4. FOUNDATION ENGINEERING AND MATERIALS

4.1 Foundation Engineering

As shown in Table 2, the soil is for the most part sandy up to the depth of 3 m and falls under the classification of "SM". The soil in the zone deeper than 3 m is classified in appearance in sand, clayey sand or sandy clay.

Results of sounding of those zones are as follows:

Geological zoning	Soil classification	N-value of SPT	Resistance to penetration qc kg/cm^2
Completely weathered granite	Sand, clayey sand	Not more than 15	5 to 15 for majority. 36 in maximum.
Highly weathered granite	Sand, clayey sand, sandy clay	15 to 80	Not penetrable
Slightly weathered granite	Rock fragments, sand with clay	Not less than 80	Not penetrable

Table 3 shows the depthwise variation of N-value and the geological zoning, together with ground heights of the drilling spots. It is seen in this table that the highly weathered zone tends to be thicker in the places of higher elevation.

Foundation engineering problems involved in this scheme are as follows:

(1) Pipeline

As weight of the pipeline buried under the ground surface is less than the replaced soil, uplift of the structure should be taken into consideration for design, while no serious problem is envisaged for the bearing strength so far as there are no sharp variations of mechanical characteristics in the foundation bed. As revealed by the sub-surface exploration, a fairly homogeneous condition can be expected for the completely weathered and highly weathered granite zones, where the pipeline will be laid. Therefore, the foundation has only to be compacted sufficiently and homogeneously.

Careful compaction will be required for backfill after installation of the pipeline. Special care should be taken for difficult operation of homogeneous compaction under lower periphery of the pipe.

An approximate value of deformation modulus for backfilled soil is estimated by the following equation according to Terzaghi (1995).

For sandy soil $E_s = k_s \cdot h$

For cohesive soil $E_s = k_c$

where, Es ; Deformation modulus of soil (kg/cm^2)

h ; Thickness of overburden (cm)

k_s, k_c; Coefficient of horizontal subgrade reaction (kg/cm^2), of which values are as listed below.

Sandy soil		Cohesive soil	
Condition	k_s (kg/cm^2)	Condition	k_c (kg/cm^2)
Loose	0.04 - 0.11	Stiff	35 - 70
Medium	0.11 - 0.33	Very stiff	70 - 140
Dense	0.33 -	Hard	140 -

Considering that the foundation bed of the pipeline is dominantly sandy and the overburden is about 2 m thick, and assuming a mean value of medium condition for k_s of the sandy soil, the deformation modulus of the pipeline foundation is estimated as follows:

$$E_s = \frac{0.11 + 0.33}{2} \times 200 = 44 \ (kg/cm^2)$$

As deformation modulus varies depending on the condition of compaction, it is most important to realize the homogeneous compaction.

Unit weight of the backfill soil for preliminary design was determined with reference to compaction test data for a Dok Krai - Map Ta Phut Water Pipeline Project, that is:

Optimum moisture content	11.1 - 20.7 %
Dry density	1.63 - 1.97 t/m^3

From the test data of Nong Kho - Laem Chabang Water Pipeline Project, that indicate 7 to 25 % for natual moisture content and 2.5 to 2.8 for specific gravity, the following values are assumed.

Moisture content	15 %
Dry density	1.6 t/m^3 under 85 % in degree of compaction
Specific gravity	2.65

From the above values the unit weight is estimated approximately at 1.8 t/m^3. It would be about 2.0 t/m^3 when saturated. These values of unit weight are proposed for the design.

(2) Other structures

The highly weathered granite zone with considerably high bearing capacity is encountered within a small depth from the ground surface. Neither serious problem of settlement is envisaged because there is no soft clayey layer which might effect consolidation under load of the structures.

The structures for intake, river and railway crossings and receiving well will be able to found on the highly weathered granite zone directly with footings. Pile or open caisson would be necessitated only exceptionally in case that the structure is very heavy or the supporting bed is extraordinarily deep.

(3) Groundwater

Groundwater table observed in the field invetigation at the end of wet season is generally high, located at the depths within 3 m from the ground surface. (See Fig. 3) It is even as high as less than 50 cm in depth in some places in low terrain and in the vicinity of rivers. However, it is alleged by local people that a considerable drawdown of groundwater takes place in dry season.

(4) Corrosion of pipe

As shown in Table 2, the value of PH of the soil falls under the range of weak acidity from 5 to 6 for the most part and 4.5 in the minimum. Acidic corrosion of steel is strong when PH is less than 4.0, and the measured value is barely out of the limit for that.

So far as the PH is concerned, effect of corrosion seems to be not intensive.

4.2 Materials

As seen in Fig. 5, the results of test on samples of the coastal sand in Rayong indicate that grading of the sand is deviated to finer side from the standard, lacking coarse particles. Concrete made of this sort of fine aggregate would be likely to generate cracks. Artificial adjustment of grain size distribution will be required if this sand is utilized. Sodium chloride (NaCl) content shows only 66 ppm in the maximum, that can satisfy the condition of not exceeding 0.1 % of absolute dry weight of sand as prescribed in the standard specification. (See Table 2)

5. CONCLUSION

Bedrock is granite for almost all the route of the pipeline. Depth of the pipeline embedding is within 3 m, where the granite is weathered into sand, sandy clay and clayey sand. These soils are observed to be good for embankment or backfill material, though it was not confirmed by compaction test.

It is deemed that the highly weathered granite zone encountered at about 3 m of depth provides a competent sub-base for the structures, upon which the structures can be placed directly except for a very rarely possible case requiring pile or caisson foundation because of insufficient bearing capacity within a reasonable depth from the ground surface.

Excavation for embedding the pipeline will be rather easy in dry season when the groundwater table is low. However, in the areas of low altitude where the groundwater can be within the depth of 3 m even in dry season, works for de-watering and drainage would be required for the excavation. Wet season with high groundwater table is not favourable for the excavation and the pipe installation.

Sand from Rayong would require the artificial control of grading by adding coarser material. Sodium chloride content is satisfactorily low for fine aggregate of concrete.

6. FUTURE INVESTIGATION

Further detailed investigations will be required for the detailed design of the Project in the future, which are advised as follows:

- Core drilling with standard penetration tests at the exact locations of all important project structures.

- Observation of groundwater table through wet and dry seasons at several representative locations, by the use of existing wells and boreholes which are deeper than the planned level for foundation of the structures and lined or cased with sufficiently porous material.

- Detailed soil mechanical tests for the following items.

  In-situ density and moisture content,

  Specific gravity, gradation, Atterberg's limits and compaction.

- In-situ corrosion test at three spots.

- Reserach of concrete aggregate source and laboratory test

  Granite could be the nearest source of coarse aggregate, if it is not deeply weathered.

  Coastal sand deposit deserves the further investigation for fine aggregate, though the Rayong sand turned out to be inferior in quality.

TABLES

Table 1 LIST OF SUBSURFACE EXPLORATION

Drill Hole No.	Elevation (m)	Depth (m)	Groundwater Level in Depth (m)	Location
B.1	58.30	12.45	1.60 - 2.00	0k + 155m, Intake
2	53.39	10.65	1.38 - 1.50	2k + 849m
3	44.11	9.25	1.30	4k + 515m
4	38.59	7.90	0.05	6k + 352m
5	24.75	7.60	0.60 - 1.20	8k + 064m
6	20.53	4.80	0.44	10k + 245m
7	15.01	7.95	0.00	0k + 097m, Huai Lek River
8	31.27	3.30	2.55	0k + 643m, Rail way
9	26(by map)	10.80	3.20	Receiving well
10	46.48	9.15	-	Receiving well
Total		83.85		10 locations

Auger No.	Elevation (m)	Depth (m)	Groundwater Level in Depth (m)	Location
A.1	55.65	3.00	1.90	1k + 056m
2	55.91	3.00	1.50	3k + 482m
3	39.71	3.00	0.45	6k + 450m
4	21.02	1.30	0.20	8k + 400m
5	21.31	1.90	0.35	9k + 798m
6	19.40	2.30	0.50	11k + 220m
7	17.07	1.50	0.25	13k + 216m
8	32.08	1.30	0.30	1k + 398m
Total		17.30		8 locations

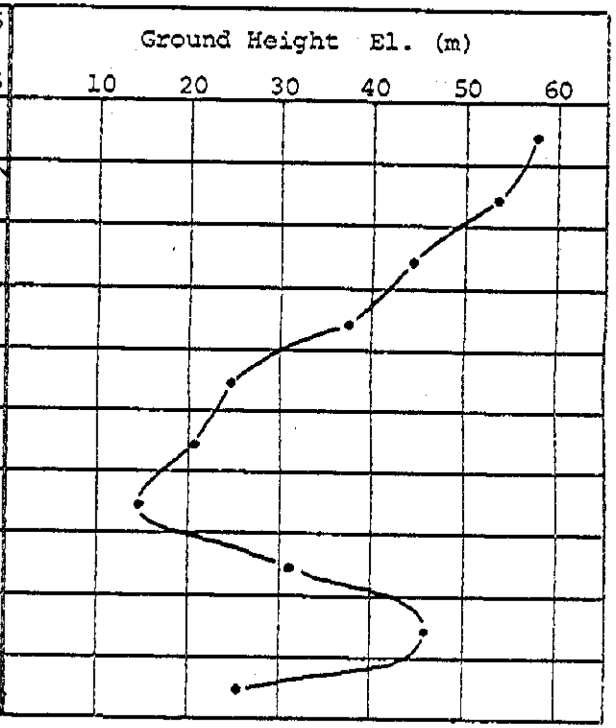
Test Pit No.	Elevation	Depth (m)	Groundwater Level in Depth (m)	Location
T.1	58.30	2.30	2.20	0k + 155m, Intake
2	56.12	3.00	2.75	1k + 851m
3	52.78	1.00	0.45	3k + 932m
4	41.34	3.00	0.50	5k + 450m
5	39.64	2.00	1.40	7k + 170m
6	21.27	1.50	0.40	9k + 452m
7	20.68	2.00	0.90	10k + 807m
8	16.46	2.00	1.65	13k + 598m
9	28.68	1.00	0.55	1k + 035m
10	46.48	3.00	-	Receiving well
11	41.98	3.00	0.75	4k + 340m
12	39.81	2.00	0.70	7k + 717m
13	33.15	3.00	2.65	9k + 400m
14	19.04	2.00	1.40	12k + 505m
Total		30.80		14 locations

Table 2 SUMMARY OF SOIL TEST

Pit/ Borehole No.	Location	Depth (m ∿ m)	Classification by Observation	Gradation Percent Passing % (40) 420μ	(200) 74μ	Classification by Soil Test	Moisture Content %	Specific Gravity	PH	NaCl p.p.m.
T.1	0k + 155m	0.50 ∿ 0.75	Sand	97.84	30.62	SM	9.48	2.66	5.05	
"	"	1.25 ∿ 1.50	Sand						4.70	
T.2	1k + 851m	0.25 ∿ 0.50	Clayey sand						6.40	
"	"	1.75 ∿ 2.00	Sand	95.00	18.97	SM	11.02	2.69	5.65	
"	"	2.50 ∿ 2.75	Sand						5.80	
T.3	3k + 932m	0.25 ∿ 0.50	Sand	100.00	13.46	SM	13.27	2.64	4.50	
T.4	5k + 450m	0.50 ∿ 0.75	Sand						5.85	
"	"	2.75 ∿ 3.00	Sand	85.29	18.47	SM	12.29	2.50	4.70	
T.5	7k + 170m	0.50 ∿ 0.75	Sand						5.50	
"	"	1.50 ∿ 1.75	Sand	100.00	12.42	SM	10.05	2.57	5.15	
T.6	9k + 452m	0.25 ∿ 0.50	Sand						4.95	
"	"	1.00 ∿ 1.25	Sand	100.00	15.81	SM	12.77	2.69	5.45	
T.7	10k + 807m	0.60 ∿ 0.75	Sand						5.90	
"	"	1.50 ∿ 1.75	Sand	100.00	9.59	SM-SW	12.15	2.62	5.35	
T.8	11k + 598m (South)	0.25 ∿ 0.50	Clayey sand						6.05	
"	"	1.50 ∿ 1.75	Sandy clay	100.00	46.98	SM	14.33	2.70	5.65	
T.9	1k + 035m	0.50 ∿ 0.75	Sand						6.05	
T.10		0.75 ∿ 1.00	Sand	100.00	8.90	SM-SP	17.06	2.55	5.45	
"		2.25 ∿ 2.50	Sand	96.56	20.75	SM	7.47	2.57	5.20	
"		2.75 ∿ 3.00	Sand						5.50	
T.11	4k + 340m (South)	0.25 ∿ 0.50	Sand						6.05	
"	"	1.25 ∿ 1.50	Sand						5.30	
"	"	2.50 ∿ 2.75	Sand	87.57	11.93	SM-SW	17.59	2.65		
T.12	7k + 717m (South)	0.25 ∿ 0.50	Sand						5.50	
"	"	1.75 ∿ 2.00	Sand	100.00	15.91	SM	15.37	2.65	5.75	
T.13	9k + 400m (South)	0.50 ∿ 0.75	Sand						4.90	
"	"	1.75 ∿ 2.00	Sand	94.75	9.61	SM-SP	6.60	2.62	5.15	
"	"	2.50 ∿ 2.75	Sand						4.75	
T.14	12k + 505m (South)	0.50 ∿ 0.75	Sand						5.40	
"	"	1.50 ∿ 1.75	Sand	99.52	25.48	SM	25.15	2.56	5.25	
A.1	1k + 0.56m	1.90 ∿ 2.00	Sand	91.90	21.95	SM	14.11	2.61	5.85	
"	"	2.90 ∿ 3.00	Sand						5.10	
A.2	3k + 482m	2.70 ∿ 3.00	Sand	91.28	17.06	SM	13.80	2.76	5.15	
A.3	6k + 450m	2.50 ∿ 2.60	Sand	91.03	14.34	SM	12.34	2.54	5.25	
A.5	9k + 798m	1.60 ∿ 1.70	Sand	100.00	28.97	SM	23.87	2.60	5.00	
A.6	11k + 220m	2.20 ∿ 2.30	Sand	100.00	29.30	SM	10.70	2.60	5.85	
R.1	Borrow pit RAYONG		Sand	99.99	0.44	SP	2.47	2.54	5.90	49
R.2			Sand	100.00	1.05	SP	3.07	2.77	6.00	66
R.3			Sand	99.98	1.15	SP	1.98	2.62	6.1	49

Table 3 N-VALUE OF STANDARD PENETRATION TEST

Bore-Hole No. \ Depth (m)	1.15 ∿ 1.45	2.15 ∿ 2.45	3.15 ∿ 3.45	4.65 ∿ 4.95	6.15 ∿ 6.45	7.65 ∿ 7.95	9.15 ∿ 9.45	10.65 ∿ 10.95	12.15 ∿ 12.45
B - 1	4	3	27	35	60	31	41	50	65
B - 2	15	4	16	23	35	66	71/15	91/15	
B - 3	2	2	32	40	36	77	80/10		
B - 4	2	2	26	31	40	80/25			
B - 5	2	2	12	37	60/10	80/10			
B - 6	23	75	48	55/15					
B - 7	11	27	23	18	31	39			
B - 8	8	35	61/15						
B - 10	4	67	36	31	66	80/15	60/15		
B - 9	5	15	17	41	46	82	60	50/15	



(1) Completely weathered granite

(2) Highly weathered granite

(3) Slightly weathered granite

FIGURES

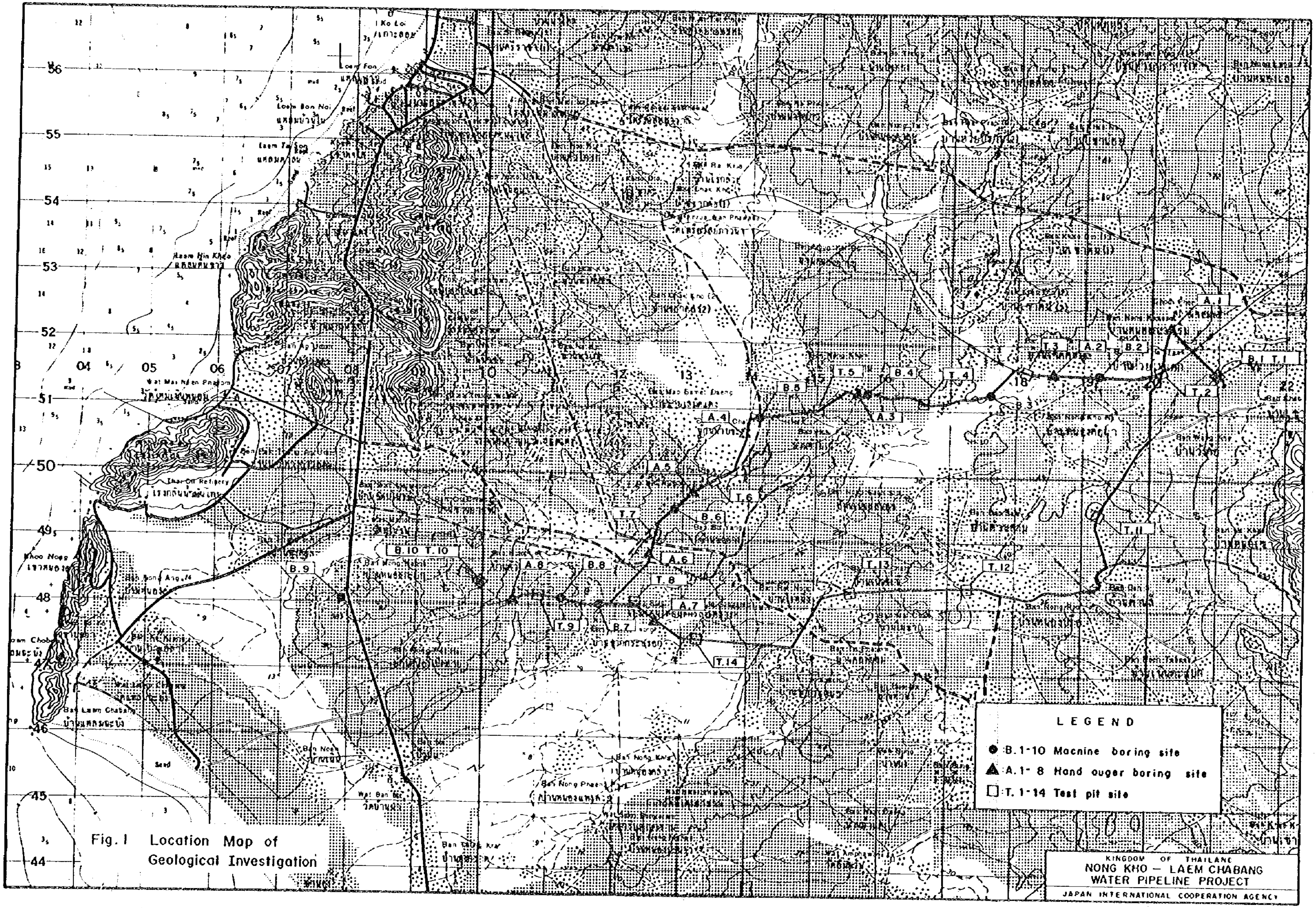


Fig. I Location Map of Geological Investigation

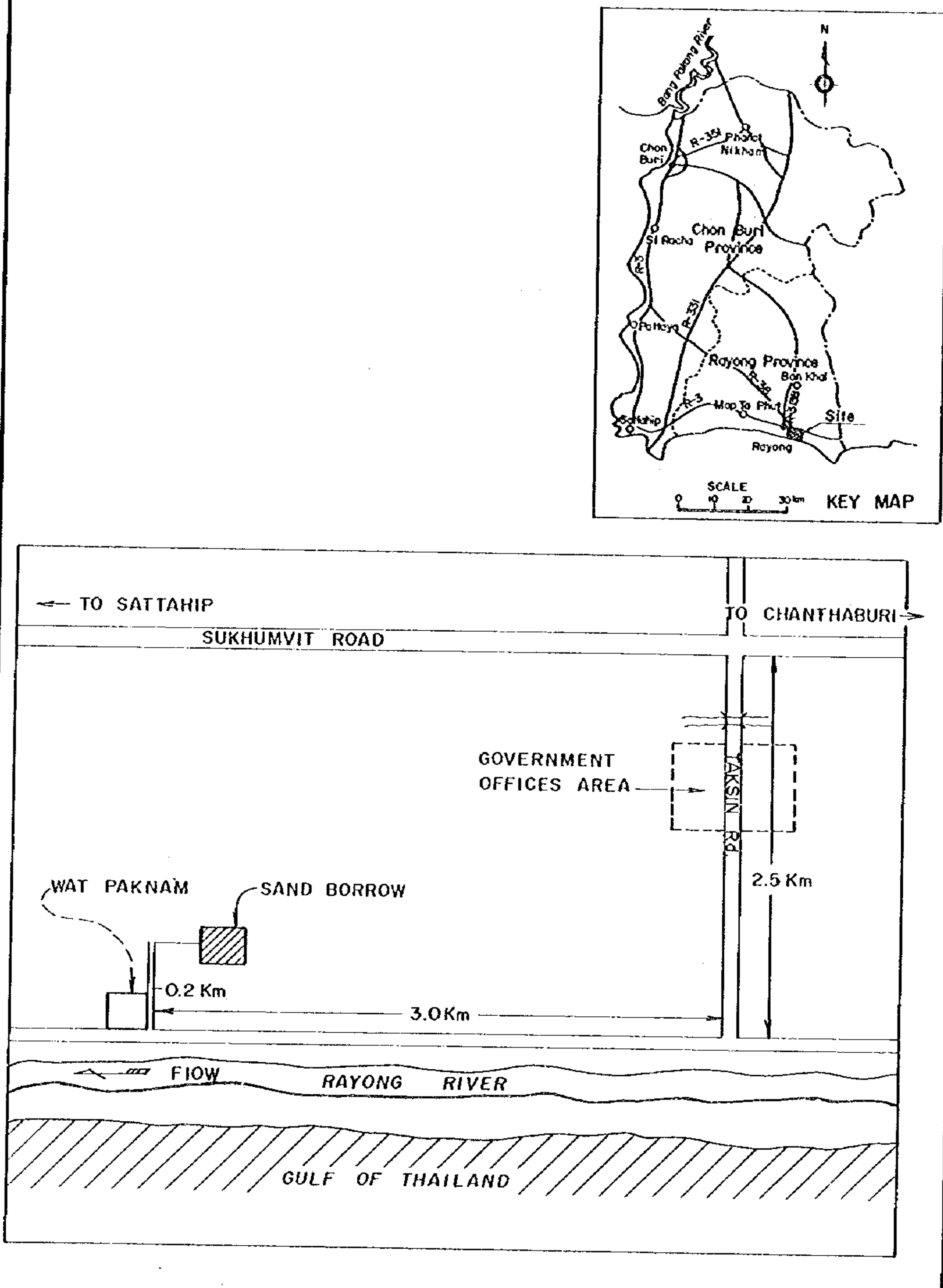


Fig. 2 Location Map of Material Survey

KINGDOM OF THAILAND
NONG KHO – LAEM CHABANG
WATER PIPELINE PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

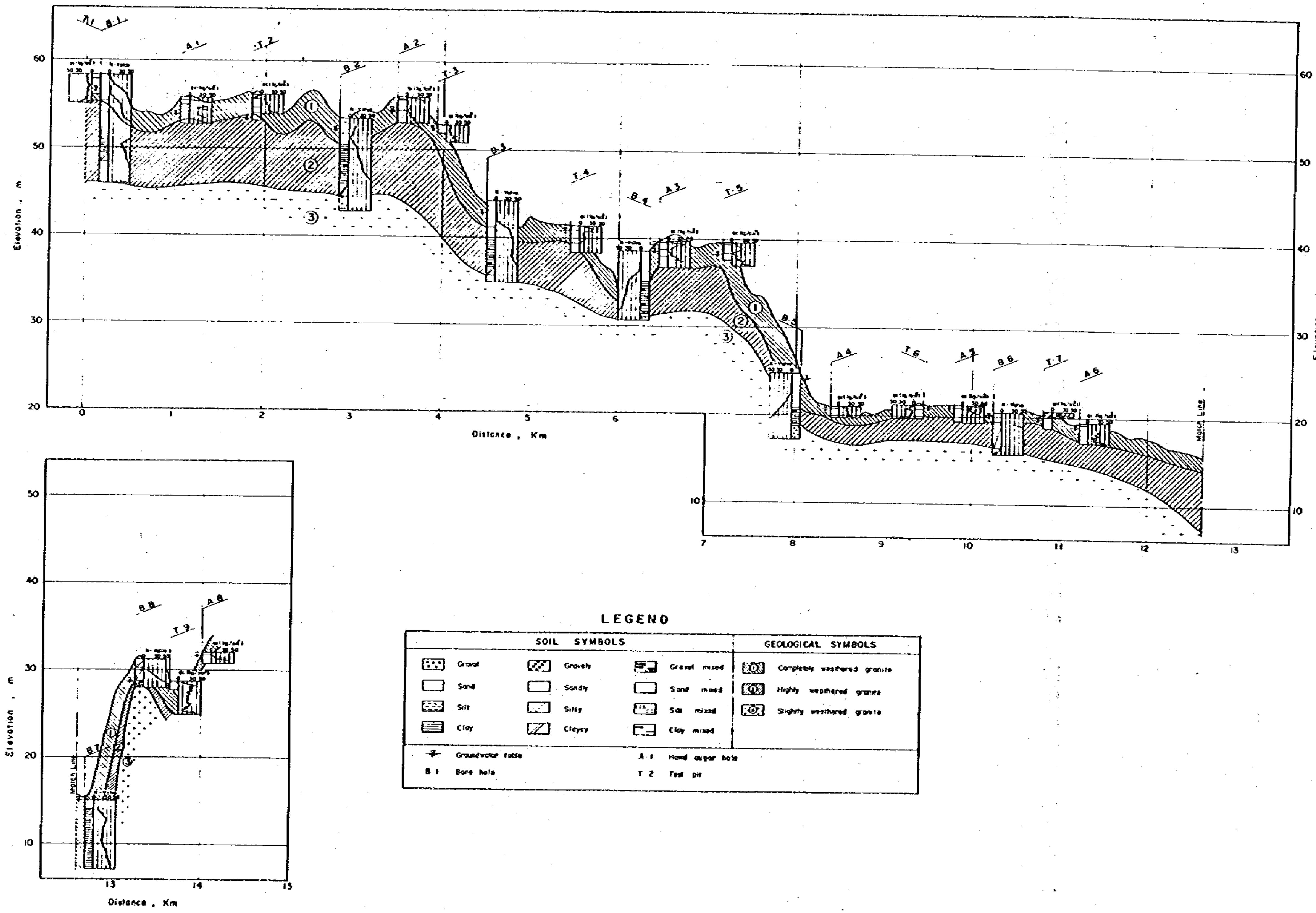


Fig.3 Geological Profile along Proposed Pipeline Route (Middle Route)

KINGDOM OF THAILAND
NONG KHO — LAEM CHABANG
WATER PIPELINE PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

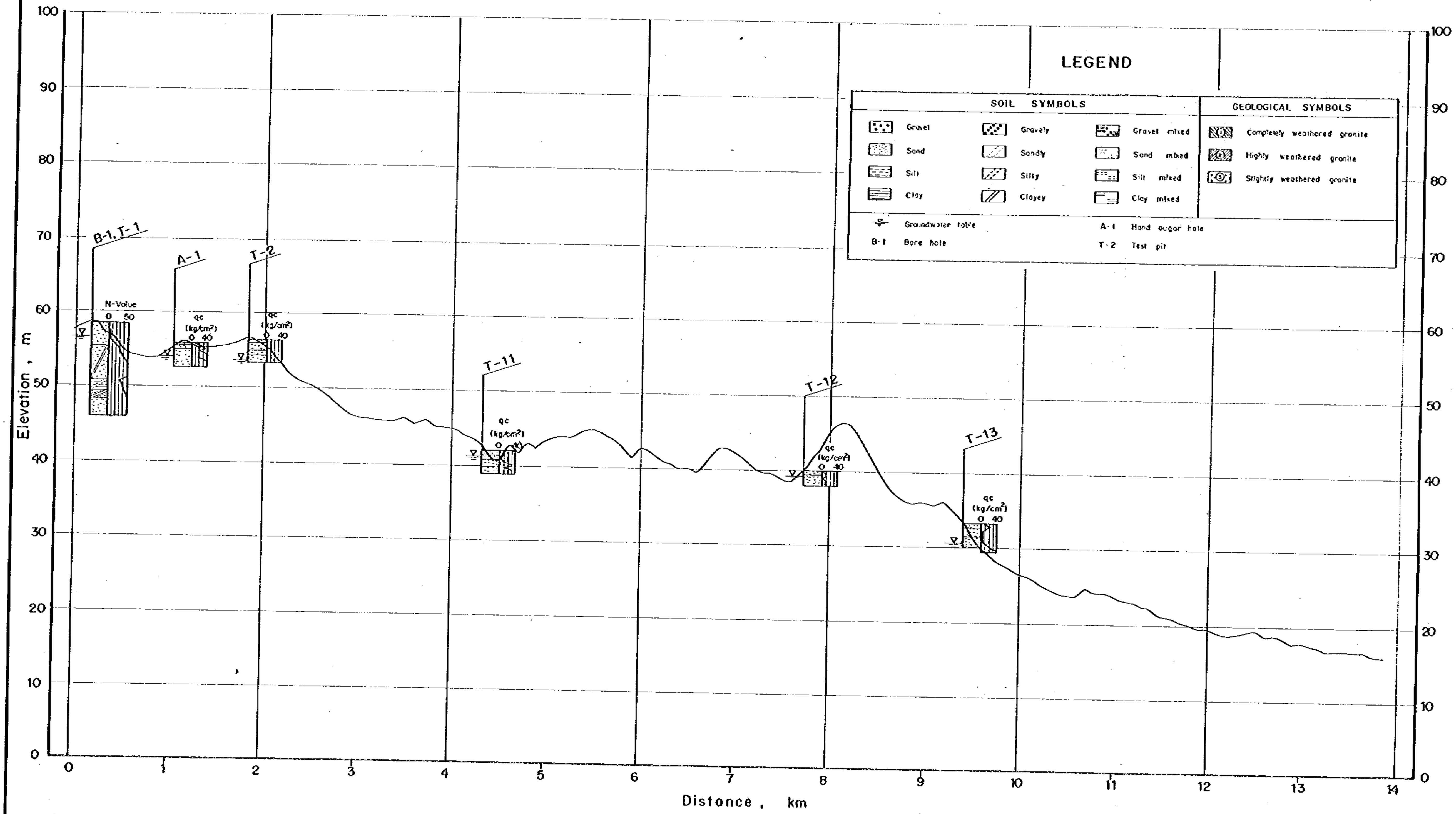


Fig. 4 Geological Profile along Pipeline Route (South Route)

KINGDOM OF THAILAND
NONG KHO – LAEM CHABANG
WATER PIPELINE PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

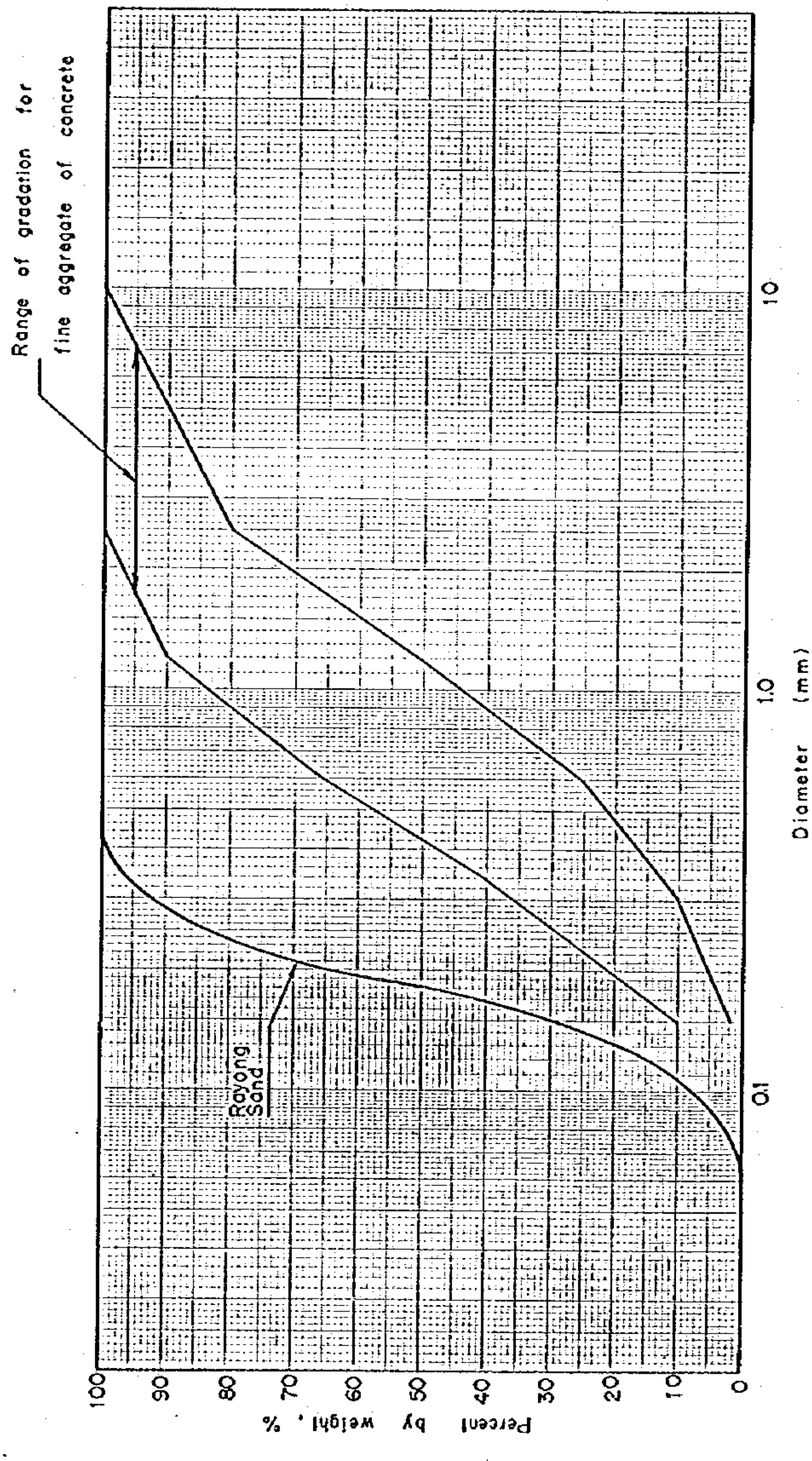


Fig. 5 Particle Size Distribution Curve of Sand in Rayong

KINGDOM OF THAILAND
NONG KHO – LAEM CHABANG WATER PIPELINE PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

REFERENCE DATA

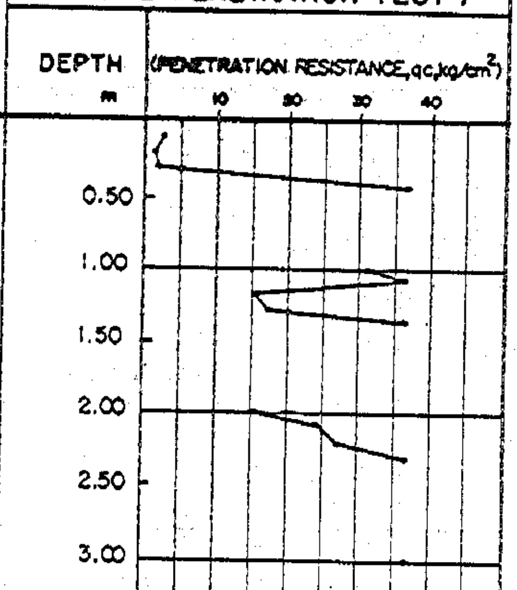
BOREHOLE LOG

LOCATION 1^k + 056^m ELEVATION 55.65 m DATE 21 Oct. 1983

BORE HOLE No. A-1 METHOD OF BORING Hand Auger, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	55.35	0.30	0.30		Sand	Reddish brown	Coase sand. Filled soil for road.		
1	54.80	0.85	0.55		Sand	Gray / light brownish gray	Fine sand. Filled soil for road.		
2, 3	52.65	3.00	2.15		Sand	Reddish brown	Contained clay fraction. Clay is sticky.	1.90	1.90 – 2.00; 2.90 – 3.00

(CONE PENETRATION TEST)



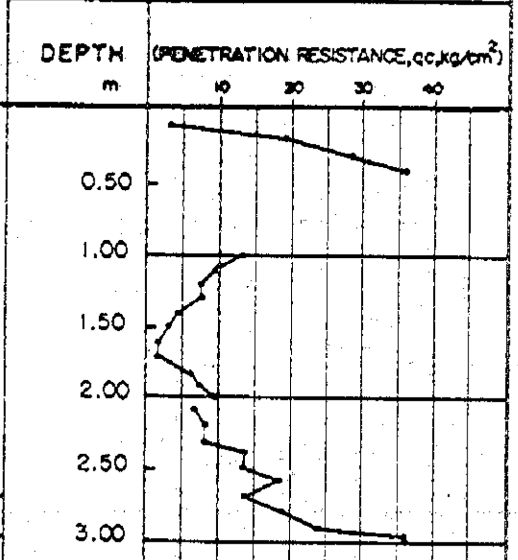
BOREHOLE LOG

LOCATION 3 K + 482 m　　ELEVATION 55.91 m　　DATE 21 Oct., 1983

BORE HOLE No. A-2　　METHOD OF BORING Hand Auger, Cone Penetration Test.　　TESTED BY NAKAGAMI

ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
55.65	0.25	0.25		Sand	Gray	Filled soil for road. Contained clay fraction.		
55.51	0.40	0.15		Gravel	Reddish brown	Filled soil for road.		
54.41	1.50	1.10		Sand	Brownish gray	Sand is medium sand. Contained clay fraction.	1.50	
52.91	3.00	1.50		Sand	Brownish gray and reddish brown; White gray	Sand is coase sand. Contained clay fraction and gravel.		2.70; 3.00

(CONE PENETRATION TEST)



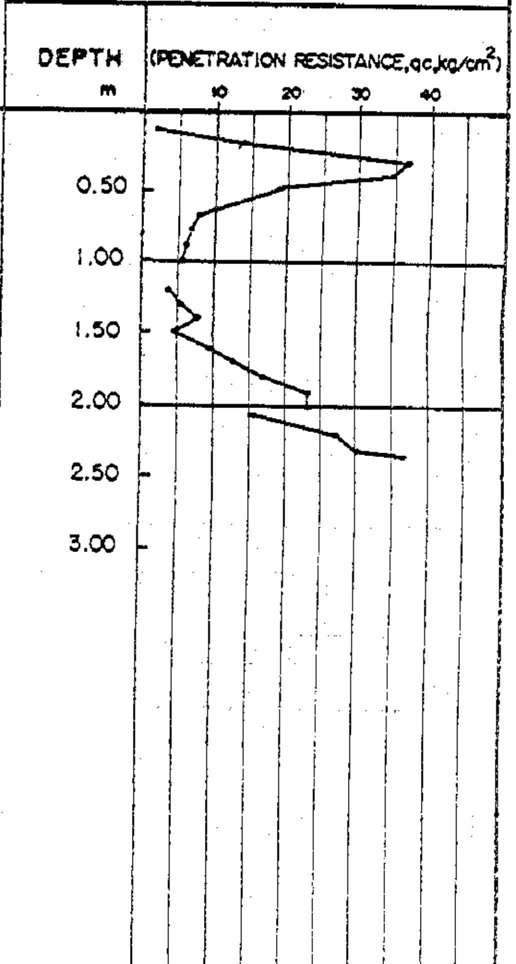
BOREHOLE LOG

LOCATION 6 K + 450 m ELEVATION 39.71 m DATE 20 Oct., 1983

BORE HOLE No. A-3 METHOD OF BORING Hand Auger, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	39.51	0.20	0.20	Sand	Brown	Surface soil. Fine sand. Contained road.		
1	38.71	1.00	0.80	Sand	Light brown	Sand is fine sand. Very loose under the ground water.	0.45	
2, 3	36.71	3.00	2.00	Sand	Reddish brown / Yellowish brown / Reddish brown	Sand is coase sand. Contained angular gravel.		2.50, 2.60

(CONE PENETRATION TEST)



BOREHOLE LOG

LOCATION 8^k + 400^m ELEVATION 21.02 m DATE 21 Oct., 1983

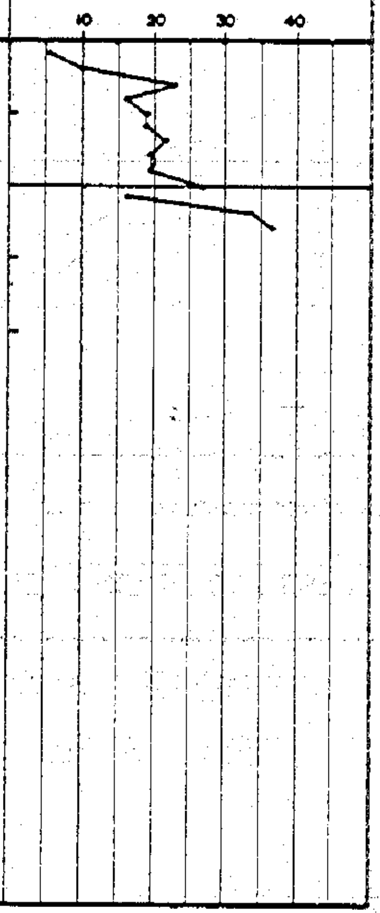
BORE HOLE No. A・4 METHOD OF BORING Hand Auger, Cone Penetration Test. TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	21.83	0.20	0.20		Sand	Dark gray	Surface soil.	0.20	
1	20.73	1.30	1.10		Sand	Reddish brown	Loose.		
2									

(CONE PENETRATION TEST)

DEPTH m: 0.50, 1.00, 1.50, 2.00

(PENETRATION RESISTANCE, qc, kg/cm²)



BOREHOLE LOG

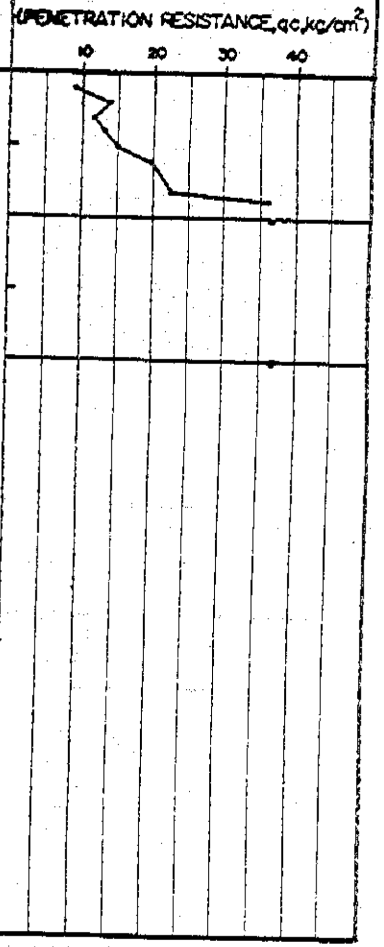
LOCATION 9^{k} + 798^{m} ELEVATION 21.31 DATE 20 Oct. 1983

BORE HOLE No. A-5 METHOD OF BORING Hand Auger, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	21.01	0.30	0.30		Sand	Dark gray	Surface soil.	0.35	
1					Sand	Light brown	Sand is fine sand.		
2	19.41	1.90	1.60			Yellowish brown	Contained clay fraction.		1.60 1.70

(CONE PENETRATION TEST)

DEPTH m: 0.50, 1.00, 1.50, 2.00



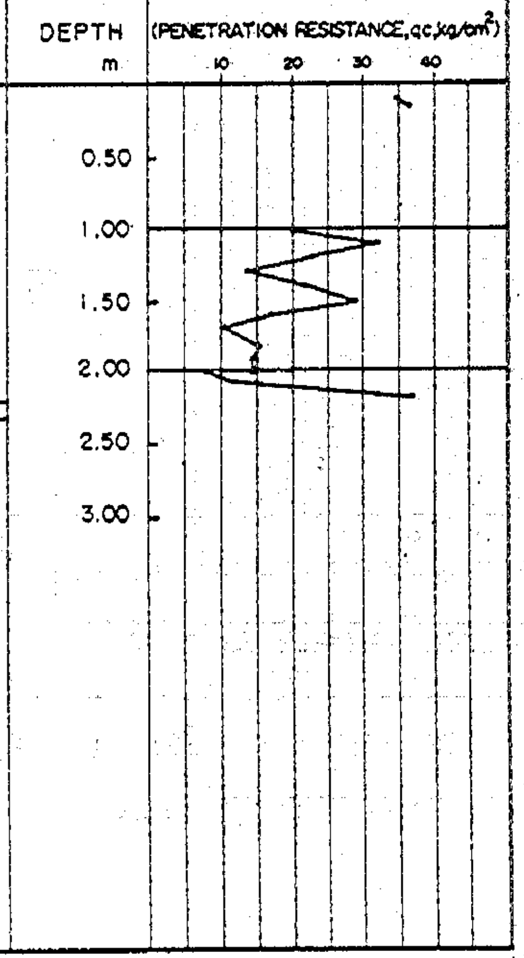
BOREHOLE LOG

LOCATION: 11^{k} + 220^{m} ELEVATION: 19.40 m DATE: 20 Oct. 1983

BORE HOLE No.: A·6 METHOD OF BORING: Hand Auger, Cone Penetration Test TESTED BY: NAKAGAMI

ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
19.15	0.25	0.25		Sand	Reddish brown	Filled soil.	0.50	
17.10	2.30	2.05		Sand	Reddish and yellowish brown Yellowish brown Reddish brown	Contained clay fraction.		2.20 2.30

(CONE PENETRATION TEST)



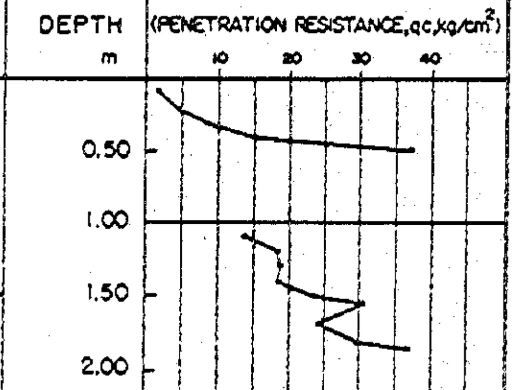
BOREHOLE LOG

LOCATION 13^k + 216^m ELEVATION 17.07 m DATE 20 Oct., 1983

BORE HOLE No. A - 7 METHOD OF BORING Hand Auger, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	16.57	0.50	0.50		Silty sand	Dark gray	Surface soil.	0.25	
1	15.57	1.50	1.00		Sand	Yellowish brown	Contained clay fraction. Clay is sticky.		
2									

(CONE PENETRATION TEST)



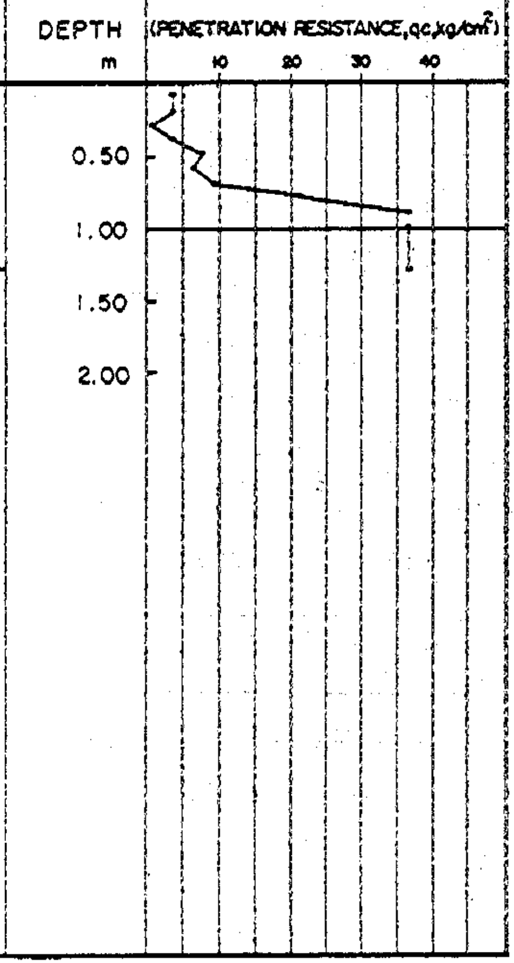
BOREHOLE LOG

LOCATION $1^k + 398^m$ ELEVATION 32.08 m DATE 21 Oct., 1983

BORE HOLE No. A - 8 METHOD OF BORING Hand Auger, Cone Penetration Test. TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	31.88	0.20	0.20		Sand	Reddish gray	Surface soil.	0.30	
1	30.78	1.30	1.10		Sand	White brown	Sand is fine sand. Contained clay fraction.		
2									

(CONE PENETRATION TEST)



BOREHOLE LOG

LOCATION: $0^{k} + 155^{m}$ ELEVATION: 58.30 m DATE: 24 Oct., 1983

BORE HOLE No.: B-1 METHOD OF BORING: Machine (Acker), S.P.T. Cone Penetration Test TESTED BY: SANSERN

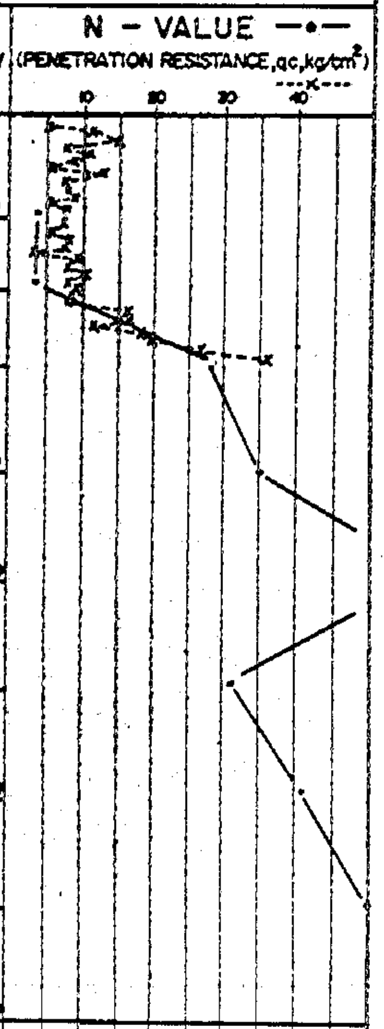
SOIL PROFILE

ELEVATION m	DEPTH m	STRATUM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS
55.30	3.00	3.00	Sand	Light brown	1 Completely weathered granite. Very loose. Fine sand.
50.80	7.50	4.50	Clayey sand	Light brown and yellowish brown / Yellow / White and pink	2 Highly weathered granite. Dense. Sand is fine to coase. Contained angular gravel. Clay is fat clay.
49.30	9.00	1.50	Sandy clay	White gray	2 Highly weathered granite. Very hard. Clay is fat clay.
48.30	10.00	1.00	Clayey sand	White and gray	2 Highly weathered granite. Dense.
45.85	12.45	2.45	Sand	Gray	2 Highly weathered granite. Very dense. Contained rock fragment.

GROUND WATER LEVEL m: 27 Oct. 1.60; 24 Oct. 2.00

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BLOW /cm
1.15 – 1.45	4/30
2.15 – 2.45	3/30
3.15 – 3.45	27/30
4.65 – 4.95	35/30
6.15 – 6.45	60/30
7.65 – 7.95	31/30
9.15 – 9.45	41/30
10.65 – 10.95	50/30
12.15 – 12.45	65/30



BOREHOLE LOG

LOCATION 2^k + 849^m   ELEVATION 53.39 m   DATE 25 Oct. 1983

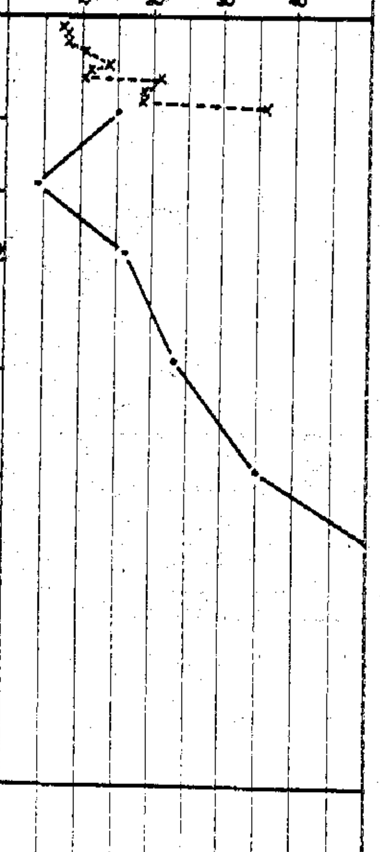
BORE HOLE No. B-2   METHOD OF BORING Machine (Acker), S.P.T. Cone Penetration Test   TESTED BY SANSERN

ELEVATION m	DEPTH m	STRATUM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS
50.39	3.00	3.00	Sand	Dark brown	1 Completely weathred granite. Surface (0.4m) is laterite (Road). Medium to loose. Mixed gravel. Contained slightly clay fraction.
45.89	7.50	4.50	Clay mixed gravel	Yellowish brown / White and greenish gray	2 Highly weathered granite. Very hard. Gravel is decomposed rock. Clay is fat clay.
44.39	9.00	1.50	Clayey sand	Greenish gray and brown	2 Highly weathered granite. Very dense. Gravel is decomposed rock.
42.74	10.65	1.65	Sand and Gravel	Brown	3 Slightly weathered granite. Very dense. Contained rock fragment. Gravel is decomposed rock.

GROUND WATER LEVEL m: 27 Oct 1.38; 25 Oct 1.50

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BLOW /cm
1.15 – 1.45	15/30
2.15 – 2.45	4/30
3.15 – 3.45	16/30
4.65 – 4.95	23/30
6.15 – 6.45	35/30
7.65 – 7.95	66/30
9.15 – 9.30	71/15
10.50 – 10.65	91/15



BOREHOLE LOG

LOCATION: 4^{K} + 515^{m} ELEVATION: 44.11 m DATE: 26 Oct. 1983

BORE HOLE No.: B - 3 METHOD OF BORING: Machine (Acker), S.P.T. / Cone Penetration Test TESTED BY: SANSERN

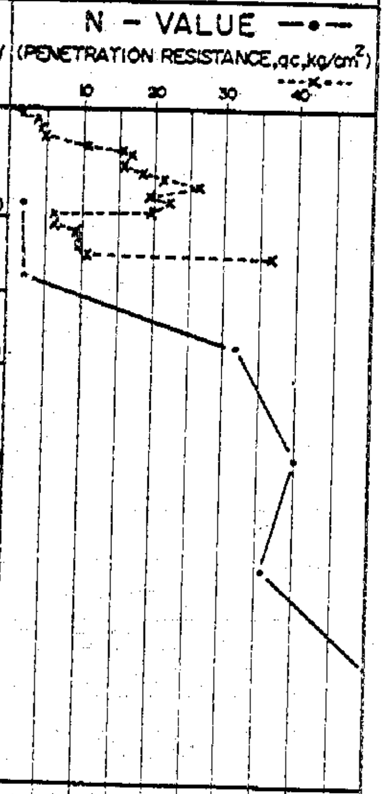
SOIL PROFILE

ELEVATION m	DEPTH m	STRATUM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS
41.11	3.00	3.00	Sand	Reddish brown / Gray and Reddish brown	1 Completely weathered granite or Alluvial deposit. Very loose. Coase sand. Contained slightly clay fraction.
39.61	4.50	1.50	Sand	Light gray	2 Highly weathered granite. Dense. Contained slightly clay fraction.
36.61	7.50	3.00	Clay mixed gravel	White and green gray / Light gray and green	2 Highly weathered granite. Very hard.
35.61	8.50	1.00	Clayey sand	White and green	2 Highly weathered granite. Very dense.
34.86	9.25	0.75	Sand	Grayish brown and green	3 Slightly weathered granite. Contained gravel and rock flagment.

GROUND WATER LEVEL m: 1.30 (26 Oct)

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BLOW /cm
1.15 – 1.45	2/30
2.15 – 2.45	2/30
3.15 – 3.45	32/30
4.65 – 4.95	40/30
6.15 – 6.45	36/30
7.65 – 7.95	77/30
9.15 – 9.25	80/10



BOREHOLE LOG

LOCATION 6ᴷ + 352ᵐ ELEVATION 38.59 m DATE 27 Oct., 1983

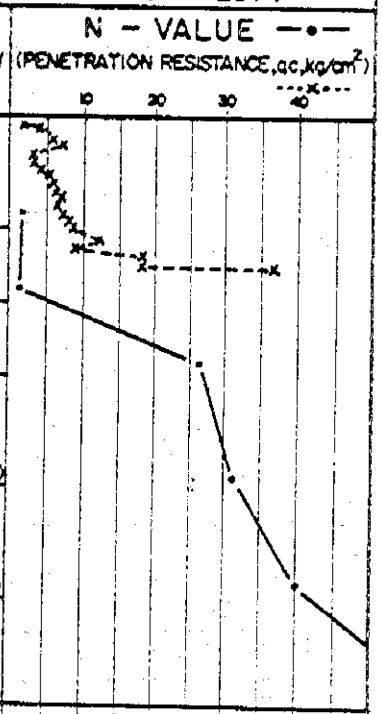
BORE HOLE No. B · 4 METHOD OF BORING Machine (Acker), S.P.T. Cone Penetration Test TESTED BY SANSERN

ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS
35.09	3.50	3.50	Sand	Reddish brown	1 Completely weathered granite. Very loose to medium. Sand is coase sand.
31.09	7.50	4.00	Clay mixed gravel	White and yellowish brown; Gray and yellowish brown	2 Highly weathered granite. Very hard. Clay is fat clay.
30.69	7.90	0.40	Sand and gravel		3 Slightly weathered granite. Very dense.

GROUND WATER LEVEL m: 0.05 (2 Nov)

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BLOW /cm
1.15 – 1.45	2/30
2.15 – 2.45	2/30
3.15 – 3.45	26/30
4.65 – 4.95	31/30
6.15 – 6.45	40/30
7.65 – 7.90	80/25



BOREHOLE LOG

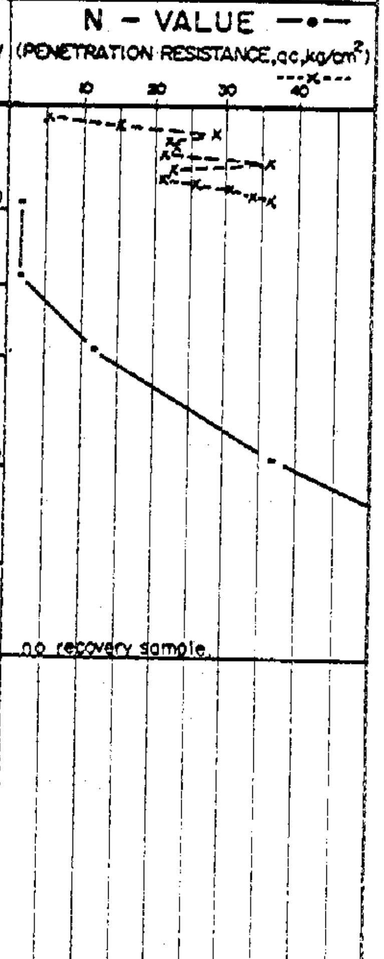
LOCATION 8[k] + 064[m] ELEVATION 24.75 m DATE 28 Oct., 1983

BORE HOLE No. B·5 METHOD OF BORING Machine (Acker), S.P.T. Cone Penetration Test TESTED BY SANSERN

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m
0–4	20.75	4.00	4.00		Sand	Light reddish brown	1 Completely weathered granite Very loose to loose. Sand is medium to fine sand.	0.60 28 Oct. 1.20 28 Oct.
4–6	18.75	6.00	2.00		Clay mixed gravel	White and yellowish brown White and green	2 Highly weathered granite. Very hard. Clay is fat clay.	
6–7.60	17.15	7.60	1.60		Sand and gravel	White and green	3 Slightly weathered granite. Very dense.	

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BLOW /cm
1.15–1.45	2/30
2.15–2.45	2/30
3.15–3.45	12/30
4.65–4.95	37/30
6.15–6.25	60/10
7.50–7.60	80/10



BOREHOLE LOG

LOCATION $10^{k} + 245^{m}$ ELEVATION 20.53 m DATE 13 Nov., 1983

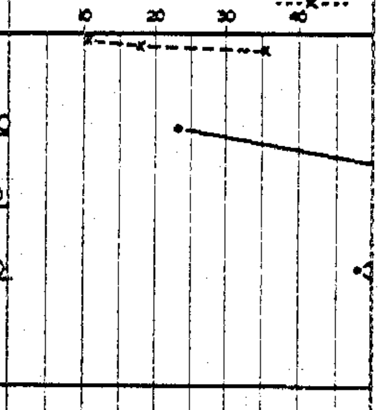
BORE HOLE No. B · 6 METHOD OF BORING ______ TESTED BY SIRIWAT

SCALE m	ELEVATION m	DEPTH m	STRATUM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m
1	19.53	1.00	1.00	Sand	Reddish brown to dark gray	1 Completely weathered granite. Loose, contained root.	0.44
2–4	16.53	4.00	3.00	Clayey sand	Light gray	2 Highly weathered granite. Very dense. Fine to coase sand.	
5	15.73	4.80	0.80	Clayey sand	Light gray	3 Slightly weathered granite. Very dense.	

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BlOW /cm
1.15 – 1.45	23/30
2.15 – 2.45	75/30
3.15 – 3.45	48/30
4.65 – 4.80	55/15

N - VALUE —•— (PENETRATION RESISTANCE, qc, kg/cm²) ---x---



BOREHOLE LOG

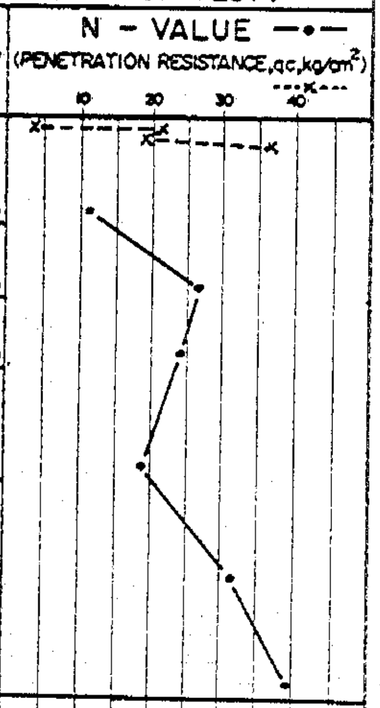
LOCATION: $0^k + 097^m$ ELEVATION: 15.01 m DATE: 11 Nov., 1983

BORE HOLE No.: B-7 METHOD OF BORING: TESTED BY: SIRIWAT

SCALE m	ELEVATION m	DEPTH m	STRATUM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m
1	14.01	1.00	1.00	Sand	Brown	Surface soil Alluvial deposit.	0.00
2	13.01	2.00	1.00	Sandy clay	Brownish yellow and light gray	1 Completely weathered granite. Hard.	
8	7.06	7.95	5.95	Sandy clay	Greenish gray Yellowish gray Light brown, and gray.	2 Highly weathered granite. Very hard. Lock coase sand, but very sticky.	

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BLOW /cm
1.15 – 1.45	11/30
2.15 – 2.45	27/30
3.15 – 3.45	23/30
4.65 – 4.95	18/30
6.15 – 6.45	31/30
7.65 – 7.95	39/30

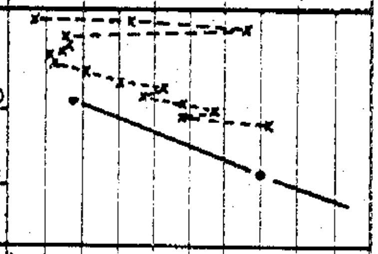


BOREHOLE LOG

LOCATION $0^k + 643^m$ ELEVATION 31.27 m DATE 14 Nov., 1983

BORE HOLE No. B-8 METHOD OF BORING ______ TESTED BY SIRIWAT

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	STANDARD PENETRATION TEST (CONE PENETRATION TEST): DEPTH m	BLOW / cm	N - VALUE (PENETRATION RESISTANCE, qc, kg/cm²)
1	30.27	1.00	1.00		Clayey sand	Reddish brown to dark brown	Surface soil Contained organic matter.		1.15 1.45	8/30	
2	28.77	2.50	1.50		Clayey sand	Light brown to reddish brown	1 Completely weathered granite. Medium to dense.	2.25	2.15 2.45	35/30	
3	28.27	3.00	0.50		Clayey sand	Brown	2 Highly weathered granite. Very dense.				
	27.97	3.30	0.30		Clayey sand	Brown	3 Slightly weathered granite Very dense. Contained rock fragments.		3.15 3.30	61/15	
4											



BOREHOLE LOG

LOCATION: Receiving well ELEVATION: 26m (by map) DATE: 15 Nov., 1983

BORE HOLE No.: B-9 METHOD OF BORING: TESTED BY: SIRIWAT

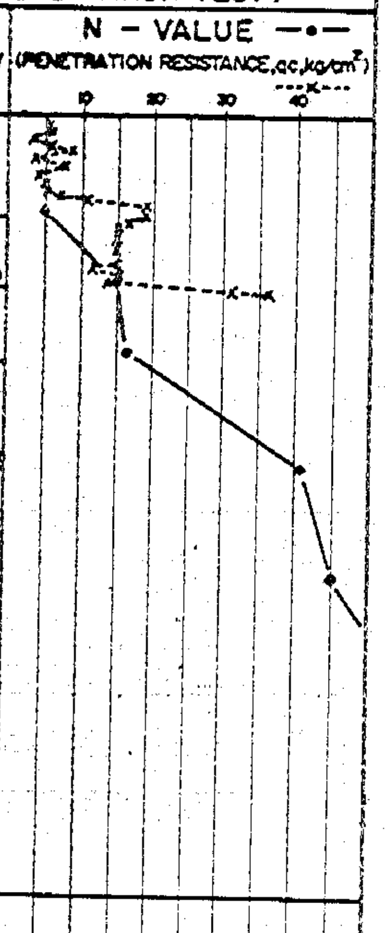
SOIL PROFILE

Elevation m	Depth m	Stratum	Classification	Color	Description of Materials & Remarks
23.0	3.00	3.00	Clayey sand	Light brown to reddish brown	1 Completely weathered granite. Loose to medium.
18.5	7.50	4.50	Clayey sand	Brownish yellow to reddish brown and light gray	2 Highly weathered granite. Dense. Clayey, fine to coase sand.
16.0	10.00	2.50	Clayey sand	Light brown to reddish brown	2 Highly weathered granite. Very dense. Clayey, fine to coase sand.
15.2	10.80	0.80	Clayey sand	Reddish brown	3 Slightly weathered granite.

Ground water level: 3.20 m

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

Depth m	Blow / cm
1.15 – 1.45	5/30
2.15 – 2.45	15/30
3.15 – 3.45	17/30
4.65 – 4.95	41/30
6.15 – 6.45	46/30
7.65 – 7.95	82/30
9.15 – 9.45	60/30
10.65 – 10.80	50/15



BOREHOLE LOG

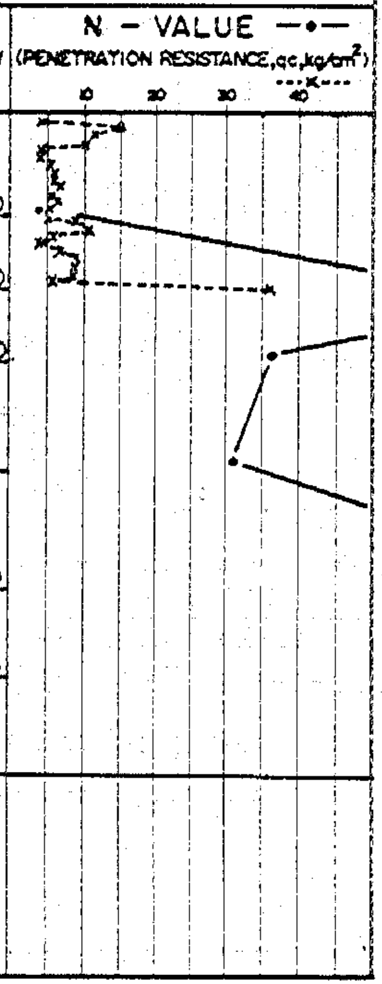
LOCATION: Receiving well   ELEVATION: 46.48 m   DATE: 12 Nov., 1983

BORE HOLE No.: B-10   METHOD OF BORING: TESTED BY: SIRIWAT

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m
0–2	44.33	2.15	2.15		Sand	Reddish brown	1 Completely weathered granite. Very loose, Fine to coase sand.	No water
2–7	39.48	7.00	4.85		Clayey sand	Reddish brown and brownish yellow	2 Highly weathered granite. Dense to very dense. Trace of gravel.	
7–9	37.33	9.15	2.15		Sand	White and brown	3 Slightly weathered granite. Very dense. Contained rock fragments	

STANDARD PENETRATION TEST (CONE PENETRATION TEST)

DEPTH m	BLOW /cm
1.15 – 1.45	4/30
2.15 – 2.45	67/30
3.15 – 3.45	36/30
4.65 – 4.95	31/30
6.15 – 6.45	66/30
7.65 – 7.80	80/15
9.00 – 9.15	60/15



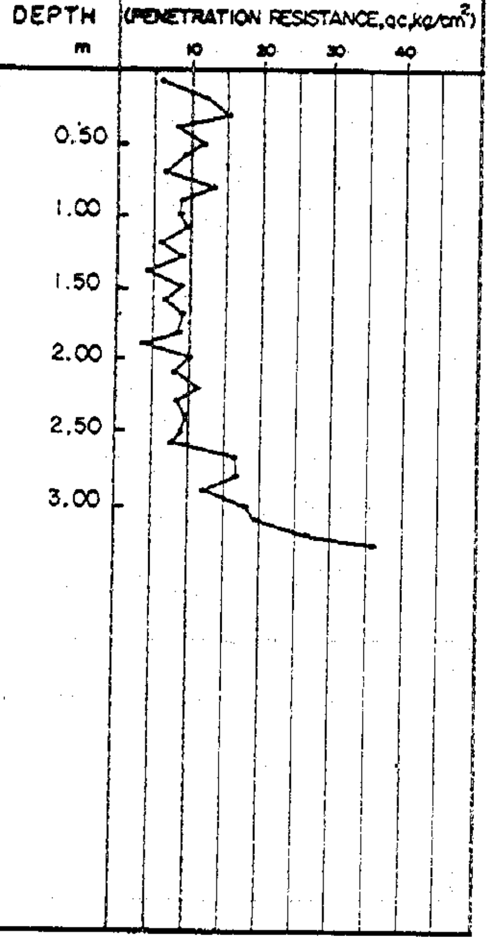
TEST PIT LOG

LOCATION 0^k + 155 m — ELEVATION 58.30 m — DATE 14 Oct. 1983

BORE HOLE No. T-1 — METHOD OF BORING Test Pit, Cone Penetration Test — TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	57.80	0.50	0.50		Sand	Light brown	Surface soil. Contained root. Slightly cohesive.		0.50
1	56.80	1.50	1.00		Sand	Reddish light brown	Very loose. Fine sand. Contained clay fraction.		0.75, 1.25
2	56.00	2.30	0.80		Sand	Brownish gray	Very loose. Contained gravel and rock fragment. Cohesive.	2.20	1.50
3									

(CONE PENETRATION TEST)



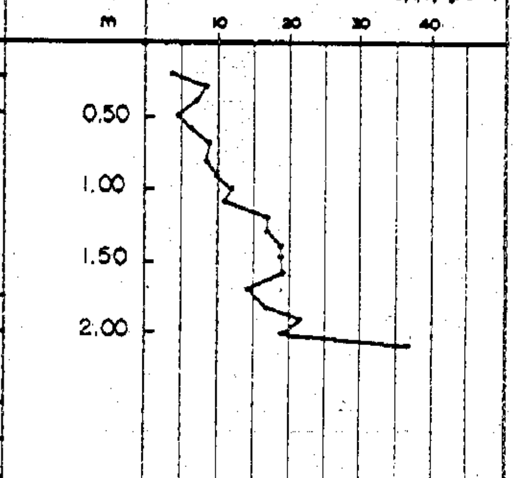
TEST PIT LOG

LOCATION 1k + 852m ELEVATION 56.12 m DATE 14 Oct., 1983

BORE HOLE No. T-2 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	55.62	0.50	0.50	Clayey sand	Brown	Surface soil. Contained root. Cohesive.		0.25
1	54.62	1.50	1.00	Sand	Brown	Very loose. Medium to coase sand.		0.50
2	54.02	2.10	0.60	Sand	Reddish brown and black	Loose. Contained gravel and rock fragment.		1.75, 2.00
3	53.12	3.00	0.90	Sand	Reddish brown, grayish brown and green	Medium. Contained gravel and rock fragment.	2.75	2.50, 2.75

(CONE PENETRATION TEST)



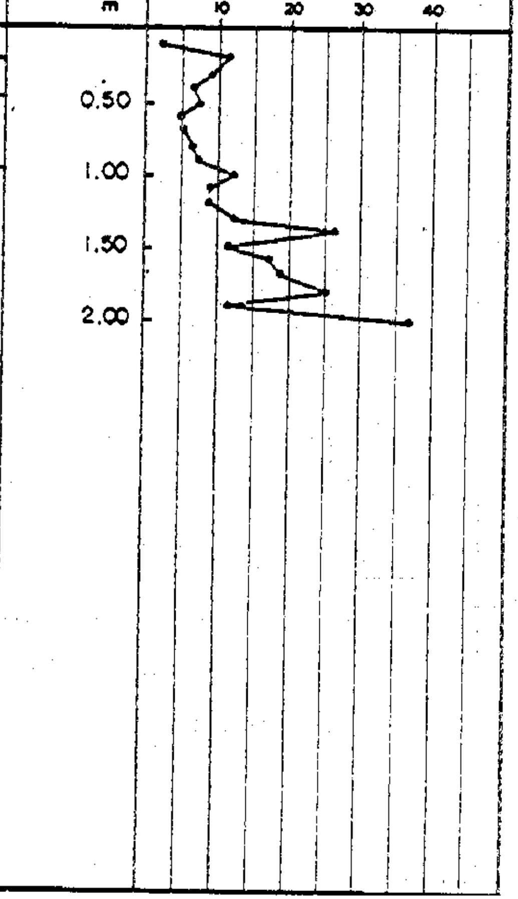
TEST PIT LOG

LOCATION 3^k + 932^m ELEVATION 52.78 m DATE 13 Oct., 1983

BORE HOLE No. T : 3 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
1	51.78	1.00	1.00		Sand	Reddish brown	Very loose. Contained slightly white clay.	0.45	0.25, 0.50
2									

(CONE PENETRATION TEST)



TEST PIT LOG

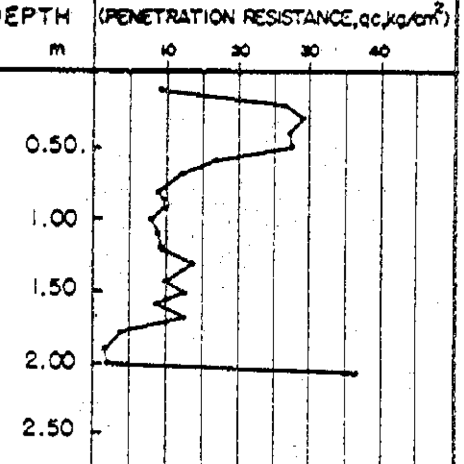
LOCATION 5ᵏ + 450ᵐ ELEVATION 41.34 m DATE 13 Oct., 1983

BORE HOLE No. T : 4 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	40.84	0.50	0.50		Sand	Dark reddish brown	Surface soil. Contained root.	0.50	0.50
1, 2	39.34	2.00	1.50		Sand	Grayish brown	Very loose. Fine to coase sand. Slightly cohesive.		0.75
3	38.34	3.00	1.00		Sand	Yellowish gray	Medium to dense. Sand is coase sand. Contained clay fraction.		2.75, 3.00

(CONE PENETRATION TEST)

DEPTH m



TEST PIT LOG

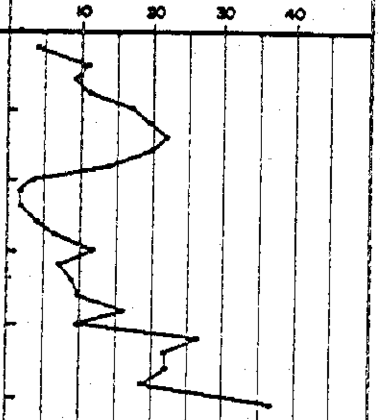
LOCATION 7^{k} + 170^{m} ELEVATION 39.64 m DATE 14 Oct. 1983

BORE HOLE No. T-5 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	39.39	0.25	0.25		Sand	Dark reddish brown	Surface soil.		
1	38.39	1.25	1.00		Sand	Reddish brown	Loose. Medium sand.		0.50 0.75
2	37.64	2.00	0.75		Sand	Reddish brown	Very loose. Contained gravel (very brittle).	1.40	1.50 1.75

(CONE PENETRATION TEST)

DEPTH m: 0.50, 1.00, 1.50, 2.00, 2.50



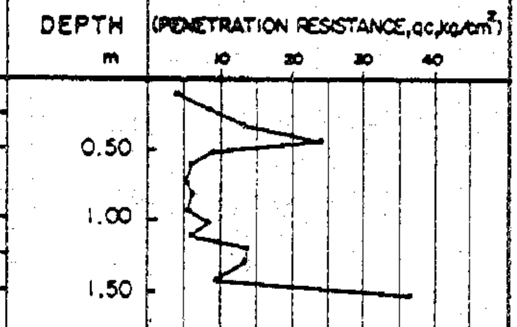
TEST PIT LOG

LOCATION 9[k] + 452[m] ELEVATION 21.27 m DATE 16 Oct., 1983

BORE HOLE No. T-6 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	20.77	0.50	0.50		Sand	Dark reddish brown	Surface soil. Coase sand.	0.40	0.25
1	19.77	1.50	1.00		Sand	Reddish brown	Very loose. Coase sand.		0.50, 1.00, 1.25
2									

(CONE PENETRATION TEST)



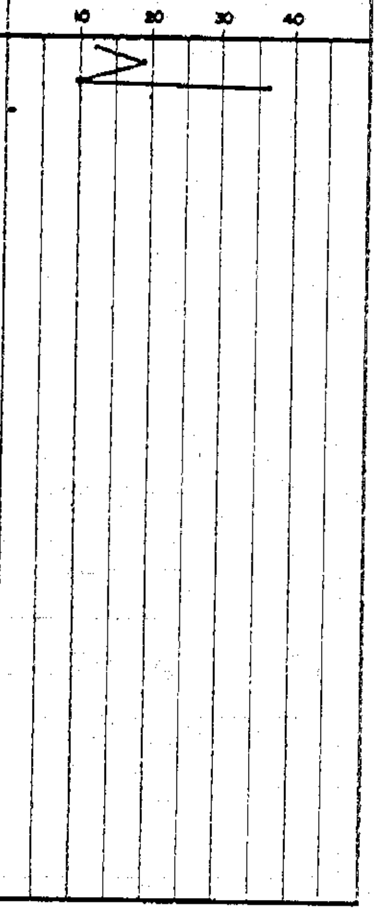
TEST PIT LOG

LOCATION 10^k + 807^m ELEVATION 20.68 m DATE 16 Oct. 1983

BORE HOLE No. T-7 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: DIAGRAM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m	(CONE PENETRATION TEST) DEPTH m
	20.08	0.60	0.60		Sandy clay	Yellowish brown, and Yellowish gray	Filled soil. Clay is fat clay.		0.60	0.50
1	18.68	2.00	1.40		Sand	Reddish brown	Coase sand.	0.90	0.75, 1.50, 1.75	
2										

(PENETRATION RESISTANCE, qc, kg/cm²)



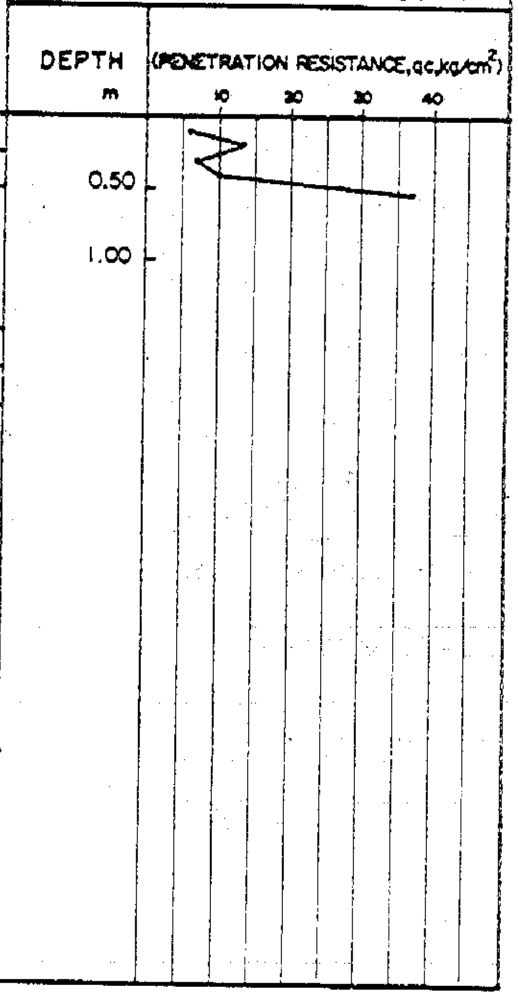
TEST PIT LOG

LOCATION 13[k] + 598[m] ELEVATION 16.46 m DATE 16 Oct., 1983

BORE HOLE No. T - 8 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	SOIL PROFILE: CLASSIFICATION	SOIL PROFILE: COLOR	SOIL PROFILE: DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	16.21	0.25	0.25	Sand	Dark gray	Surface soil. Fine sand. Contained root.		0.25
	15.96	0.50	0.25	Clayey sand	Light brown			0.50
1				Sandy clay	Dark brown and yellowish brown	Highly weathered granite. Clay is fat clay.		
2	14.46	2.00	1.50		White gray and yellowish brown		1.65	1.50, 1.75

(CONE PENETRATION TEST)



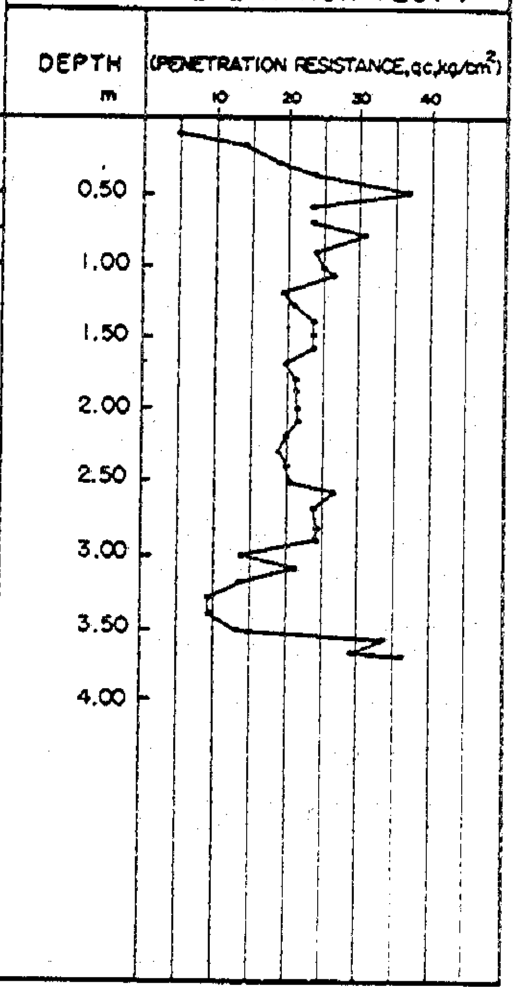
TEST PIT LOG

LOCATION 1^k + 035 m ELEVATION 28.68 m DATE 17 Oct., 1983

BORE HOLE No. T-9 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	32.90	0.25	0.25		Sand	Light reddish brown	Surface soil. Coase sand.	0.55	0.50
1	32.15	1.00	0.75		Sand	Light reddish brown	Loose. Coase sand.		0.75
2									

(CONE PENETRATION TEST)



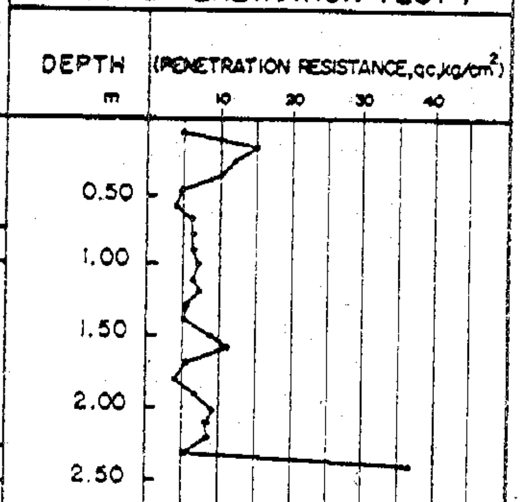
TEST PIT LOG

LOCATION: Receiving well | ELEVATION: 46.48 m | DATE: 17 Oct., 1983

BORE HOLE No.: T - 10 | METHOD OF BORING: Test Pit, Cone Penetration Test | TESTED BY: NAKAGAMI

ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	0.75	0.75		Sand	Reddish brown	Contained slightly clay. Fine sand.	No water	0.75
	2.25	1.50		Sand	Light reddish brown	Very loose. Coase sand. Contained slightly clay.		1.00, 2.25
	3.00	0.75		Sand	Light reddish brown / Yellowish brown	Highly weathered granite. Contained rock (color is black) fragment.		2.50, 2.75, 3.00

(CONE PENETRATION TEST)



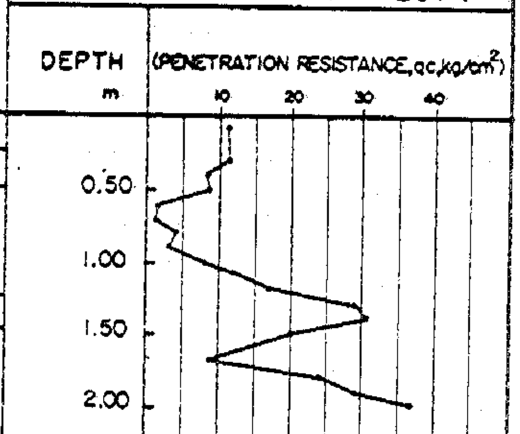
TEST PIT LOG

LOCATION 4[k] + 340[m] ELEVATION 41.98 m DATE 15 Oct. 1983

BORE HOLE No. T·11 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	41.48	0.50	0.50		Sand	Brown	Surface soil. Contained root. Contained slightly clay. Fine sand		0.25
1	40.98	1.00	0.50		Sand	Brown	Contained angular gravel. Fine sand.	0.75	0.50
2	39.98	2.00	1.00		Sand	Brown	Contained may angular gravel (color is reddish brown). Fine sand.		1.25 1.50
3	38.98	3.00	1.00		Sand	White and reddish gray	Highly weathered granite. Contained many angular gravel (color is reddish brown). Coase sand.		2.50 2.75

(CONE PENETRATION TEST)



TEST PIT LOG

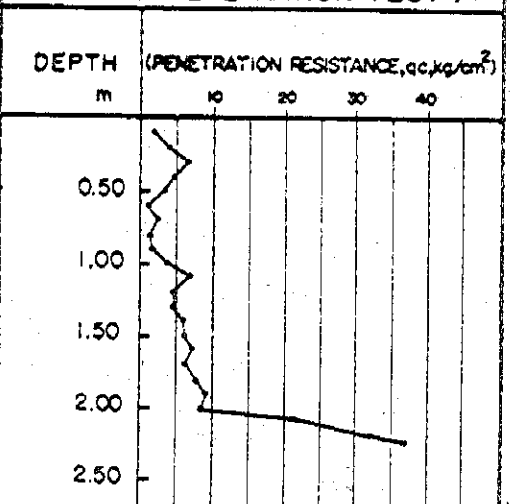
LOCATION 7^k + 717^m　ELEVATION 39.81 m　DATE 15 Oct., 1983

BORE HOLE No. T-12　METHOD OF BORING Test Pit, Cone Peneration Test　TESTED BY NAKAGAMI

ELEVATION OF CONE = 40.37^m

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	39.31	0.50	0.50		Sand	Dark reddish brown	Surface soil. Contained root.		0.25
1					Sand	Brown	Contained slightly clay (color is white gray).	0.70	0.50
2	37.81	2.00	1.50						1.75 2.00

(CONE PENETRATION TEST)



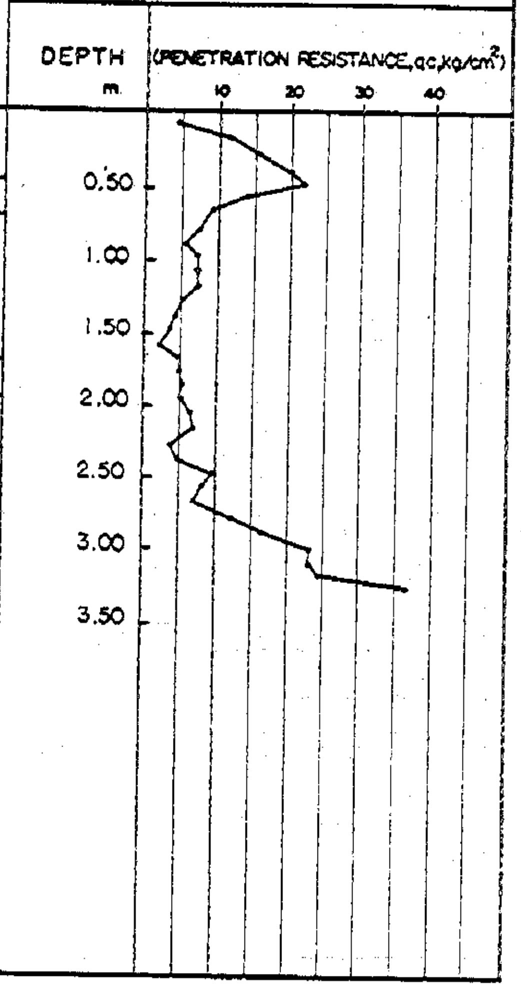
TEST PIT LOG

LOCATION 9^{k} + 400^{m} ELEVATION 33.15 m DATE 15 Oct., 1983

BORE HOLE No. T-13 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
32.65	0.50	0.50		Sand	Reddish brown	Surface soil. Contained root.		0.50
31.65	1.50	1.00		Sand	Reddish brown	Contained angular gravel.		0.75
30.25	2.90	1.40		Sand	Reddish brown	Conlained angular gravel. Sand is coase sand.	2.65	1.75, 2.00, 2.50
30.15	3.00	0.10		Sand and gravel	Light reddish brown	Highly weathered granite		2.75

(CONE PENETRATION TEST)



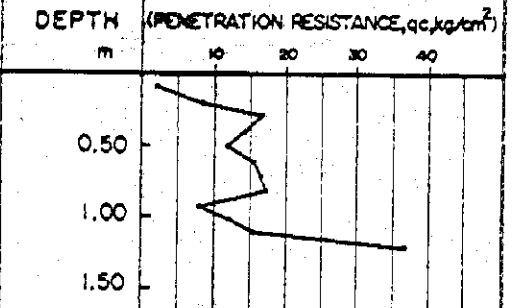
TEST PIT LOG

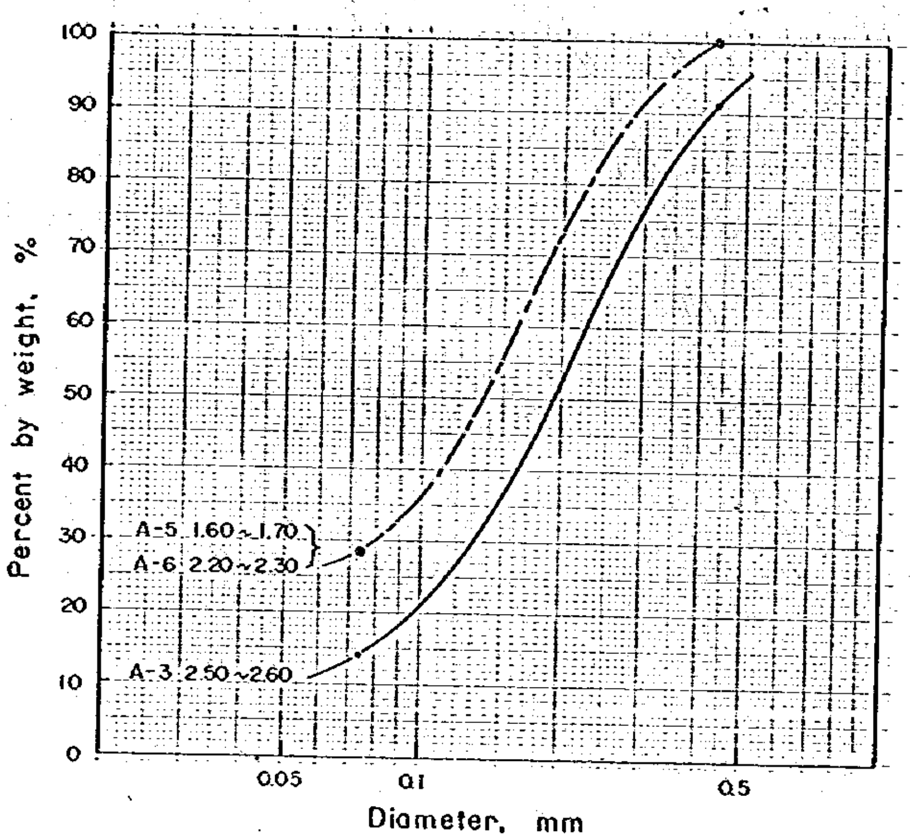
LOCATION 12[k] + 505[m] ELEVATION 19.04 m DATE 17 Oct., 1983

BORE HOLE No. T-14 METHOD OF BORING Test Pit, Cone Penetration Test TESTED BY NAKAGAMI

SCALE m	ELEVATION m	DEPTH m	STRATUM	DIAGRAM	CLASSIFICATION	COLOR	DESCRIPTION OF MATERIALS & REMARKS	GROUND WATER LEVEL m	SAMPLING DEPTH m
	18.54	0.50	0.50		Sand	White and reddishbrown	Alluvial deposit. Medium sand.		0.50
	18.24	0.80	0.30		Sand	Reddishbrown	Alluvial deposit. Coase sand.		
1	18.04	1.00	0.20		Silty sand	Dark gray	Alluvial deposit.		0.75
	17.74	1.30	0.30		Sand	Reddishbrown	Alluvial deposit. Coase sand.		
	17.54	1.50	0.20		Silty sand	Dark gray	Alluvial deposit.	1.40	1.50
2	17.04	2.00	0.50		Sand	Dark to light brownish gray	Completely weathered granite. Fine sand. Contained clay fraction.		1.75

(CONE PENETRATION TEST)





LEGEND

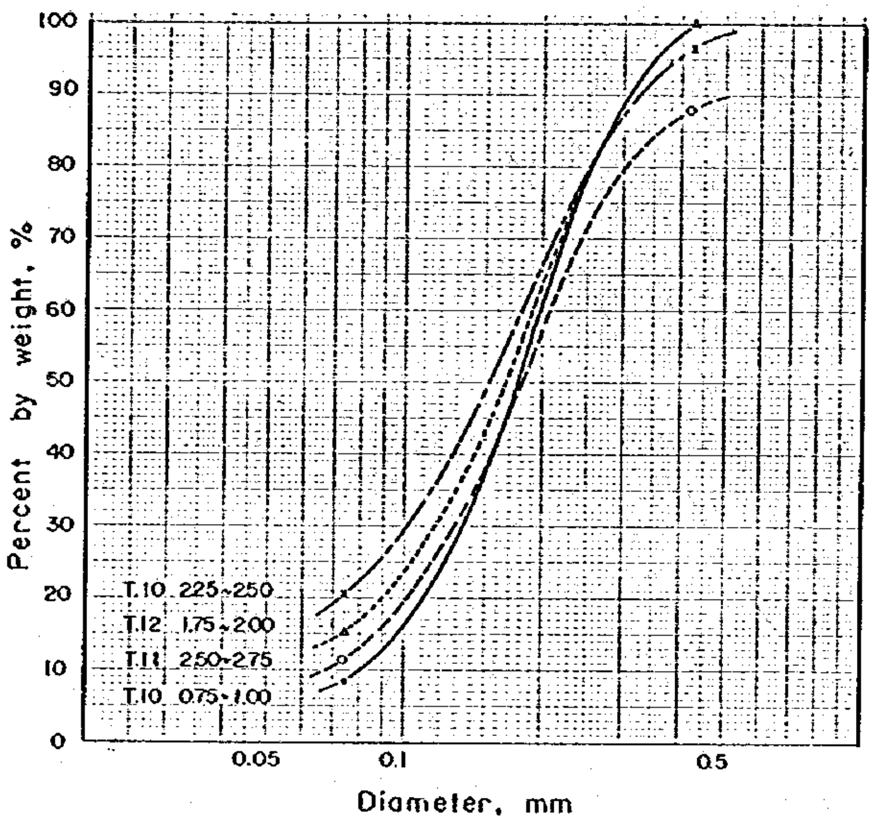
T6 1.00 - 1.25 Test pit number and sampling depth in meter

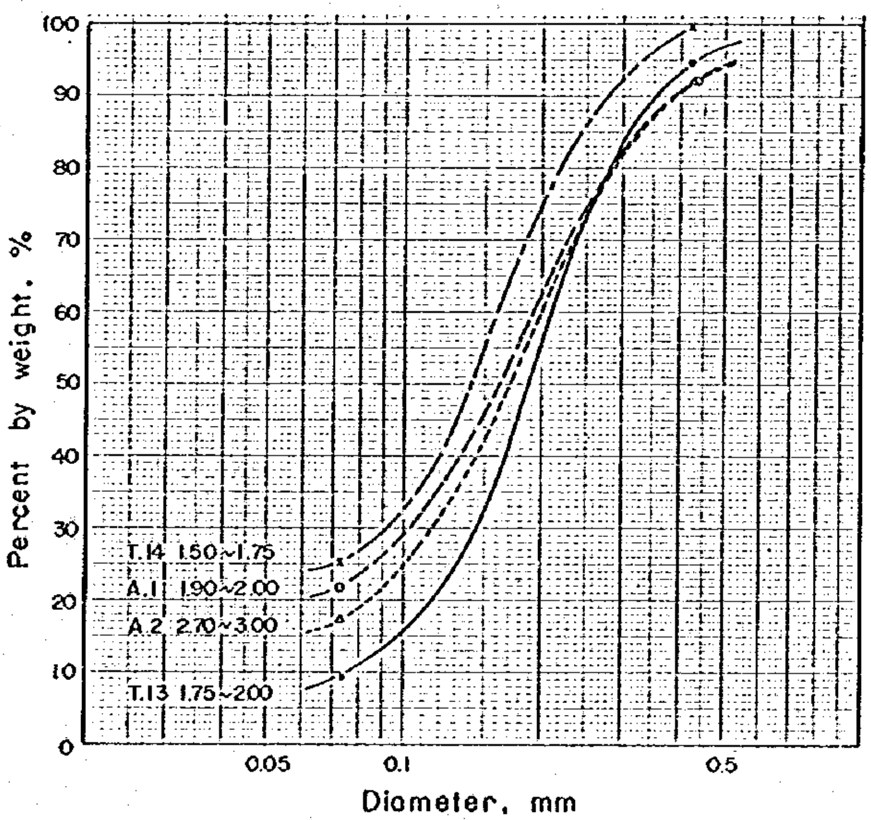
A1 1.90-2.00 Augar boring site and sampling depth in meter

Particle Size Distribution Curve of Soil Samples

KINGDOM OF THAILAND
NONG KHO — LAEM CHABANG
WATER PIPELINE PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY





LEGEND

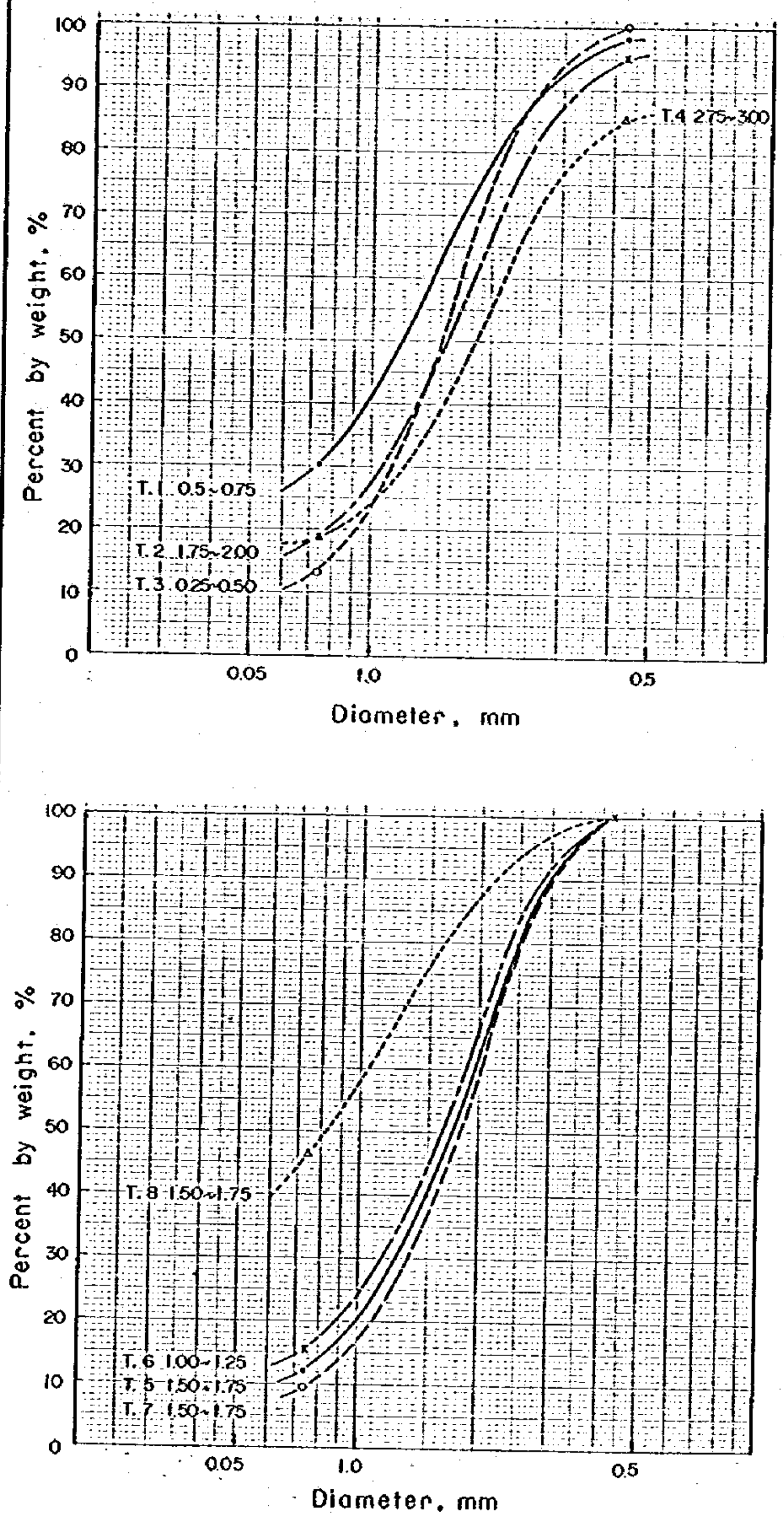
T6 1.00-1.25 Test pit number and sampling depth in meter

A1 1.90-2.00 Augar boring site and sampling depth in meter

Particle Size Distribution Curve of Soil Samples

KINGDOM OF THAILAND
NONG KHO — LAEM CHABANG
WATER PIPELINE PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND

T6 1.00-1.25 Test pir number and sampling depth in meter

A1-1.90-2.00 Augor boring site and sampling depth in meter

Particle Size Distribution Curve of Soil Samples

KINGDOM OF THAILAND
NONG KHO — LAEM CHABANG WATER PIPELINE PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

SUPPORTING REPORT IV

WATER DEMAND PROJECTION

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1. INTRODUCTION

This sectoral report presents the result of water demand projection in Laem Chabang and Pattaya Area until the target year of 2001. Water demand and supply balance study is conducted based on the projected water demand and water supply capacity of existing source facilities and optimum development plan of Nong Kho-Laem Chabang water pipeline system will be formulated.

Several master plan reports are available concerning the water demand projection of the Study Area, namely Eastern Seaboard Study (ESS), by Coopers and Lybrand associates, East Coast Water Resources Development Project, Phase I (Phse I Study) and the Phase II of the same project (Phase II Study) by Japan International Cooperation Agency (JICA). In the present study, it is attempted to elaborate the water demand of the Study Area in due consideration of the socio-eonomic characteristics and future development plan specific to the area.

Water demand projected in this sectoral report is indicated in terms of consumer demand, which is the amount of water to be produced in water works and supplied to consumers.

2. BASIS OF THE STUDY

2.1 Study Area

The Study Area with the total area of approximately 500 km^2 is located over Si Racha and Bang Lamung Districts of Chon Buri Province as shown in Fig. 1. It is devided into Laem Chabang Basin and Pattaya Basin by the river basin boundary of Khlong Bang Lamung and Huai Nong Pru rivers.

Pattaya is included in the Study Area according to the proposal of "Study Report on Long-Term Water Supply Plan" by JICA in 1983. This report indicates the necessity of raw water conveyance from Nong Kho reservoir to Pattaya area by year 1991 to cope with the expected increase of future water demand. In order to clarify the timing and amount of water to be supplied to Pattaya area, the present study incorporates Pattaya Basin into the Study Area.

Both Laem Chabang and Pattaya Basins are composed of development area (DA) and non-development area (NDA) as shown in Fig. 1. Development area covers the area where industrial, urban and tourism development is planned to be promoted by the government and the surrounding area anticipated to be urbanized as an influence of the government oriented development. Non-development area covers the rest of the basin. Boundary of development area is derived from ESS. The eastern boundary of the Laem Chabang DA is determined to be 2 km east of the railway now under construction. Boundary of Pattaya DA coincides with the boundary of Pattaya city.

2.2 Regional Development Plan

2.2.1 Laem Chabang

Laem Chabang is regarded as one of the most important bases for the industrial development of the Eastern Seaboard as well as Map Ta Phut.

Development of Laem Chabang Area consists of the three components; deep seaport, industrial estate including export procesing zone and urban development.

The deep seaport is planned to be constructed in order to ease the congestion of the existing Bangkok port and serve as the gateway for the export of industrial products from the Eastern Seaboard, especially the industrial estate planned to be located adjacent to the port. The deep seaport is planned to start operation between 1987 and 1990 and its development cost is estimated to be approximately ฿ 2,900 x 10^6.

While the industrial development in Map Ta Phut is based on heavy industries related with natural gas, industry in Laem Chabang industrial estate is planned to be small scale, labor intensive, non-polluting and export oriented type including export processing zone. The industrial development of Laem Chabang is expected to contribute to attain the major targets of the Fifth National Economic and Social Development Plan (The Fifth National Plan) such as acquisition of foreign currencies, diffusion of growth from Bangkok and generation of new employment opportunities. The development cost is estimated to be around ฿ 800 x 10^6.

In order to support the development of the deep seaport and the industrial estate mentioned above, study for the development of Laem Chabang urban area is scheduled to start soon. The study will be made on such aspects as future population, land use, housing program and development plan of basic infrastructure facilities.

Water Demand projection of the Laem Chabang Basin is conducted for the three components as industrial water demand, domestic water demand in development and non-development areas and port water demand and for the water demand of existing industries in the Study Area.

2.2.2 Pattaya

Tourism of Thailand has shown a remarkable progress recently and in 1982 its amount of foreign currency earning was at the top among all the export commodities for the first time amounting to nearly ฿ 2,400 x 10^6.

So was the case of worldly famous resort spot of Pattaya. Number of visitors to Pattaya reached nearly 600,000 in 1982 exceeding Chieng Mai which is also the famous sightseeing site in the North by around 100,000.

It has been endeavored by the government to develop the basic infrastructure to support rapid growth of the city. In 1979 Map Prachan reservoir with the gross storage capacity of 17 x $10^6 m^3/yr$ was created by RID about 8 km east of Pattaya City. Naklua-Pattaya waterworks was expanded to the plant capacity of 25,920 m^3 per day from 1,920 m^3 per day and commenced operation in 1981. To promote the tourism development of Pattaya, further development of such infrastructure facilities as road network, drainage, sewerage collection system and sewage treatment plant is at present under way.

For the Pattaya Basin, future water demand is projected for domestic water in development and non development area, tourism and existing industries.

3. WATER DEMAND PROJECTION

3.1 Industrial Water Demand

3.1.1 General

This chapter presents the methodology and result of industrial water demand projection at the Laem Chabang industrial estate. For the industrial development of the estate, definite plan has not been formulated yet except that it is planned to be based on labor intensive and pollution free light industries. From early 1984, Japan International Cooperation Agency (JICA) plans to conduct a study for formulating a master plan for the industrial estate and urban development area of Laem Chabang. Objectives of the Study will cover the industrial development propsect in future, especially, types, numbers and sizes of industry expected to move into the estate and the development plan of infrastructure facilities needed for the industrial and urban development. Industrial water demand projection in the present study, therefore, is conducted based on data and information available at present. The present projection is subject to refinement where necessary at the later stage when industrial development program becomes more concrete.

3.1.2 Type of Industry

In order to determine the types of industry to be introduced to the Laem Chabang industrial estate, the present study referred to the proposal by the "Eastern Seaboard, Industrial Opportunities Identification Study (hereafter called IOS)" by Coopers and Lybrand associates in 1982.

IOS puts forward the possible types of industry to be introduced to the Eastern Seaboard based on the analysis on international and domestic market prospect, labor intensity, international competitiveness and availability of local resources etc.

Industries related to Laem Chabang industrial estate consist of resource based industries, export processing industry, downstream manufacturing industry, ship repairing and services and other light industry. Specific types of industry for each category is shown in Table 1 together with proposed number of plants to be established at Laem Chabang industrial estate by 1991.

3.1.3 Methodology

(1) General

There are three types of methodology for industrial water demand projection in general, namely by (a) production value from industry (b) land area for industry and (c) number of workers.

For Laem Chabang industrial estate, available information is limited to the expected land area and target number of workers from industry. No information is available for production value expected from the estate.

The present study adopted the methodology by number of workers, since by this methodology more detailed information is available than the one by land area as to the time schedule of the expansion by each category of industry. Besides it is considered that increase in number of workers reflects the production increase and the resultant rise in water consumption more sensitively than the expansion of gross land area of the estate.

(2) Formula

Industrial Water Demand in year of 2001 is obtained by the following formula.

$$D_I = En \times UCn \times (1 - Rn) \times 365/(1 - UW)$$

where, D_I : Industrial water demand (m^3/yr)
En : Number of employee in 2001
UCn : Water consumption per employee (m^3/d/employee)
Rn : Rate of recycled water
UW : Rate of unaccounted for water

Concept of cyclical use of water is introduced in the present study. Certain portion of water used in the production process can be utilized repeatedly after treatment. Therefore water demand is the amount of water to be supplemented from outside of factory.

(3) Number of Employee

Number of employee can be obtained from both IOS and ESS and their figures roughly coincide with each other. The present study adopts the figure of ESS, since it provides more concrete information concerning the periodic increase of employment. Total volume of employment is presented by six categories of industry in every five year period until year 2001 as shown below.

Type of Growth	Industry Group	Year				Average Annual Growth Rate (%)
		1986	1991	1996	2001	
Natural	All industry	3,600	7,800	8,600	9,500	6.7
Induced	Downstream	250	1,250	2,500	4,000	20.3
	Light	250	1,400	3,550	7,800	25.8
	Export processing	0	2,000	5,000	11,000	18.6
	Agro-processing	250	250	250	250	0
Multi-plier	All industries	350	1,450	3,150	6,100	21.0
	Total	4,700	14,150	23,050	38,650	15.1

Source: ESS, Sector Studies "Industry"

In the present study, the four types of industry of induced growth are used as the basis of the projection.

Natural growth is expected to take place in the existing industries in the Laem Chabang area. They include Si Racha Park Estate located about 8 km east of Laem Chabang and ESSO Oil Refinery and Thai Oil Refinery both of which are situated on the northern part of Laem Chabang area adjacent to the planned industrial estate. Industrial water demand of these existing industries are obtained by the field survey and its result is presented in the Section 3.5.

Multiplier growth is expected to occur in the surrounding area of the planned industrial estate as a result of multiplier effect of government-oriented industrial development in the estate. Since it is difficult to identify specific types of these industries and its amount of water consumption will not be as big as to be treated independently, water demand of this category is assumed to be included in consumption per capita in domestic water demand.

All the types of industry in the Table 1 are reclassified into downstream, light, export processing and agro processing industries in order to obtain number of employee of each industry. The industries in the category of resource based and other light industries are classified as light industries. Ship service and repairs are excluded here and included in the port water demand.

In obtaining the number of employment of each plant, number of plant presented in Table 1 is applied to indicate weight. Therefore total number of employee in respective category is divided into each plant in proportion to the number of plant. Obtained number of employee in each plant is shown in Table 2.

(4) Unit Water Consumption

Data on water consumption per worker and per area is available from the water consumption data of the three existing industrial estates in Thailand, namely Ban Chan, Lat Krabang and Bang Poo. Total water consumption, total area, number of workers and unit water consumption in each estate are summarized as follows.

Industrial Estate	Water Consumption (m^3/d)	Number of Worker	Area (ha)	Unit Water Consumption per worker ($m^3/d/worker$)	per area ($m^3/d/ha$)
Bang Chan	2,846	5,863	74	0.49	38.46
Lat Krabang	1,488	3,202	100	0.46	14.88
Bang Poo	2,435	1,685	59	1.45	41.27
Total	6,769	10,750	233	0.63	29.05

It is deemed inappropriate, however, to apply these figures directly to the water demand projection since type and scale of industries expected to move into the Laem Chabang industrial estate is mostly not the same as the firms already established in the existing estates. Besides the number of factories is considered to be too small to be used as the statistical basis of unit water consumption.

Therefore, the present study adopted the statistical data of Japan for unit water consumption. Unit water consumption is assumd to be kept constant throughout the study period. Average water consumption per employee per day for each category is 2.8 m^3, 2.8 m^3, 6.0 m^3, 15.8 m^3 and 3.5 m^3 for light, export processing, downstream, agro processing and all the industries respectively. These rates include water used in the production process as well as water used for such non productive purposes as drinking, washing and flushing. Unit water consumption rate of each plant is presented in Table 2.

(5) Cyclical Use of Industrial Water

In the present study, cyclical use of water is assumed to increase in future in accordance with the progress of water saving technology.

In general, rate of recycling water varies considerably from industry to industry. Relatively high portion of water is recycled in industries producing such basic materials as steel and chemical products and the one related with processing and assembling of machines etc. On the contrary, the rate is low in such industries as food and apparel production. This difference is mainly due to the purpose of water use. In general, water for cooling and temperature controlling is easy to be recycled, while water for washing and water itself used as raw material requires high technology to be used cyclically.

In Japan, rate of water recycling increased quite rapidly in the recent two decades. The rate of recycling was only 36 % in 1965 for all the industries, but grew to 74 % in 1981.

In Thailand, at present, most industries are dependent on their own water resources for industrial water and cyclical use is not the common practice. In Laem Chabang industrial estate, however, it is expected that practice of water recycling will prevail in future. In this area, it is difficult to have own water resources and industries will have to be dependent on pipe water supply from waterworks. This situation will lead them to begin to adopt water recycling system for the purpose of cost saving.

In the present study, it is assumed that the rate of water recycling in Thailand will catch up with the present level of Japan in year 2001. Rate of water recycling is assumed to increase constantly for every 5 year period until 2001 as follows.

(Unit: %)

Industry Group	Year 1986	1991	1996	2001
Downstream Industry	0	11	22	34
Light Industry	0	17	34	50
Export Processing Industry	0	23	46	68
Agro Processing Industry	0	3	6	10
Total	0	14	31	50

Recycling rate in 2001 is the average rate of all the industries within a group expected to be introduced to the estate.

(6) Unaccounted for Water

Unaccounted for water is the difference between amount of water produced in the water works and the amount of water consumed by customers. This includes water loss in the distribution system and water consumeed in water works for treatment. The rate of unaccounted for water is assumed to be 15 % of the produced water in the present study. Although this rate seems rather low compared with the historical record of PWWA, the rate is set at this level in terms of target rate. This rate is considered possible to attain in consideration of actual records of such water works as Naklua-Pattaya which indicated only 10 % of unaccounted for water in 1982. This rate is appied for every type of water demand in the present study.

3.1.4 Projected Industrial Water Demand

Based on the methodology described in the previous section, future industrial water demand is projected for the year 2001 as shown in Table 2. For the previous years of 1986, 1991 and 1996, water demand is obtained by the following formula.

$$DIi = DI \times En(i) \times [1 - Rn(i)] / [En \times (1 - Rn)]$$

where, DIi: Water demand in intermediate year

DI : Water demand in 2001 (m^3/yr)

En : Number of employee in 2001

Rn : Rate of water recycling in 2001

Suffix (i) indicates the intermediate years

It is basically assumed that number of employee and rate of re-cycling of each plant grows at the same growth rate within the same category of industry.

Projected industrial water demand is presented for every five year period as below.

(Unit: $10^6 m^3$/yr)

Industry Group	Year 1986	1991	1996	2001	Average Annual Growth (%)
Downstream	0.6	2.8	5.0	6.8	17.6
Light	0.3	1.4	2.8	4.7	20.1
Export Processing	0	1.9	3.3	4.3	8.5
Agro Processing	1.7	1.6	1.6	1.5	-0.8
Total	2.6	7.7	12.7	17.3	13.5

Total industrial water demand is projected to grow rapidly in 15 years at an average annual growth rate of 13.5 %. The most rapid increase occurs between 1996 and 2001 when increase in employment is most prominent.

The most rapid increase is expected in light industries. This is due to the rapid increase of employment. Water demand of export processing zone grows relatively at a slow pace due to the high rate of water recycling in the export procesing industries. In 2001 downstream industries shares the largest proportion of 39 % in the total industrial water demand. This is the result of highly intensified water use of plastic related industries.

3.2 Domestic Water Demand

3.2.1 Methodology

Domestic water demand is calculated by the following formula.

$$Dd = Pn \times CPC \times SF \times 365/(1 - UW)$$

where, Dd : Domestic Water Demand (m^3/yr)

Pn : Population

CPC : Consumption per capita (m^3/d)

SF : Service Factor

UW : Rate of unaccounted for water

(1) Population

Historical and projected population in the Study Area is presented in Table 3 and summarized as follows.

(Unit: 1,000)

Basin	Year					Average Annual Growth (%)
	1982	1986	1991	1996	2001	
Laem Chabang	54.7	64.2	84.6	111.7	154.9	5.6
Pattaya	62.2	77.8	97.0	116.3	132.4	4.1
Total	116.9	142.0	181.6	228.0	287.3	4.8

Population for 1982 is estimated based on the actual population data in 1982 obtained from the local government office. Future population is derived from the population projection by ESS.

Population of the Pattaya Basin includes the population of Bang Lamung sanitary district which is located in the Laem Chabang Basin. This adjustment is made based on the future water supply development plan of Provincial Water Works Authority (PWWA). In its five year development plan, Bang

Lamung sanitary district (SD) is planned to start receiving pipe water supply from the Naklua-Pattaya waterworks.

(2) Water Consumption Per Capita

Rate of water consumption per capita varies with such factors as living standard, water tariff, and prevalence rate of washing machine, flushig system and bath. It is possible to determine the future rate of water consumption per capita by taking all these factors into account, when sufficient data is available and future situation of water use can be foreseen. In the present study, however, an analysis to that degree of detail is not conducted because of the scarcity of relevant information. Future consumption per capita is determined based on the currently prevailing rate in Thailand and assumed growth rate in future.

Table 4 presents the statistical data regarding consumption per capita. Listed 14 waterworks belong to the Region 1, which covers 5 provinces of Chachoengsao, Chon Buri, Rayong, Trad and Chantaburi, by the regional classification of PWWA. According to this, average consumption rate of the 14 waterworks is 188 liter per capita per day (lcd). When focusing on the waterworks with served population of more than 10,000 except Naklua-Pattaya, the figure goes down to 173 lcd. In the present study, 180 lcd is applied as per capita consumption rate for Laem Chabang DA and Bang Lamung SD in consideration of the data above. For Pattaya DA, 250 lcd is applied with reference to the standard rate of Bangkok considering the existence of many tourism related service industries in Pattaya.

The rate of consumption per capita is considered to comprise portions of residential water use and commercial and institutional use in such facilities as office, school, hospital, other public facilities and service industries. The latter is included in the domestic water demand, since its amount is deemed too small to be projected independently and it is reasonable to assume that water demand of this type will increase along with the population increase.

A survey by Metropolitan Water Works Authority (Ref. 5) reports that in Bangkok area, 146 lcd out of 250 lcd of consumption per capita is regarded as for residential use. From this it is assumed that 180 lcd in Laem Chabang DA and Bang Lamung SD is devided into 140 lcd of residential use and 40 lcd of commercial and institutional use. In Pattaya DA, 110 lcd out of 250 lcd or 44 % is regarded as water for commercial and institutional use. In non-development aras, commercial and institutional use is deemed to be neglegibly small and the rate of consumption per capita is assumed to be 140 lcd.

In future, consumption per capita is expected to grow in accordance with economic development and upgrading of living standard. Assuming the average annual growth rate of 1 %, consumption per capita is set until 2001 as follows.

(Unit: lcd)

Area	Year				
	1982	1986	1991	1996	2001
Laem Chabang DA and Bang lamung	180	190	200	210	220
Pattaya DA	250	265	280	290	300
Non-development Area	140	148	155	163	170

(3) Service Factor

Service factor is the ratio of the population supplied with pipe water service to the total population in the service area.

In the present study, service factor is assumed until year 2001 as follows.

(Unit: %)

Area	Year			
	1986	1991	1996	2001
Dovelopment Area	100	100	100	100
Non-development Area	10	15	20	30

This is rather a target rate than a rate to be attained as a result of the present growth trend. Timely development of infrastructure facilities including water supply in development areas is the pre-requisite for the smooth implementation and promotion of industrial and urban development in Laem Chabang and tourism development in Pattaya. It is especially so for Laem Chabang since success in the development there depends much on the responsiveness of the private sector.

Service factor of non-development areas is assumed in consideration of the well balanced development of the water supply facilities in the Study Area.

3.2.2 Projected Domestic Water Demand

Projected domestic water demand is presented in Table 3 and summarized as follows.

(Unit: 10^6 m^3/yr)

Basin	Year					Average Annual
	1982	1986	1991	1996	2001	Growth Rate (%)
Laem Chabang	0.4	2.7	4.5	7.3	12.1	19.7
Pattaya	1.7	6.6	9.2	11.9	14.8	12.0
Total	2.1	9.3	13.7	19.2	26.9	14.3

Total domestic water demand grows at an average annual growth rate of 14.3 % and reaches 26.9 x $10^6 m^3$ per year in 2001. The most prominent increase will take place in the Laem Chabang DA where rapid industrial expansion is planned.

3.3 Port Water Demand

Port water demand is classified into two categories; one for such port activities as loading and unloading, general administration and such port related industries as ship repair and services and the other for ship use. Port water demand is calculated by the following formula.

$$Dp = [(W \times UCw) \times 365 + (Cv \times UCc)] / (1 - UW)$$

where,

Dp	:	Port water demand (m^3/yr)
W	:	Number of workers at port
UCw	:	Water consumption per worker (m^3/day)
Cv	:	Cargo handling volume ($10^6 ton/yr$)
UCc	:	Water consumption per cargo volume ($m^3/t/yr$)
UW	:	Rate of unaccounted for water

(W x UCw) is for port activities and (Cv x UCc) is for ship use.

Figures for each factor and obtained port water demand is presented for 1991 as follows.

Number of worker	;	2,800
Water consumption per worker	;	0.15 $m^3/d/worker$
Cargo handling volume	;	3.1 x $10^6 t/yr$
Water consumption per cargo	;	4.1 liter/t/yr
Unaccounted for water	;	15 %
Port Water Demand	;	195.3 x $10^3 m^3/yr$

Port water demand for 1991 is projected at 0.2 x $10^6 m^3/yr$. Data on number of worker is obtained from the National Housing Authority (NHA). NHA is considered to have made the estimate for number of workers for the planning of the future housing development program. Water consumption per worker and per cargo volume are derived from the rate applied in the master plan study for the Development of Map Ta Phut Port by JICA (Ref. 7).

Projected cargo volume in future is obtained from the Feasibility Study for the Laem Chabang Port by Louis Berger International (Ref. 6). However, its figure is the total cargo handling volume of the Bangkok Port and Laem Chabang Port. The portion for the Laem Chabang Port, therefore, is obtained by subtracting the expected cargo handling capacity of Bangkok Port from the projected cargo volume. At present, approximately 4.8×10^6t/yr is handled at Bangkok Port, while its capacity is 5.3×10^6t/yr. The Port Authority of Thailand (PAT) has a plan to expand the port to the cargo handling capacity of $6.5 \times 10^6 m^3$/yr by 1985. By subtracting this from the total projected cargo volume, cargo throughput at Laem Chabang Port is projected to be 3.1×10^6t/yr, 6.3×10^6t/yr and 9.0×10^6t/yr for 1991, 1996 and 2001 respectively. Port water demand for the year 1996 and 2001 is considered to grow in proportion to the increase of cargo throughput and obtained as follows.

Item	Unit	Year 1991	Year 1996	Year 2001
Cargo throughput	10^6t/yr	3.1	6.3	9.0
Port Water Demand	$10^6 m^3$/yr	0.2	0.4	0.5

3.4 Tourism Water Demand

Tourism water demand is obtained by the following formula.

$$Dt = T \times Ct \times 365/(1 - UW)$$

where,
- Dt . Tourism water demand (m^3/yr)
- T : Number of tourist
- Ct : Water consumption per tourist (lcd)
- UW : Rate of unaccounted for water

Number of tourists who visited Pattaya have increased remarkably these years as summarized below.

Year	Number of Hotel arrival
1979	386,400
1980	476,600
1981	505,800
1982	599,500

Average length of stay was 5.58 days for foreign and Thai tourist to Pattaya in 1982. It is prospectd in the Fifth National Plan that the number of tourist will increase at an average annual growth rate of 8.4 % and the length of stay per tourist will grow from present 5.1 days to 5.5 days in 1986 as a nation whole.

Concerning the future prospect on number of tourist and average length of stay in Pattaya, two studies provides information, namely, "Pattaya Tourism Development" by JICA in 1978 and Eastern Seaboard Study in 1982. In the present study, forecast figure of ESS is applied to water demand projection, since ESS is conducted more recently and its forecast is considered to be based on more updated information. Forecast number of arrivals, average length of stay and average number of tourist are shown in Table 5. Average number of tourist is given as below. .

Year	Average Number of Tourist
1982	9,200
1986	12,600
1991	18,100
1996	24,800
2001	30,900

Water consumption per tourist is assumed to be 400 liter per day throughout the study period based on the general rate of Japan which is between 300 and 500 liter per day. This rate includes water use in hotels for customer and such hotel facilities as restaurant and pool.

Unaccounted for water is assumed to be 15 %. It is assumed that all the tourists to Pattaya will be provided with pipe water supply throughout the study period. Projected tourism water demand is presented in Table 6 and summarized below.

Year	Tourism Water Demand ($10^6 m^3/yr$)
1982	1.6
1986	2.2
1991	3.1
1996	4.3
2001	5.3

3.5 Water Demand of Existing Industry

Field survey was conducted during the study in order to identify existing and planned large scale water consumers in the Study Area. As a result, five factories were identified; namely Thai Oil Refinery, ESSO Oil Refinery, Si Racha Park Estate, Si Racha Sugar Factory and Kho Chang Cassava Industry. Through interview with these factories, information was collected on present water use, future expansion plan, anticipated water consumption after expansion and water source as presented in Table 7. It is clarified that water demand of existing industry will grow from 2.9 x $10^6 m^3/yr$ in 1982 to 6.5 x $10^6 m^3$ in 1991 and thereafter, as summarized below.

(Unit: 10^6 m^3/yr)

Basin	1982	1986	1991	1996	1001
Laem Chabang	2.9	3.6	5.6	5.6	5.6
Pattaya	0	0.9	0.9	0.9	0.9
Total	2.9	4.5	6.5	6.5	6.5

3.6 Total Water Demand

Total water demand is presented in Table 8 and Fig. 2 and summarized as follows.

(Unit: 10^6 m^3/yr)

Basin	1982	1986	1991	1996	2001	Average Annual Growth Rate (%)
Laem Chabang	3.3	8.9	18.0	26.0	35.5	13.4
Pattaya	3.3	9.7	13.2	17.1	21.0	10.2
Total	6.6	18.6	31.2	43.1	56.5	12.0

Total water demand of the Study Area grows rapidly at an average annual growth rate of 12.0 % and reaches 56.5 x $10^6 m^3/yr$ in 2001. This rapid increase of water demand is mainly the result of rapid devleopment induced by the government in the industrial estate and urban ara of Laem Chabang and tourism oriented urban development in Pattaya.

After consumer water demand presented in this sectoral report is adjusted to source water demand by taking into account the water loss between intake and water works, projected water demand will serve as the basis of regional water demand and supply balance study.

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6. FEASIBILITY STUDY OF THE DEVELOPMENT OF LAEM CHABANG PORT, LOUIS BERGER INTERNATIONAL INC. DECEMBER 1982

7. DRAFT FINAL REPORT FOR THE DEVELOPMENT PROJECT OF THE INDUSTRIAL PORT ON THE EASTERN SEABOARD IN THE KINGDOM OF THAILAND (PAHSE II) JAPAN INTERNATIONAL COOPERATION AGENCY, SEPTEMBER 1983

TABLES

Table 1 TYPE OF INDUSTRY AND NUMBER OF PLANT TO BE INTRODUCED TO THE LAEM CHABANG INDUSTRIAL ESTATE BY 1991

Category	Type of Industry	Number of Plant
Resource based	Animal feeds production	1/1
	Leather goods manufacture	5
	Rubber products	2
	Plywood and veneer	3
Export processing	Electronics	5
	Machinery	1
	Aluminum products	1
	Pharmaceutical	1
	Cosmetics	1
	Jewelry	1
	Watch and clock	1
	Toys and games	1
	Sports goods	1
Downstream	Plastic products	7
Ship services and reparis	-	1
Other light industry	Small scale energy intensive industry/2	26

/1 : Large scale

/2 : Includes structural product such as brick and clay, ice, noodles, bread, cake and confectionery, paper product, joint materials, general engineering works, hand and edge tools and metal household utensils.

Table 2 PROJECTED WATER DEMAND FOR INDUCED INDUSTRIES IN 2001

Types of Industries	En	Uc	Rn	Uw	Projected Demand ($10^3 m^3/yr$)
Downstream Industry					6,778
1. Plastic product for export/1	3,000	4.26	0.40	0.15	3,293
2. Plastic (feedstock processing)/2	500	14.93	0.20	0.15	2,564
3. Plastic (for packing)	500	7.15	0.40	0.15	921
Light Industry					4,690
1. Leather product	1,040	0.35	0.30	0.15	109
2. Rubber product	470	9.60	0.80	0.15	388
3. Wooden product/3	650	1.62	0.30	0.15	317
4. Structural product/4	470	1.74	0.20	0.15	281
5. Ice	470	4.90	0	0.15	989
6. Noodles	470	2.30	0.10	0.15	418
7. Bread	470	2.38	0.70	0.15	144
8. Cake and confectionery	470	3.13	0.30	0.15	442
9. Paper product	470	3.00	0.30	0.15	424
10. Joint materials/5	470	1.14	0.30	0.15	161
11. General engineering works	470	1.56	0.30	0.15	220
12. Hand and edge tools	470	1.56	0.30	0.15	220
13. Metal household effects	470	1.45	0.20	0.15	234
14. Motor vehicle parts	470	7.30	0.90	0.15	147
15. Marine engines and parts	470	3.23	0.70	0.15	196
Export Processing Industry					4,291
1. Electronics	4,600	3.22	0.80	0.15	1,272
2. Machinery	800	1.17	0.50	0.15	201
3. Aluminium product	800	2.73	0.30	0.15	657
4. Pharmaceutical	800	12.02	0.70	0.15	1,239
5. Cosmetics	800	1.53	0.40	0.15	315
6. Jewelry	800	0.33	0	0.15	113
7. Watch and clock	800	1.08	0.60	0.15	148
8. Toys and games	800	0.38	0.10	0.15	118
9. Sports goods	800	0.95	0.30	0.15	228
Agro-processing Industry	250	15.77	0.10	0.15	1,520
Total					17,279

/1 : Such as plastic flower, toys and sports goods
/2 : Artificial leather etc.
/3 : Veneer and plywood
/4 : Brick, tiles and clay
/5 : Bolts, nuts, rivets and screw machine parts

Note; En: number of employee
Uc: water consumption per employee, m^3/employee/day
Rn: rate of recycling
Uw: rate of unaccounted for water

Table 3 PROJECTED POPULATION AND DOMESTIC WATER DEMAND

Description	Unit	1982	1986	1991	1996	2001
Laem Chabang Basin						
1. Development area						
Population	10^3	23.9	30.2	47.4	75.3	119.5
Consumption rate	lcd	-	190	200	210	220
Service factor	%	-	100	100	100	100
Unaccounted for water	%	-/1	15	15	15	15
Water demand	$10^3m^3/yr$	437	2,464	4,071	6,790	11,289
2. Non-development area						
Population	10^3	30.8	34.0	37.2	36.4	35.3
Consumption rate	lcd	-	148	155	163	170
Service factor	%	-	10	15	20	30
Unaccounted for water	%	-	15	15	15	15
Water demand	$10^3m^3/yr$	0	216	371	509	773
3. Bang Lamung S/D						
Population	10^3	8.2	8.4	9.1	10.4	11.4
Consumption rate	lcd	-	190	200	210	220
Service factor	%	-	100	100	100	100
Unaccounted for water	%	-	15	15	15	15
Water demand	$10^3m^3/yr$	0	685	781	938	1,077
Pattaya Basin						
1. Development area						
Population	10^3	38.4	51.4	67.9	85.8	103.0
Consumption rate	lcd	-	265	280	290	300
Service factor	%	-	100	100	100	100
Unaccounted for water	%	-/2	15	15	15	15
Water demand	$10^3m^3/yr$	1,748	5,849	8,164	10,685	13,269
2. Non-development area						
Population	10^3	15.6	18.1	20.0	20.1	18.0
Consumption rate	lcd	-	148	155	163	170
Service factor	%	-	10	15	20	30
Unaccounted for water	%	-	15	15	15	15
Water demand	$10^3m^3/yr$	0	115	200	281	394
Total Water Demand	$10^3m^3/yr$	2,185	9,329	13,587	19,203	26,802

/1 : Actual water supply by Ao Udom waterworks
/2 : Actual water supply by Naklua-Pattaya waterworks

Data Source: IOS, ESS

Table 4 RECORD OF WATER CONSUMPTION PER CAPITA AND UNACCOUNTED FOR WATER IN 1982

Water Works	Produced Water (m^3/d)	Consumed Water/1 (m^3/d)	Unaccounted for Water		Served Population	Consumed Water per capita(lcd)
			Amount (m^3/d)	Rate (%)		
1. Chon Buri	37,871	20,758	17,113	45.2	110,122	189
2. Ban Bung	284	241	43	15.1	2,220	109
3. Phanat Nikhom	1,326	1,136	190	14.3	8,010	142
4. Naklua Pattaya	9,118	8,162	956	10.5	12,855/2	635
5. Chachoengsao	6,355	3,824	2,531	39.8	23,514	163
6. Bang Kla	822	690	132	16.1	4,360	158
7. Panom Sarakam	1,204	661	543	45.1	4,296	154
8. Bang Pakong	1,930	1,271	659	34.1	6,450	197
9. Rayong	6,072	4,127	1,945	32.0	21,360	193
10. Paknam Prasae	559	504	55	9.8	6,720	75
11. Chantaburi	9,719	7,274	2,445	25.2	48,210	151
12. Klung	1,100	852	248	22.5	8,620	99
13. Trad	2,277	1,838	439	19.3	15,150	121
14. Khlong Yai	601	464	137	22.8	3,140	148
Total	79,238	51,802	27,436	34.6	275,027	188

/1 : This includes water sold to private and public consumer and supplied free of charge to public facilities.

/2 : This does not include tourist.

Note: Water works in the Region 1 according to the classification of PWWA are listed.

Data Source : PWWA.

Table 5 NUMBER OF TOURIST TO PATTAYA

Item		Year 1982/1	1986	1991	1996	2001
Number of Arrival to Eastern Seaboard	Foreign	450,000	644,500	903,900	1,209,600	1,543,800
	Thai	149,500	244,100	319,000	395,600	465,100
	Total	599,500	888,600	1,222,900	1,605,200	2,008,900
Average Length of stay	Foreign	-	6.75	7.25	7.75	8.25
	Thai	-	3.30	3.85	4.40	5.00
	Total	5.58/2	5.80	6.36	6.92	7.49
Average Number of tourist (tourist/day)	Foreign	-	11,900	18,000	25,700	34,900
	Thai	-	2,200	3,400	4,800	6,300
	Total	9,200	14,100	21,400	30,500	41,200
Portion to Pattaya	(%)	-	89.4	84.7	81.3	75.0
Average Number of Tourist to Pattaya	(tourist/day)	9,200	12,600	18,100	24,800	30,900

/1 : Actual figure

/2 : Data is available only for total.

Data Source : ESS, Sector Studies "Tourism"

Tourism Authority of Thailand

Table 6 PROJECTED TOURISM WATER DEMAND

Item	Unit	Year 1982	1986	1991	1996	2001
Number of Tourist	person/day	9,200	12,600	18,100	24,800	30,900
Unit Water Consumption	lcd	400	400	400	400	400
Unaccounted for Water	%	15	15	15	15	15
Tourism Water Demand	$10^3 m^3/yr$	1,580.2	2,164.2	3,108.9	4,259.8	5,307.5

TABLE 7 FUTURE WATER DEMAND OF EXISTING INDUSTRY

Factory	Water Consumption in 1982 ($10^3 m^3/yr$)	Water Consumption After expansion ($10^3 m^3/yr$)	Year of Expansion	Present Water Source	Future Water Source
Laem Chabang Basin					
Thai Oil Refinery	857	2,000	1987	Bang Phra	Bang Phra
Esso Oil Refinery	788	1,546	1985	Sea Water	Sea Water
Si Racha Park Estate	412	1,289	1987	Ground Water & Stream	Nong Kho
Si Racha Sugar Factory	800	800	-	Stream	Nong Kho
Pattaya Basin					
Kho Chang Cassava Industry	0	858	1986	-	Map Prachan

Table 8 PROJECTED TOTAL WATER DEMAND

(Unit: $10^6 m^3/yr$)

Description		1982	1986	1991	1996	2001
Laem Chabang Basin		3.3	8.9	18.0	26.0	35.5
Industry,	induced	0	2.6	7.7	12.7	17.3
	existing	2.9	3.6	5.6	5.6	5.6
Domestic,	development area	0.4	2.5	4.1	6.8	11.3
	non-development area	0	0.2	0.4	0.5	0.8
Port		0	0	0.2	0.4	0.5
Pattaya Basin		3.3	9.7	13.2	17.1	21.0
Industry,	existing	0	0.9	0.9	0.9	0.9
Domestic,	development area	1.7	5.8	8.2	10.7	13.3
	non-development area	0	0.1	0.2	0.3	0.4
	Bang Lamung S/D	0	0.7	0.8	0.9	1.1
Tourism		1.6	2.2	3.1	4.3	5.3
Study Area		6.6	18.6	31.2	43.1	56.5
Industry,	induced	0	2.6	7.7	12.7	17.3
	existing	2.9	4.5	6.5	6.5	6.5
Domestic,	development area	2.1	8.3	12.3	17.5	24.6
	non-development area	0	0.3	0.6	0.8	1.2
	Bang Lamung S/D	0	0.7	0.8	0.9	1.1
Port		0	0	0.2	0.4	0.5
Tourism		1.6	2.2	3.1	4.3	5.3

Note: Figures are indicated in terms of consumer demand.

FIGURES

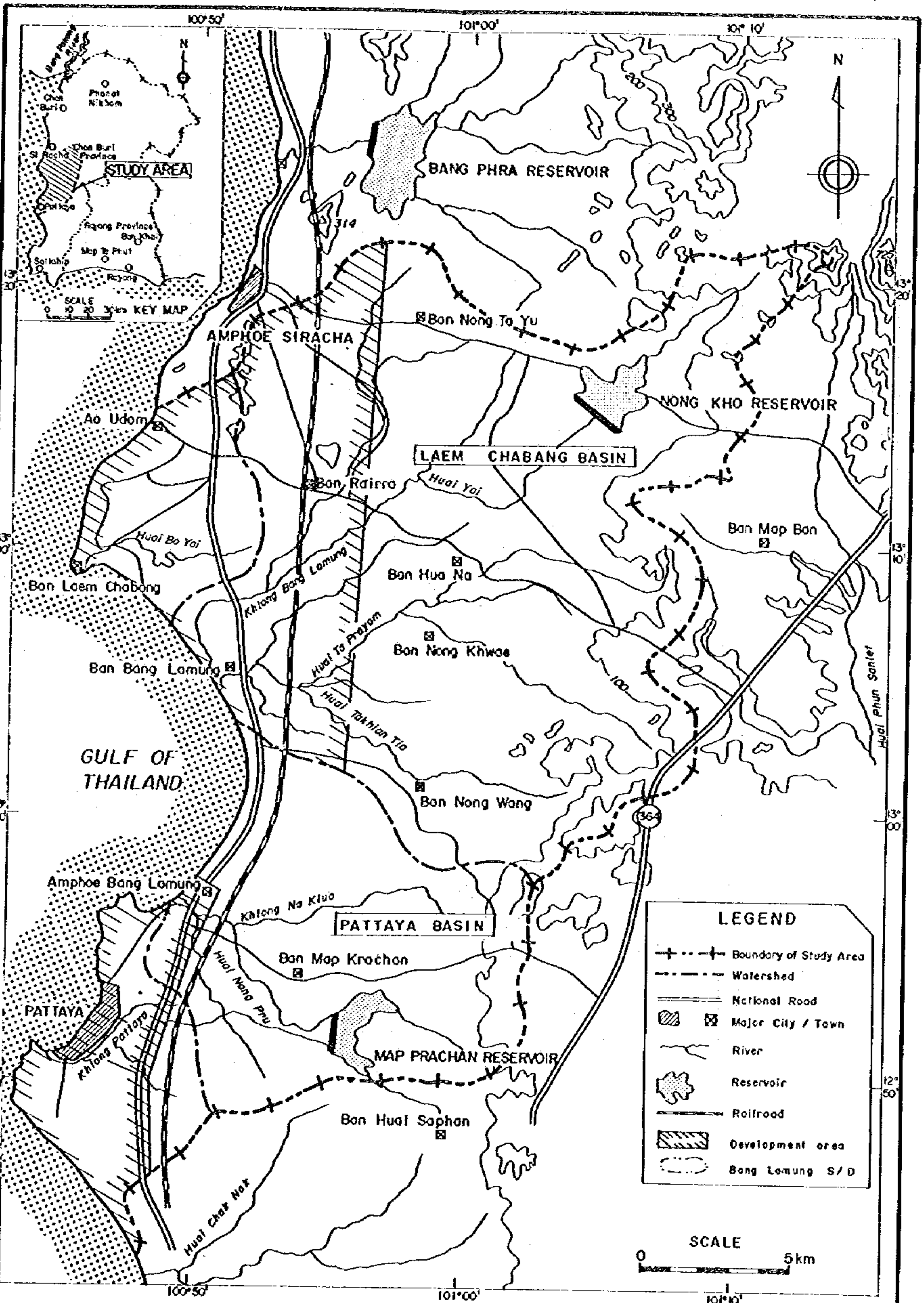

Fig. 1 Map of Study Area

KINGDOM OF THAILAND
NONG KHO – LAEM CHABANG WATER PIPELINE PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

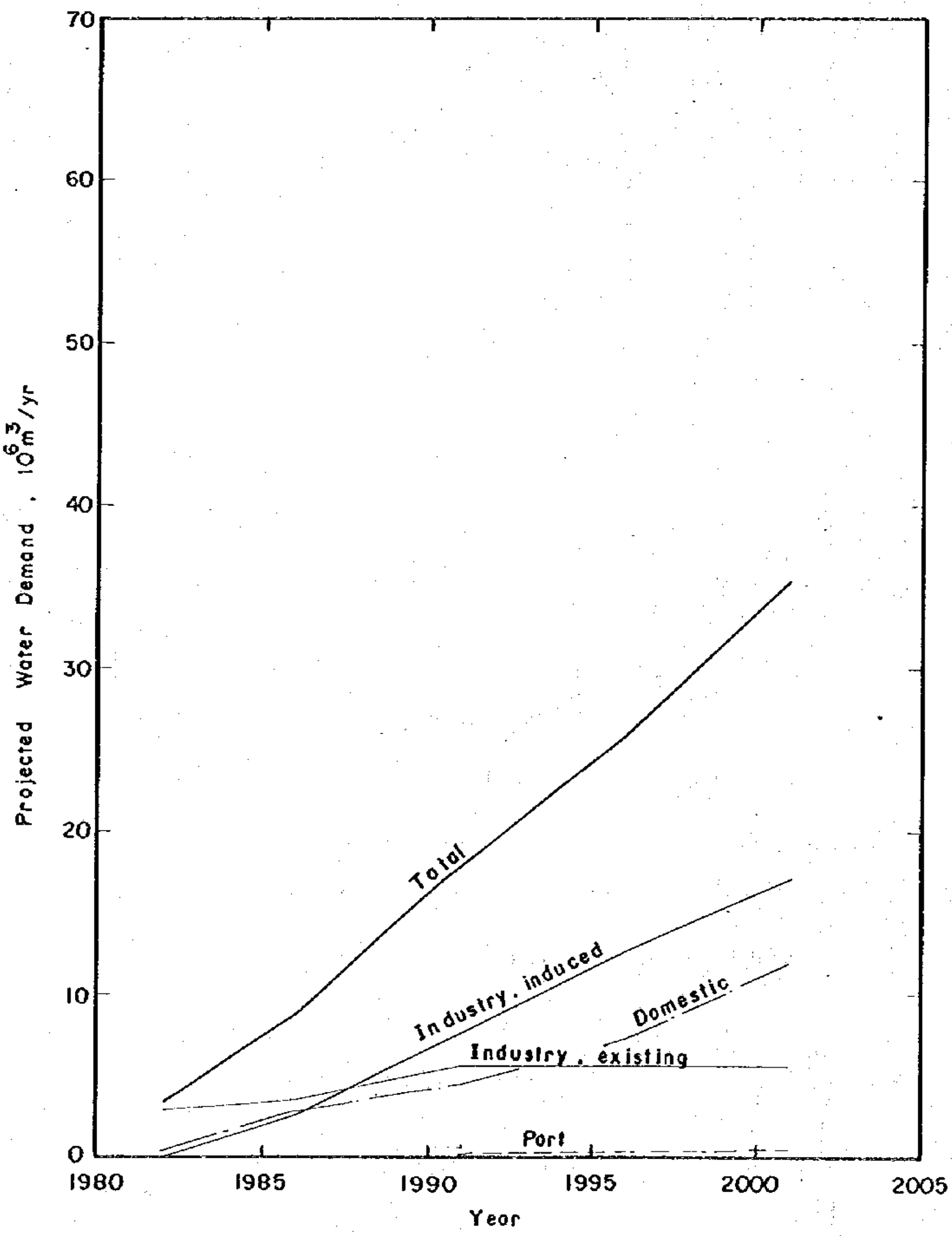

Fig. 2 (1) Projected Water Demand, Laem Chabang Basin

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NONG KHO – LAEM CHABANG WATER PIPELINE PROJECT
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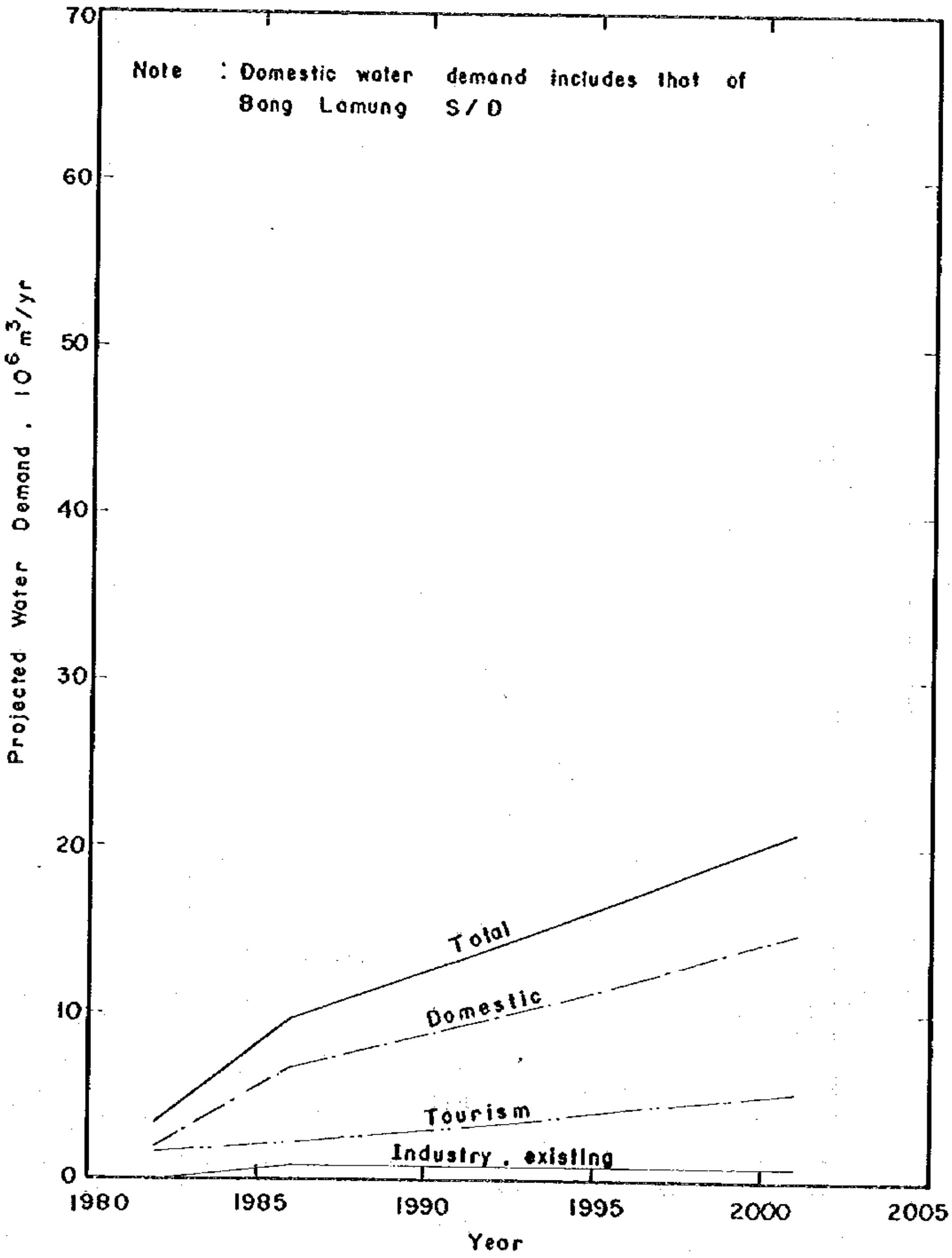

Fig. 2 (2) Projected Water Demand, Pattaya Basin.

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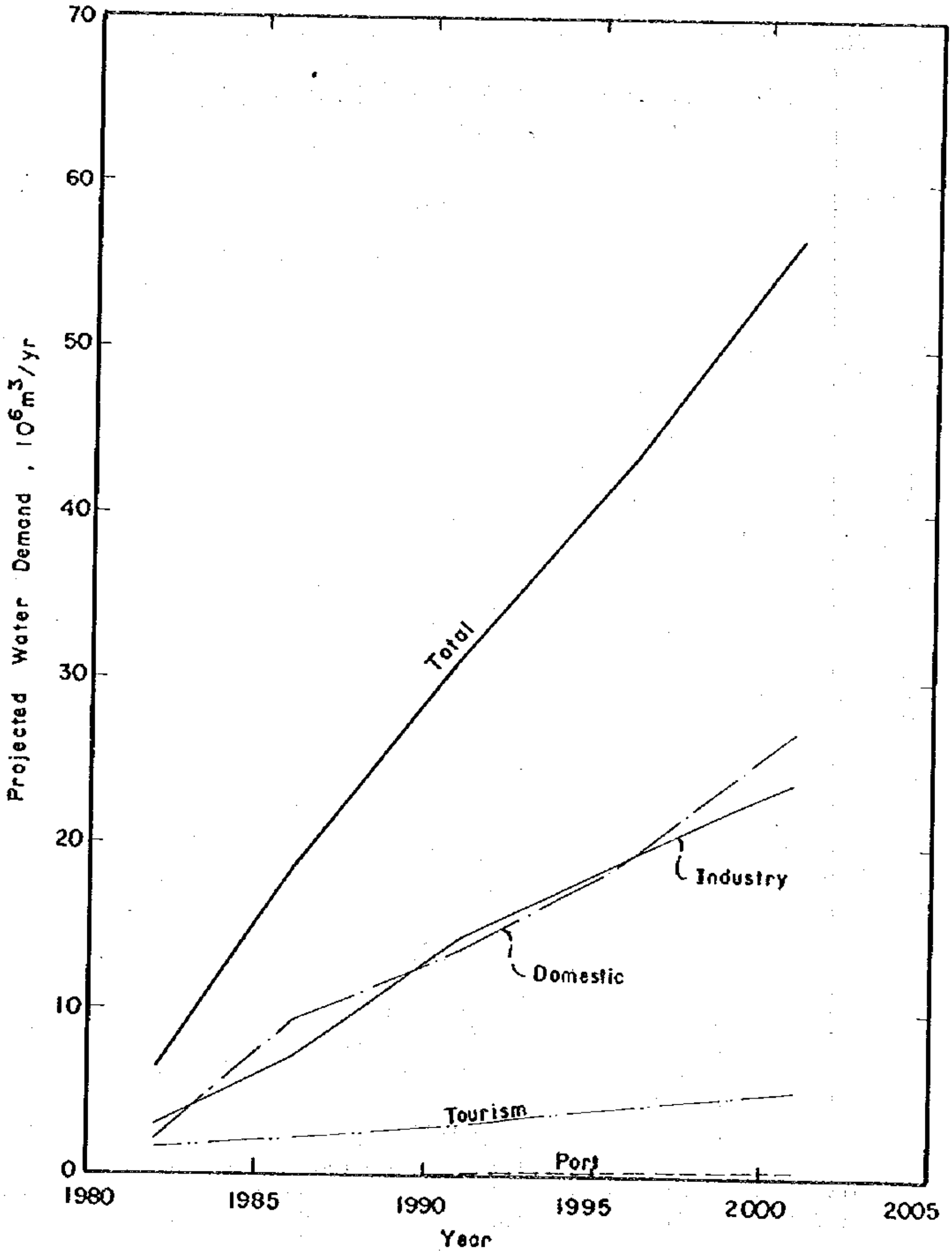

Fig. 2(3) Projected Water Demand, Study Area

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SUPPORTING REPORT V
ENGINEERING DATA AND PRICED BILL OF QUANTITY

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1. INTRODUCTION

This supporting report compiles the results of hydraulic examination and the priced Bill of Quantity of the proposed raw water pipeline system.

The hydraulic examination consists of loss head calculation and water hammer analysis of the pipeline system. The loss head calculation was conducted by either the Hazen-Williams and Manning's formulas. Both formula resulted in almost the same head loss. The water level in the receiving well was determined by deducting the loss head through the pipeline system from the designed low water level in Nong Kho reservoir.

Priced bill of quantity is prepared for the proposed raw water pipeline system based on the established unit price of each work item and estimated construction quantity.

2. DETERMINATION OF WATER LEVEL

2.1 Loss Head Calculation by Hazen-Williams Formula

(i) Given Conditions

		Pipe by Diameter		
		ø600	ø1,000	ø900
Length of Pipe	(m)	93.2	10,950	3,490
Cross Sectional Area	(m^2)	0.283	0.785	0.636
Discharge (1st)	(m^3/s)	0.82	0.82	0.74
(2nd)	(m^3/s)	0.82	0.82	0.82
Velocity (1st)	(m/s)	2.90	1.04	1.16
(2nd)	(m/s)	2.90	1.04	1.29

(ii) Equation

$$hf = 10.666\ C^{-1.85}\ D^{-4.87}\ Q^{1.85}\ L$$

where, hf: Loss head (m)
C : Coefficient of velocity, assumed (110)
D : Diameter of pipe (m)
Q : Discharge (m^3/s)
L : Length of pipe (m)

(iii) Loss Head

	Loss Head by Pipe (m)			
Loss Head	ø600	ø1,000	ø900	Total
1st Stage	1.39	13.53	5.96	20.88
2nd Stage	1.39	13.53	7.21	22.12

2.2 Loss Head Calculation by Manning Formula

(i) Coefficient of Loss

	Coefficient of Loss	Occurrence of Loss ø600	Occurrence of Loss ø1,000	Occurrence of Loss ø900
a. Entrance (fe)	0.5	*	-	-
b. Bend (fb)				
90°	1.12	-	-	5
78°	0.88	-	-	1
72°	0.63	-	1	-
58°	0.42	-	-	1
53°45'	0.33	-	-	-
52°	0.32	-	-	1
46°45'	0.25	-	1	-
45°	0.24	4	31	13
33°45'	0.14	-	1	-
33°	0.13	-	1	-
27°30'	0.10	-	-	1
27°	0.10	-	-	1
23°30'	0.08	-	1	-
22°30'	0.07	-	10	-
18°30'	0.06	-	-	1
16°30'	0.05	-	-	1
11°15'	0.03	-	5	7
9°	0.03	-	-	1
8°45'	0.03	-	-	1
7°	0.02	-	1	1
5°30'	0.02	-	1	-
c. Valve (fv)				
- butterfly	0.3	-	4	7
- sleeve	5.5	-	-	1
d. Branch (f_L)	-0.01	-	*	-
e. Gradual expansion (fge)	0.032	*	*	-
f. Friction n	0.012	*	*	*
g. Outlet fo	1	-	-	*

Notes: (1) Loss head occurs where a mark with * is shown.

(2) Figures express the number of bends and valves.

(ii) Loss Head

Item	Equation	Loss Head (m) 1st Stage	2nd Stage
Entrance Loss	$he = 0.051\ feV^2$	0.21	0.21
Bend Loss	$hb = 0.051\ \Sigma fbV^2$	0.33	2.58
Valve Loss	$hv = 0.051\ \Sigma fvV^2$	0.59	0.71
Loss due to Branch	$hr = 0.051\ f_L V^2$	0	-
Loss of Gradual Expansion	$hge = 0.051\ fge\ (V_2-V_1)^2$	0.06	0.06
Friction Loss	$hf = 6.350\ \Sigma \frac{n^2 L\ V^2}{D^{4/3}}$	17.33	18.53
Outlet Loss	$ho = 0.051\ foV^2$	0.07	0.08
Total		20.59	22.18

2.3 Water Level of Receiving Well

(i) By Hazen-Williams' formula

WL of receiving well = El. 58.9 - 22.12 ≑ El. 36.7 m

(ii) By Manning's formula

WL of receiving well = El. 58.9 - 22.18 ≑ El. 36.7 m

Based on the above calculation, water level of receiving well is determined at El. 36.7 m.

3. WATER HAMMER

3.1 Propagation Velocity

(i) Equation

$$a = \frac{1425}{\sqrt{1 + \frac{K}{E} \cdot \frac{D}{e}}}$$

where; a: Propagation velocity (m/sec)

K: Volume modulus of water (2.07×10^8 kg/m^2)

E: Elastic modulus of pipe (2.1×10^{10} kg/m^2)

D: Diameter of pipe (0.6, 1.0, 0.9 m)

e: Width of pipe (0.0079, 0.0095, 0.006 m)

(ii) Velocity of dynamic water pressure

	Diameter of Pipe		
	ø600	ø1,000	ø900
a (m/s)	1,011.3	998.3	978.0

$$\bar{a} \text{ (mean velocity)} = \frac{\Sigma\, Li}{\Sigma\left(\frac{Li}{ai}\right)}$$

$$= \frac{14,533.2}{\frac{93.2}{1,011.3} + \frac{10,950}{998.3} + \frac{3,490}{978.0}}$$

$$= 993.4 \text{ m/sec}$$

3.2 Equivalent Closed Time of Valve

(i) Equation

$$Q = 3.477\, D^2 \sqrt{\frac{Ha}{fe + \Sigma\, fb + \Sigma fv + f_1 + fge + fo + \Sigma \frac{n^2 . L . 2g}{(\frac{D}{4})^{4/3}}}}$$

Ha: Total loss head (22.2 m)

D : Diameter of Pipe

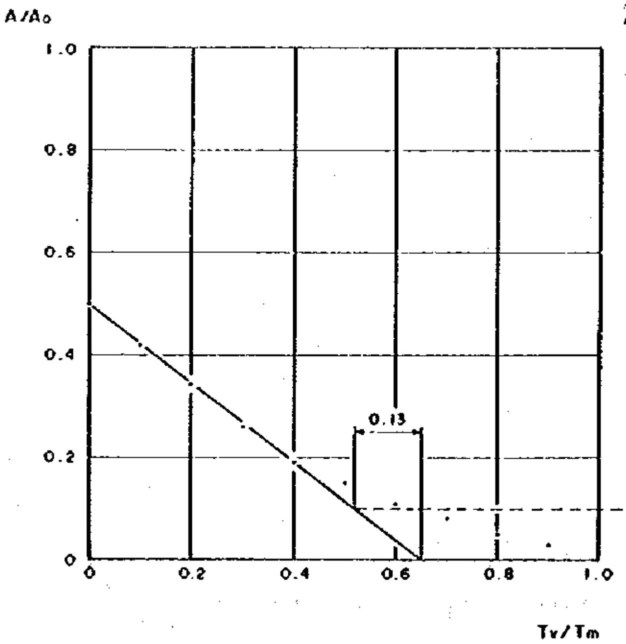
(ii) Valve Opening - Discharge Relation of Sleeve Valve

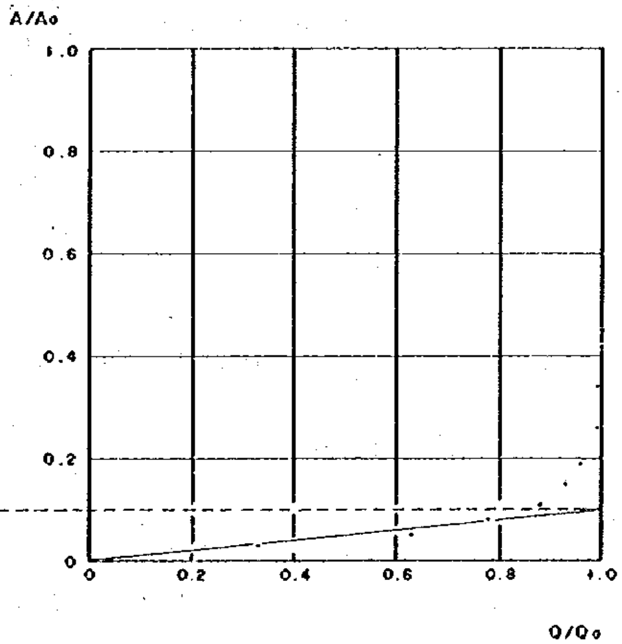
T/Tm	fu	Q	Q/Qo /1	Q/Ao /2
0	5.5	0.82	1.00	0.50
0.1	7.5	0.82	1.00	0.42
0.2	11	0.81	0.99	0.34
0.3	19	0.81	0.99	0.26
0.4	36	0.79	0.96	0.19
0.5	60	0.76	0.93	0.15
0.6	115	0.72	0.88	0.11
0.7	230	0.64	0.78	0.08
0.8	550	0.52	0.62	0.05
0.9	3,000	0.27	0.33	0.03
1.0	∞	0	0	0

/1: Qo = 0.82 m^3/s

/2: Ao is cross sectional area of .full opened valve

The aove results are summarized below.





From the above figure, equivalent closed time (Tv) is given by the following equation.

$$Tv = 0.13\ Tm$$
$$= 0.13 \times 15 \times 60$$
$$= 117 \text{ seconds}$$
$$Tv > L/300 = 48$$

$$Tv > 2L/\bar{a} = 29$$

where, Tm: closing time

Based on the above result, the water hammer of the pipeline system can be computed by the Allievi's equation (slow closed).

3.3 Calculation of Water Hammer

(i) Equation by Allievi

$$\frac{Hmax}{Ha} = \frac{K1}{2} + \sqrt{K1 + \frac{K1^2}{4}}$$

$$\frac{-Hmax}{Ha} = \frac{K1}{2} - \sqrt{K1 + \frac{K1^2}{4}}$$

$$K1 = \left(\frac{L.(V1 - V2)}{g.Ha.Tv}\right)^2$$

where, Hmax: maximum water hammer

Ha : total loss of head (22.2 m)

V1 : mean velocity (1.112 m/sec)

$$V1 = \frac{\Sigma Li}{\Sigma(\frac{Li}{Vi})}$$

V2 : velocity after valve closed (0 m/s)

L : total length of pipe (14,533.2 m)

(ii) Calculation of water hammer

$$Kl = \left[\frac{14{,}533.2 \times (1.112 - 0)}{9.8 \times 22.2 \times 117}\right]^2$$

$$= 0.40$$

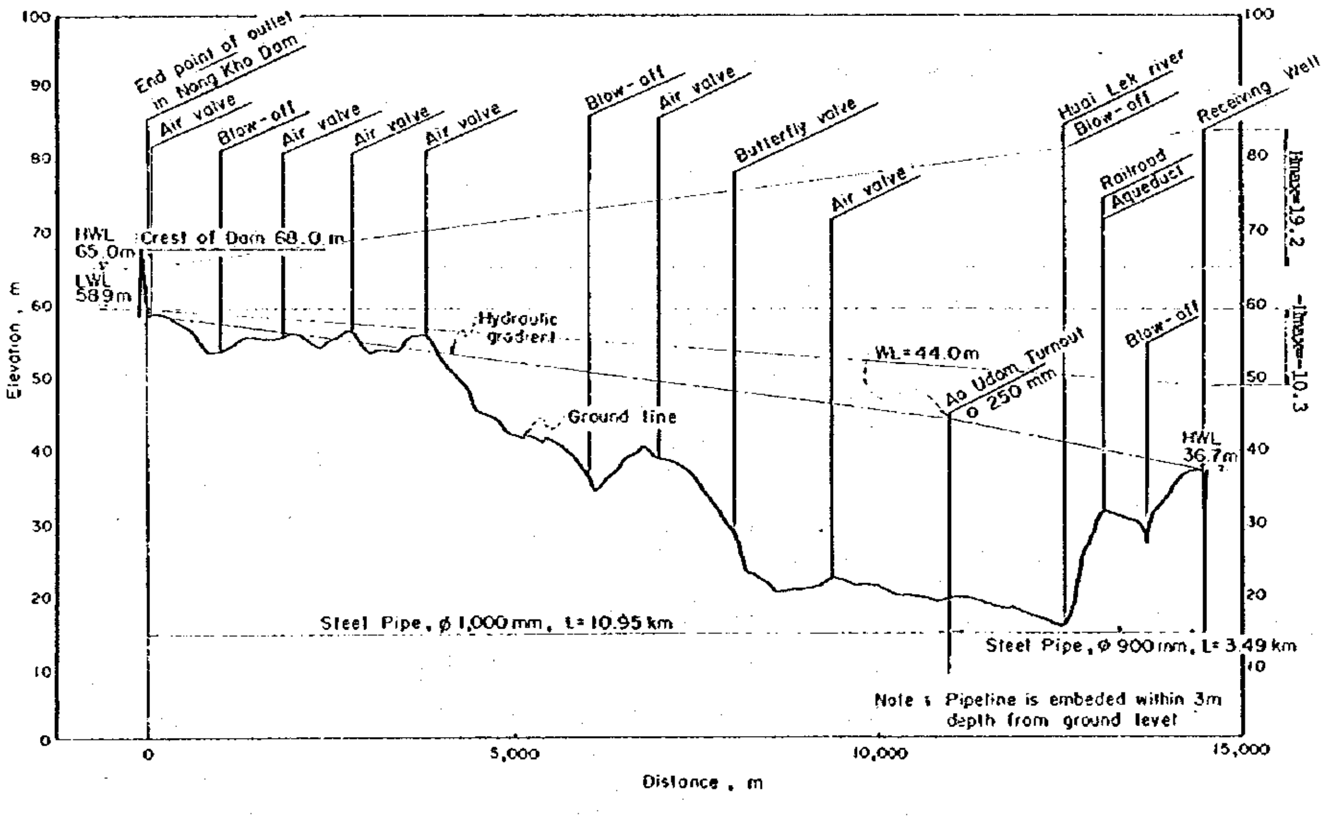
$$Hmax = 22.2 \times \left(\frac{0.40}{2} + \sqrt{0.040 + \frac{0.40^2}{4}}\right)$$

$$= 19.2 \text{ m}$$

$$-Hmax = 22.2 \times \left(\frac{0.4}{2} - \sqrt{0.4 + \frac{0.4^2}{4}}\right)$$

$$= -10.3 \text{ m}$$

Calculated result is shown below.



4. PRICED BILL OF QUANTITY

CONSTRUCTION COST, FIRST STAGE

Item No.	Work	Unit	Quantity	Foreign Currency Unit Price (Ø)	Foreign Currency Amount (10^3Ø)	Local Currency Unit Price (Ø)	Local Currency Amount (10^3Ø)	Total (10^3Ø)
1.	Preparatory Work		L.S.		9,600.2		5,291.6	14,891.8
2.	Raw Water Pipeline							
2.1	Earth Works							
	Stripping & Clearance	m^3	15,380	9.8	150.7	12.2	187.6	338.3
	Trench Excavation	m^3	98,430	50.9	5,010.1	26.3	2,588.7	7,595.8
	Trench Excavation with Wooden Piling	m^3	4,655	438.9	2,043.1	688.3	3,204.0	5,247.1
	Backfill	m^3	103,820	49.7	5,160.3	29.8	3,094.1	8,254.4
	Embankment	m^3	8,142	53.6	436.4	29.0	236.1	672.5
	Sub-total for 2.1				12,800.6		9,307.5	22,108.1
2.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe							
	(Ø1,000 mm)	ton	2,581	22,682	58,542.2	12,526	32,329.6	90,871.8
	(Ø 900 mm)	ton	597	22,696	13,549.5	12,587	7,514.4	21,063.9
	(Ø 600 mm)	ton	1.6	23,379	37.4	12,238	19.6	57.0
	(Ø 400 mm)	ton	5.1	23,482	119.8	12,295	62.7	182.5
	Supply and Installation of Butterfly Valve (Ø1,000 mm)	unit	4	446,610	1,786.4	163,377	653.5	2,439.9
	(Ø 900 mm)	unit	5	383,276	1,916.4	140,416	702.1	2,618.5
	Supply and Installation of Air Valve (Ø1,000 mm)	unit	6	23,537	141.2	10,846	65.1	206.3
	Supply and Installation of Sluice Valve (Ø400 mm)	unit	4	188,000	752.0	69,300	277.2	1,029.2
	Sub-total for 2.2				76,844.9		41,624.2	118,469.1

Item No.	Work	Unit	Quantity	Foreign Currency		Local Currency		Total
				Unit Price	Amount	Unit Price	Amount	
2.3	Mechanical Works							
	Supply and Installation of Flow Meter	unit	1	708,892	708.9	283,418	283.4	992.3
2.4	Concrete Works							
	Concrete	m^3	236	1,769	417.5	1,475	348.1	765.6
	Reinforcing Steel	ton	6.6	6,507	42.9	3,503	23.1	66.0
	Sub-total for 2.4				460.4		371.2	831.6
2.5	Miscellaneous Works							
	Metal Works	ton	7.7	14,000	107.8	14,000	107.8	215.6
	Asphalt Pavement	m^2	72	58	4.2	51	3.7	7.9
	Sub-total for 2.5				112.0		111.5	223.5
	Total (2.1 thru 2.5)				90,926.8		51,697.8	142,624.6
3.	Ao Udom Turnout							
3.1	Earth works							
	Trench Excavation with Timbering	m^3	27	438.9	11.9	688.3	18.6	30.5
	Backfill	m^3	26	49.7	1.3	29.8	0.8	2.1
	Sub-total for 3.1				13.2		19.4	32.6
3.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe (ø250 mm)	ton	0.9	10,180	9.2	6,608	5.9	15.1
	Supply and Installation of Sluice Valve (ø250 mm)	unit	2	18,608	37.2	7,834	15.7	52.9
	Sub-total for 3.2				46.4		21.6	68.0
3.3	Mechanical Works							
	Supply and Installation of Flow Meter	unit	1	583,058	583.1	232,702	232.7	815.8

Item No.	Work	Unit	Quantity	Foreign Currency		Local Currency		Total
				Unit Price	Amount	Unit Price	Amount	
3.4	Concrete Works							
	Concrete	m^3	5.4	1,769	9.6	1,475	8.0	17.6
	Reinforcing Steel	ton	0.2	6,507	1.3	3,503	0.7	2.0
	Sub-total for 3.4				10.9		8.7	19.6
3.5	Miscellaneous Works							
	Metal Works	ton	0.3	14,000	4.2	14,000	4.2	8.4
	Total (3.1 thru 3.5)				657.8		286.6	944.4
4.	Aqueduct							
4.1	Earth Works							
	Open Excavation	m^3	361	49	17.7	29.4	10.6	28.3
	Backfill	m^3	108	49.7	5.4	29.8	3.2	8.6
	Sub-total for 4.1				23.1		13.8	36.9
4.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe (ø900 mm)	ton	15.7	22,696	356.6	12,587	197.6	554.2
	Supply and Installation of Air Valve (ø900 mm)	unit	1	22,411	22.4	10,419	10.4	32.8
	Sub-total for 4.2				379.0		208.0	587.0
4.3	Concrete Works							
	Concrete	m^3	253	1,769	447.6	1,475	373.2	820.8
	Reinforcing Steel	ton	12.7	6,507	82.6	3,503	44.5	127.1
	Sub-total for 4.3				530.2		417.7	947.9

Item No.	Work	Unit	Quantity	Foreign Currency		Local Currency		Total
				Unit Price	Amount	Unit Price	Amount	
4.4	Miscellaneous Works							
	Metal Works	ton	3.1	14,000	43.4	14,000	43.4	86.8
	Total (4.1 thru 4.4)				975.7		682.9	1,658.6
5.	Receiving Well							
5.1	Earth Works							
	Stripping & Clearance	m^3	89	9.8	0.9	12.2	1.1	2.0
	Trench Excavation	m^3	540	50.9	27.5	26.3	14.2	41.7
	Open Excavation	m^3	1,270	49.0	62.2	29.4	37.3	99.5
	Backfill	m^3	1,263	49.7	62.8	29.8	37.6	100.4
	Sub-total for 5.1				153.4		90.2	243.6
5.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe							
	(ø900 mm)	ton	17.9	22,696	406.3	12,587	225.3	631.6
	(ø400 mm)	ton	0.3	23,482	7.0	12,295	3.6	10.6
	(ø200 mm)	ton	0.6	17,525	10.5	9,032	5.4	15.9
	Supply and Installation of Sleeve valve (ø900 mm)	unit	1	2,536,808	2,536.8	1,022,440	1,022.4	3,559.2
	Supply and Installation of Butterfly Valve (ø900 mm)	unit	4	383,276	1,533.1	140,416	561.7	2,094.8
	Supply and Installation of Sluice Valve (ø200 mm)	unit	3	15,583	46.7	7,387	22.2	68.9
	Sub-total for 5.2				4,540.4		1,840.6	6,381.0
5.3	Mechanical Works							
	Supply and Installation of Flow Meter	unit	1	696,308	696.3	278,347	278.3	974.6

Item No.	Work	Unit	Quantity	Foreign Currency		Local Currency		Total
				Unit Price	Amount	Unit Price	Amount	
5.4	Concrete Works							
	Concrete	m^3	329	1,769	582.0	1,475	485.3	1,067.3
	Reinforcing Valve	ton	28.9	6,507	188.1	3,503	101.2	289.3
	Sub-total for 5.4				770.1		586.5	1,356.6
5.5	Miscellaneous Works							
	Metal Works	ton	1.5	14,000	21.0	14,000	21.0	42.0
	Control House	m^2	30	3,205	96.2	3,150	94.5	190.7
	Sub-total for 5.5				117.2		115.5	232.7
	Total (5.1 thru 5.5)				6,277.4		2,911.1	9,188.5
	Grand Total				108,437.9		60,870.0	169,307.9

CONSTRUCTION COST, SECOND STAGE

Item No.	Work	Unit	Quantity	Foreign Currency Unit Price (Ø)	Foreign Currency Amount (10^3Ø)	Local Currency Unit Price (Ø)	Local Currency Amount (10^3Ø)	Total (10^3Ø)
1.	Preparatory Work		L.S.		9,589.3		5,311.3	14,900.6
2.	Raw Water Pipeline							
2.1	Earth Works							
	Stripping & Clearance	m^3	15,380	9.8	150.7	12.2	187.6	338.3
	Trench Excavation	m^3	98,430	50.9	5,010.1	26.3	2,588.7	7,598.8
	Trench Excavation with Wooden Piling	m^3	4,650	438.9	2,040.9	688.3	3,200.6	5,241.5
	Backfill	m^3	103,670	49.7	5,150.5	30	3,110.2	8,260.7
	Embankment	m^3	252	53.6	13.5	29	7.3	20.8
	Sub-total for 2.1				12,365.7		9,094.4	21,460.1
2.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe							
	(Ø1,000 mm)	ton	2,581	22,682	58,542.2	12,526	32,329.6	90,871.8
	(Ø 900 mm)	ton	597	22,696	13,549.5	12,587	7,514.4	21,063.9
	(Ø 600 mm)	ton	1.3	23,379	30.4	12,238	15.9	47.7
	(Ø 400 mm)	ton	4.2	23,482	98.6	12,295	51.6	148.8
	Supply and Installation of Butterfly Valve (Ø1,000 mm)	unit	4.2	446,610	1,786.4	163,377	653.5	2,439.9
	(Ø 900 mm)	unit	5	383,276	1,916.4	140,416	702.1	2,618.5
	Supply and Installation of Air Valve (Ø150 mm)	unit	6	23,537	141.2	10,846	65.1	206.3
	Supply and Installation of Sluice Valve (Ø400 mm)	unit	4	188,000	752.0	69,300	277.2	1,029.2
	Sub-total for 2.2				76,816.7		41,609.4	118,426.1

Item No.	Work	Unit	Quantity	Foreign Currency		Local Currency		Total
				Unit Price	Amount	Unit Price	Amount	
2.3	Mechanical Works							
	Supply and Installation of Flow Meter	unit	1	708.9	708.9	283,418	283.4	992.3
2.4	Concrete Works							
	Concrete	m^3	211	1,769	373.3	1,475	311.2	684.5
	Reinforcing Steel	ton	5.9	6,507	38.4	3,503	20.7	59.1
	Sub-total for 2.4				411.7		331.9	743.6
2.5	Miscellaneous Works							
	Metal Works	ton	7.7	14,000	107.8	14,000	107.8	215.6
	Asphalt Pavement	m^2	72	58	4.2	51	3.7	7.9
	Sub-total for 2.5				112.0		111.5	223.5
	Total (2.1 thru 2.5)				90,415.0		51,430.6	141,845.6
3.	Ao Udom Turnout							
3.1	Earth works							
	Trench Excavation with Timbering	m^3	23	438.9	10.1	688.3	15.8	25.9
	Backfill	m^3	22	49.7	1.1	29.8	0.7	1.8
	Sub-total for 3.1				11.2		16.5	27.7
3.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe (ø250 mm)	ton	0.8	10,180	8.1	6,608	5.3	13.4
	Total (3.1 thru 3.2)				19.3		21.8	41.1

Item No.	Work	Unit	Quantity	Foreign Currency		Local Currency		Total
				Unit Price	Amount	Unit Price	Amount	
4.	Aqueduct							
4.1	Earth Works							
	Open Excavation	m^3	361	49	17.7	29.4	10.6	28.3
	Backfill	m^3	108	49.7	5.4	29.8	3.2	8.6
	Sub-total for 4.1				23.1		13.8	36.9
4.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe (ø900 mm)	ton	15.7	22,696	356.3	12,587	197.6	553.9
	Supply and Installation of Air Valve (ø150 mm)	unit	1	22,411	22.4	10,419	10.4	32.8
	Sub-total for 4.2				378.7		208.0	586.7
4.3	Concrete Works							
	Concrete	m^3	253	1,769	447.6	1,475	373.2	820.8
	Reinforcing Steel	ton	12.7	6,507	82.6	3,503	44.5	127.1
	Sub-total for 4.3				530.2		417.7	947.9
4.4	Miscellaneous Works							
	Metal Works	ton	3.1	14,000	43.4	14,000	43.4	86.8
	Total (4.1 thru 4.4)				975.4		682.9	1,658.3
5.	Receiving Well							
5.1	Earth Works							
	Stripping & Clearance	m^3	115	9.8	1.1	12.2	1.4	2.5
	Trench Excavation	m^3	696	50.9	35.4	26.3	18.3	53.7
	Open Excavation	m^3	1,270	49	62.2	29.4	37.3	99.5
	Backfill	m^3	1,430	49.7	71.0	29.8	42.6	113.6
	Sub-total for 5.1				169.7		99.6	269.3

Item No.	Work	Unit	Quantity	Foreign Currency		Local Currency		Total
				Unit Price	Amount	Unit Price	Amount	
5.2	Pipe & Valve Works							
	Supply and Installation of Steel Pipe							
	(ø900 mm)	ton	22.1	22,696	501.6	12,587	278.2	779.8
	(ø400 mm)	ton	0.3	23,482	7.0	12,295	3.7	10.7
	(ø200 mm)	ton	0.6	17,525	10.5	9,032	5.4	15.9
	Supply and Installation of Sleeve valve (ø900 mm)	unit	1	2,536,808	2,536.8	1,022,440	1,022.4	3,559.2
	Supply and Installation of Butterfly Valve (ø900 mm)	unit	4	383,276	1,533.1	140,416	561.7	2,094.8
	Supply and Installation of Sluice Valve (ø200 mm)	unit	3	15,583	46.7	7,387	22.2	68.9
	Sub-total for 5.2				4,635.7		1,893.6	6,529.3
5.3	Mechanical Works							
	Supply and Installation of Flow Meter	unit	1	696,308	696.3	278,347	278.3	974.6
5.4	Concrete Works							
	Concrete	m^3	329.2	1,769	582.0	1,475	485.3	1,067.3
	Reinforcing Steel	ton	28.9	6,507	188.1	3,503	101.2	289.3
	Sub-total for 5.4				770.1		586.5	1,356.6
5.5	Miscellaneous Works							
	Metal Works	ton	1.7	14,000	23.8	14,000	23.8	47.6
	Total (5.1 thru 5.5)				6,295.6		2,881.8	9,177.4
	Grand Total				107,294.6		60,328.4	167,623.0