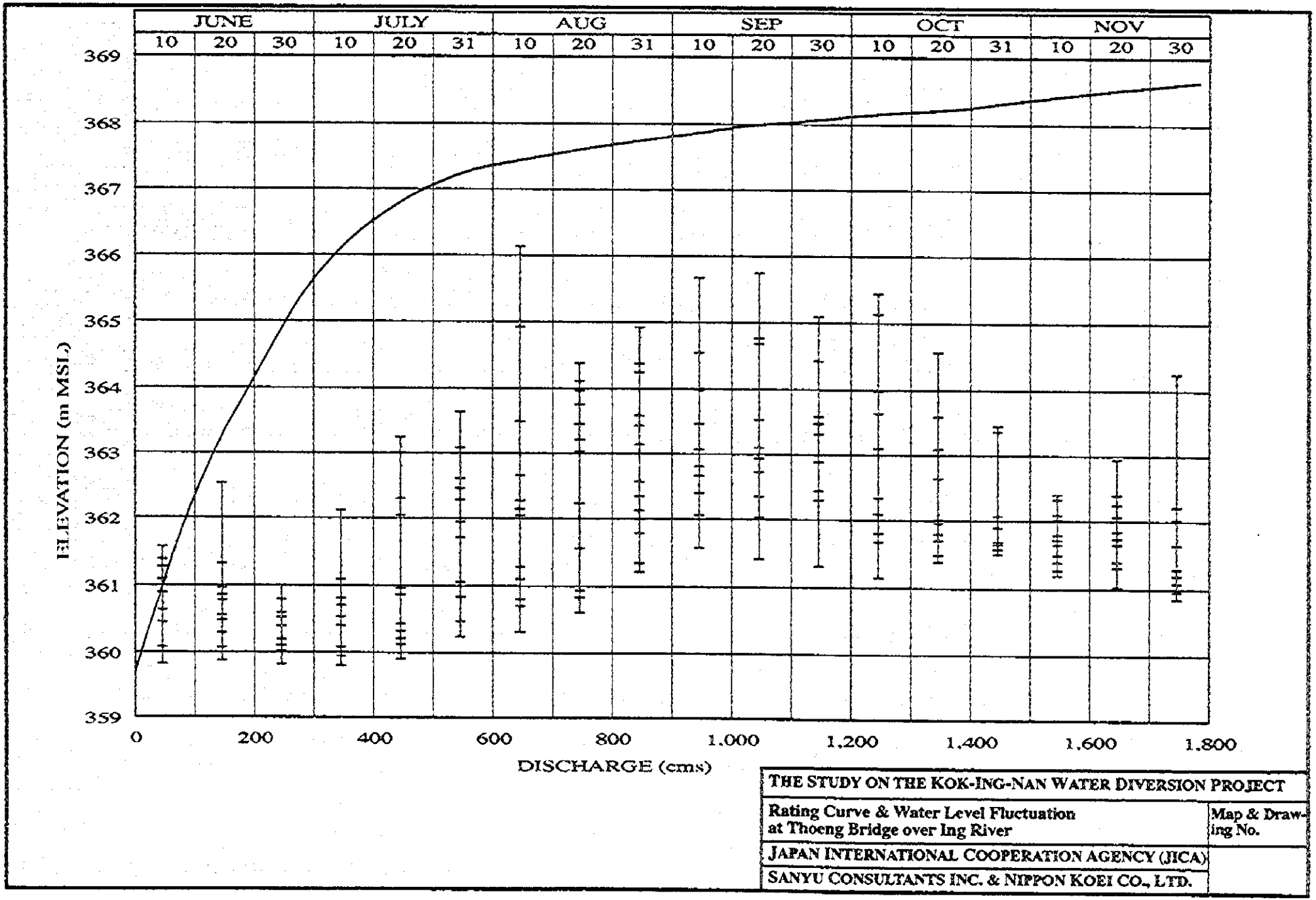
(3) Layout of Diversion Dam Structure

The Ing diversion dam is recommended as combined type dam which is composed of reinforced concrete dam with regulating gates and rubber dam. The regulating gates are recommended for the regulation of water level. The intake high water level will be set at 365 m MSL and low water level at 363.5 m MSL.

Conceptual layout of the diversion dam, polder dike and Lao river flood diversion canal is shown in Figure S.5.5.2. Principal features of the conceptual plan of the weir is shown in Table S.5.5.1.

Table 5.5.1 Principal Features of Ing Diversion Dam

Principal Features	Unit	Recommended by Thai Side Study	Recommended by JICA Study Team
Regulating Pond		none	
- High water level	m MSL		365
- Low water level	m MSL		363.5
- Reservoir surface area	km^2		5
- Gross storage	MCM		6
Dam facilities			
- Type of dam		Rubber dam	Reinforced concrete dam and rubber dam
- Type of gate		none	Radial gate
- Height of gate (weir)	m		7
- Width of gate (crest length)	m		10
- Numbers of gate	nos.		1
- River bed elevation at upstream and downstream	m MSL	approximately 358	approximately 359
- Weir sill elevation	m MSL	359.00	359.0
- Weir crest elevation	m MSL	363.50	363.5 (concrete dam) 365.0 (rubber dam)
- Control water level	m MSL	363.50	HWL 365.0 LWL 363.5
- Maximum water level before the rubber weir deflated	m MSL	364.40	
Intake/Dike			
- Peak discharge in 100 year return period	m^3/s	780	780
- Maximum water level in 100 year return period	m MSL	367.6	367.6
- Crest level	m MSL	369.13	368.6
- Original bank elevation	m MSL	364	364
- Length	km		7



THE STUDY ON THE KOK-ING-NAN WATER DIVERSION PROJECT	
Rating Curve & Water Level Fluctuation at Thoeng Bridge over Ing River	Map & Drawing No.
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
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