- As individual end-users require water of different qualities, water purification in the vicinity of Dok Krai reservoir is not economical.
- The raw water pipeline is easier in maintenance and administration.
- Since the quality of the raw water is good, practically no corrosion and abration in the pipe is anticipated.

3.1.2 Design Conditions

Design Criteria

Applicable Japanese design criteria are used extensively in this Report.

Water Source

The Nong Pla Lai sub-project is a prerequisite of construction of the Nong Pla Lai dam and a supply of municipal and industrial water depends on the Dok Krai reservoir while irrigation water on the Nong Pla Lai dam. So, in the study of this Project, an intake from the existing Dok Krai reservoir is investigated.

Design Discharge

Daily maximum design water supply is taken as the basis of the design discharge. The formula below is based on the annual demand water.

$$Qd = Wd/365/86{,}400 \cdot fw/C$$

Where

Qd : design discharge, m^3/sec.
Wd : demand water, MCM/yr.
fw : leakage ratio
Cf : load factor

"Cf" is coefficient of fluctuation of demand. The Cf value varies with scale, type and operation of receiving factories in industrial water. Furthermore the municipal water demand varies with seasons, change in living standard, etc. Cf=1/1.5 is a larger value of the range observed actually in the past. As for leakage, mostly observed value in the purification plant. Leakage ratio (fw) of 1.1 is used here.

The design discharge of the respective routes is shown below.

Route	Q (m^3/sec)
Dok Krai Res. - Mab Ta Pud	3.02
Mab Ta Pud - Sattahip	1.02
Dok Krai Res. - Laem Chabang	1.16

3.2 WATER TRANSMISSION SYSTEM

3.2.1 Selection of Possible Routes

The possible routes between the Dok Krai dam and the receiving ends are shown in Fig. 3-1 and Table 3-1.

Table 3-1 Possible Routes

M-1	The shortest route linking Dok Krai dam to Mab Ta Pud. Capacity to serve one of the three areas: (a) Rayong region only, (b) Rayong and Sattahip areas, and (c) Rayong, Sattahip and Laem Chabang areas.
M-2	Alternative of M-1. Plan to intake spill water of Dok Krai dam from the irrigation channel at its down-stream.
S-1	For water transmission to Sattahip no direct route is available. The route via Mab Ta Pud is the only route.
L-1	Direct route for water transmission from Dok Krai to Laem Chabang. For the water supply to Pattaya, an effective utilization of water can be reached by a branch line to Map Prachan dam at the point on the midway of the pipeline "L-1".
L-2	The route to Laem Chabang via Mab Ta Pud and Sattahip. It is easier to supply water to cities and town along the coast such as Pattaya.

Comparison between Routes M-1 and M-2 are omitted here as it will be treated in 3.2.2. Regarding L-1 and L-2, the former is for direct supply to Laem Chabang while the latter is via Mab Ta Pud and Sattahip. Therefore, the length of L-2 route becomes longer, and the pipe diameter of both routes M and S becomes larger, and needs larger capacity of booster pump(s). These are definite economic disadvantages. The merit is easier water supply to coastal town such as Pattaya, however, the supply is also available to Pattaya from Route L-1. So there is no particular reason to lay transmission pipeline along the National Highway Route 3.

3.2.2 Route for Rayong - Sattahip area

Route from Dok Krai Reservoir to Mab Ta Pud

Three alternative plans are considered in the route from Dok Krai reservoir to Mab Ta Pud as shown in Fig. 3-2.

After comparison of Plans A, B & C as described below, it is concluded that Plan A is the most advantageous.

1) Brief description of plans

Plan-A (Pipeline System)

Pumping up at Dok Krai dam site to the head tank located beside Highway Route 3191, and through pipeline the water will be conveyed to Mab Ta Pud by gravity flow.

Plan-B (Irrigation Canal and Pipeline System)

Transmitted through the existing irrigation channel located on the right bank of the Rayong River, pumping-up in the vicinity of Ban Nong Saphan, conveyed to Mab Ta Pud under pressure. Required volume of water is available from Dok Krai reservoir.

Plan-C (Open Conduit System)

Pumping up at Dok Krai dam site to the regulating basin located beside the right side of Dok Krai dam site and conveyed through open conduit across the eastern slope of Mt. Chom Hae and Mt. Khvok down to Mab Ta Pud. Open conduit is mostly used.

Brief description of main facilities

Plan-A

To be described in detail in 3.2.6.

Plan-B

1) Intake and pumping station

The intake is located where the irrigation channel turning left toward the Rayong River in the neighborhood of Ban Nong Saphan.

The pumping station is also to be located at the same area. The highest spot of the surrounding hilly terrain is about 80 meters in elevation. If the head tank is located at the high land area, a booster pumping station may be required before it reached to Mab Ta Pud. The general plan of pumping station is shown in Fig. 3-3.

2) Pipeline

Total length of the pipeline is about 23.0 km starting from the pumping station, running down to the south until reaching to Route 3, changing direction at the intersection and running parallel with Route 3 to reach Mab Ta Pud. The pipeline route and its profile are shown in Figs. 3-4 and 3-5, respectively.

Diameter of the pipe is tentatively fixed at 1,500 mm and a further study in detail will be neccessary in this matter from view point of the pumping cost.

3) Irrigation channel

The existing irrigation channel, starting at the intake at Ban Khai, is to be utilized.

Plan-C

1) Intake and pumping station

Location and type of the intake and pumping station are the same as those of Plan-A, except the total pump head which is more than 30 meters smaller.

Characteristics of pumping station

- Rate of flow : 36.24 m^3/min/pump
- Suction level : H.W.L. +52.000 m
L.W.L. +42.000 m
- Actual pump head : 43.0 m
- Friction loss : 12.0 m
- Total pump head : 55.0 m

2) Regulating basin

A regulating basin is to be located at the hilly terrain, EL.+85.0m, on the right bank of Dok Krai dam.

As the conduit downstream of the regulating basin is open conduit, it is required to maintain stage fluctuation of the basin to the possible minimum. Here, the effective capacity of the regulating basin is determined at 162,000 m^3 (232 m x 232 m x 3.0 m) with stage fluctuation of 10 cm per 30 minutes.

3) Open conduit

The conduit system between the regulating basin and receiving well at the purification plant mostly consists of open conduit. Though there are various types of open conduits, here, an embeded type conduit will be used. In this case, the internal pressure is equivalent to head cause by water depth, therefore, it is considered that a reinforced concrete pipe will serve the purpose well enough. (Refer to Fig. 3-6.)

The natural topographic slope dictates the gradient of the conduit between 1/500 and 1/1,000. Though called "open conduit", actually it has to be a culvert. In this case, pre-cast concrete conduit such as "Rocla Pipe" is considered most suitable from the viewpoints of workability and economy. (Refer to Fig. 3-7.)

Section of the conduit, assuming the circular shape, is calculated and the required diameter (D) of the pipe is as below:

i=1/1,000	D=1,800 mm
i=1/500	D=1,650 mm

The maximum diameter of "Rocla Pipe" available at present is 1,500 mm, therefore, double-pipe system is adopted here. By the same procedure in the foregoing, the required diameter (D) of the pipe is as follows:

i=1/1,000	2 x D = 1,500 mm
i=1/500	2 x D = 1,350 mm

Comparative Study

Comparative list is shown in Table 3-2. The list shows an obvious disadvantage of Plan-B because higher running cost though the initial cost is lower than Plan-A. Furthermore, Plan-B has a fatal drawback, i.e., unsteadiness in water supply capability. Plan "C" is the one with open conduit and the construction cost is lower than that of Plan-A. Plan-C, however, requires much land acquisition along the entire route. When the use of "Rocla Pipe" is considered, it takes 4 to 5 years for construction. This is because of small production capacity of manufacturing.

A cast-in-place concrete conduit may be considered as an alternative, however, longer construction period and higher cost is quite obvious.

Route from Mab Ta Pud to Sattahip

For the route linking Mab Ta Pud to Sattahip, it is apparent that the one running along Route 3 is most advantageous, though a detour for a portion is required because of the high elevation. Since the inside pressure of the pipe is low the use of pipes made of some other materials such as Rocla, ductile, etc. may be considered suitable. However, here it is recommended use of the steel pipe with the advantage of certified leak proof quality, workability and material cost.

3.2.3 Route for Laem Chabang Area

Route from Dok Krai to Laem Chabang

The route to Laem Chabang is crossing the mountain of EL. 150 m approx., so most of the entire length of the route is a pipeline. At the present study, the route from Sattahip has been abandoned at the initial stage because it is unsuitable for practical purpose. Several other routes to Laem Chabang may be found. The one running parallel with Route 36 is selected as most practical because no road is existing along the other routes.

On the above-mentioned selected route, one booster pumping station on the route, and a rock tunnel of about 9.0 km in length where the route is crossing the mountain of EL. 150 m. The straight alignment across the mountain will require one more booster station and leads to a a definite disadvantage. Regarding the route to Laem Chabang, still better one might be found after further detailed study taking topography of the region and condition of the existing roads into consideration. However the result of the subject study shows the proposed route is the most feasible. According to the schedule of the occurence of demand, construction of Laem Chabang Route will be somewhat late to that of Mab Ta Pud Route. When Construction of Laem Chabang Route is started, no extension of the pumping station is considered. Up-grading of the capacity of pump(s) and motor(s) is considered as a countermeasure, instead.

No additional pipeline to the one between Dok Krai res. - Head Tank, running along Route-3191, is considered. But one additional head tank will be constructed, and from there the pipeline to Laem Chabang will be branched out.

3.2.4 Pipeline

Pipe Materials

Since the pipeline is embeded along almost the entire length, pipe materials resistant to internal as well as external pressure is required. The pipe required is 1,000 to 1,500 mm in diameter. There are a number of different pipe materials suitable for this project but for the range of the diameter of the pipe mentioned above, only pipes of concrete, ductile iron and steel may be available. The study results are presented in details in Tables 3-3 and 3-4.

The following is some major factors to be considered in the comparison pipe materials.

1) Strength

Internal pressure is estimated at 10.0 kg/cm^2 taking effect of water hammer into consideration. Pipes must be sufficiently durable against external

pressure caused by traffic load, buoyancy and land subsidence observed at poor soil.

2) Leakage

Leakage at pipe joints lowers the supply capacity, causes bad effect to paved road, and also causes a serious hindrance to the road maintenance and repair. It is required to select suitable pipe materials to avoid all problems mentioned above.

3) Anti-corrosion

For a longer life and to maintain the required flow capacity of pipeline, material resistant to corrosion or the one accept pre-treatment for anti-corrosion may have to be selected.

4) Availability

Pipe materials to be produced and delivered to the field in time of specified date of delivery.

<u>Number of Pipes</u>

Number of pipes of the proposed pipelines is determined by safety, economy, efficiency in construction execution, etc. Here, comparison between single and double pipeline shown in Fig. 3-8 will be made on the proposed pipeline between Dok Krai dam and Mab Ta Pud as an example.

1) Study conditions

Design Discharge	Q = 3.02 m^3/sec.
L.W.L. of head tank	EL. + 105.0 m
H.W.L. of receiving well	EL. + 60.0 m
Distance between head tank and receiving well	L = 20.8 km
Coefficient of flow velocity	C = 120

2) Pipe diameter

For calculation of the required pipe diameter, Hazen and Williams's formula is used.

$$D = 1.6258 \times C^{-0.38} \times Q^{+0.38} \times I^{-0.205}$$

Where:

Q : rate of flow, m^3/sec.
I : hydraulic gradient
C : coefficient of velocity (C=120)
D : Inner dia. of pipe, m

Single Pipeline

$$D = 1.625 \times 120^{-0.38} \times 3.02^{+0.38}$$

$$\times \left(\frac{105.0 - 60.0}{20.8 \times 10^3} \right)^{-0.205}$$

$$= 1.41 \doteqdot 1.5 \text{ m}$$

Double Pipeline

$$D = 1.625 \times 120^{-0.38} \times \left(\frac{3.02}{2} \right)^{+0.38}$$

$$\times \left(\frac{105.0 - 60.0}{2.08 \times 10^3} \right)^{-0.205}$$

$$= 1.08 \doteqdot 1.1 \text{ m}$$

Comparative Study

Comparative item of single and double pipeline is shown in Table 3-5. From the viewpoint of diversification of risks, the double line is definitely advantageous. An increase in the construction cost is almost unavoidable, i.e., about 24% more in direct construction cost, and higher land procurement cost. As the wall thickness of embeded pipe is determined taking the balance of vertical earth pressure and side pressure caused by backfilling, a wider spacing between the two pipes than that shown in Fig. 3-8, might be required.

3.2.5 Purification Plant

Though the purification plant project is not included in the scope of the present study, the location of the plant is too important to be neglected in the design of the receiving well. Comparative study of the location of the proposed plant is shown below.

Rayong-Sattahip Area

1) Mab Ta Pud

New industrial and urban development project of Mab Ta Pud is shown in Fig. 3-9.

The location of the purification plant is to be studied and fixed from the comprehensive viewpoint of the most effective delivery of water over the service areas. The two plans as shown in Fig. 3-9 are compared.

Plan-A

Location of the purification plant in this Plan is close to the northern border of the industrial region, and an average ground height of the area is about EL. +45.0 m. Pumping-up may have to be considered for the water delivery to a part of the region. In the case of water supply to Sattahip, it is necessary to boost up the water at the intermediate booster station. The lift of the pump(s) at Dok Krai dam will become low accordingly.

Plan-B

The purification plant, in this Plan, is located on the spot at the right side of Route 3 where the route bends to the right to the direction of Rayong, and an average height of the area is around EL. +60.0m. Besides for the water supply to the new urban area, booster station may be required.

Here, Plan-B is selected by the reasons as below.

- Elevation of the receiving well is high enough to distribute to industrial factories by gravity flow.

- The surrounding area is wide enough and better suited for the future extention.

2) Sattahip

Major supply ends in Sattahip are the proposed soda ash factory, port and municipal households. The location of the soda ash factory has not been fixed yet. For the location of the proposed purification plant, somewhere on midway between Sattahip port and the urban center is deemed advantageous. The ground height of the supply end areas is around EL. + 10.0 m, and the receiving well of the purification plant is estimated at between EL. + 30.0 m and + 40.0 m. Taking the foregoing conditions into consideration, the location of the plant was deter-

mined at the lot, as shown in Fig. 3-10, along the Route 3. For purification, three plans, A, B and C, as shown below are formed.
Plan-A

The purification plant at Mab Ta Pud supplies treated drinking water, and only distribution reservoir is located at Sattahip.

Plan-B

The purification plant at Mab Ta Pud supplies treated industrial water, and at Sattahip, a purification plant only for drinking water will be located.

Plan-C

The raw water will be treated at Sattahip purification plant for both drinking and industrial water.

Here, the Plan-C deemed most advantageous for the reason as below.

- In the Plan-A, for the industrial water required at Sattahip area, the drinking quality water will be supplied which is not economically advantageous.

- Soda ash factory is more desirous of supply of the raw water.

However, quality of the raw water, and the required purification standards of industrial water are not fixed yet, a further and detailed study is a prerequisite.

Leam Chabang Area

The proposed Laem Chabang Industrial Complex is likely to extend over the low-laying land about 4.0 km toward the sea from the Route 3. As the major cities in this area are scattered on the east and west sides of the Route 3, the proposed purification plant will be located at the highland along the Route 3. Though the location of the supply ends is not fixed yet, the receiving well will be located at between EL. + 40.0 m and + 50.0 m.

3.2.6 Project Description

A brief description of major data of the respective routes is given below:

From Dok Krai Reservoir to Mab Ta Pud

1) Pumping station at Dok Krai Reservoir

Design discharge	:	$Q = 3.02\ m^3/sec.$ ($Q=36.24\ m^3/min/pump$)
Number of pumps	:	6 (1 for stand-by)
Total pump head	:	$H_T = 90.0$ m
Total output power	:	$P_W = 3{,}400$ KW

2) Pipeline

Total length	:	L = 27.6 km
Steel pipe	:	ϕ = 1,500 mm

3) Head tank

Location	:	6.0 km south from Dok Krai pumping station
Volume	:	2 x 3,000 m^3

4) Purification plant

Location	:	West of Ban Chak Luk Ya along Route 3.

From Mab Ta Pud to Sattahip

1) Pipeline

Design discharge	:	$Q = 1.02\ m^3/sec.$
Total length	:	L = 21.9 km
Steel pipe	:	ϕ = 1,100mm

2) Purification plant

Location	:	About 5.0 km east of Ampho Sattahip, north of Route 3

From Dok Krai to Laem Chabang

1) Pumping station at Dok Krai Reservoir

Design discharge	:	$Q = 4.18\ m^3/sec$
Total pump head	:	$H_T = 90.0$ m

Design discharge	:	$Q = 1.16\ m^3/sec$ $(Q = 34.80\ m^3/min/pump)$
Number of pumps	:	3 (1 for stand-by)
Total pump head	:	$H_T = 45.0\ m$
Total output power	:	$P_W = 650\ KW$

3) Pipeline

Total length	:	L = 60.5 km
Steel pipe	:	ϕ = 1,000 mm L = 45.0 km
		ϕ = 1,200 mm L = 6.5 km
Tunnel section	:	ϕ = 1,500 mm (concrete lining) L = 9.0 km

4) Head Tank

Location	:	6.0 km South from Dok Krai pumping station
Volume	:	$V_1 = 1 \times 2{,}000\ m^3$
Location	:	5.0 km North west from Booster pumping station
Volume	:	$V_2 = 1 \times 2{,}000\ m^3$

5) Purification plant

Location	:	South of Ban Thung Suk La along Route 3.

Fig. 3-10 shows General plan of Water Transmissin System. Longitudinal Profiles with General plans of the respective routes mentioned above are shown in Figs. 3-11, 3-12 and 3-13.

4. PRELIMINARY DESIGN OF WATER TRANSMISSION FACILITIES

4.1 INTAKE AND PUMPING STATION

Intake and pumping station, especially pumping station is the most critical of all the water transmission facilities.

In the project, intake from the existing Dok Krai reservoir is a prerequisite. The under-water construction of intake structure in the existing reservoir is much more difficult than construction by dry work. Intake and pumping station are usually separate facilities. However, under some circumstances, these two are considered as integral. In the following study, some alternatives are compared from this point of view.

Accompanied with the general condition at the intake facilities area and general construction criteria, there are various plans for intake structure, pump and pumping station.

The relation between the items and plans are as follows.

General Condition at the location of the intake facilities:	4.1.1
General Construction criteria:	4.1.2
Intake structure:	4.1.3
Pump:	4.1.4
Pumping Station:	4.1.5

Considering about relations mentioned above, Plan B-3 is recommended by the view point mentioned below.

- High reliability on pumps and pumping station.
- Maintenance is easy.
- Transmission cost is low.
- Construciton is not easy but has certainly.

The details are mentioned in Table 4-1 to 4-8.

4.1.1 General Conditions at the Location of Facilities

1) Geographical and Geological Conditions

The topography of the areas surrounding the dam site is mild ups and downs, and the shore of the lake is a mild slope flatland. For the proposed construction work, the condition is quite favorable. The granite is the bed rock of the area. The surface is a deposit of silty and/or clayey sand, and weathered rock and sand in between. The weathered layer is about 5 - 10 meters deep. The foundation of the pumping station may have to reach the bed rock. (Refer to Fig. 4-1)

2) Climate

In the execution of the work,, rainy season presents problems. Though the area belongs to a relatively low annual rainfall, some problems still remain to be solved, i.e., protection of finished slopes after excavation and welding works in the rain. Especially some countermeasures may have to be worked out for a on-schedule welding during rainy seasons.

3) Reservoir Stage

In the present study, the basic assumed premise is that reservoir stage will be maintained during the construction of the intake tower and pumping station. This means, unless reservoir stage is down to almost complete dry, the method of construction remains substantially unchanged. However, the foregoing matters have to be re-checked prior to the stage of detailed design.

4.1.2 General Construction Condition

With regard to intake and pumping station, three types may be considered as follows. (Refer to Fig. 4-2)

Type-A

Reservoir storage is taken from the channel leading to the spillway at the down stream of the dam, and through intake basin, pumping up the water to the semi-underground pumping station.

Type-B

Intake tower and pumping station, composite in a single structure, are constructed in the reservoir, and water pumped up is transmitted to the opposite bank by an aqueduct bridge. Wet construction is almost unavoidable.

Type-C

Water from the intake tower in the reservoir is conveyed to the semi-underground pumping station located at the downstream face of the saddle levee through the embeded conduit connecting the two.

4.1.3 Intake Structure

A comparative study on three types mentioned below has been made, the details of which are presented in Tables 4-6 to 4-8. The quality of water of the Dok Krai reservoir is relatively satisfactory and turbidity is low, problems of abrasion on impeller of pump and iron deposit on the interior surface of pipe are not at all serious. Therefore, sedimentation basin before pumping up is not required. For intake, surface water intake is considered more suitable. For surface water intake, a cylinder gate with float may be used. As it is not required to consider water temperature here. It is preferrable that a conventional type of sluice gate requiring minimum of maintenance and administration is employed.

Type-A

Open type intake basin which is the most conventional, is satisfactory for this type. This makes the adoption of the standard type sink tank. This reduces load to be imposed on the pump. (Refer to Figs. 4-3, 4-4 and 4-5.)

Type-B

Double wall intake tower, with multiple intake gates in the outer wall for surface water intake, and a pump(s) installed inside of the inner wall. The space between the outer and inner walls is filled with surface water for pumping up. The dimension and spacings of the intake facility are squeezed to the required minimum.
(Refer to Figs.4-6, 4-7, 4-8, and 4-9)

Type-C

The surface water is taken from the intake tower located in the reservior. The intake tower is circular structure of 6.0 meters in diameter. The construction of the tower is by the open caisson. The convey conduit is a shield tunnel of 2.0 meters in diameter. The suction sump is a part of the pressure pipe. (Refer to Figs. 4-10 and 4-11.)

4.1.4 Pump

1) Design Requirements

Number of pump	6 (incl. 1 Stand-by)
Design Discharge	Qp = 36.24 m^3/min/pump
Suction Level, m	H.W.L. +52.600
	N.W.L. +50.600
	L.W.L. +42.000*

Note: * L.W.L. required for pumping-up

Delivery Level, m	H.W.L. +112.000
	H.W.L. +105.000
Actual pump head	Ha = 70 m
	(112.0 m - 42.0 m)
Friction Loss	Hf = 20 m
Total pump head	Ht = 90 m

2) For the pump, two types mentioned below is taken into consideration.

- Vertical Shaft Mixed Flow Pump

  Since the total head of 90.0 meters is quite high, a two-stage impeller is to be adopted.

The length of suction pipe, 15 meters is a rare example.

- Double Suction Centrifugal Pump

  The centrifugal pumps are known by their high efficiency, and more suitable to operation under a high lift. In actual use, more centrifugal pumps are used than mixed flow pumps. They are available in two types; namely, 1) vertical shaft double suction centrifugal pump, and 2) horizontal shaft double suction centrifugal pump. (Refer to Tables 4-1 to 4-4.)

4.1.5 Pumping Station

Three types of pumping station as mentioned below is taken into consideration.

1) Semi-underground Type

   Under the Plans specifying location of pumping station on the downstream of a dam and/or an auxiliary dam, the station takes the form of a semi-underground structure. This means construction execution of a pumping station is easier, and shows that maintenance and administration of pumping station is also easier.

2) Surface Structure Type

   Surface structure type pumping station are divided into two types, one is a platform type (Stationary or fixed) and the other is a floating type (mobil). Actual application of the latter is limited to only a small scale as a temporary facility and lacks safety and dependability in service, hence it is inferior to the former.

3) Underwater Structure Type

   As underwater pumping station there are two types, one is using immersion pump and the other is using ordinary pump installed in water tight structure. Because of extreme difficulties in maintenance and administration, the former is not suitable for this purpose. And there are many types in the latter according to the type of foundation, etc., however, only the two types are the subject of the study in this Report.

4.2 PIPELINE

Pipe Thickness

Regarding pipes to be used for pipeline, wall thickness of the pipe affects the total construction cost considerably, therefore, a special attention may have to be paid in design. As an example, the design particulars to be applied to the Dok Krai dam to Mab Ta Pud Route are shown below.

From the result of following study, it is concluded that required wall thickness of the pipe will be t = 12.7 mm.

1) Design Condition

Pipe, dia	D = 1,500 mm
Load	
Distributed load	$q = 1.0\ t/m^2$
Wheel load	T-20
Internal Pressure	$P = 1.5 \times \gamma_w \times h$
where	γ_w : unit weight of water
	h : hydrostatic head
Allowable Stress	σs_D: 1,400 kg/cm^2
	σs : 1,740 kg/cm^2

2) Internal Pressure

The internal pressure, (P) caused by hydrostatic head and impact of water hammer is:

$$P = 1.5\ gh$$

h = 71.0 m (based on the Elevation of the Station 2 of the Longitudinal Levelling)

$$P = 1.5 \times 0.102 \times 9.8 \times 71$$

$$= 106\ (t/m^2)$$

therefore, tensile stress caused by the internal pressure is expressed as below:

$$\sigma = \frac{PD}{2t}$$

Where

σ : stress
P : internal pressure, kg/cm^2
D : pipe diameter, cm
t : pipe wall thickness, cm

From the above, the formula below is obtained.

$$\sigma = \frac{106 \times 10^{-1} \times 150}{2 \times t} < 1{,}400 \times 1.5$$

$$t > \frac{106 \times 10^{-1} \times 150}{2 \times 1{,}400 \times 1.5} = 0.38 \text{ cm}$$

This shows the required pipe wall thickness is more than 4.0 mm to withstand the internal pressure.

3) External Pressure

- Earth Load, W_1

$$W_1 = Cd \times H \times Bd$$

where

W_1 : earth load (t/m^2)
Cd : coefficient (Marston Formula)
γ : unit weight of earth t/m^3, = 1.8

$$Cd = \frac{1 - e^{-2K\frac{H}{Bd}}}{2Ku}$$

where

H : height of backfill, 2.0 m
Bd : width of excavation, 4.0 m
K : coefficient of earth pressure
u : coefficient of friction
H/Bd: 0.5 Cd = 0.45

$W_1 = 0.45 \times 1.8 \times 4 = 3.24$ (t/m^2)
L_1 : earth load per unit length of steel pipe (t/m)

$$W_1 = D \times W_1 = 1.5 \times 3.24 = 4.9 \text{ t/m}$$

- Car Load, W_2

$$W_2 = \frac{nP(1 + K')}{(L + t' + 2Htan\phi_s)(S + 2Htan\phi_s)}$$

where

n : number of wheels n = 2
P : wheel load T-20 P = 8t
K' : coefficient of impact
H < 1.50 K = 0.5

$1.50 < H < 6.50 \quad K = 0.65 - 0.1H$

$6.50 < H \quad K = 0$

L	:	wheel center distance	L = 175 cm
t'	:	tread width	t' = 50 cm
H	:	hight of backfill	H = 2.0 m
ϕ_s	:	support angle (sand)	ϕ_s = 30°
S	:	contact width	S = 20 cm

$$W_2 = \frac{2 \times 8 \times (1 + 0.5)}{(1.75+0.5+2\times2.0\times\tan30°)(0.2+2\times2.0\times\tan30°)}$$

$$= 2.1$$

$$L_2 = W_2 \times D$$
$$= 2.1 \times 1.5$$
$$= 3.1 \text{ t/m}$$

where,

L_2 = wheel load per unit length of steel pipe (t/m)

therefore

$$W = L_1 + L_2$$
$$= 4.9 + 3.1$$
$$= 8.0 \text{ t/m}$$

Bending stress and deformation on steel pipe is expressed by the formula as below.

$$\sigma = \frac{6}{t^2} \times \frac{R[(At^3 + B\times e\times R^4)L + (Ct^3 + D\times e\times R^4)\times q\times R^2]}{t^3 + 2.59 \times 10^{-4} \times R^4 \times e}$$

t = 11.1 mm
R = 75.6 cm
L = 8.0 t/m
q = 1×10^{-6} t/cm^2

If the support angle is β = 90°

n = 0.549
m = 1
A = 0.157
B = 0.080×10^{-4}
C = 0.321
D = 0.236×10^{-4}
e = 7×10^{-4} t/cm^3

then

$$\sigma = 1.90 \text{ t/cm}^2 > 1.74 \text{ t/cm}^2$$

therefore

$t = 12.7$ mm

then

$\sigma = 1.68 < 1.74$ t/cm^2

Deformation is calculated by the formula below.

$$\delta = \frac{R^3 \times 10^{-3} (n \times L + m.q.R^2)}{t^3 + 2.59 \times 10^{-4} \times e \times R^4}$$

where

$t = 12.7$ mm
$e = 7 \times 10^{-4}$ t/cm^2
$R = 756$ mm
$n = 0.549$
$m = 1$
$q = 1 \times 10^{-6}$ (t/cm^3)

$\delta = 2.8 < 0.03D = 0.03 \times 152.4 = 4.572$

In the case of concrete lining, allowable deformation is 3.0% of inner diameter of the pipe.

Appurtenant Facilities

Regarding such supplementary components as air valves, drain valves, butterfly valves, etc., the layout of their respective location is shown in Figs. 3-11, 3-12 and 3-13. At river crossings, construction of aqueducts are considered, as required, and for highway crossings, pipe jacking method is applied. In that case, construction of vertical shafts, etc. is required for the purpose.

Air Chamber

As the head of pumps to be installed at Dok Krai reservoir and Laem Chabang route is considerably high, it is necessary to make a study of effects caused by the impact of water hammer. A reduction of water hammer pressure by a surge tank and/or an air chamber may have to be considered. The findings in Fig. 4-12 shows at least three surge tanks are required because of the topographic complexities of the region. This is not economically feasible, therefore, construction of air chambers with total capacity of 120 m^3, consisting of three air chambers of 40 m^3 each, is proposed. (Refer to Fig. 8-10.)

4.3 HEAD TANK

Capacity and Number of Head Tanks

The volume of water to be stored in the head tank is determined by a water level control switch operating the pump and by filling water in pipeline in the case of power suspension.

tes. With 30 minutes, the storage capacity required of head tanks of Rayong-Sattahip and Laem Chabang Routes is as shown below.

- Rayong-Sattahip

$V = 3.02 \times 30 \times 60 = 5,440\ m^3$

- Laem Chabang

$V = 1.16 \times 30 \times 60 = 2,090\ m^3$

For the convenience of operation and maintenance of the proposed head tanks, total capacity of 8,000 m^3, construction of three tanks consisting of two 3,000 m^3 each for Rayong-Sattahip (refer to Fig.8-11) and one 2,000 m^3 for Laem Chabang, is considered.

Comparative Study of Head Tanks

From the results of the comparative study, shown in Table 4-8, it is concluded that PC Tank is the most advantageous of the three.

4.4 RECEIVING FACILITY

Capacity

The capacity of the respective receiving wells mentioned below is determined taking their 5-minute volume.

Mab Ta Pud	900 m^3
Sattahip	300 m^3
Laem Chabang	350 m^3

The receiving well is an integral portion of the purification facilities, therefore, where a time lag is anticipated between the time of construction of the purification facilities and that of receiving well as in the case of Mab Ta Pud, receiving basin for temporaly use is included in the design.

The receiving basin is designed to allow the storage for three hours taking the part as a sedimentation basin into consideration. The storage for the receiving basin is required around 21,000 m^3 in capacity.

In the design of the administration facilities of the purification plant and receiving well, adequate measures for a smooth takeover (in the future) by the proposed centralized administration system of the purification plant are to be considered.

The general plan of receiving well is shown in Fig.8-12.

5. CONSTRUCTION PLAN

With regard to the proposed pipeline, a brief study is carried on the two work items which are likely to present problems during the construction. The major constraints in execution of construction are, 1) construction period is much limited and 2) the source of intake is the existing reservoir.

5.1. PUMPING STATION

1) Method of Execution

By presupposing "Plan B-3" as the result of comparative study of pumping station, method of execution of construction is given in brief. The pumping station, in this Plan, consists of intakes and pumps, by a composite construction method of pile and caisson foundations and, is located on the bottom of the reservoir.

The lower portion of the caisson which constitutes the body is constructed at the caisson yard near the shore, and towed to the temporary location to receive an additional concrete placement to complete the structure, then towed again to the final destination and fixed by means of reverse circulation drill piles worked from the interior of the caisson.

The structure demands a high grade engineering technique in construction because it is required to execute the work in making dead weight of the caisson body and the buoyancy well in balance all during construction and its towing is a permanent underwater structure of which watertightness of the structure is the utmost prerequisite and, furthermore, it has a composite foundation consisting of caisson and pile foundation. The general construction procedure is illustrated in Fig. 5-1.

5.2 PIPELINE

1) Execution of work (Dok Krai - Mab Ta Pud)

As the pipeline is running along Routes 3191 and 3, no special problem with regard to topography and/or geology of the region is anticipated. The construction work at the site where the existing gas pipeline and the proposed water pipeline are running close together may present some problems.

A further study may have to be made at the time of detailed design, regarding the degree of closeness between the gas and water pipelines. Only a brief description of more general construction procedures is given in Fig. 5-2.

2) Specific sections

The below is section in the pipeline which calls for a specialized engineering technique.

- Road crossings (Routes 36 & 3)

  Application of jacking method will solve the problems.

- River crossings and poor subsoil area

  Open-cut by relocation of channel or temporary coffering, jacking method or aqueduct of pipe beam is considered, however, in this study, the embeded pipeline is considered as suitable. In this case, countermeasures for uplift and prevention of scour may become necessary.

- Portions where gas and water pipelines running close together

  Utmost care is to be exercised in the construction of the water pipeline running close parallel to the existing gas pipeline to avoid damage such as cracks in weld joints and/or pipe which may trigger a fatal accident. Further detailed study on the closest distance between the gas and water pipelines, adverse effects of heavy construction equipment, etc. may have to be made. However, at the present stage, an open excavation without pipe retaining walls is only considered.

3) Laem Chabang Route

With regard to Laem Chabang Route pipeline, type of execution of the pipeline work is almost the same as Mab Ta Pud Route, therefore, there is nothing to be specially added. There is a tunnel section in 9.0 km on this route. As geological conditions of the tunnel section is not clarified yet, it is too early to study about construction method. It is anticipated, however, that there is almost no obstacles in construction as the tunnel is small, the diameter only about 2 meters, and almost no possibility of spring water.

II. PLAN I (Mab Ta Pud, Sattahip and Laem Chabang routes)

6. GENERAL

The water demand in development centers of Rayong except "other-municipal water" of Rayong, Sattahip and Laem Chabang is to be met by the water from Dok Krai dam through pipe line system.

The other municipal water to the central area of present Rayong city which is situated in the down stream area is conveyed through the Rayong river.

7. WATER DEMAND AND SUPPLY

7.1 WATER DEMAND

Estimation of annual water demand for industrial and municipal use is mentioned in the Main Report. (Refer to CHAPTER III WATER DEMAND AND WATER RESOURCES DEVELOPMENT)

Table 7-1 shows the water demand for Rayong, and Sattahip area and Laem Chabang area .

7.2 WATER SUPPLY

7.2.1 Water Supply Plan

The water supply to Rayong, which is comparatively small, is assumed to be tapped at present intake weir of Ban Khai. The design and cost estimate of water transmission system to Rayong is thus excluded from the present study.

As for the route from Dok Krai to Mab Ta Pud and from Mab Ta Pud to Sattahip, design discharge corresponds to the demand expected in the target year of 2000. On the other hand, route from Dok Krai to Laem Chabang is designed to meet the expected demand in 1995, then the total demand reaches to 80 MCM/year.

7.2.2 Capacity of Pipeline

As described in 2.1 Water Demand, water demand does not occur at one time, but increases from year to year. Therefore, the capacity of pipeline which can meet the water demand does not occur at one time, but increase from year to year. Therefore, the capacity of pipeline which can meet the water demand at some specific time is studied for the Dok Krai - Mab Ta Pud route. Capacity of pipeline is calculated as below:

Diameter (D) (m)	Discharge (Q) (m^3/sec)	Capacity (Wd) (MCM/year) *cf = 1.2	cf = 1.3	cf = 1.5
0.8	0.78	18.6	17.2	14.9
0.9	1.06	25.4	23.4	20.3
1.0	1.40	33.5	30.9	26.8
1.1	1.80	43.0	39.7	34.4
1.2	2.26	54.1	49.9	43.3
1.35	3.09	73.7	67.0	59.0
1.50	4.07	97.3	89.8	77.8

*cf: Load factor. In this study cf=1.3 is adopted.
$Wd = Q \times 86{,}400 \times 365 \times 10^{-6}/cf$

If case smaller capacity pipeline is adopted, the project can enjoy a smaller initial investment, but earlier the demand will overrun the capacity. Fig. 7-1 shows that pipe of 1.2m dia. can only meet the demand up to 1993 and another pipe of 0.9 m dia. is to be constructed to meet the further demand.

Since the double pipe system is found to be inferior to the single pipe system in the foregoing chapter, in this study single pipe system with dia. 1.35 m which can meet 2000 year demand is to be adopted.

For another route, too, single pipeline system is adopted.

8. PROJECT FORMULATION

8.1 DESIGN CONDITION

All the design conditions are same as in PRELIMINARY STUDY but the design discharge is changed as shown below:

Design Discharge

Design discharge is determined as the basis of the annual demand water taking Cf=1/1.3 and fw = 1.1 using the abovementioned formula. That is Qd - Wd/365/86,400 Fw/Cf where, ratio of load "Cf" is determined by the following reasons.

Generally, daily fluctuation of demand water is larger in municipal water than that of industry.

As municipal water of Rayong not related to industry is excluded in water supply, percentage of municipal demand water in total demand decreased.

The design discharge of the respective routes is shown below:

Route	Design discharge (m^3/sec)
Dok Krai -Mab Ta Pud	2.62
Mab Ta Pud - Sattahip	1.09
Dok Krai - Laem Chabang	1.01

Fig 8-1 shows the general plan of water supply system.

8.2 DIAMETER OF PIPE AND PUMPING HEAD

The appropriate diameter of pipe is to be selected with due consideration to construction cost, pumping head as well as operating cost of the system.

Required pipe diameter is calculated using the foregoing Hazen-William's formula. That is

$$D = 1.6258 \times C^{-0.38} \times Q^{+0.38} \times I^{-0.25}$$

or

$$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$$

Fig. 8-2 shows Hydraulic gradient of the pipeline.

- Dok Krai to Mab Ta Pud route

In case of pipe diameter ∅ = 1200 mm, the low water level of head tank would be 135.5 m, which requires head tank of 40 m high placed a top of hill. This should be avoided in respect of engineering difficulty and high cost.

In comparison of ∅ = 1350 and ∅ = 1500, the present value of construction cost including operation and maintenance cost would be little less for ∅ 1350 mm. The diameter ∅ = 1350 is selected for this route.

- Mab Ta Pud to Sattahip route

The comparative study on pipe diameter for their present value of construction cost has revealed that steel pipe of ∅ = 900 mm with booster pump head of H = 36 m and ∅ = 1,000 mm with booster pump head H = 11 m are about equal, while ∅ = 1,100 mm with no booster pump is less advantageous. Out of the two comparing equal, ∅ = 1,000 mm is selected on the account of less pump head and therefore less power bill. If the location and elevation of receiving well in Sattahip which is temporarily fixed in PLAN I, may be transferred elsewhere in the vicinity, pump-up system will be a better solution.

8.3 PROJECT DESCRIPTION

To the all area except the other municipal water in Rayong, the water will be supplied by the pipeline.

From Dok Krai to Mab Ta Pud (refer to Fig. 8-3)

1) Pumping station at Dok Krai reservoir

Type of pumping station:		Concrete caisson
Type of pump	:	Vertical shaft volute type pump
Design discharge/1	:	$Q = 3.63\ m^3/sec$ ($Q = 43.56\ m^3/min/pump$)
Number of pumps	:	6 (1 for stand-by) pump
Total pump head	:	Ht = 107 m
Motor output	:	Pw = 5,250 kw

The profile and General plan of pumping station are shown in Figs 8-6, 8-7. The general plan of aqueduct bridge and air chamber are shown in Figs 8-8, 8-9.

2) Pipeline

Total length	:	L = 27.6 km
Steel pipe	:	D = 1,350 mm t = 11.9 mm

3) Head Tank

Location	:	5.0km south of Dok Krai pumping station
Volume	:	$2 \times 3{,}000\ m^3$

The standard dimension of Head Tank is shown in Fig. 8-10.

4) Receiving facility

Location	:	West of Ban Chan Luk Ya along Route-3
Receiving well	:	$V = 780\ m^3$
Receiving basin	:	$V = 21{,}000\ m^3$

The general plan of recieving well is shown in Fig. 8-11.

/1: Service area is Mab Ta Pud, Sattahip and Laem Chabang

From Mab Ta Pud to Sattahip (refer to Fig. 8-4)

1) Booster pumping station at Mab Ta Pud

Type of pump	:	Horizontal shaft volute type pump
Design discharge	:	Q = 1.09 m^3/sec (Q = 32.70 m^3/min/pump)
Number of pumps	:	3 (1 for stand-by)
Total pump head	:	Ht = 11 m
Motor output	:	Pw = 150 kW

2) Pipeline

Design discharge	:	Q = 1.09 m^3/sec
Total Length	:	L = 21.9 km
Steel Pipe	:	D = 1,000 mm t = 8.7 mm

3) Receiving well

Location	:	Approx. 5 km east of Amphoe Sattahip
Volume	:	V = 350 m^3

From Dok Krai to Laem Chabang (refer to Fig. 8-5)

1) Booster pumping station

Location	:	7.5 km southwest of Dok Krai pumping station
Type of pump	:	Horizontal shaft volute type pump
Design discharge	:	Q = 1.01 m^3/sec (Q = 30.30 m^3/min/unit)
Number of pumps	:	3 (1 for stand-by) pump
Total pump head	:	H = 45 m
Motor output	:	Pw = 600 kw

2) Pipeline

Total length	:	L = 53.0 km		
Steel pipe	:	D = 900 mm	t = 7.9 mm	L = 24.5 km
		D = 1,000mm	t = 8.7 mm	L = 13.0 km
		D = 1,200mm	t =11.1 mm	L = 6.5 km
Tunnel section	:	D = 1,500mm		L = 9.0 km

3) Head tank for booster pumping station

Location	:	5.0km northwest of booster pumping station
Volume	:	V = 2,000 m^3

4) Receiving well

Location	:	South of Bang Thung Suk La along Route-3
Volume	:	V = 300 m^3

9. CONSTRUCTION SCHEDULE AND COST

9.1 CONSTRUCTION SCHEDULE

With regard to the construction schedule of the pumping station and pipeline, a comparative study of methods in Schedules-A and B is carried out.

The shown below are items of the particulars of the respective plans.

Schedule-A (refer to Fig.9-1)

- No special consideration for a shorter construction period.
- The steel pipe (ϕ=1,350 mm.) will be manufactured by Thai makers using imported raw materials.
- 4 gangs will be thrown into the field execution.

Schedule-B (refer to Fig.9-2)

- Construciton shcedule shall be squeezed as short as possible.
- The steel pipe (o=1,350 mm) will be manufactured by Thai makers using imported raw materials.
- 8 gangs will be thrown into the field execution, including welders of about 50 men/day.
- The Critical Path in this plan is the construction of the pumping station.

Fig.9-3 shows the implementing schedule of pipeline system.

9.2 CONSTRUCTION COST

Construction Cost

The construction cost is estimated taking the condition below into consideration.

1) The construction cost has been estimated on the contract basis and on 1981 prices.

2) Implementing schedule of the route from Dok Krai to Mab Ta Pud is formulated on the basis of Schdule-B.

3) Duties and taxes levied on the hot-coil imported into Thailand are estimated at 5.3% of CIF.

4) Duties and taxes levied on pumps and valves are estimated at 12% of CIF.

5) The same computation procedures of the cost estimation for the dam (Nong Pla Lai and Ban Bung) are applied for the proposed civil construction works, except physical contingency which is 10%.

6) All related cost and charges on communication facilities are assumed as minimum systems.

Construction cost of each route is shown in Table 9-1.

The breakdown of the project cost is shown in Tables 9-2, 9-3, and 9-4 for each route, and disbursment schedule is in Table 9-5.

Operation and Maintenance Cost

The operation and maintenance cost mainly comprises pumping up power cost. Annual power cost is composed of the folowings.

Unit energy cost : 1.19 ฿/KWH

Electric power : $P = \frac{1.1 \times 9.8 \times 1.0 \times H \times Q}{0.88 \times 86,400 \times 365}$ (kW)

Annual power cost : $Cp = 1.19 \times 24 \times 365 \times p$ ($\times 10^6$ ฿)

where H : Total head (m)
Q : Discharge (MCM/year)

The annual cost for operation and maintenance is estimated at 1.41 million US$/year at full operation.

III. PLAN II (Mab Ta Pud and Sattahip Routes)

10. GENERAL

In formulation of PLAN II, the supply of water to Laem Chabang is excluded while Rayong, Mab Ta Pud and Sattahip areas enjoy the service. By this plan, municipal-industrial water demand by the final target year of 2000 could be met by the water to be developed by Nong Pla Lai Sub-Project.

Pipeline transmission will be limited to Mab Ta Pud and Sattahip areas. As for Rayong area, discharge of water from Dok Krai reservoir will be tapped in the middle reaches of Rayong river for respective use.

11. WATER DEMAND AND SUPPLY

11.1 WATER DEMAND

Water demand for industrial and municipal use is the same as PLAN I (refer to 7.1). Here, the areas supplied by the pipeline system are Mab Ta Pud and Sattahip.

Table 11-1 shows breakdown of the water demand in Rayong area and Sattahip area.

11.2 WATER SUPPLY

11.2.1 Water Supply Plan

For the water demand arising from Rayong, Mab Ta Pud and Sattahip areas, Mab Ta Pud and Sattahip will be served by a pipeline system equivalent to PLAN I. As for Rayong, water released from Dok Krai reservoir will be tapped in the middle reaches of Rayong river with an assumption that water is conveyed to a location adjacent to city area. The conveyance method may be altered by the location of demand.

11.2.2 Pipeline

On the system between Mab Ta Pud and Sattahip, the section between Dok Krai to Mab Ta Pud is to have an uniform discharge capacity and is equivalent to PLAN I. The section between Mab Ta Pud and Sattahip is to be altered due to discharge change.

12. PROJECT FORMULATION

12.1 PIPELINE

All the design conditions are same as PLAN I. But the design discharge is changed as shown below:

Design Discharge

The design discharge of the respective routes are shown below.

Route	Design discharge (m^3/sec)
Dok Krai - Mab Ta Pud	2.62
Mab Ta Pud - Sattahip	1.09
Ban Khai Head Works - Ban Khai	1.01

Pipeline Route

As for the route from Dok Krai to Mab Ta Pud, the pipeline route is the same as PLAN I. As for the route from Mab Ta Pud to Sattahip, most of the route is along the route-3 without 200 m long detour at Ban Krok Tabaek.

The concrete pipe of ϕ=1,500 mm will be adopted for the route of 1.0 km from Ban Khai head works to the receiving well. General plan of the water supply system is shown in Fig.12-1.

Pipe Diameter

As the design discharge of the pipeline from Dok Krai to Mab Ta Pud and from Mab Ta Pud to Sattahip is the same as the PLAN I, pipe diameter is the same as that of PLAN I.

12.2 HEAD WORKS

The water of 22.2 MCM/year for Rayong will be tapped from Rayong river by using proposed head works which will be constructed on the upper stream of the existing Ban Khai irrigation facility.

With regard to the river cource from Dok Krai to the proposed head works, the existing river is assumed to be utilizable.

The proposed head works has been designed as movable type considering water-intake during dry season.

12.3 PROJECT DESCRIPTION

12.2.1 Pipeline

To the all area except Rayong, the water will be suplied by the pipeline.

From Dok Krai to Mab Ta Pud (Refer to Fig. 12-2)

1) Pumping station at Dok Krai reservoir

Type of pumping station	:	Concrete caisson with pile foundation
Type of pump	:	Vertical shaft volute type pump
Design discharge	:	$Q = 2.62\ m^3/sec$ ($Q = 31.44\ m^3/min/pump$)
Number of pumps	:	6 (1 for stand-by)
Total pump head	:	Ht = 90 m
Motor output	:	Pw = 3,000 kW

2) Pipeline

Total length	:	L = 27.6 km
Steel pipe	:	D = 1,350 mm t = 11.9 mm

3) Heads Tank : 6.0 km south of Dok Krai pumping station

Volume	:	$2 \times 3,000\ m^3$

4) Receiving facility :

Location	:	West of Ban Chan Luk Ya along Route-3
Receiving well	:	$V = 780\ m^3$
Receiving basin	:	$V = 21,000\ m^3$

From Mab Ta Pud to Sattahip (Refer to Fig. 12-3)

1) Booster pumping station at Mab Ta Pud

Type of pump	:	Horizontal shaft volute type pump
Design discharge	:	$Q = 1.09\ m^3/sec$ ($Q = 32.70\ m^3/min/pump$)
Number of pumps	:	3 (1 for stand-by)
Total pump head	:	Ht = 11 m
Motor output	:	Pw = 150 kw

2) Pipeline

Design discharge	:	$Q = 1.09\ m^3/sec$
Total length	:	L = 21.9 km
Steel pipe	:	D = 1,000 mm t = 8.7 mm

3) Receiving well

Location : Approx. 5 km east of Amphoe Sattahip

Volume : $V = 350\ m^3$

12.3.2 Head Works

Weir (refer to Fig.12-4)

Location : Up stream of Ban Khai fixed weir on Rayong river
Flood gate : 2 gates x 20 m (W) x 2.5 m (H)
Regulating gate : 10 m (W) x 3.0 m (H)

Intake and Transmission Facilities

Design discharge : $Q = 1.01\ m^3/sec$
Pipeline
length : L = 1.0 km
concrete pipe : D = 1,500 mm

Receiving Well

Location : Ban Khai
Volume : $V = 300\ m^3$

13. CONSTRUCTION SCHEDULE AND COST

13.1 CONSTRUCTION SCHEDULE

The construction schedule of pipeline is equivalent to PLAN I except Laem Chabang route (refer to Fig.9-3).

For the construction of head works at Ban Khai, the same works schedule for the construction of Mab Ta Pud to Sattahip route may be followed.

13.2 CONSTRUCTION COST

Construction Cost

The PLAN I is followed for the cost estimate. The cost estimated for Ban Khai head works is rather rough compared to that of pipeline system.

The construction cost of pipeline from Dok Krai to Mab Ta Pud, from Mab Ta Pud to Sattahip and Ban Khai head works are shown in Tables 13-1.

The breakdown of the cost is shown in Tables 13-2 to 13-4 for each route, and disbursment schedule is in Table 13-5.

Operation and Maintenance Cost

The annual operation and maintenance cost is estimated by the same method as PLAN I and the cost is 1.33 million US$/year at full operation.

Table 2-1 Water Demand

Unit: MCM/Year

Region	Year	1990	1995	2000
Rayong	Municipal	12.9	15.3	28.1
	Industrial	23.1	23.1	27.9
	Total	36.0	38.4	56.0
Sattahip	Municipal	3.9	5.1	6.8
	Industrial	13.7	14.3	17.2
	Total	17.6	19.4	24.0
Laem Chabang	Municipal	6.3	10.2	12.5
	Industrial	6.6	12.0	16.8
	Total	12.9	22.2	29.3
Total	Municipal	23.1	30.6	47.4
	Industrial	43.4	49.4	61.9
	Total	66.5	80.0	109.3

Note: Rayong includes Rayong Municipality, Amphoe Muang Rayong, King Ampho Ban Chang, Ampho Ban Khai.

Sattahip includes Amphoe Sattahip.

Laem Chabang includes Amphoe Si Racha, Si Racha Municipality

Table 2-2 Water Quality Analyses

(1) Heavy Metals (Date Sampled: May 5, 1981)

	Location	
	Nong Pla Lai	Dok Krai
Cadmium	Unfound	Unfound
Cyanide	Unfound	Unfound
Phosphorus	0.04	0.03
Chromium	Unfound	Unfound
Arsenic.	0.001	0.001

(2) Mineral Constituent of Dok Krai Reservoir

(Date Sampled: August 16, 1981)

<table>
<tr><th colspan="2"></th><th>Value</th><th></th><th>Value</th></tr>
<tr><td colspan="2">PH</td><td>7.1</td><td>Ec x 10^6</td><td>100</td></tr>
<tr><td colspan="2">CO (ppm)</td><td>10</td><td>SSP</td><td>23</td></tr>
<tr><td colspan="2">Mg (ppm)</td><td>4</td><td>SAR</td><td>0.4</td></tr>
<tr><td rowspan="2">Fe</td><td>total (ppm)</td><td>0.1</td><td>TS (ppm)</td><td>0.01</td></tr>
<tr><td>diss. (ppm)</td><td>0</td><td>TDS (ppm)</td><td>93</td></tr>
<tr><td colspan="2">Mn</td><td>0</td><td>SS (ppm)</td><td>68</td></tr>
<tr><td colspan="2">CO_3</td><td>0</td><td rowspan="2">Alkalinity as $CaCO_3$ (ppm)</td><td rowspan="2">40</td></tr>
<tr><td colspan="2">HCO_3 (ppm)</td><td>49</td></tr>
<tr><td colspan="2">Cl (ppm)</td><td>8</td><td rowspan="2">Total Hardness as $CaCO_3$ (ppm)</td><td rowspan="2">40</td></tr>
<tr><td colspan="2">SO_4 (ppm)</td><td>2</td></tr>
</table>

Table 2-3 Water Analysis of Dok Krai Reservoir

(January 1979 - June 1981)

	Upstream of Dam				Downstream of Dam			
	No. of Samples	Average	Maximum	Minimum	No. of Samples	Average	Maximum	Minimum
Depth Metre	-	-	-	-	-	-	-	-
PH	25	7.1	7.9	6.4	25	7.1	7.7	6.3
EC x 10^6 at 25°C	27	116	130	100	27	145	410	110
SAR	18	0.5	0.6	0.4	18	0.5	0.9	0.2
SSP	18	28	32	25	18	25	36	7
RSC meq/l	18	0.08	0.25	0	18	0.08	0.32	0
Ca ppm	18	10,3	11.9	7.5	18	17.3	60.6	8.7
Mg ppm	18	3.2	5.1	1.7	18	3.7	10.7	2.4
Na ppm	18	6.9	8.1	6.0	18	7.8	17.3	6.0
K	-	-	-	-	-	-	-	-
Fe Total	-	-	-	-	-	-	-	-
Fe Diss.	-	-	-	-	-	-	-	-
CO_3	0	0	0	0	0	0	0	0
HCO_3 ppm	18	62	237	42	18	71	257	42
Cl ppm	18	7.1	8.2	5.7	18	7.1	8.2	5.7
SO_4 ppm	18	1.0	2.9	0	18	6.7	40.3	0
NO_3	-	-	-	-	-	-	-	-
PO_4	-	-	-	-	-	-	-	-
B ppm	-	-	-	-	-	-	-	-

NOTE: Abbreviations:

PH : Glass Electrode
EC x 10^6: Electrical Conductivity micromhos/cm
RSC : Residual Sodium Carbonate
SSP : Soluke Sodium Percentage
SAR : Sodium Adsorption Radio
TS : Total Solid
TDS : Total Dissolved Solid
SS : Suspended Solid

Table 2-4 Water Quality Standards (For drinking)

A requirement prescribed in Article 4, Paragraph 1, Item 1. (Not to be affected by any pathogenic organism nor to contain any organism or substance which gives ground for suspicion of being affected by pathogenic organism)	Nitrite nitrogen and Nitrate nitrogen Chloride ion Organic substances (as potassium permanganate consumption) Total colonies Coliform group	Max. 10 mg/l Max. 200 mg/l Max. 10 mg/l (colony counts per ml) Max. 100 Not to be detected
A requirement prescribed in Article 4, Paragraph 1, Item 2. (Not to contain cyanide, mercury and other poisonous substances)	Cyanide ion Mercury Organic phosphate	Not to be detected Not to be detected Not to be detected
A requirement prescribed in Article 4, Paragraph 1, Item 3. (Not to contain copper, iron, fluorine, phenols and other substances in excess of their allowable quantities)	Copper Iron Manganese Zinc Lead Chromium (hexavalent) Cadmium Arsenic Fluoride Calium, Magnesium (hardness) Total residue Phenols Surface-active agents (anionic)	Max. 1.0 mg/l Max. 0.3 mg/l Max. 0.3 mg/l Max. 1.0 mg/l Max. 0.1 mg/l Max. 0.05 mg/l Max. 0.01 mg/l Max. 0.05 mg/l Max. 0.8 mg/l Max. 300 mg/l Max. 500 mg/l Max. 0.005 mg/l as phenol Max. 0.5 mg/l
A requirement prescribed in Article 4, Paragraph 1, Item 4. (Not to assume abnormal acidity or alkalinity)	pH value	From Max. 8.6 to min. 5.8 as pH value
A requirement prescribed in Article 4, Paragraph 1, Item 5. (Not to give an offensive smell, except the smell caused by sterilization)	Odor Taste	Not to be abnormal Not to be abnormal
A requirement prescribed in Article 4, Paragraph 1, Item 6. (To be almost colorless and transparent in appearance)	Color Turbidity	Max. 5 degree Max. 2 degree

Table 2-5 Japanese Industrial Water Quality Standards

Turbidity (ppm)	PH (- log H)	Alkalinity $CaCO_3$ (ppm)	Hardness $CaCO_3$ (ppm)	Evaporation Residue (ppm)	Chlorine Ion Cl (ppm)	Iron Fe (ppm)	Manganese Mn (ppm)
20	6.5-8.0	75	120	250	80	0.3	0.2

Table 2-6 Water Quality Standards - WHO (Drinking Water)

Coliform Group	Max. MPN10
Bacteria	Not specified
Odor	ditto
Taste	ditto
Color	ditto
Turbidity	ditto
Evaporation Residue	ditto
pH Value	7.0 ∿ 8.5 (6.5 ∿ 9.2)
Total Hardness	100 ∿ 500
Potassium Permanganate Consumption	10
Chloride	200 (400)
Sulfate	200 (400)
Ammonia	0.5 (as N)
Nitrite Nitrogen	Not specified
Nitrate Nitrogen	40 (80)
Iron	0.3 (1.0)
Manganese	0.1 (0.5)
Fluoride	1.0 (1.5)
Lead	0.1
Arsenic	0.2
Selenium	0.05
Chromium (Hexavalent)	0.05
Copper	1.0
Zinc	50 (150)
Phenols	0.001 (0.002)
Cyanide Ion	0.01
Mercury	Not specified
Barium	ditto
Cadmium	ditto
ABS	ditto
Radio Activity	α 10^{-9} μc/mℓ β 10^{-9} μc/mℓ
Organic Phosphates	Not specified
Free Chlorine	ditto
Magnesium	50 (150)
Calcium	75 (200)
Vanadium	Not specified

Note: All values are in ppm except pH and other values specified otherwise.

Table 3-2 Comparison of Pipeline Route

	Intake Facility		Water Transmission Facilities		Merit and Demerit	Cost (x10^6US$)	Evaluation
		Particulars		Particulars			
Plan - A	° Pumping Station: Location Dok Krai dam Type Q = $3.02m^3$/sec. H_a = 70.0m H_c = 90.0m W.L.= 42.0-52.0m	Storage water of Dok Krai dam is pumped up by the pump installed on the intake tower to the head tank by the pipe line running parallel with Route "R-3191".	Steel Pipe ° L =27.0km ° I.D.=1,500mm ° Cement Mortar Lined	Pipe line between the head tank and purification plant at Mab Ta Pud is for gravity flow. Pipe line is embeded along the Route "R-3191".	° As major portion of the pipe line runs parallel with the Route 3191, the required volume of land acquisition is the smallest of the three plans. ° For the same reason, the construction period is the shortest, and it is possible to complete the construction within the scheduled construction period of the major facilities. ° Leak on the pipe line is considered practically nil steel pipe is used.	36	Available
Plan - B	° Intake: Location Ban Nong Saphan Type ° Pumping Station: Type Horizontal Shaft Double Suction Centrifugal Pump Q = $3.02m^3$/sec. H_a = 55.0m H_c = 100.0m W.L.= 5.0m	Intake from the existing irrigation channel on the right bank of the Rayon River. Pump is a closed system therefore, it is necessary to consider countermeasures to prevent water hammer in the system.	Steel Pipe ° L =23.0km ° I.D.=1,500mm ° Cement Mortar Lined	Pipe line is a closed system, therefore, it is necessary to consider countermeasures to prevent water hammer in the system. Almost entire length of the pipe line is embeded along the Route 3.	° As the pump system is a closed type, operation and control is extremely difficult. ° As the major portion of the pipe line is running along the Route 3, it is advantageous in acquisition of the required land and also to shorten the period required for construction work. ° Since the existing irrigation warter is used, it involves problems to be solved in water quantity and quality. ° Therefore, the operation cost of the purification plant becomes higher, seasonal fluctuations are greater, and maintenance and administration are more difficult.	35	Not Available
Plan - C	° Pumping Station: Location Dok Krai dam Type Q = $3.02m^3$/sec. H_a = 45.0m H_c = 60.0m W.L.= 42.0-52.0m	Storage water of Dok Krai dam is pumped up by the pump installed on the intake tower to the regulating reservoir located on the hilly terrain on the right bank of the dam.	Kocla Pipe ° L =16.0km I.D.=1,650&1,800mm Steel Pipe ° L =3.0 & 2.0km ° I.D.=1,400&1,500mm ° Cement Mortar Lined Aqueduct ° L =30.0&60.0m (Pipe Beam) ° Number Req'd: 7	Major portion of transmission line is open conduit. As the natural gradient of the hilly terrain is considered in the design, detour and large volume of excavation is likely to be involved. At crossing of low-lying ground, such as river bed, syphon and/or aqueduct are to be considered.	° Land acquisition is required all along the pipe line. ° Construction and administration roads are required. ° Because of the above, weight of the pipe is heavy, and earthwork required is larger, the construction cost is the highest of the three. ° Pipe line is of Kocla pipe, therefore, leakage prevention is difficult and location of leak is also difficult. ° Depending on natural gradient wherever possible, results a number of embankments and cuts. Danger of collapse by heavy rain is especially frequent in embankments.	28	Not Available

Table 3-3 Comparative Study of Pipes (1/2)

	Concrete Pipe	Ductile Cast-iron Pipe	Steel Pipe
Strength	Require a suitable protective work (concrete foundation and/or concrete lining). Not suitable for use under high pressure.	High strength. Only the next to steel pipe in toughness and anti-impact registance value.	Highest in strength of the other two. Allows joints by welding for the same strength as that of pipe itself. Shows a sufficient strength to endure internal and external stresses under wheel load and water hammer.
Weight	About 3.3 times heavier than steel pipe makes transportation and laying work awkward. (1,560.0 kg/m)	About 1.7 times heavier than steel pipe. (804.0 kg/m)	Lightest of the three. About 113 of concrete pipe and 112 of ductile iron pipe makes transportation and laying work most convenient. (473.0 kg/m)
Flow Capacity	No incrustation on interior surface to effect a decrease in flow capacity, however, at joints and bends, where cast iron is used, may require such countermeasures as protective coating.	When non-treated, surface gathers incrustation, however, when mortar-lined, no change in interior surface roughness, chances of incrustation is greatly reduced.	Same as ductile cast-iron pipe shown on the left.
Leakage	Normally, flexible joints with rubber ring gaskets are used, involves a possibility of leakage at joints.	In mechanical joints, leakage develops gradually with long years of service due mostly to loosening at joints.	With welded joints, leakage is practically eliminated.
Corrosion	High resistance to corrosion.	Without protection, wall is getting thin due to corrosion enough to present problem in structural strength.	Though liable to electrolytic corrosion, corrosion proofing can be achieved by protective coating and/or cathodic protection.
Aseismicity	At sections where they are subject to external load, it is not suitable especially from the viewpoint of very possible leakage at joints and bends.	High strength and high impact resistance.	Because of the high strength and high impact resistence of the material, able to withstand extra heavy internal and external pressure.

Table 3-4 Comparative Study of Pipes (2/2)

	Concrete Pipe	Ductile Cast-iron Pipe	Steel Pipe
River Crossings	Needs a special bridge for the pipe line, this means a higher construction cost and also less easier work convenience.	Same as concrete pipe shown on the left.	The fact that steel pipes can be used as integral parts of the structural component of the bridge, means a lower construction cost.
Pipe Laying Works	The stock length of the pipe is the shortest of the three, only 2.43 meters. This means that number of diggings required at joints is the biggest of the three, hence, the construction cost is also the highest. Protective and/or bedding are required at joints. This is a problem, especially over poor subsoil areas.	With the standard length of the pipe of 6.0 meters, number of diggings at pipe joints are still bigger than that of steel pipes. Protective and/or bedding are required at joints. This is a problem, especially over poor subsoil areas.	Several number of pipes can be welded on the ground surface to make one long pipe, then, lowered into the excavated trench, this reduces the required number of diggings considerably and also reduces the construction cost accordingly. Prompt adoption of countermeasures against unexpected obstacles is easier by making a detour, for example. And further, no need of protection at bends and/or beddings at poor subsoil areas.
Construction Cost	284 US$/m	619 US$/m	596 US$/m
Evaluation	Construction cost is low. However, effective strength of the pipe is also low, field workability is poor, and, on top of those, the poosibility of leakage is extremely high, make the pipe not suitable for the purpose intended.	High in both effective strength and corrosion resistance of the pipe makes it high suitable for the intended purpose, however, the construction cost is the highest of the three.	Though construction cost is relatively high, the field workability is better, and it is most reliable of the three in every respect especially in the effective strength.

Table 3-5 Comparative List

	One-pipe	Two-pipe
Pipe, Dia.	1,500 mm	1,100 mm
Merits and Demerits	° Pipe line accident may likely cause water supply cut-off. ° Initial ivestment is higher. ° Practically no difference in construction methods between one- and two-pipe lines ° Supply of the steel pipe is guaranteed. ° Application of interior mortar lining of pipes laid is possible.	° Chance of supply cut-off by accident is much less. ° Easier maintenance and administration ° Start with one-pipe line, then, add another, as circumstances demand. ° Taking possible damage to the existing one-pipe pipe line at the time of construction of the additional one-pipe line into consideration, the width of the required lot will become fairly wider. ° Hence, an increase in land procurement and compensation costs.
Construction Cost	940 US$/m	1,160 US$/m
Rating	High	Low

Table 4-1 Comparison of Types of Pump

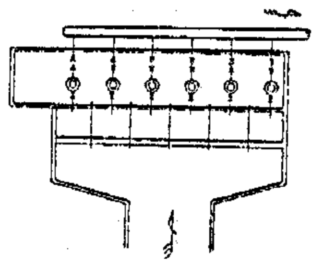
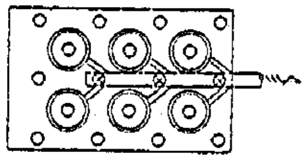
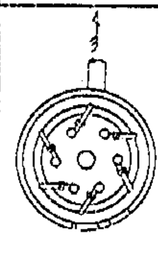
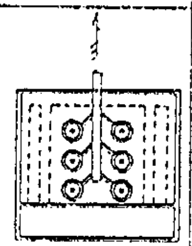
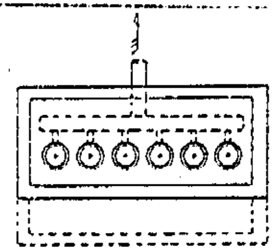
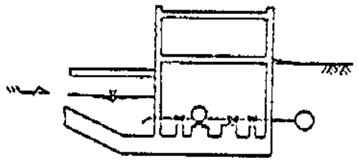
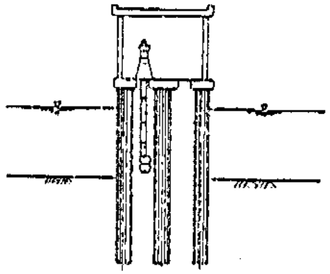
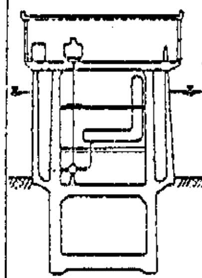
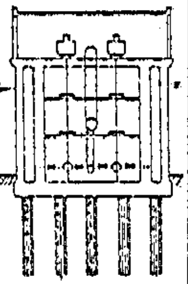
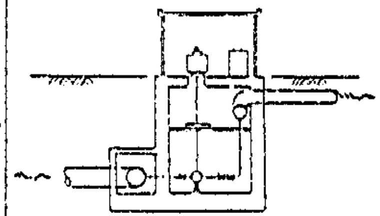
No.	Item \ Plan		A	B-1	B-2 / B-3	C
1	Type		Horizontal Shaft Double Suction Centrifugal Pump	Vertical Shaft Mixed-Flow Pump	Vertical Shaft Double Suction Centrifugal Pump	Vertical Shaft Double Suction Centrifugal Pump
2	Layout	Plan			B-2:  B-3: 	
		Section			B-2:  B-3: 	
3	Pump-Structural Characteristics		•In overhaul, only removal of the upper cover is enough. •Because equipped with two shaft bearings, replacement of bearing is easy. •Weight is distributed over a wide area of floor.	•In overhaul, motor has to be removed first, then the whole pump has to be pulled up. •Hence bearings are under-water their replacement is not easy. •All weight is distributed only over motor floor.	•In overhaul, motor has to be removed first. •Repair and replacement of two vertical shaft bearings are not easy. •The weight is shared by motor and pump floors.	Same as Plans B-2 & 3.

Table 4-2 Comparison of Types of Pump

No.	Item \ Plan		A	B-1	B-2, B-3	C
4	Pump Performance	Pump Efficiency	High efficiency and suitable for continuous operation.	Efficiency is about 20% lower than double suction centrifugal.	High efficiency and suitable for continuous operation.	Same as Plans B-2 & 3.
		Motor Output	Because of high efficiency pump, relatively smaller output motor is required, if the total pump head is the same as plans B & C.	A larger output is required because of lower efficiency of the pump in the case of double suction centrifugal.	Because of high efficiency pump, relatively smaller output motor is required.	Same as Plans B-2 & 3.
		Flow-Head Characteristics	Efficiency curve is milder than that of mixed flow pumps. Starting head (delivery valve closed) is low.	Efficiency curve is steeper than that of centrifugal pumps. Starting head (delivery valve closed) is high.	Efficiency curve is milder than that of mixed flow pumps. Starting head (delivery valve closed) is low.	Same as Plans B-2 & 3.
		Suction Characteristics	Condition is good. Because suction is under pressure.	Sams as "A" on the left. (Cavitation may occur in guide vane under wide load variations)	Condition is good. Because suction is under pressure.	Same as Plans B-2 & 3.
5	Pump-Weight (Crane Capacity)		Lightest in weight of all five.	Heaviest in weight of all five, hence, needs the biggest crane capacity.	Same as A on the left, except an intermediate shaft and bearing supports.	Same as Plans B-2 & 3.
6	Relative Difficulties in Assembly, Installation and Hauling	Installation Accuracy	Installation is easier when compared with mixed flow pump and multi-floor type pump.	Needs accuracy in installation.	Needs accuracy in centering of pump and motor axles.	Same as Plans B-2 & 3.
		Component Parts	Fewer than those of mixed flow pump.	More are required than those of centrifugal pumps.	Same as A on the left, except such extras as intermediate shafts and the bearing supports.	Same as Plans B-2 & 3.
		Technical Level Required	In installation, centering is simple.	High level of skill and technique is required in installation and centering.	Intermediate technical level of "A" and "B" is required in installation and centering.	Same as Plans B-2 & 3.

Table 4-3 Comparison of Types of Pump

No.	Item		A	B-1	B-2 & B-3	C
7	Repair & Inspection	Vane	Simplest of all. Just remove the upper cover is all what is needed.	Most complicated. (Motor has to be removed for overhaul)	Complicated but less than the case of Plan "B-1".	Same as Plans B-2 & 3.
		Seal & Bearing	Simple.	Most complicated.	Relatively complicated.	Less complicated than the case of Plans "B-2" and "B-3".
		Inspection Level Required	Average	High	Relatively high	Same as Plans B-2 & 3.
8	Vibration & Noise		Slightest of all.	Both higher than those of other centrifugal pumps.	Slightly higher than those of centrifugal pump in Plan "A".	Same as Plans B-2 & 3.
9	Cost	Pump	Lowest of all	Due to the longest length, highest of all.	Somewhere between Plans "A" and "B-1".	Same as Plans B-2 & 3.
		Running Cost	Not economically valuable due to 15m higher pumping head. (in spite of high efficiancy)	Not economical because efficiency of the pump is somewhat lower than other centrifugal pumps.	Economical because efficiency of the pump is high.	Same as Plans B-2 & 3.
10	Operation Procedure		Since suction is under pressure, practically no difference in operation procedure.	Same as Plan A.	Same as Plan A.	Same as Plan A.
11	Suction Well Type		Ordinary	Barrel type suction well likely to present some problems.	Some problems in the type of well.	Ordinary

Table 4-4 Comparison of Types of Pump

No.	Item \ Plan	A	B-1	B-2, B-3	C
12	Comprehensive Evaluation	•Horizontal pumps cause less strain on auxiliary equipment to go with, hence, lower in overall cost. •For the same reason, easier in maintenance and inspection. •Because of higher efficiency, suitable for continuous operation.	•Cost of auxiliary equipment to go with vertical pumps is highest in cost. •Maintenance & inspection, and replacement of parts are difficult. •Actual application of such long length pump is extremely rare. •Vibration of pump and resulting resonance of floor create some problems. •Shape of suction well is also a problem. •Adverse effects of wind and wave pressure on pump shaft are unavoidable.	•Cost of auxiliary equipment to go with vertical pumps is relatively high. •Maintenance and inspection are a bit more difficult than the pump in "A". •Suitable for continuous operation because of higher efficiency of the pump. •Longer vertical shaft likely to cause vibration. •Shape of suction well likely to present a problem.	•Cost of auxiliary equipment is relatively high. •Maintenance and inspection are a bit more difficult than the pump in "A". •Suitable for continuous operation because of higher efficiency of the pump. •Longer vertical shaft likely to cause vibration.

Table 4-5 Comparison of Intake Facilities

	A	B-1	B-2	B-3	C
General Features (Merits and Demerits)	•With horizontal pumps, maintenance, inspection and repair are easy as well as highly dependable. •Location down-stream of dam makes construction of intake facilities easiest. •The fact that intake level is about 15 meters below N.W.L. of reservoir means an increase of power cost. •Due to low elevation of intake gate, sediment basin is required to eliminate sacking up of sand at spillway. •Control of intake will become more complicated, thus, independent operational control is difficult. •Require land requisition. •Foreseeable possibility of hindrance to crest raising.	•Involves biggest problem in maintenance, inspection and repair of pump. •Execution of work is easiest only second to "A", except accuracy required for placement of jacket. •Performance efficiency of pump is the lowest. •Require accuracy in placement of platform, and high accuracy in installation of pump. •Problem of wear on pump shaft by eccentricity caused by impact of wind and/or wave and non-uniform settlement of foundation is extremely large. •Safety against impact of up-lift pressure caused by wave during storm is not assured. •Reliability of rigidity at joints between jacket and platform presents some problems.	•Pump used is a vertical centrifugal which is highly reliable. •Temporary caisson yard is required. •Stability of cylinderical concrete structure in tow to the destination is not well secured. •Underwater excavation of rock bed is a problem. •Underwater concrete placement is required for surface trimming and concrete subslub.	•Vertical centrifugal pump to be used is highly reliable. •As compared with "B-2", a smaller scale temporary caisson yard is required. •Because of rectangular concrete structure, stability in tow to the destination is better secured than "B-2". •As same as "B-2", requires a floating workshop. •Pile foundation to be considered makes execution of work easier than "B-2", and practically free from underwater works.	•Use of a vertical centrifugal pump which is highly reliable is considered. •For intake of reservoir water, this is the most conventional. •As pumping station is located at shore of the reservoir, maintenance and inspection are easy. •Considerable difficulties are anticipated as the tunnel linking the shore and intake tower is underwater, and also considerable variations of geologic features in the vicinity is foreseeable. •Construction period required is the longest, and it takes a long time for design and assembly of the shield. •Intake tower is smaller as compared with "B", and construction is easier since no high accuracy is required in the work. •Protective works such as chemical grouting may be required in the vicinity of intake tower. •As same as "B", requires a floating workshop but only smaller.

Table 4-6 Comparison of Intake Facilities

		A	B-1	B-2	B-3	C
Construction	Method	Open-Cut	Jacket	Stationary Caisson	Composite Pile-Caisson	Open-Cut, Shield & Open Caisson
	Brief Description	•Adoption of open-cut method which is the most conventional and simple is possible. •Countermeasure for groundwater, forced drainage may have to be considered.	•Two units of jackets are assembled at the shore. •Towed to and settled at the destination. •Then put in jacket legs by on the spot pile driver. (Reverse Circulation Drill) •Add platform and housing.	•Cylindrical structure of 15 - 20m dia., is constructed at the caisson yard, and towed to destination. •In the midway, an additional placement of concrete to complete. •In parallel to the above, foundation excavation will be performed. Then, the structure sunk at the destination.	•Rectangular structure, likewise "B-2", sunk at the proposed site. •By the aid of stand pipes, installed in the structure, drive foundation piles. (Reverse Circulation Drill)	•Pumping station is to be constructed by open-cut method. •Set up intake tower on the excavated foundation by open caisson. •Drive intake tunnel between pumping station, as starting shaft, and intake tower, as terminal shaft.
Temporary Facilities		•Construction road. •Steel pile retaining walls, in areas as required.	•Temporary pier for machinery and equipment handling. •Temporary pier for pile driver.	•Caisson yard for precast concrete structures (25m x 25m) •Launching slip-way. •Floater for concrete placement on the surface. •Temporary pier for machinery and equipment handling.	•Caisson yard for precast concrete structures (25m x 25m) •Launching slip-way. •Temporary pier for machinery and equipment handling.	•Steel pile retaining wall in shore pumping station for starting pit. •Casting yard for precast concrete intake tower. •Temporary pier for machinery and equipment handling.

Table 4-7 Comparison of Intake Facilities

	A	B-1	B-2	B-3	C
Construction Problem	•All on shore makes construction easiest. •Pump to be used is horizontal type, hence, accuracy required for installation is not as strict as others.	•Accuracy of underwater placement of jackets is a problem. •On the surface work is the easiest of "B" and "C".	•Though difficulties in underwater excavation of rock-bed depends on the capacity of floating workshop and hardness of the rock-bed, use of a simple floater is almost hopeless. •On the surface work is the most difficult of "B" and "C". •Towing of caissons demands utmost care in planning, design and execution (especially in stability of caissons in transit).	•Towing of caissons demands utmost care in planning, design and execution. •Water tightness at joints of caisson and piles may present some problems.	•Tunnel driving by shield is practically impossible in rock-bed while chemical grouting is required in poor subsoil areas. Both construction period and cost will become longest and highest respectively. •Assembly of shield takes considerably long time.
Construction Cost (Direct)	4.2×10^6 US$	5.9×10^6 US$	6.0×10^6 US$	5.8×10^6 US$	8.4×10^6 US$
Priority Rating	Secand	Fifth	Fourth	First	Third

Table 4-8 Comparative Study of PC, RC and Steel Head Tanks

	PC TANK	RC TANK	STEEL TANK
Structural Features	Because of the PC construction, the side wall becomes thin, and also it is excellent in elastic, aseismic and waterproof properties.	Because of the heavy wall, it requires a large volume of concrete and reinforcements.	Simpler in construction, and also safer because of its high flexibility to wind pressure, irregular settlement, etc.
Property of Tanks	The wall reinforced by PC wires can withstand the stress caused by storage water, therefore, no crack and no leak hence no waterproofing.	Easy to get cracked, so less reliable in water tightness resulting a possibility of appreciable leakage enough to justify waterproofing works.	Full consideration for the anti-corrosion is a must.
Materials	Because of a thin wall, concrete volume required is small, however, it needs high tensile strength piano wire.	Requires a substancial volume of concrete and reinforcements.	For bolted joints, a large number of bolts and rubber washers is required.
Execution of Work and Period of Construction	In construction, wire prestressing works follow almost immediately after placement of concrete, thus, the construction period will appreciably be shortened. Require skilled hands for the required pre-tension of wire.	Because of the huge volume of concrete required, period of concrete placement will become longer.	It is important that prevention of such initial failures as buckling, local deformation, etc. likely to be observed during construction. Period of construction is shorter, except a considerable time required for bolted joint work.
Construction Cost	The fact that it needs expensive piano wire but require much less concrete keeps the total construction low. 2.7×10^5 US$	Though cost of materials is low but the total construction cost is high because volume required of concrete and reinforcement is considerably large. 3.2×10^5 US$	Maintenance and administration costs are higher because of anti-corrosive paint job, etc. 3.6×10^5 US$
Overall Evaluation	High priority	—	—

Table 7-1 Water Demand for Industrial and Municipal Use (Nong Pla Lai Sub-Project)

Unit: MCM/Year

Year	Rayong				Sattahip				Sub-Total				Laem Chabang				Total				Year
	Industry	Industry -related municipal	Other municipal	Total	Industry	Industry -related municipal	Other municipal	Total	Industry	Industry -related municipal	Other municipal	Total	Industry	Industry -related municipal	Other municipal	Total	Industry	Industry -related municipal	Other municipal	Total	
1980	-	-	1.5	1.5	-	-	0.3	0.3	-	-	1.8	1.8	-	-	0.3	0.3	-	-	2.1	2.1	1980
1981	-	-	1.8	1.8	-	-	0.6	0.6	-	-	2.4	2.4	-	-	0.5	0.5	-	-	2.9	2.9	1981
1982	-	-	2.1	2.1	-	-	0.9	0.9	-	-	3.0	3.0	-	-	0.7	0.7	-	-	3.7	3.7	1982
1983	-	-	2.4	2.4	-	-	1.1	1.1	-	-	3.5	3.5	-	-	1.0	1.0	-	-	4.5	4.5	1983
1984	7.8	-	2.7	10.5	-	-	1.4	1.4	7.8	-	4.1	11.9	-	-	1.3	1.3	7.8	-	5.4	13.2	1984
1985	18.3	-	3.0	21.3	10.2	0.3	1.7	12.2	28.5	0.3	4.7	33.5	3.3	1.7	1.6	6.6	31.8	2.0	6.3	40.1	1985
1986	20.7	3.7	3.2	27.6	12.3	0.6	2.0	14.9	33.0	4.3	5.2	42.5	3.3	1.7	1.8	6.8	36.3	6.0	7.0	49.3	1986
1987	20.7	3.7	3.5	27.9	12.3	0.6	2.3	15.2	33.0	4.3	5.8	43.1	3.3	1.7	2.1	7.1	36.3	6.0	7.9	50.2	1987
1988	20.7	3.7	3.8	28.2	12.3	0.6	2.5	15.4	33.0	4.3	6.3	43.6	3.3	1.7	2.4	7.4	36.3	6.0	8.7	51.0	1988
1989	20.7	3.7	4.1	28.5	12.3	0.6	2.8	15.7	33.0	4.3	6.9	44.2	3.3	1.7	2.6	7.6	36.3	6.0	9.5	51.8	1989
1990	23.1	8.5	4.4	36.0	13.7	0.8	3.1	17.6	36.8	9.3	7.5	53.6	6.6	3.4	2.9	12.9	43.4	12.7	10.4	66.5	1990
1991	23.1	8.5	4.9	36.5	13.7	0.8	3.3	17.8	36.8	9.3	8.2	54.3	6.6	3.4	3.2	13.2	43.4	12.7	11.4	67.5	1991
1992	23.1	8.5	5.3	36.9	13.7	0.8	3.5	18.0	36.8	9.3	8.8	54.9	6.6	3.4	3.4	13.4	43.4	12.7	12.2	68.3	1992
1993	23.1	8.5	5.8	37.4	13.7	0.8	3.8	18.3	36.8	9.3	9.6	55.7	6.6	3.4	3.7	13.7	43.4	12.7	13.3	69.4	1993
1994	23.1	8.5	6.3	37.9	13.7	0.8	4.0	18.5	36.8	9.3	10.3	56.4	6.6	3.4	3.9	13.9	43.4	12.7	14.2	70.3	1994
1995	23.1	8.5	6.8	38.4	14.3	0.9	4.2	19.4	37.4	9.4	11.0	57.8	12.0	6.0	4.2	22.2	49.4	15.4	15.2	80.0	1995
1996	23.1	8.5	8.0	39.6	15.5	1.2	4.4	21.1	38.6	9.7	12.4	60.7	15.0	7.0	4.5	26.5	53.6	16.7	16.9	87.2	1996
1997	23.1	8.5	9.2	40.8	15.5	1.2	4.6	21.3	38.6	9.7	13.8	62.1	15.0	7.0	4.7	26.7	53.6	16.7	18.5	88.8	1997
1998	23.1	8.5	10.4	42.0	15.5	1.2	4.9	21.6	38.6	9.7	15.3	63.6	15.0	7.0	5.0	27.0	53.6	16.7	20.3	90.6	1998
1999	23.1	8.5	11.6	43.2	15.5	1.2	5.1	21.8	38.6	9.7	16.7	65.0	15.0	7.0	5.2	27.2	53.6	16.7	21.9	92.2	1999
2000	27.9	15.5	12.6	56.0	17.2	1.5	5.3	24.0	45.1	17.0	17.9	80.0	16.8	7.0	5.5	29.3	61.9	24.0	23.4	109.3	2000

Note: Rayong includes Rayong Municipality, Amphoe Muang Rayong, King Amphoe Ban Chang, Amphoe Ban Khai.
Sattahip includes Amphoe Sattahip.
Laem Chabang includes Amphoe Si Racha, Si Racha Municipality.

Table 9-1 Construction Cost of Water Transmission System

Unit : million US$

Item	Grand Total			Dok Krai-Mab Ta Pud			Mab Ta Pud-Sattahip			Dok Krai - Laem Chabang		
	L.C.	F.C.	Total	L.C.	F.C.	Total	L.C.	F.C.	Total	L.C.	F.C.	Total
1. Direct Construction Cost	25.15	52.47	77.62	9.31	24.29	33.60	4.80	10.98	15.78	11.04	17.20	28.24
Civil Works	18.37	24.54	42.91	6.17	10.37	16.54	3.51	5.86	9.37	8.69	8.31	17.00
Equipment & materials	6.78	27.93	34.71	3.14	13.92	17.06	1.29	5.12	6.41	2.35	8.89	11.24
2. Road Relocation	-	-	-	-	-	-	-	-	-	-	-	-
3. Compensation	0.08	-	0.08	0.04	-	0.04	0.04	-	0.04	-	-	-
4. Engineering Cost	1.09	7.37	8.46	0.31	2.11	2.42	0.27	1.80	2.07	0.51	3.46	3.97
Sub-total (1-4)	26.32	59.84	86.16	9.66	26.40	36.06	5.11	12.78	17.89	11.55	20.66	32.21
5. Contingencies	20.69	25.69	46.38	4.12	7.49	11.61	4.47	6.40	10.87	12.10	11.80	23.90
Physical	2.64	5.98	8.62	0.97	2.64	3.61	0.51	1.28	1.79	1.16	2.06	3.22
Price	18.05	19.71	37.76	3.15	4.85	8.00	3.96	5.12	9.08	10.94	9.74	20.68
6. Interest during Construction	-	2.84	2.84	-	1.05	1.05	-	0.54	0.54	-	1.25	1.25
Total (1-6)	47.01	88.37	135.38	13.78	34.94	48.72	9.58	19.72	29.30	23.65	33.71	57.36

Table 9-2 Breakdown of Construction Cost (1)

Water Transmission System
Route; Dok Krai-Mab Ta Pud

Financail Cost Base
Unit: Million US$

Item	Unit	Quantity	Local Currencies	Foreign Currencies	Total
1. Main Civil Works			6.17	10.37	16.54
1.1 Intake and Pumping Station	m^3	Concrete 4,000	2.16	2.86	5.02
1.2 Head Tank	L.S.	2	0.47	0.40	0.87
1.3 Pipeline	km	27.6	2.51	5.69	8.20
1.4 Receiving Well	m^3	Concrete 350	1.03	1.42	2.95
1.5 Booster Pumping Station	place	-	-	-	-
2. Metal Works			3.14	13.92	17.06
2.1 Pump Q = 31.44 m^3/min	L.S.	6	0.47	3.93	4.40
2.2 Steel Pipe ϕ = 1,350 mm	ton	9,500	2.56	9.12	11.68
2.3 Gate & Valve	L.S.	1	0.11	0.87	0.98
3. Land Acquisition & Compensation	ha	40	0.04	-	0.04
4. Engineering Service	L.S.	1	0.31	2.11	2.42
5. Contingencies			4.12	7.49	11.61
5.1 Phisical Contingency	L.S.		0.97	2.64	3.61
5.2 Price Contingency	L.S.		3.15	4.85	8.00
6. Interest during Construction	L.S.		-	1.05	1.05
Total			13.78	34.94	48.72

Table 9-3 Breakdown of Construction Cost (2)

Water Transmission System
Route; Mab Ta Pud-Sattahip

Financial Cost Base
Unit: Million US$

Item	Unit	Quantity	Local Currencies	Foreign Currencies	Total
1. Main Civil Works			3.51	5.86	9.37
1.1 Intake and Pumping Station	m^3	-	-	-	-
1.2 Head Tank	L.S.	1	0.19	0.05	0.24
1.3 Pipeline	km	21.9	1.92	3.89	5.81
1.4 Receiving Well	m^3	Concrete 300	1.01	1.40	2.41
1.5 Booster Pumping Station	place	1	0.39	0.52	0.91
2. Metal Works			1.29	5.12	6.41
2.1 Pump Q = 24.60 m^3/min	L.S.	3	0.06	0.40	0.46
2.2 Steel Pipe ϕ = 1,000 mm	ton	4,700	1.16	4.10	5.26
2.3 Gate & Valve	L.S.	1	0.07	0.62	0.69
3. Land Acquisition & Compensation	ha	40	0.04	-	0.04
4. Engineering Service	L.S.		0.27	1.80	2.07
5. Contingencies			4.47	6.40	10.87
5.1 Phisical Contingency	L.S.		0.51	1.28	1.79
5.2 Price Contingency	L.S.		3.96	5.12	9.08
6. Interest during Construction	L.S.		-	0.54	0.54
Total			9.58	19.72	29.30

Table 9-4 Breakdown of Construction Cost (3)

Water Transmission System
Route; Dok Krai-Laem Chabang

Financial Cost Base
Unit: Million US$

Item	Unit	Quantity	Local Currencies	Foreign Currencies	Total
1. Main Civil Works			8.69	8.31	17.00
1.1 Intake and Pumping Station	m^3	-	-	-	-
1.2 Head Tank	L.S.	2	0.37	0.08	0.45
1.3 Pipeline	km	53.0	6.96	6.37	13.33
1.4 Receiving Well	m^3	Concrete 300	0.97	1.34	2.31
1.5 Booster Pumping Station	place	1	0.39	0.52	0.91
2. Metal Works			2.35	8.89	11.24
2.1 Pump Q = 30.30 m^3/min	L.S.	3	0.06	0.40	0.46
2.2 Steel Pipe ϕ 900, 1,000, 1,200 mm	ton	9,300	2.24	7.95	10.19
2.3 Gate & Valve	L.S.	1	0.11	0.94	1.05
3. Land Acquisition & Compensation	ha	-	-	-	-
4. Engineering Service	L.S.		0.51	3.46	3.97
5. Contingencies			12.70	12.33	25.03
5.1 Phisical Contingency	L.S.		1.16	2.06	3.22
5.2 Price Contingency	L.S.		10.94	9.74	20.68
6. Interest during Construction	L.S.		-	1.25	1.25
Total			23.65	33.71	57.36

Table 9-5 Disbursement Schedule of Financial Cost (PLAN - II)

1 US$ = 23 ฿ = ¥ 230

Item	Total MILLION US$			Annual Disbursement									
				1982		1983		1984		1985		1986	
	Total	F.C	L.C	F.C	L.C	F.C	L.C	F.C	L.C	F.C	L.C	F.C	L.C
1. Civil Work	42.91	24.54	18.37	-	-	7.66	4.81	5.55	3.28	6.70	5.61	4.63	4.67
2. Equipment	34.71	27.93	6.78	-	-	8.72	1 77	6.31	1.21	7.62	2.07	5.28	1.73
3. Compensation	0.08	-	0.08	-	-	-	0.04	-	0.04	-	-	-	-
4. Engineering Service	8.46	7.37	1.09	1.29	0.19	3.20	0.46	1.47	0.23	1.00	0.15	0.41	0.06
(Sub-Total)	86.16	59.84	26.32	1.29	0.19	19.58	7.08	13.33	4.76	15.32	7.83	10.32	6.46
5. Physical Contingency	8.62	5.98	2.64	0.13	0.02	1.96	0.71	1.33	0.48	1.53	0.78	1.03	0.65
6. Price Contingency	37.76	19.71	18.05	0.10	0.03	3.38	2.05	3.78	2.49	6.77	6.56	5.68	6.92
(Sub-Total)	132.54	85.53	47.01	1.52	0.24	24.92	9.84	18.44	7.73	23.62	15.17	17.03	14.03
7. Interest (3.0%)	2.84	2.84	-	0.02	-	0.33	-	0.92	-	0.59	-	0.98	-
TOTAL	135.38	88.37	47.01	1.54	0.24	25.25	9.84	19.36	7.73	24.21	15.17	18.01	14.03

Table 11-1 Water Demand of the Area Supplied by the Pipeline System and Head Works on the Rayong River

Unit: MCM/Year

Year	Rayong				Mab Ta Pud			Sattahip				Total			
	Industry	Industry -related Municipal	Other Municipal	Total	Industry	Industry -related Municipal	Total	Industry	Industry -related Municipal	Other Municipal	Total	Industry	Industry -related Municipal	Other Municipal	Total
1986	1.6	0.0	3.2	4.6	19.1	3.7	22.8	12.3	0.6	2.0	14.9	33.0	4.3	5.2	42.5
1990	1.6	0.0	4.4	6.0	21.5	8.5	30.0	13.7	0.8	3.1	17.6	36.8	9.3	7.5	53.6
1995	1.6	0.0	6.8	8.4	21.5	8.5	30.0	14.3	0.9	4.2	19.4	37.4	9.4	11.0	57.8
2000	6.4	3.2	12.6	22.2	21.5	12.3	33.8	17.2	1.5	5.3	24.0	45.1	17.0	17.9	80.0

Table 13-1 Construction Cost of Water Transmission System

Unit : million US$

Item	Grand Total			Dok Krai-Mab Ta Pud			Mab Ta Pud-Sattahip			Ban Khai Head Works		
	L.C.	F.C.	Total	L.C.	F.C.	Total	L.C.	F.C.	Total	L.C.	F.C.	Total
1. Direct Construction Cost	17.03	39.58	56.61	8.93	22.60	31.53	4.80	10.98	15.78	3.30	6.00	9.30
Civil Works	12.54	21.41	33.95	5.96	10.10	16.06	3.51	5.86	9.37	3.07	5.45	8.52
Equipment & materials	4.49	18.17	22.66	2.97	12.50	15.47	1.29	5.12	6.41	0.23	0.55	0.78
2. Road Relocation	-	-	-	-	-	-	-	-	-	-	-	-
3. Compensation	0.08	-	0.08	0.04	-	0.04	0.04	-	0.04	-	-	-
4. Engineering Cost	0.78	5.41	6.19	0.31	2.11	2.42	0.27	1.80	2.07	0.20	1.50	1.70
Sub-total (1-4)	17.89	44.99	62.88	9.28	24.71	33.99	5.11	12.78	17.89	3.50	7.50	11.00
5. Contingencies	11.18	16.78	27.96	3.91	6.88	10.79	4.47	6.40	10.87	2.80	3.50	6.30
Physical	1.78	4.50	6.28	0.93	2.47	3.40	0.51	1.28	1.79	0.34	0.75	1.09
Price	9.40	12.28	21.68	2.98	4.41	7.39	3.96	5.12	9.08	2.46	2.75	5.21
6. Interest during Construction	-	1.96	1.96	-	1.01	1.01	-	0.54	0.54	-	0.41	0.41
Total (1-6)	29.07	63.73	92.80	13.19	32.60	45.79	9.58	19.72	29.30	6.30	11.41	17.71

Table 13-2 Breakdown of Construction Cost (1)

Water Transmission System
Route; Dok Krai-Mab Ta Pud

Financial Cost Base
Unit: Million US$

Item	Unit	Quantity	Local Currencies	Foreign Currencies	Total
1. Main Civil Works			5.96	10.10	16.06
1.1 Intake and Pumping Station	m^3	Concrete 4,000	19.50	2.59	4.54
1.2 Head Tank	L.S.	2	0.47	0.40	0.87
1.3 Pipeline	km	27.6	2.51	5.69	8.20
1.4 Receiving Well	m^3	Concrete 350	1.03	1.42	2.45
1.5 Booster Pumping Station	place	-	-	-	-
2. Metal Works			2.97	12.50	15.47
2.1 Pump Q = 43.56 m^3/min	L.S.	6	0.30	2.51	2.81
2.2 Steel Pipe ϕ = 1,350 mm	ton	9,500	2.56	9.12	11.68
2.3 Gate & Valve	L.S.	1	0.11	0.87	0.98
3. Land Acquisition & Compensation	ha	40	0.04	-	0.04
4. Engineering Service	L.S.		0.31	2.11	2.42
5. Contingencies			3.91	6.88	10.79
5.1 Phisical Contingency	L.S.		0.93	2.47	3.40
5.2 Price Contingency	L.S.		2.98	4.41	7.39
6. Interest during Construction	L.S.		-	1.01	1.01
Total			13.19	32.60	45.79

Table 13-3 Breakdown of Construction Cost (2)

Water Transmission System
Route; Mab Ta Pud-Sattahip

Financial Cost Base
Unit: Million US$

Item	Unit	Quantity	Local Currencies	Foreign Currencies	Total
1. Main Civil Works			3.51	5.86	9.37
1.1 Intake and Pumping Station	m^3	-	-	-	-
1.2 Head Tank	L.S.	1	0.19	0.05	0.24
1.3 Pipeline	km	21.9	1.92	3.89	5.81
1.4 Receiving Well	m^3	Concrete 300	1.01	1.40	2.41
1.5 Booster Pumping Station	place	1	0.39	0.52	0.91
2. Metal Works			1.29	5.12	6.41
2.1 Pump Q = 24.60 m^3/min	L.S.	3	0.06	0.40	0.46
2.2 Steel Pipe ϕ = 1,000 mm	ton	4,700	1.16	4.10	5.26
2.3 Gate & Valve	L.S.	1	0.07	0.62	0.69
3. Land Acquisition & Compensation	ha	40	0.04	-	0.04
4. Engineering Service	L.S.		0.27	1.80	2.07
5. Contingencies			4.47	6.40	10.87
5.1 Phisical Contingency	L.S.		0.51	1.28	1.79
5.2 Price Contingency	L.S.		3.96	5.12	9.08
6. Interest during Construction	L.S.		-	0.54	0.54
Total			9.58	19.72	29.30

Table 13-4 Breakdown of Construction Cost (3)

Water Transmission System
Ban Khai Head Works

Financial Cost Base
Unit: Million US$

Item	Unit	Quantity	Local Currencies	Foreign Currencies	Total
1. Main Civil Works			3.07	5.45	8.52
1.1 Weir and Intake	m^3	Concrete 4,000	1.58	3.29	4.87
1.2 Pipeline ϕ 1,500	km	1	1.36	2.03	3.39
1.3 Receiving Well	m^3	Concrete 100	0.13	0.13	0.26
2. Metal Works			0.23	0.55	0.78
2.1 Gate	ton	70	0.23	0.55	0.78
3. Land Acquisition & Compensation	ha	-	-	-	-
4. Engineering Service	L.S.		0.20	1.50	1.70
5. Contingencies			2.80	3.50	6.30
5.1 Phisical Contingency	L.S.		0.34	0.75	1.09
5.2 Price Contingency	L.S.		2.46	2.75	5.21
6. Interest during Construction	L.S.		-	0.41	0.41
Total			6.30	11.41	17.71

Table 13-5 Disbursement Schedule of Financial Cost (PLAN - III)

1 US$ = 23 ฿ = ¥ 230

Item	Total MILLION US$			Annual Disbursement							
				1982		1983		1984		1985	
	Total	F.C	L.C	F.C	L.C	F.C	L.C	F.C	L.C	F.C	L.C
1. Civil Work	33.95	21.41	12.54			8.89	4.84	7.15	4.14	5.37	3.56
2. Equipment	22.66	18.17	4.49			7.55	1 73	6.06	1.48	4.56	1.28
3. Compensation	0.08	-	0.08	-	2.34	-	0.04	-	0.04	-	-
4. Engineering Service	6.19	5.41	0.78	1.29	0.19	1.94	0.25	1.33	0.21	0.85	0.13
(Sub-Total)	62.88	44.99	17.89	1.29	0.19	18.38	6.86	14.54	5.87	10.78	4.97
5. Physical Contingency	6.28	4.50	1.78	0.13	0.02	1.83	0.69	1.46	0.58	1.08	0.49
6. Price Contingency	21.68	12.28	9.40	0.10	0.03	3.06	1.95	4.35	3.25	4.77	4.17
(Sub-Total)	90.84	61.77	29.07	1.52	0.24	23.27	9.50	20.35	9.70	16.63	9.63
7. Interest (3.0%)	1.96	1.96	-	0.02	-	0.31	-	0.87	-	0.66	-
TOTAL	92.80	63.73	29.07	1.54	0.24	23.58	9.50	21.22	9.70	17.39	9.63

Fig. 2-1 Water Demand

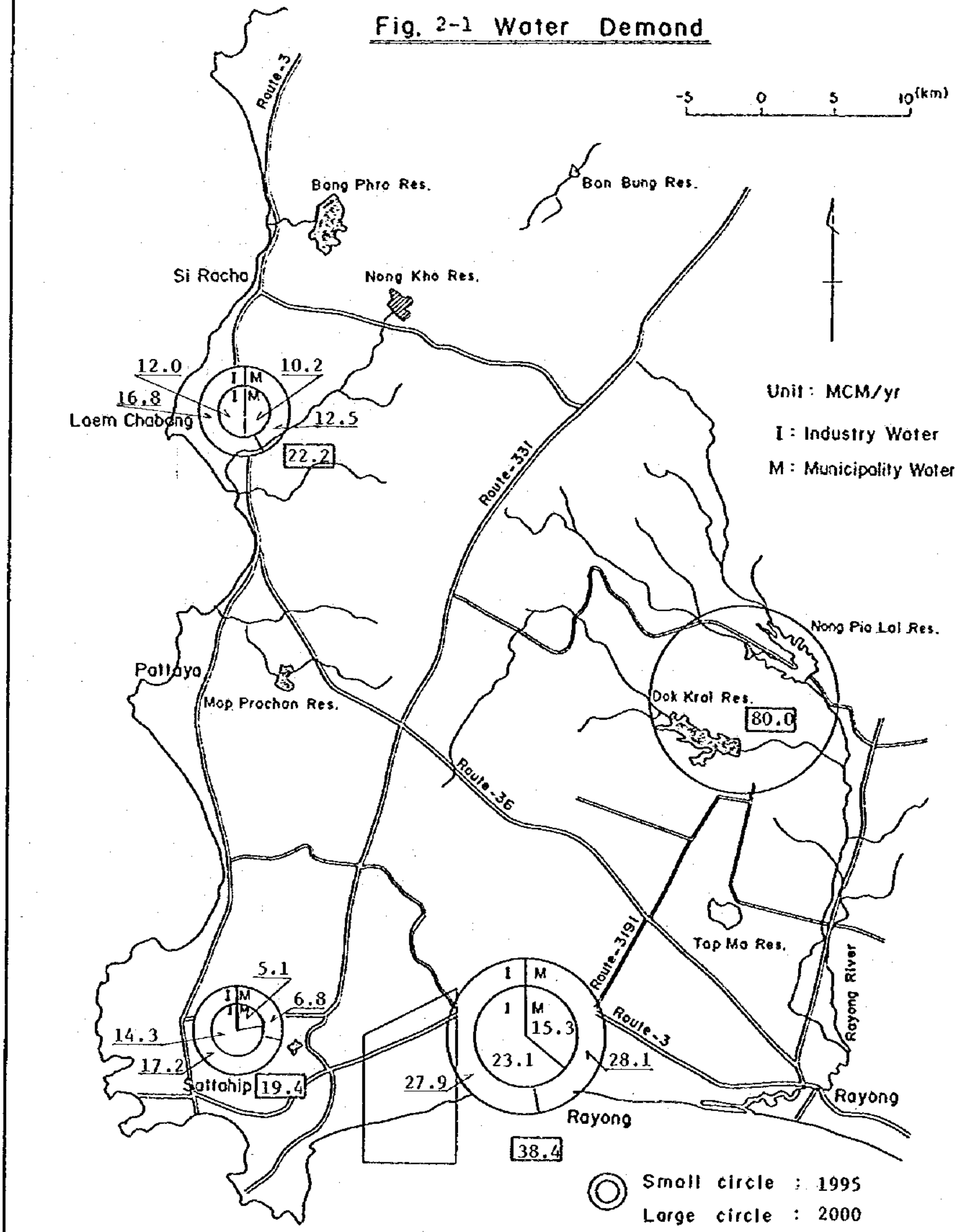


Fig. 2-2 Location Map of the Pumping Station

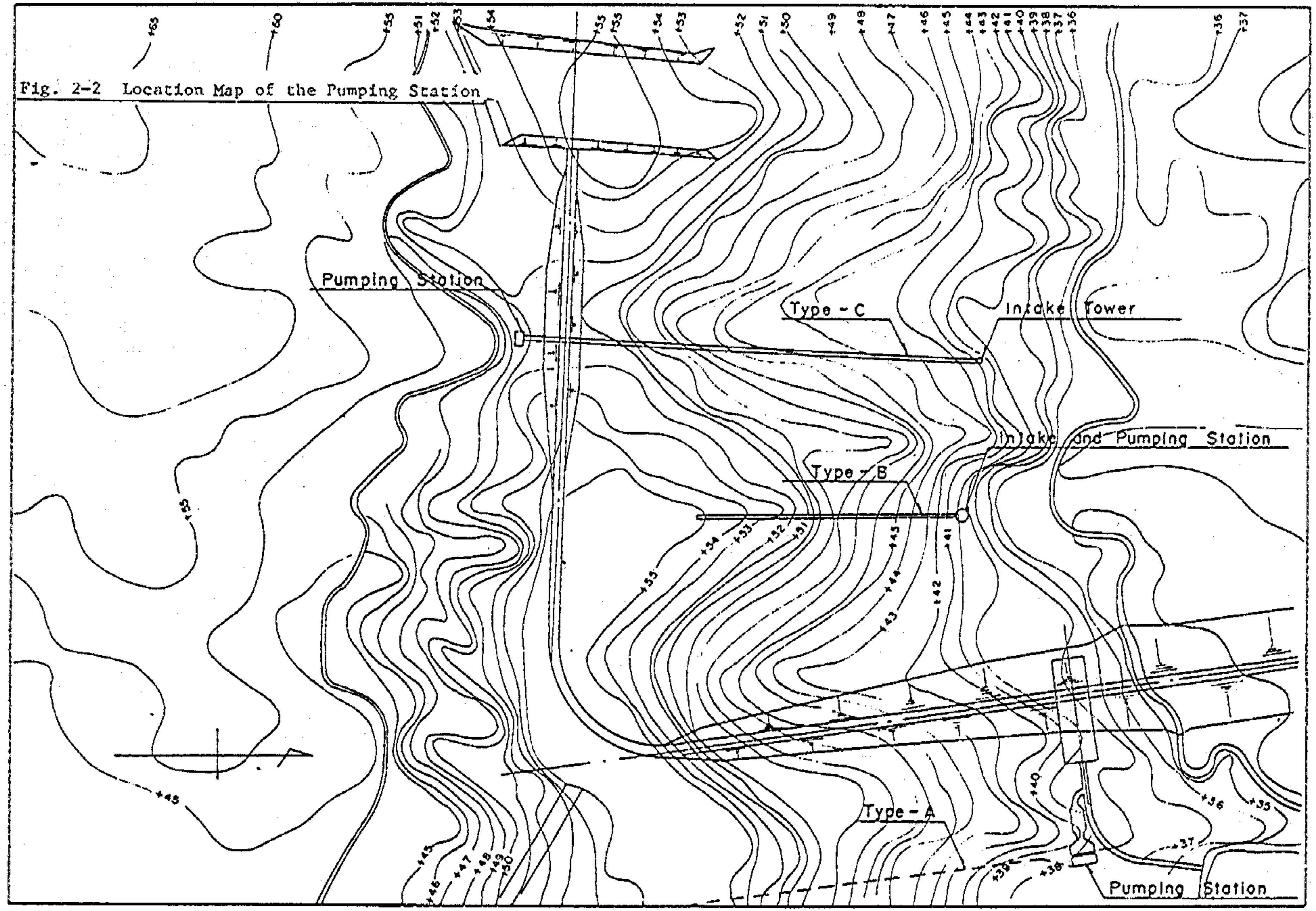


Fig. 2-3 Geological Profile of Pumping Station and Discharge Pipe of Type-A

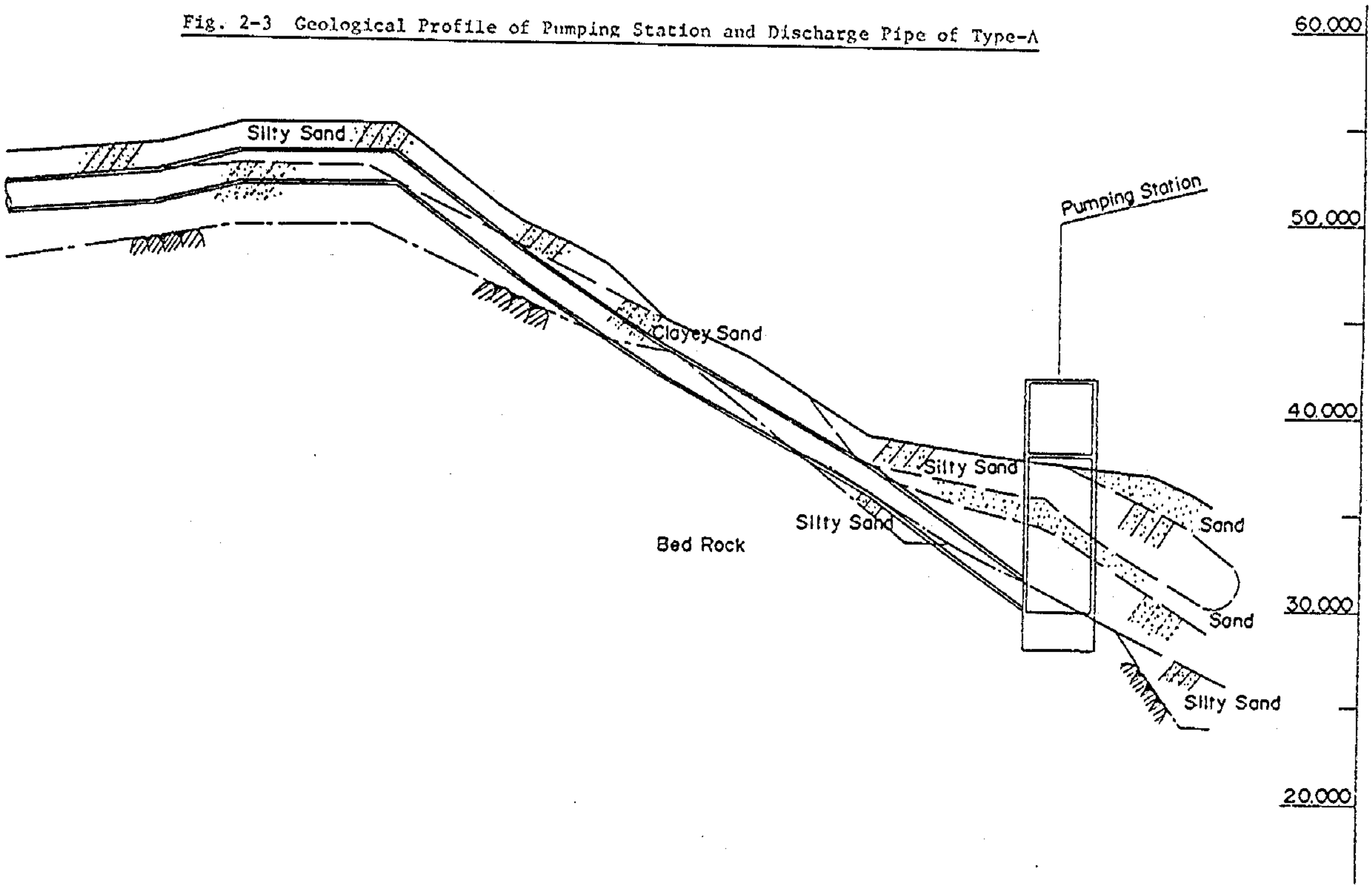


Fig. 2-4 Geological Profile of Pumping Station and Discharge Pipe of Type-B

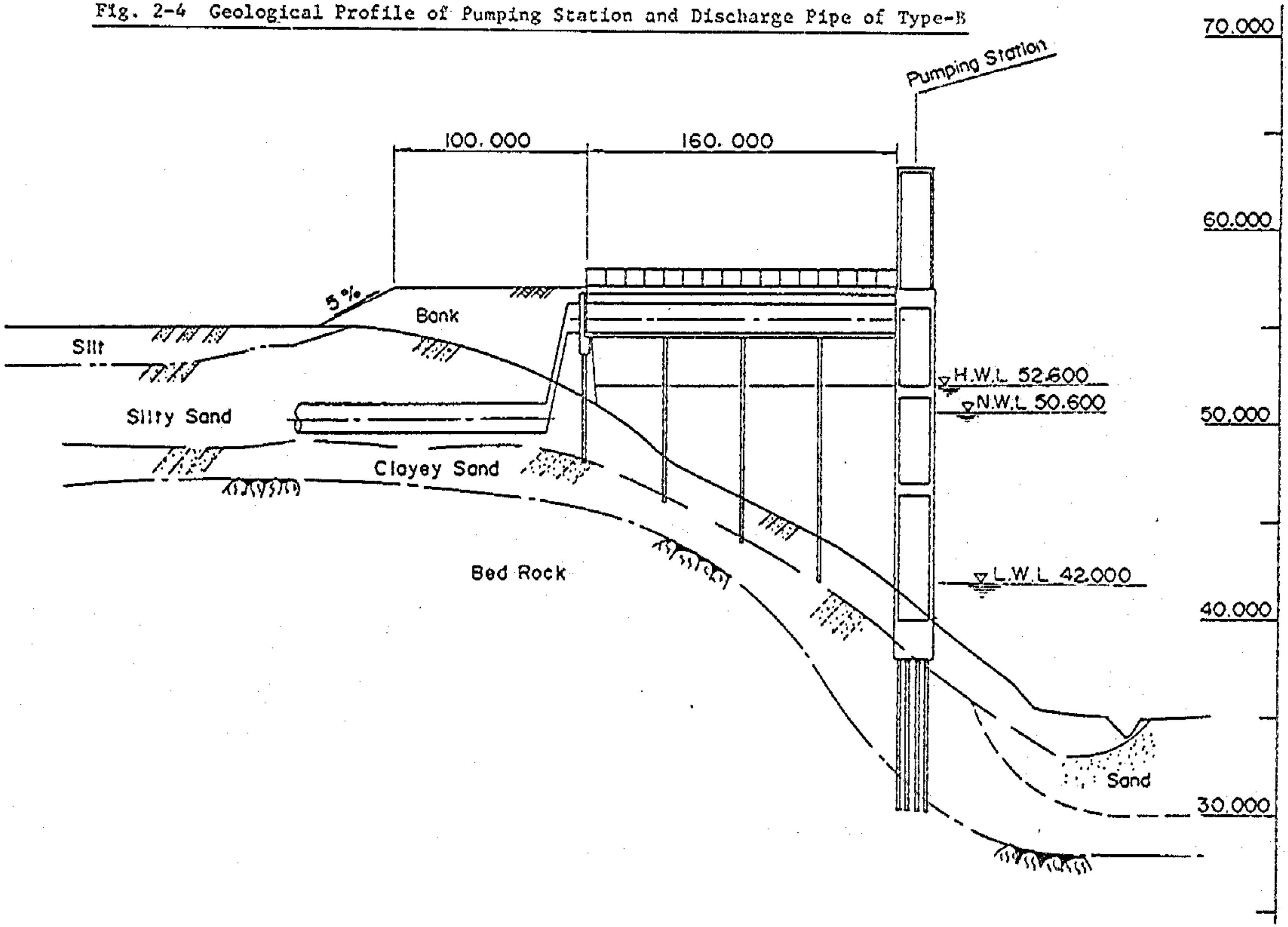


Fig. 2-5 Geological Profile of Pumping Station and Suction Conduit of Type-C

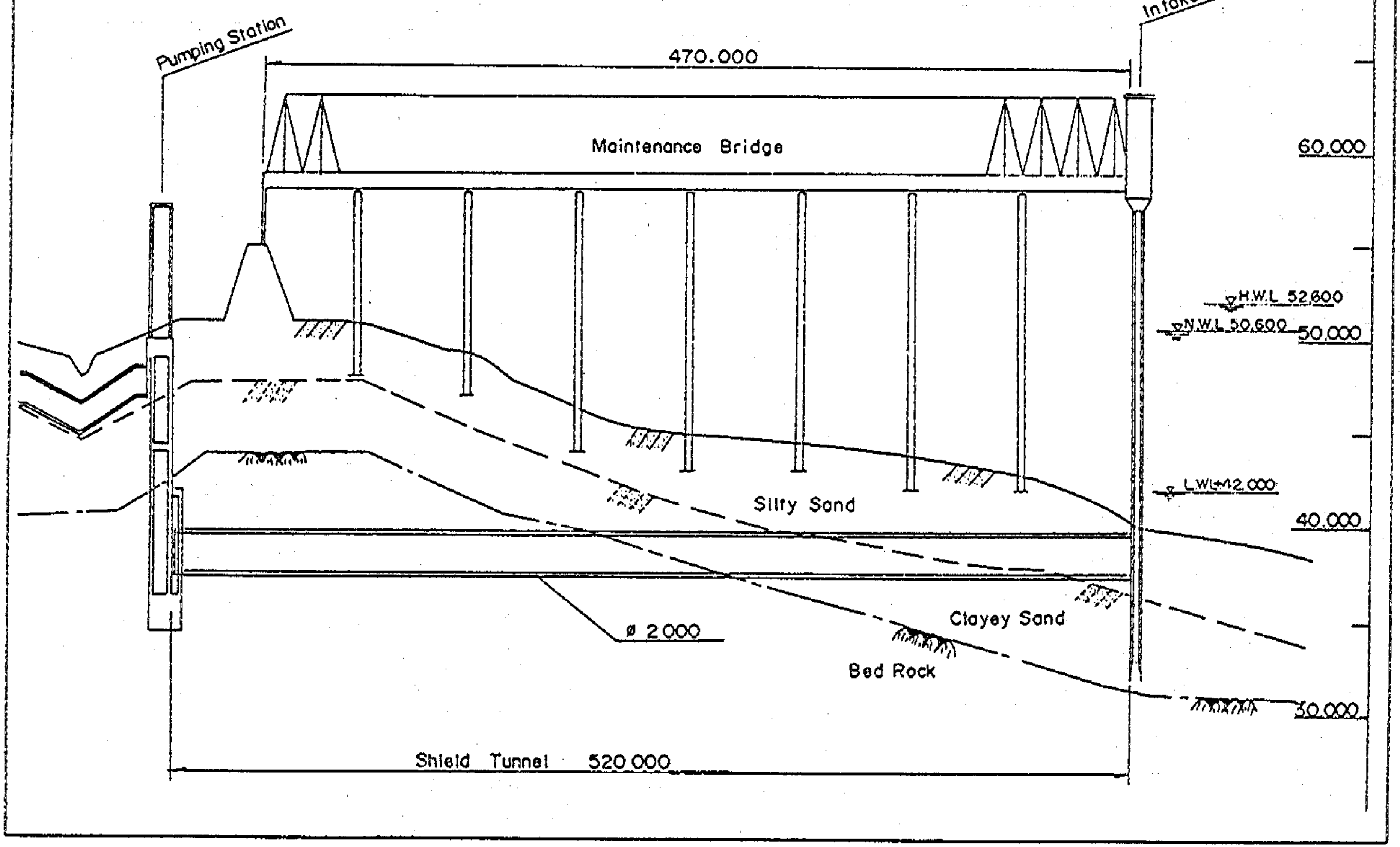


Fig. 2-6 Gelogical Map from Dok Krai to Mab Ta Pud

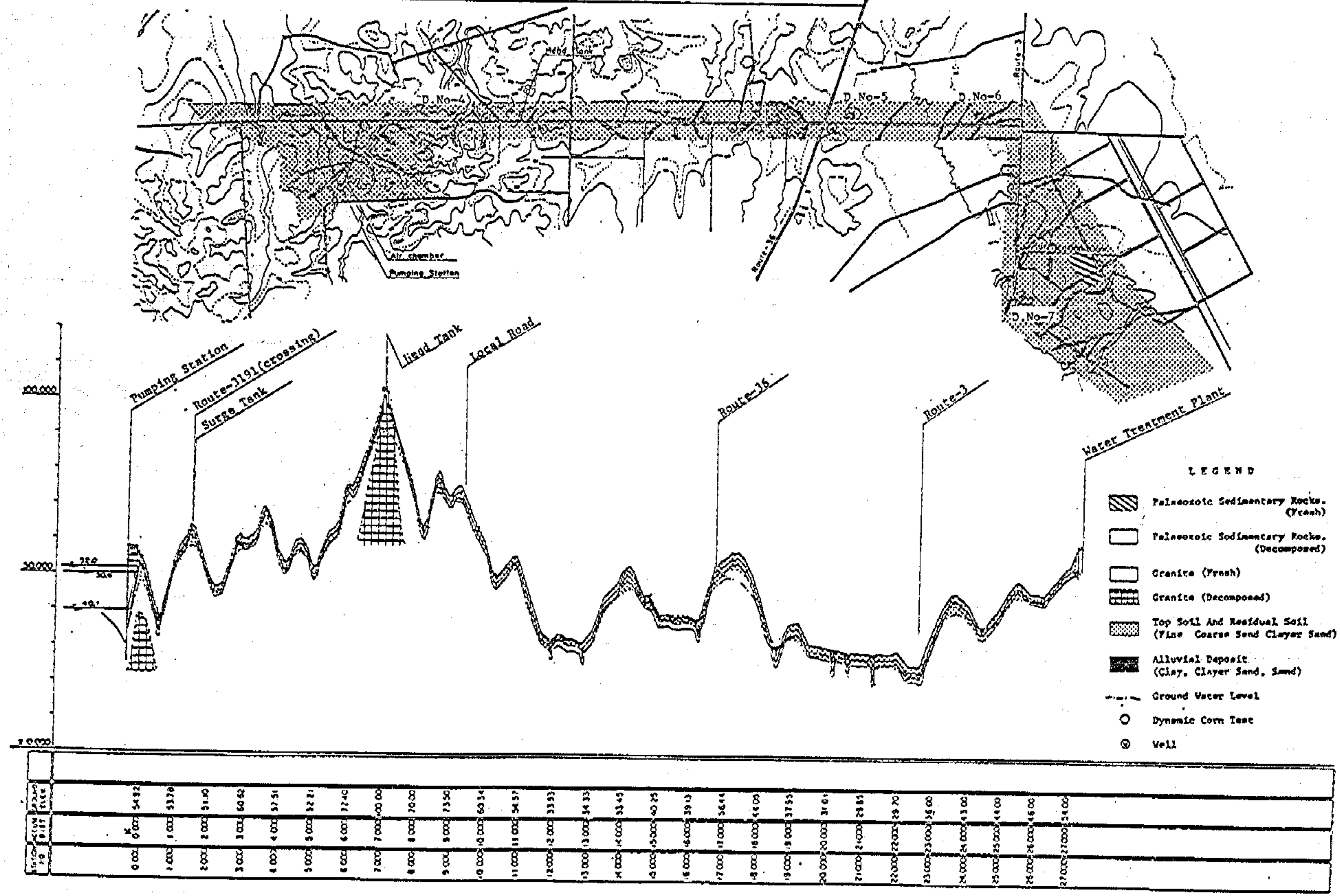


Fig 2-7 Geological Map from Mab Ta Pud to Sattahip

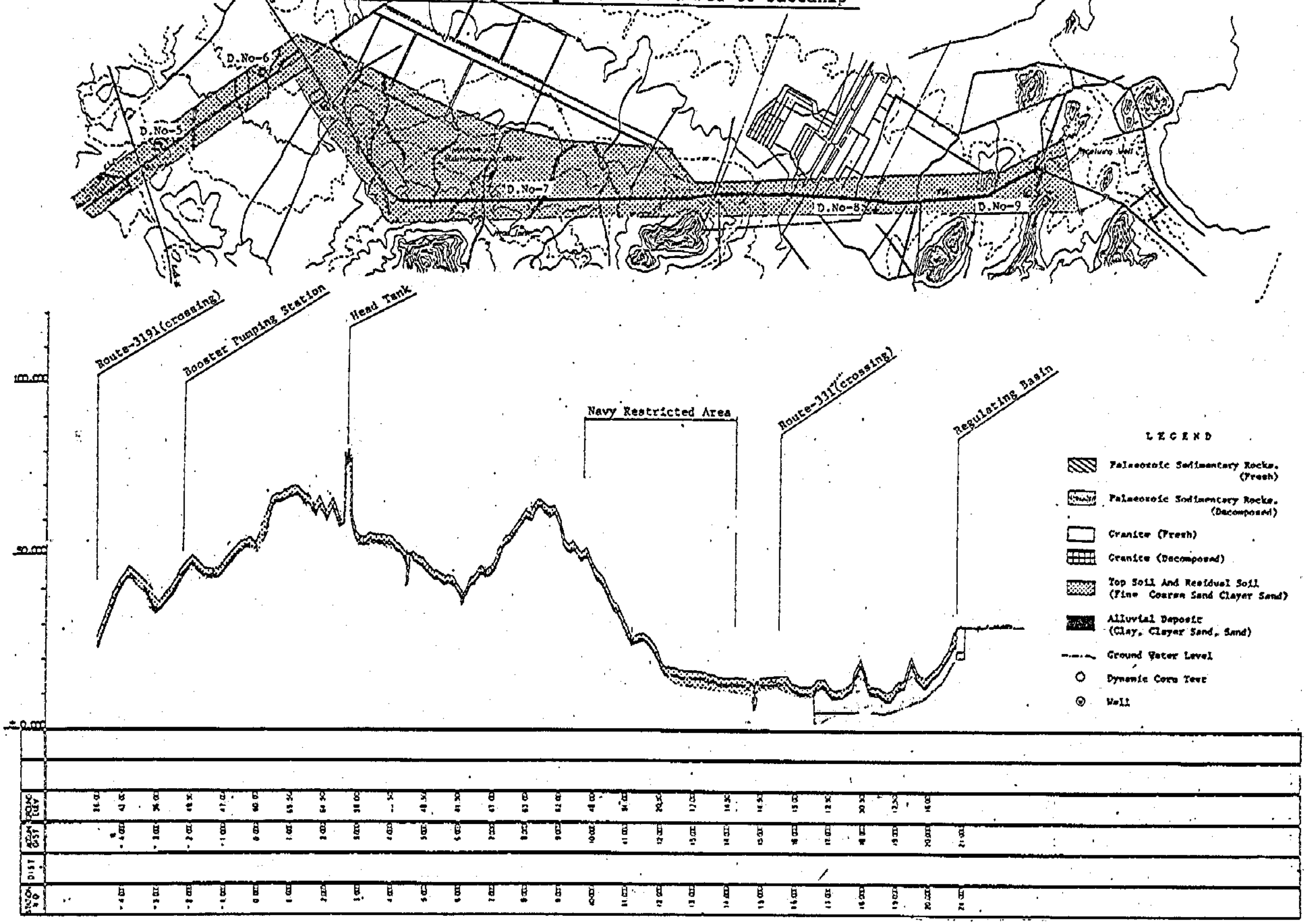


Fig. 2-8 Geological Map from Mab Ta Pud to Sattahip

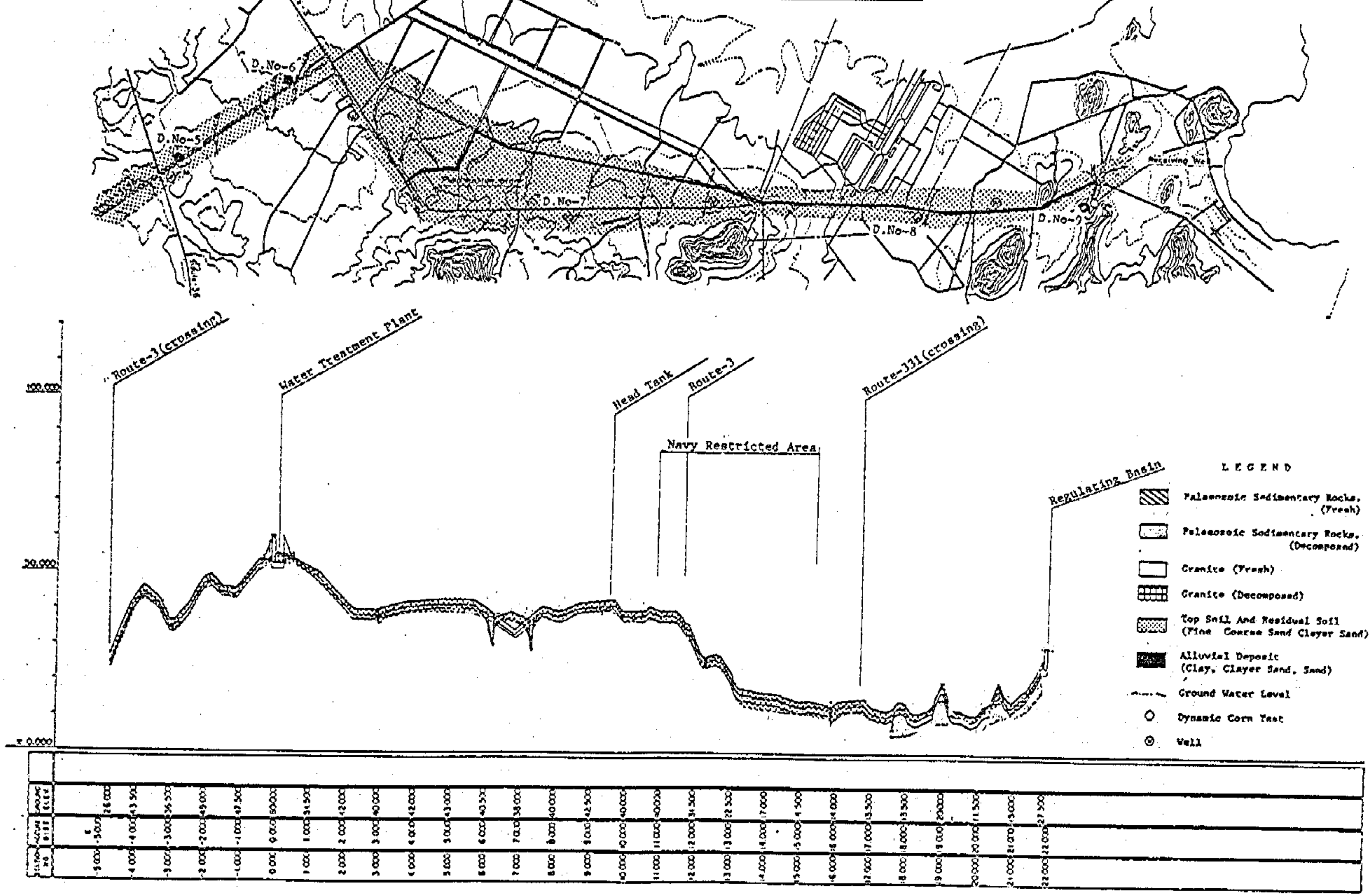


Fig. 2-9 Geological Profile from Dok Krai to Laem Chabang

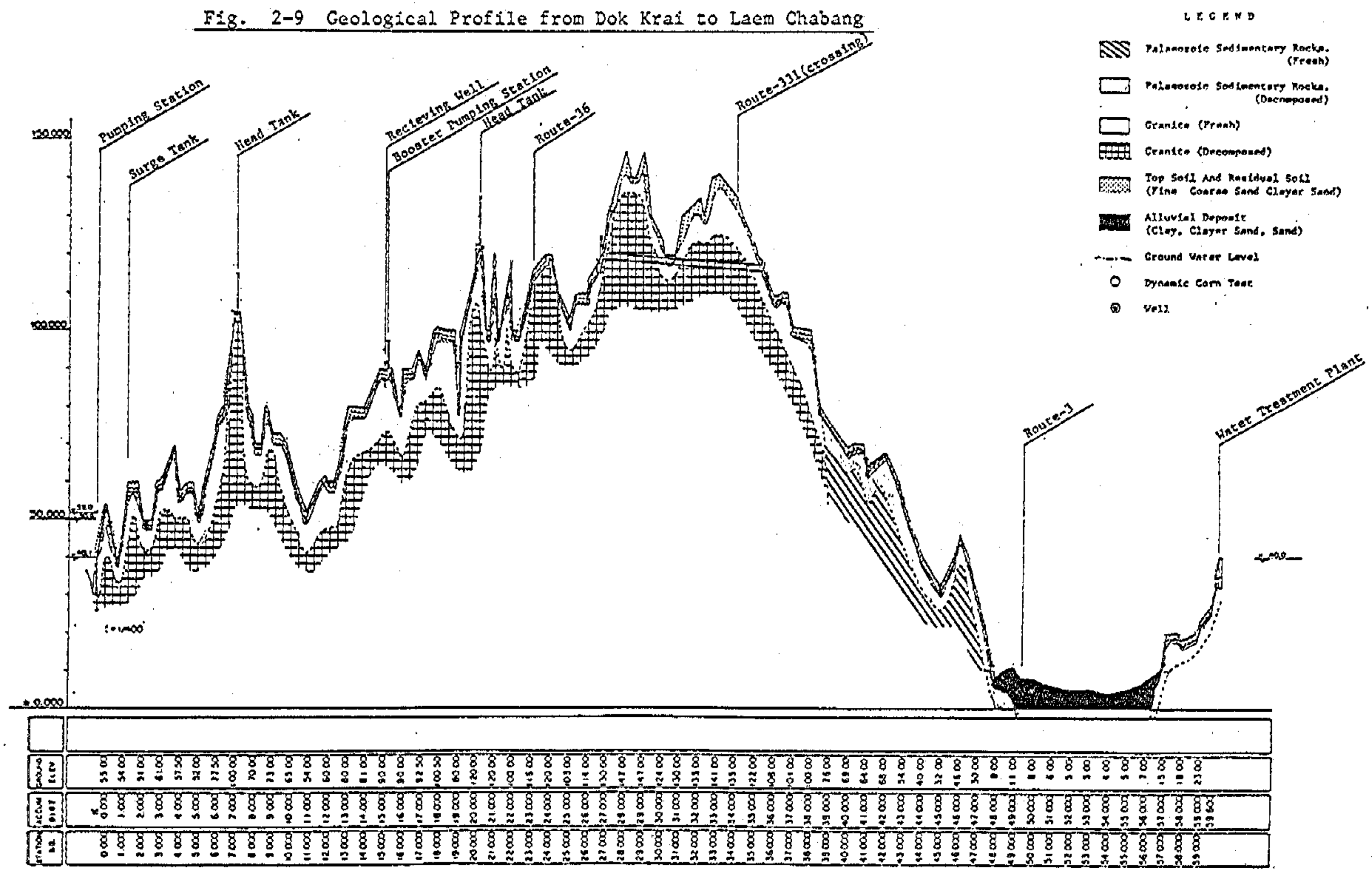


Fig. 2-10 Dynamic Cone Test Log.

PROJECT : Water pipe line JOB NO. :

LOCATION : DOKKRAI - SATTAHIP DATE : August 22,1981

CLIENT : CTI Engineering Co.,Ltd PLOTTED BY : TN.

DYNAMIC PENETRATION TEST NO. 4

SOIL DESCRIPTION	DEPTH m.		BLOW COUNT N / 20 CM
LOOSE SAND		.20	1
		.40	1
		.60	2
		.80	3
	1	.00	3
		.20	4
CLAYEY SAND		.40	6
		.60	8
		.80	10
	2	.00	9
		.20	10
		.40	10
		.60	12
		.80	14
	3	.00	15
LOOSE SAND OR CLAY		.20	12
SAND		.40	19
		.60	20
		.80	24
	4	.00	20
		.20	24
		.40	23
		.60	27
DECOMPOSED GRANITE		.80	29
	5	.00	34
		.20	38
		.40	
		.60	
		.80	
	6	.00	
		.20	
		.40	
		.60	
		.80	
	7	.00	
		.20	
		.40	
		.60	
		.80	
	8	.00	
		.20	
		.40	
		.60	
		.80	
	9	.00	
		.20	
		.40	
		.60	
		.80	
	10	.00	

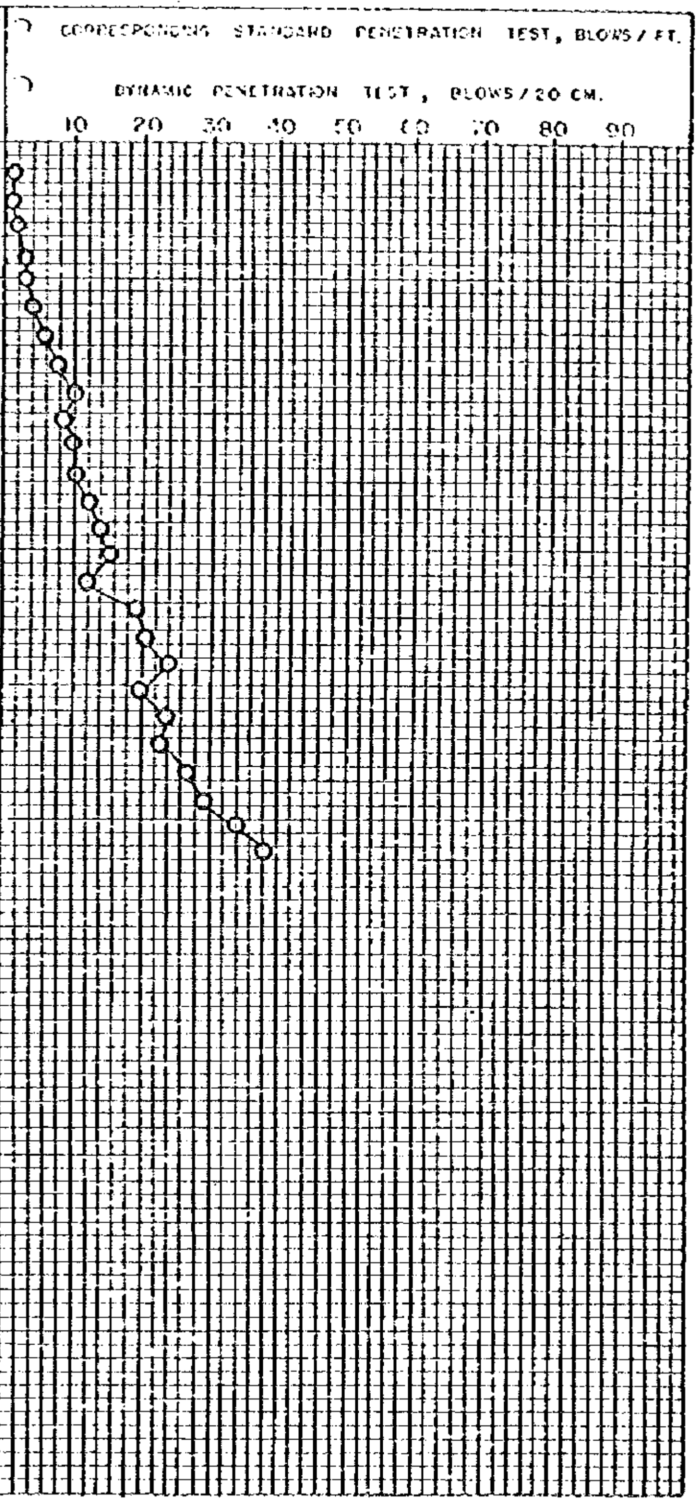


Fig. 2-11 Dynamic Cone Test Log.

PROJECT : Water pipe line | JOB NO. :

LOCATION : DOKKRAI-SATTAHIP | DATE : August 22,1981

CLIENT : CTI Engineering Co.,Ltd. | PLOTTED BY : TN

DYNAMIC PENETRATION TEST NO. 5

SOIL DESCRIPTION	DEPTH m.		BLOW COUNT N / 20 CM.
SAND (FINE TO MEDIUM)		.20	1
		.40	1
		.60	2
		.80	4
	1	.00	5
RESIDUAL SOIL (CLAYEY SAND)		.20	9
		.40	10
		.60	10
		.80	12
	2	.00	14
		.20	14
		.40	17
		.60	15
		.80	17
	3	.00	19
		.20	17
		.40	21
		.60	20
		.80	23
	4	.00	24
DECOMPOSED GRANITE		.20	29
		.40	
		.60	
		.80	
	5	.00	
		.20	
		.40	
		.60	
		.80	
	6	.00	
		.20	
		.40	
		.60	
		.80	
	7	.00	
		.20	
		.40	
		.60	
		.80	
	8	.00	
		.20	
		.40	
		.60	
		.80	
	9	.00	
		.20	
		.40	
		.60	
		.80	
	10	.00	

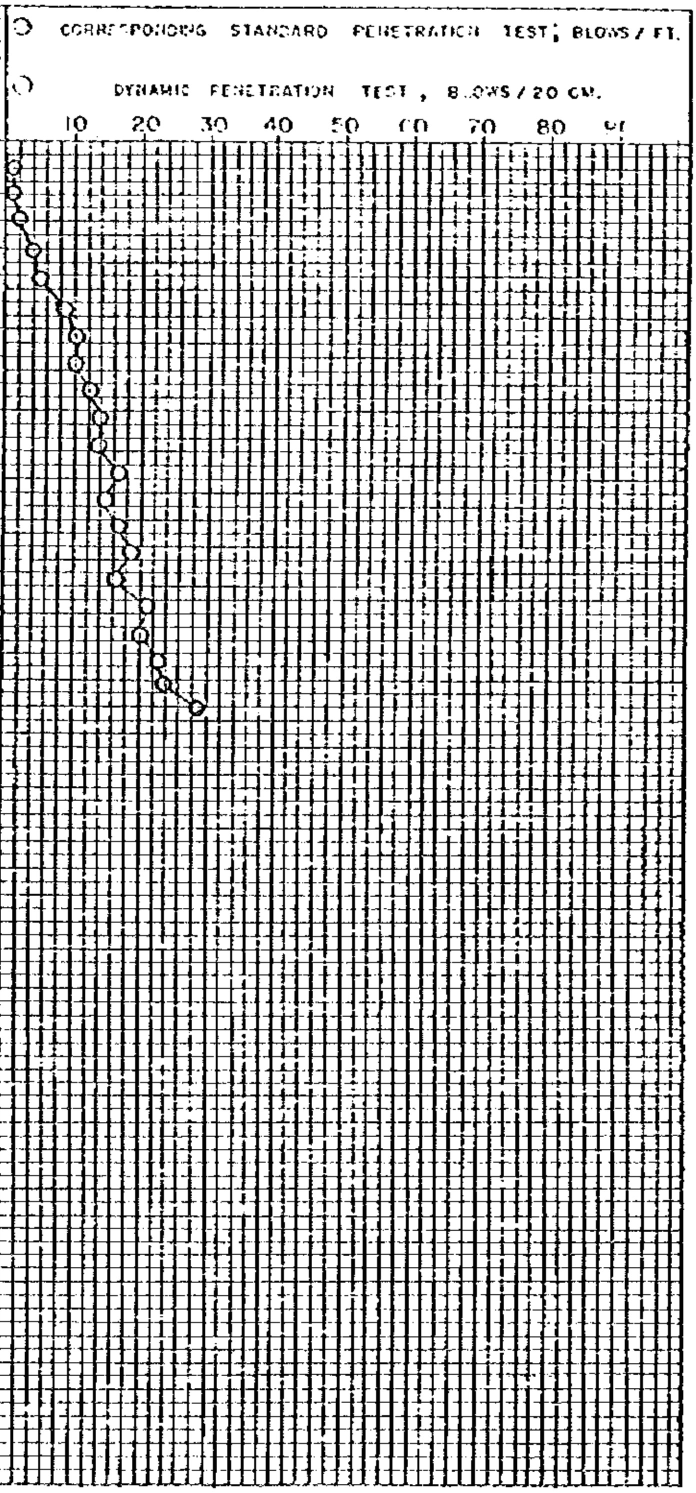


Fig. 2-12 Dynamic Cone Test Log.

PROJECT : Water pipe line
JOB NO. :
LOCATION : DOKKRAI-SATTAHIP
DATE : August 22,1981
CLIENT : CTI Engineering Co.,Ltd
PLOTTED BY : TN

DYNAMIC PENETRATION TEST NO. 6

SOIL DESCRIPTION	DEPTH m.	BLOW COUNT N/20 CM.
SAND	.20	6
	.40	8
	.60	9
CLAYEY SAND	.80	14
	1.00	17
	.20	12
	.40	10
CLAYEY SAND	.60	6
	.80	7
	2.00	5
	.20	7
	.40	8
RESIDUAL SOIL (CLAYEY SAND)	.60	10
	.80	14
	3.00	17
	.20	19
	.40	21
	.60	24
	.80	27
DECOMPOSED GRANITE	4.00	35
	.20	
	.40	
	.60	
	.80	
	5.00	
	.20	
	.40	
	.60	
	.80	
	6.00	
	.20	
	.40	
	.60	
	.80	
	7.00	
	.20	
	.40	
	.60	
	.80	
	8.00	
	.20	
	.40	
	.60	
	.80	
	9.00	
	.20	
	.40	
	.60	
	.80	
	10.00	

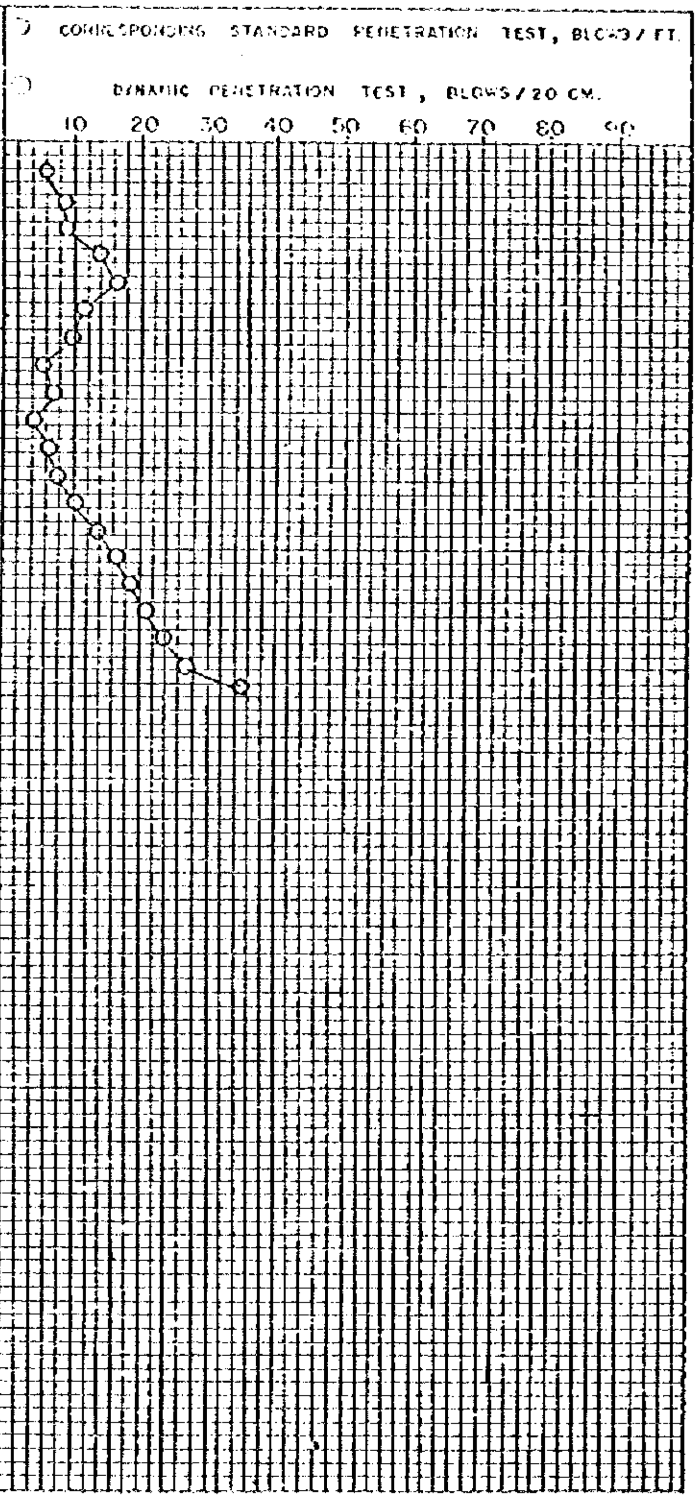


Fig. 2-13 Dynamic Cone Test Log.

PROJECT : Water pipe line   JOB NO. :

LOCATION : DOKKRAI-SATTAHIP   DATE : August 21,1981

CLIENT : CTI Engineering Co.,Ltd   PLOTTED BY : TN

DYNAMIC PENETRATION TEST NO. 7

SOIL DESCRIPTION	DEPTH m.		BLOW COUNT N/20 CM.
SAND		.20	4
		.40	3
		.60	2
		.80	2
	1	.00	3
		.20	5
		.40	3
CLAYEY SAND		.60	7
		.80	7
	2	.00	7
		.20	8
		.40	9
		.60	11
		.80	11
	3	.00	11
		.20	13
		.40	14
		.60	11
		.80	13
	4	.00	14
		.20	
		.40	
		.60	
		.80	
	5	.00	
		.20	
		.40	
		.60	
		.80	
	6	.00	
		.20	
		.40	
		.60	
		.80	
	7	.00	
		.20	
		.40	
		.60	
		.80	
	8	.00	
		.20	
		.40	
		.60	
		.80	
	9	.00	
		.20	
		.40	
		.60	
		.80	
	0	.00	

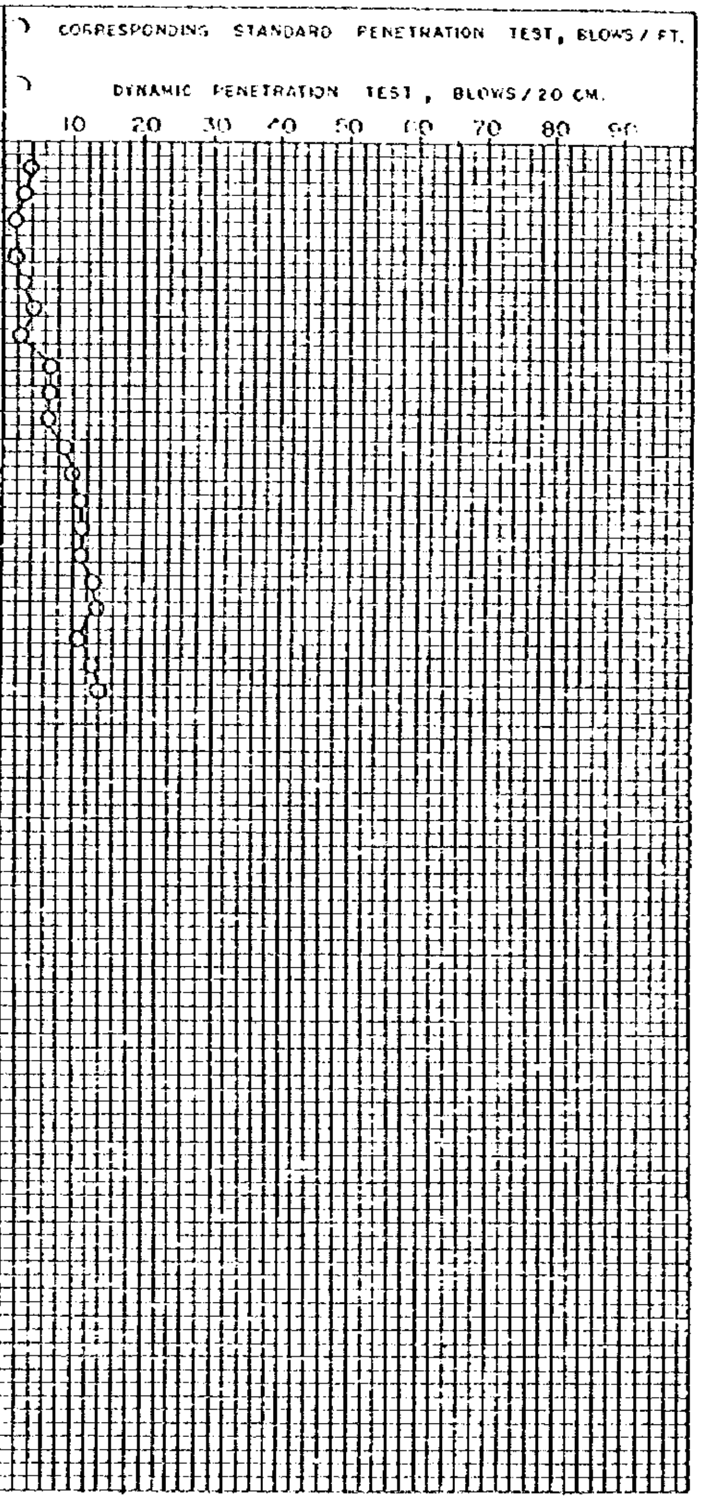


Fig. 2-14 Dynamic Cone Test Log.

PROJECT : Water pipe line
JOB NO. :
LOCATION : DOKKRAI-SATTAHIP
DATE : August 20,1981
CLIENT : CTI Engineering Co.,Ltd
PLOTTED BY : TN

DYNAMIC PENETRATION TEST NO. 8

SOIL DESCRIPTION	DEPTH m.		BLOW COUNT N / 20 CM.
		.20	3
SAND		.40	2
		.60	2
		.80	6
CLAYEY SAND	1	.00	7
		.20	9
		.40	4
		.60	3
		.80	4
SAND OR CLAYEY SAND	2	.00	5
		.20	9
		.40	5
		.60	8
		.80	12
CLAYEY SAND	3	.00	16
		.20	22
		.40	47
		.60	45
WEATHERED GRANITE		.80	54
	4	.00	57
		.20	60
		.40	67
		.60	85
		.80	90
	5	.00	95
		.20	98
		.40	100
		.60	109
		.80	
	6	.00	
		.20	
		.40	
		.60	
		.80	
	7	.00	
		.20	
		.40	
		.60	
		.80	
	8	.00	
		.20	
		.40	
		.60	
		.80	
	9	.00	
		.20	
		.40	
		.60	
		.00	
	0	.00	

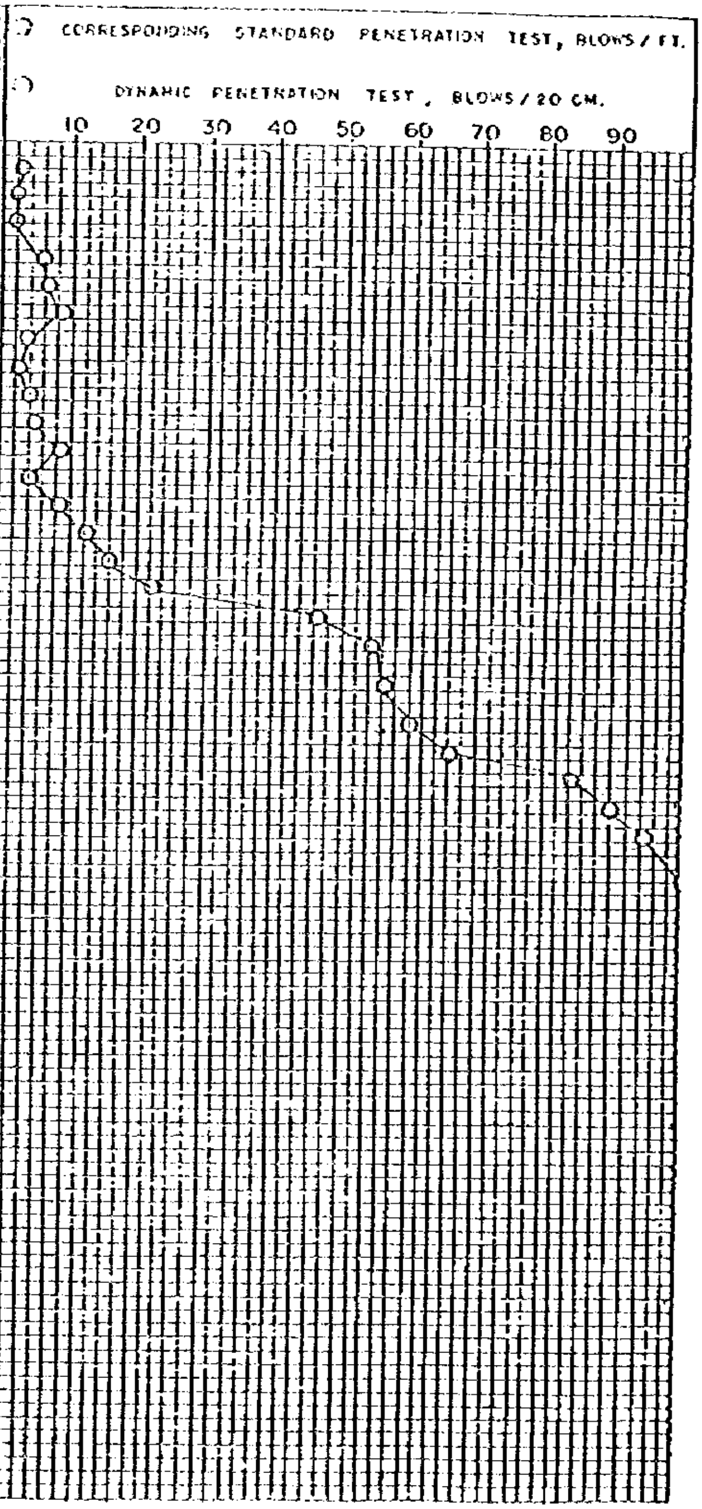


Fig. 2-15 Dynamic Cone Test Log.

PROJECT	: Water pipe line	JOB NO.	:
LOCATION	: DOKKRAI-SATTAHIP	DATE	: August 21,1981
CLIENT	: CTI Engineering Co.,Ltd	FLOTTED BY	: TN

DYNAMIC PENETRATION TEST NO. 9

SOIL DESCRIPTION	DEPTH m.		BLOW COUNT N / 20 CM.
CLAY WITH		.20	1
		.40	2
		.60	4
		.80	3
	1	.00	3
		.20	3
		.40	4
		.60	6
WEATHERED SLATE		.80	9
	2	.00	12
		.20	16
		.40	17
		.60	19
		.80	20
	3	.00	22
		.20	24
		.40	27
		.60	25
		.80	27
	4	.00	
		.20	
		.40	
		.60	
		.80	
	5	.00	
		.20	
		.40	
		.60	
		.80	
	6	.00	
		.20	
		.40	
		.60	
		.80	
	7	.00	
		.20	
		.40	
		.60	
		.80	
	8	.00	
		.20	
		.40	
		.60	
		.80	
	9	.00	
		.20	
		.40	
		.60	
		.80	
	10	.00	

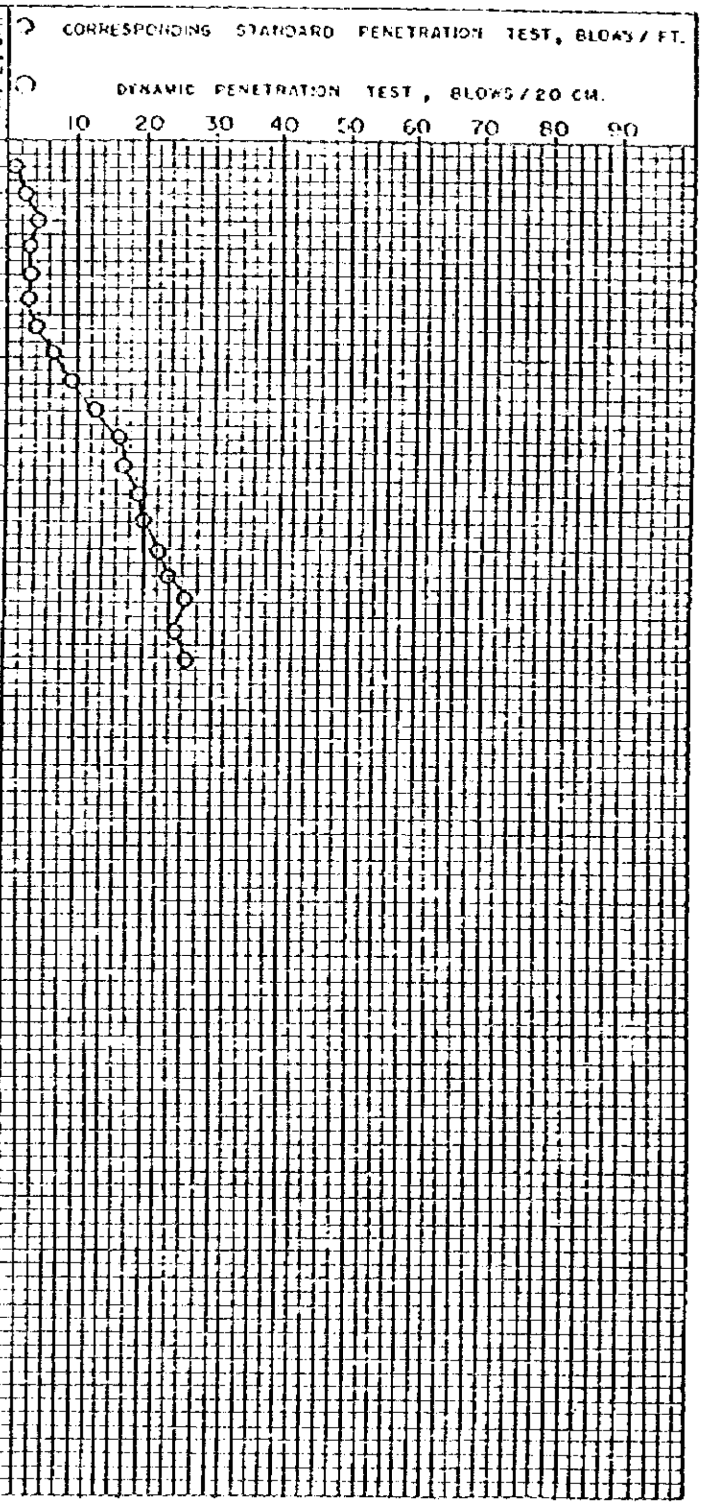


Fig.2-16 Location Map of Transmission Line

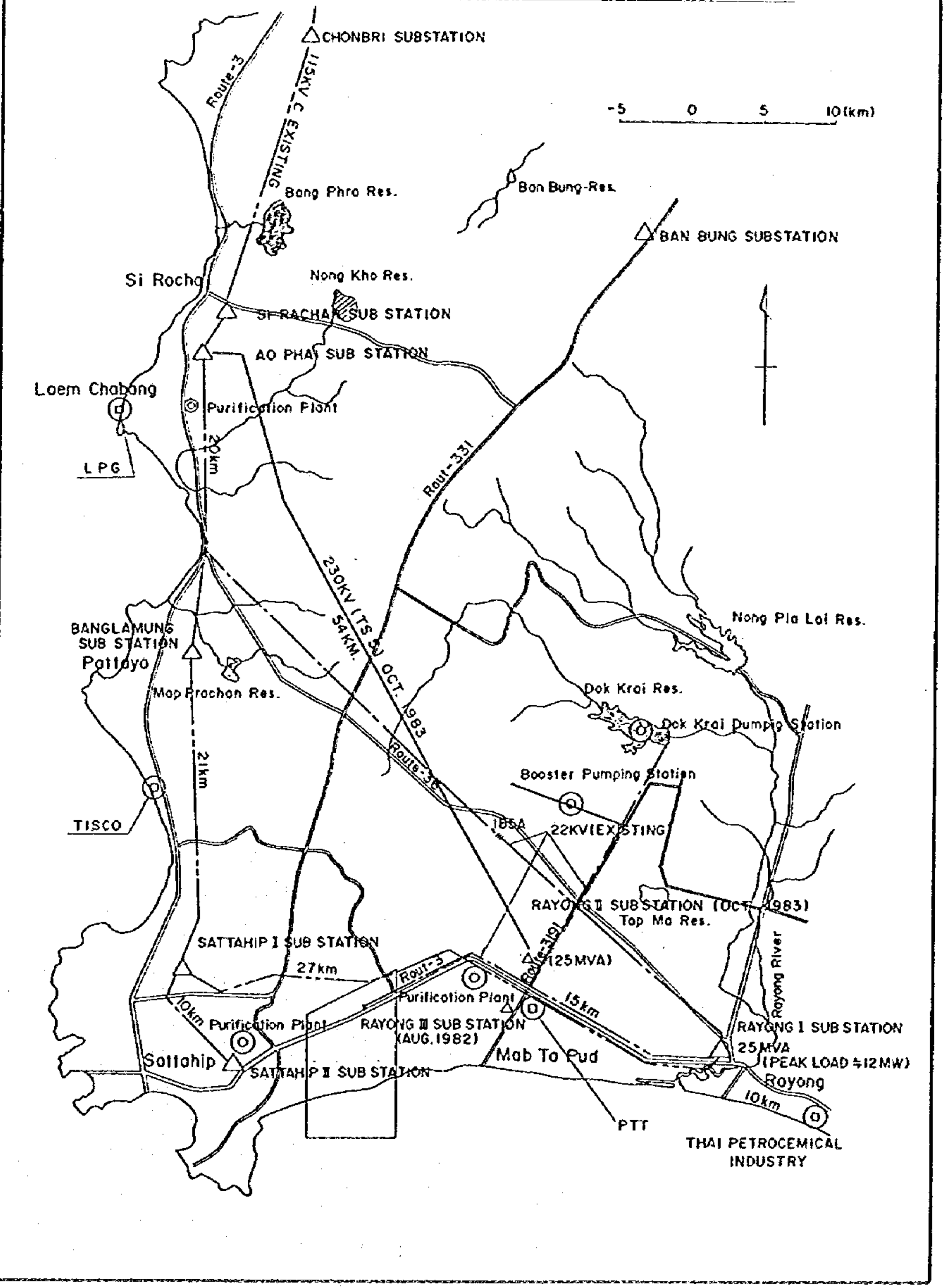


Fig. 2-17 Route of Gas Pipeline

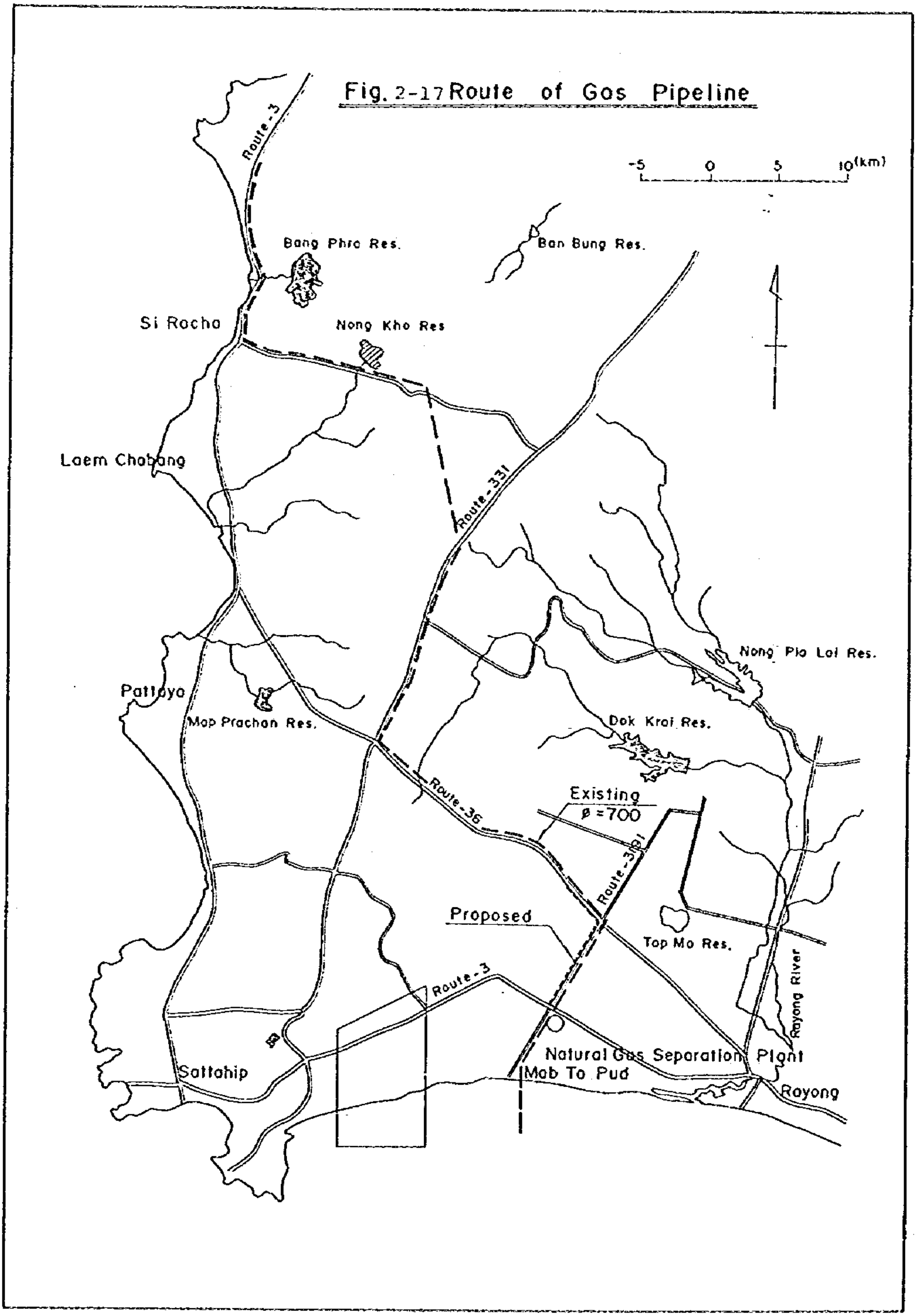


Fig. 2-18 Standard Cross Section of Route - 3191

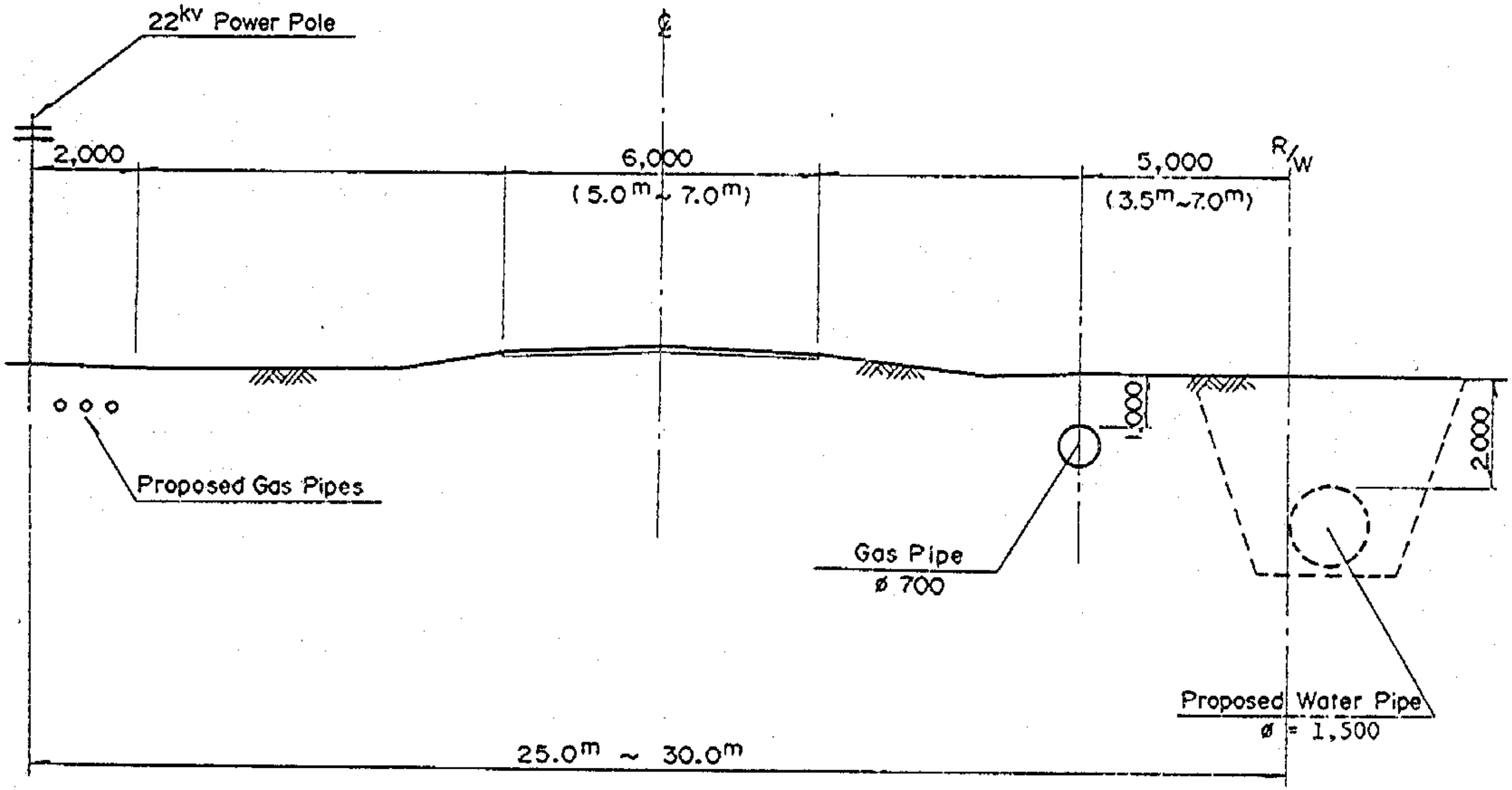


Fig. 3-1 Route of Water Transmission Line

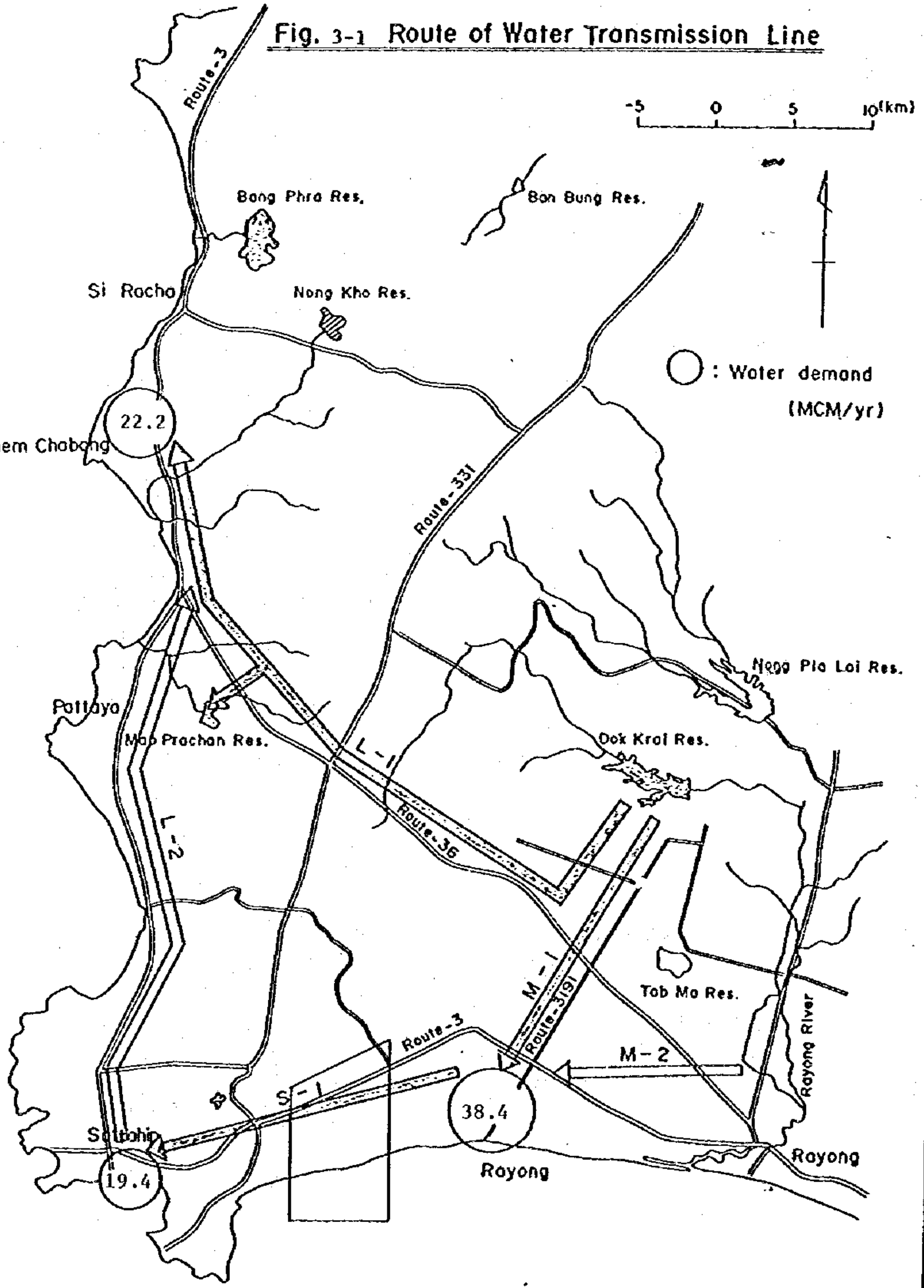


Fig. 3-2 General Plan of Water Transmission Line
(from Dok Krai Res. to Mab To Pud)

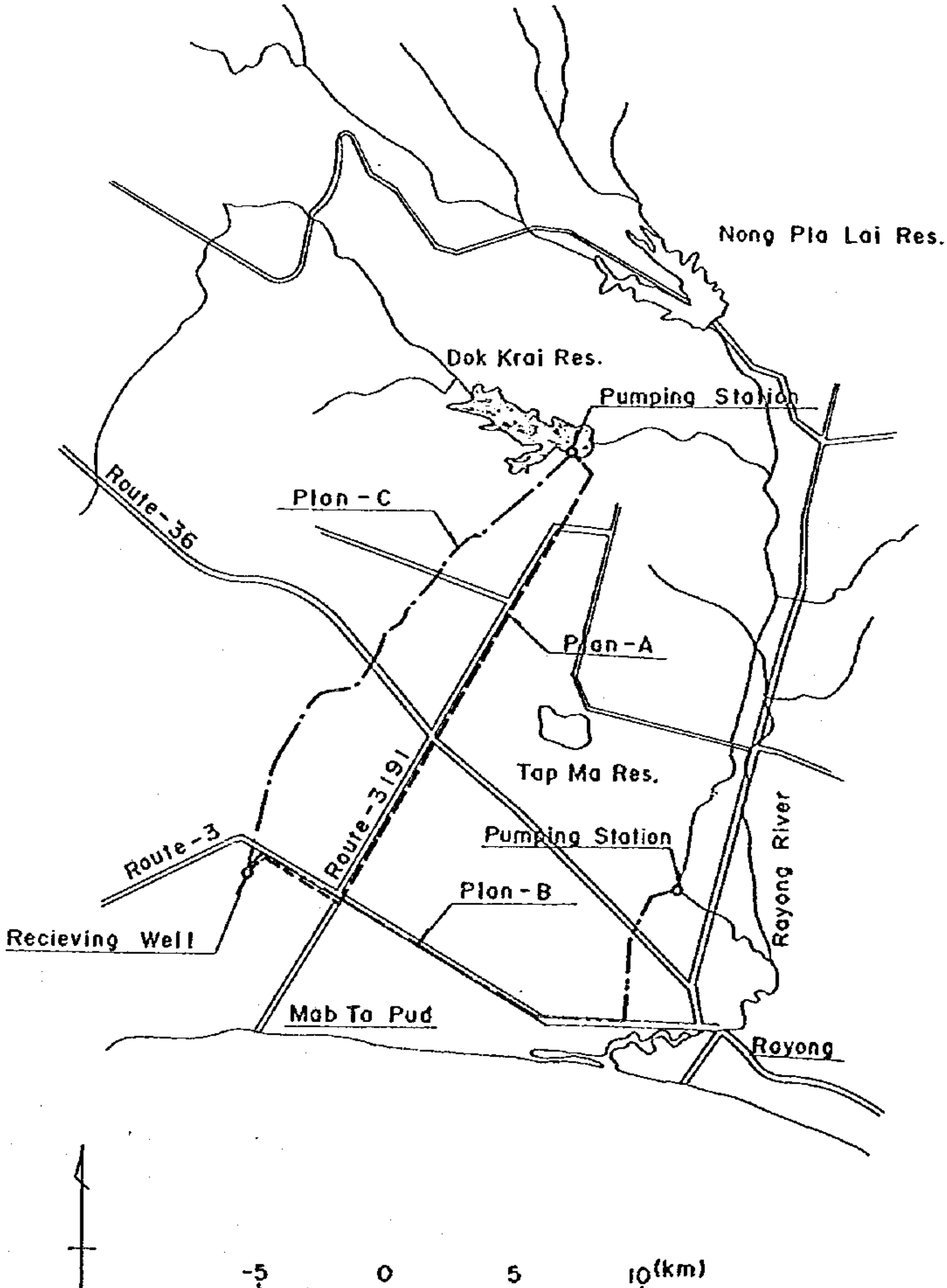


Fig. 3-3 General Plan of Pumping Station of Plan-B

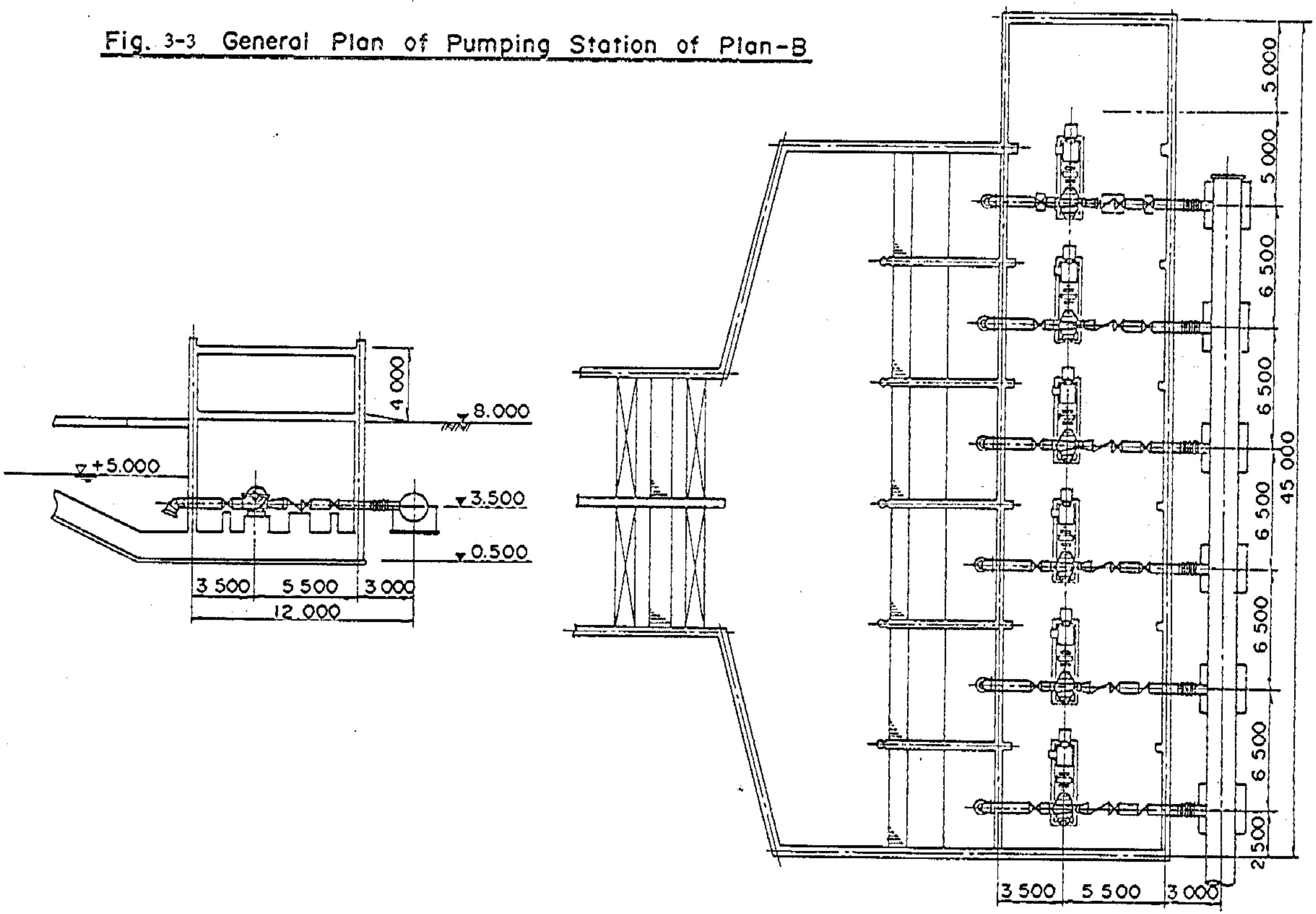


Fig. 3-4 Pipeline Route of Plan-B

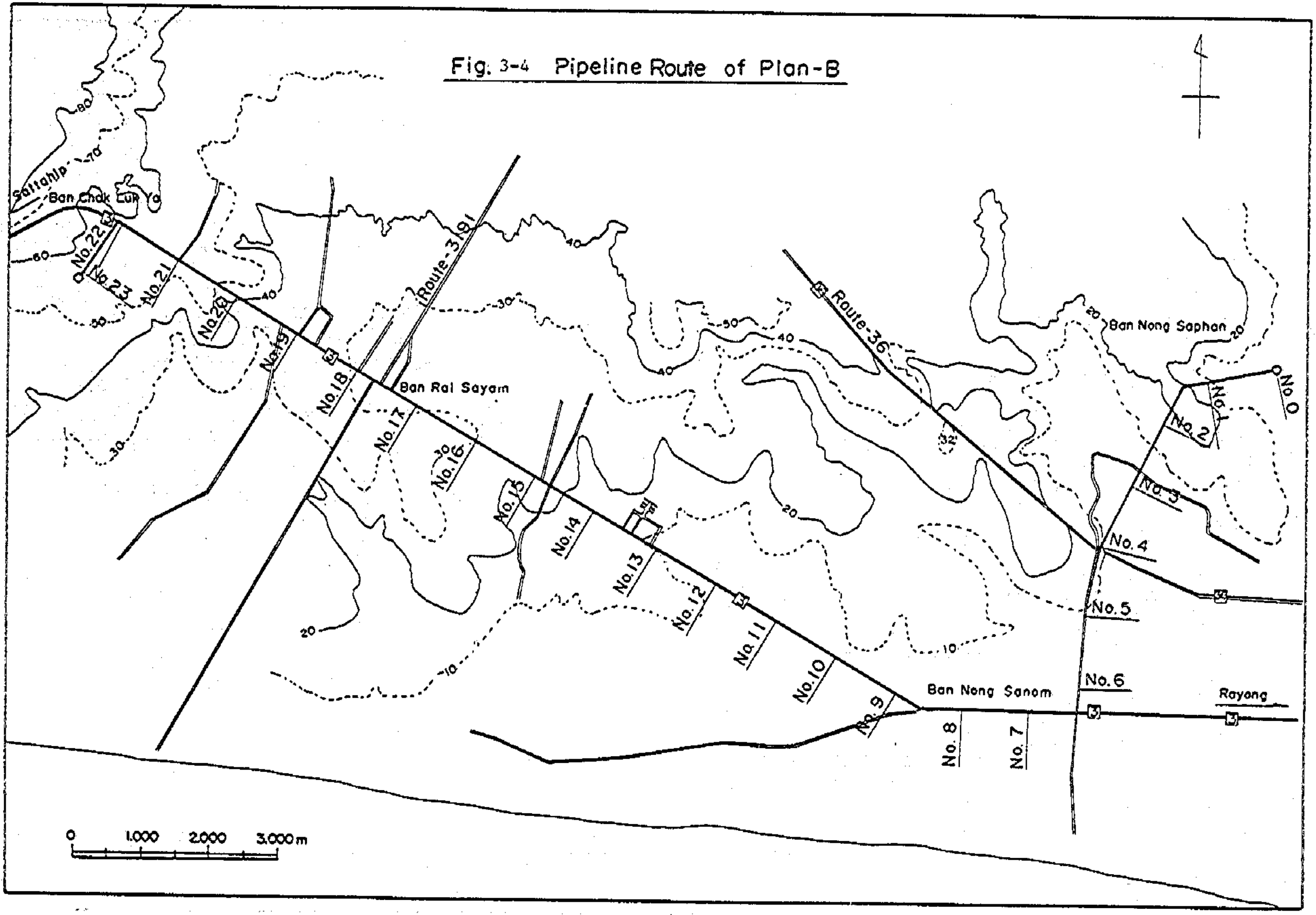
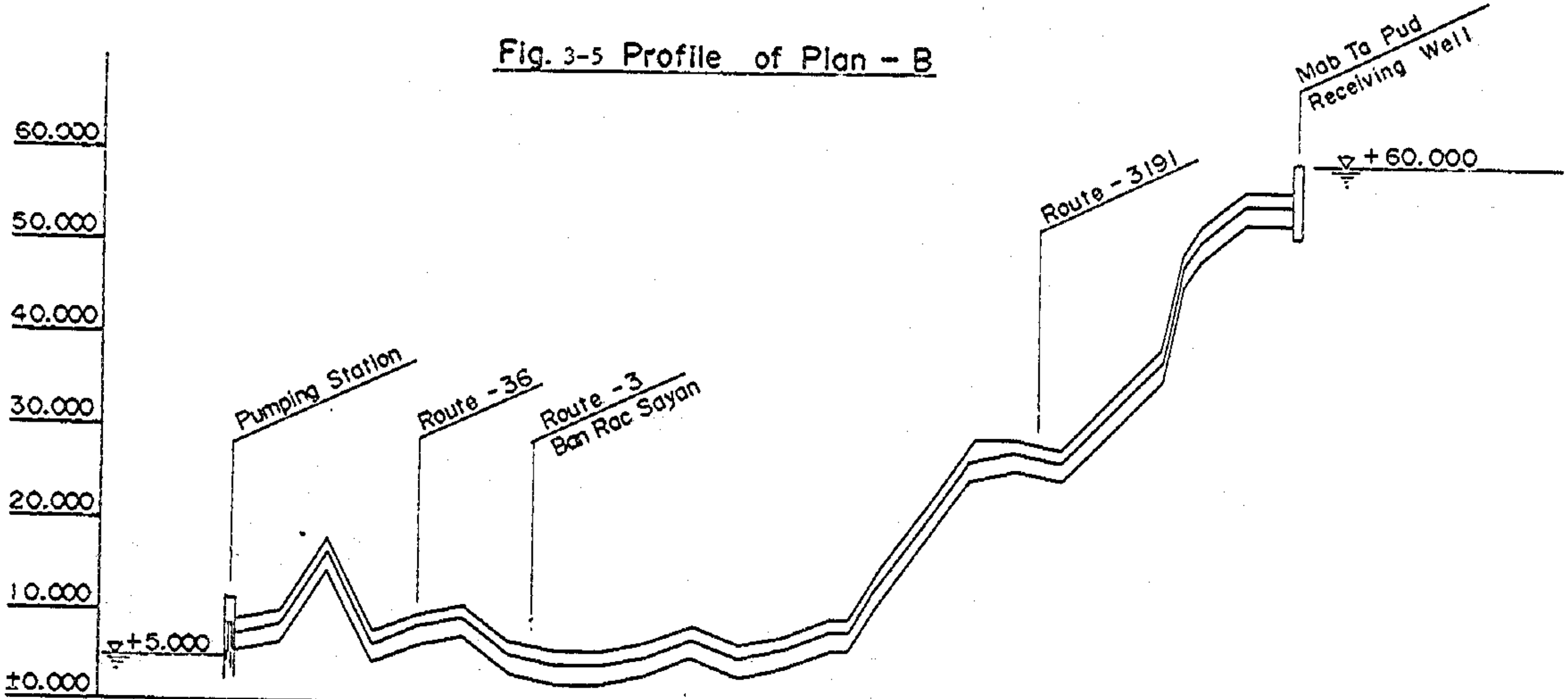


Fig. 3-5 Profile of Plan - B



GROUND ELEV	8.000	10.000	18.000	8.000	10.000	11.000	7.000	6.000	6.000	7.000	9.000	7.000	8.000	10.000	15.000	22.000	29.000	30.000	29.000	34.000	39.000	53.000	57.000	57.000
ACCUM DIST	0.000	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000	10.000	11.000	12.000	13.000	14.000	15.000	16.000	17.000	18.000	19.000	20.000	21.000	22.000	23.000
STATION NO	No.0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

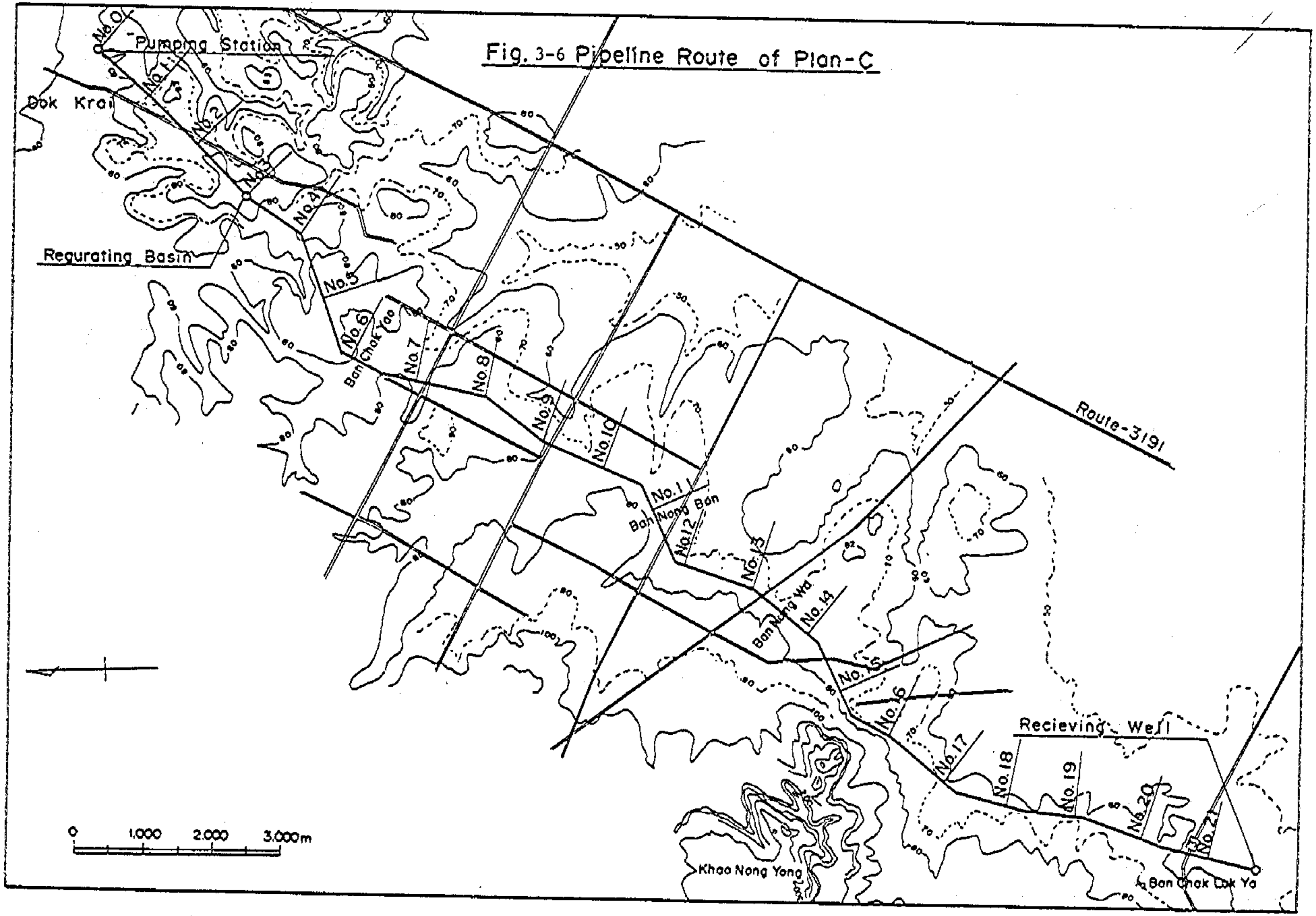
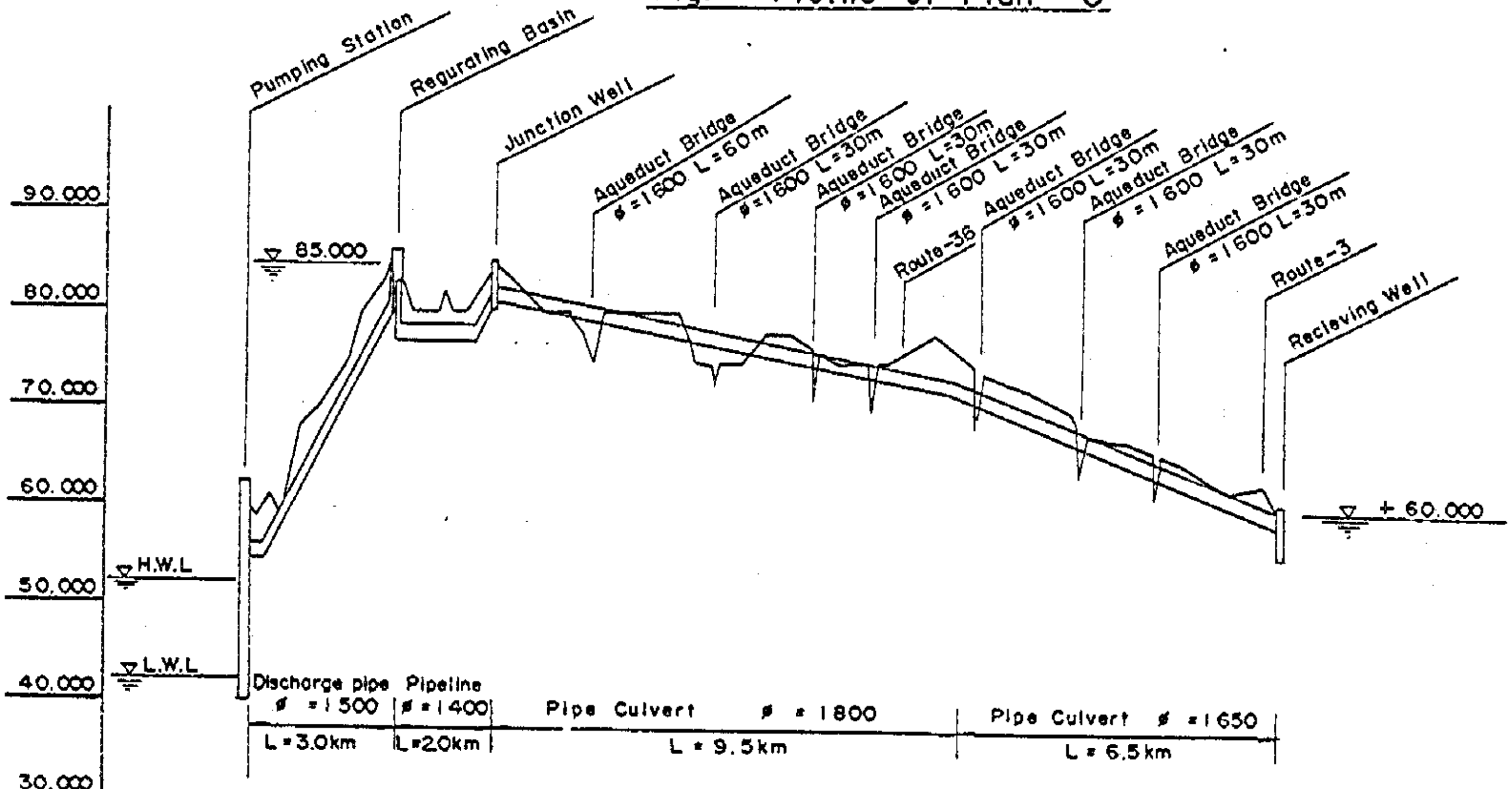


Fig. 3-6 Pipeline Route of Plan-C

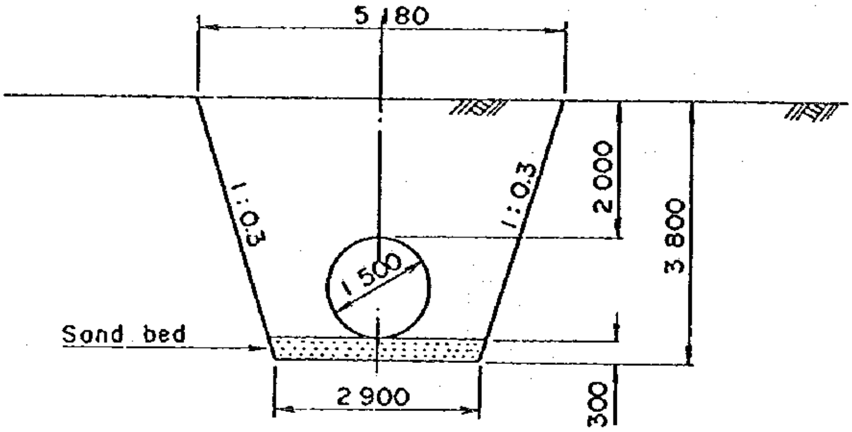
Fig.3-7 Profile of Plan - C



STATION NO.	ACCUM DIST	GROUND ELEV
0	0.000	60.000
1	1.000	68.000
2	2.000	75.000
3	3.000	85.000
4	4.000	82.000
5	5.000	85.000
6	6.000	80.000
7	7.000	78.000
8	8.000	80.000
9	9.000	80.000
10	10.000	78.000
11	11.000	78.000
12	12.000	75.000
13	13.000	75.000
14	14.000	78.000
15	15.000	74.000
16	16.000	72.000
17	17.000	64.000
18	18.000	67.000
19	19.000	65.000
20	20.000	62.000
21	21.000	58.000

Fig. 3-8 Typical Cross Section of Pipeline

One - pipe



Two - pipe

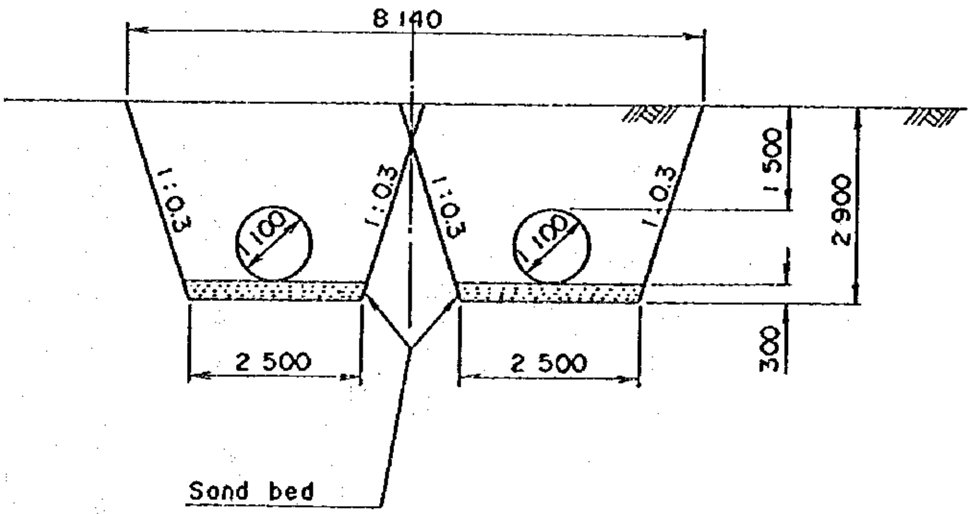


Fig. 3-9 Location Map of Purification Plant
(at Mab Ta Pud)

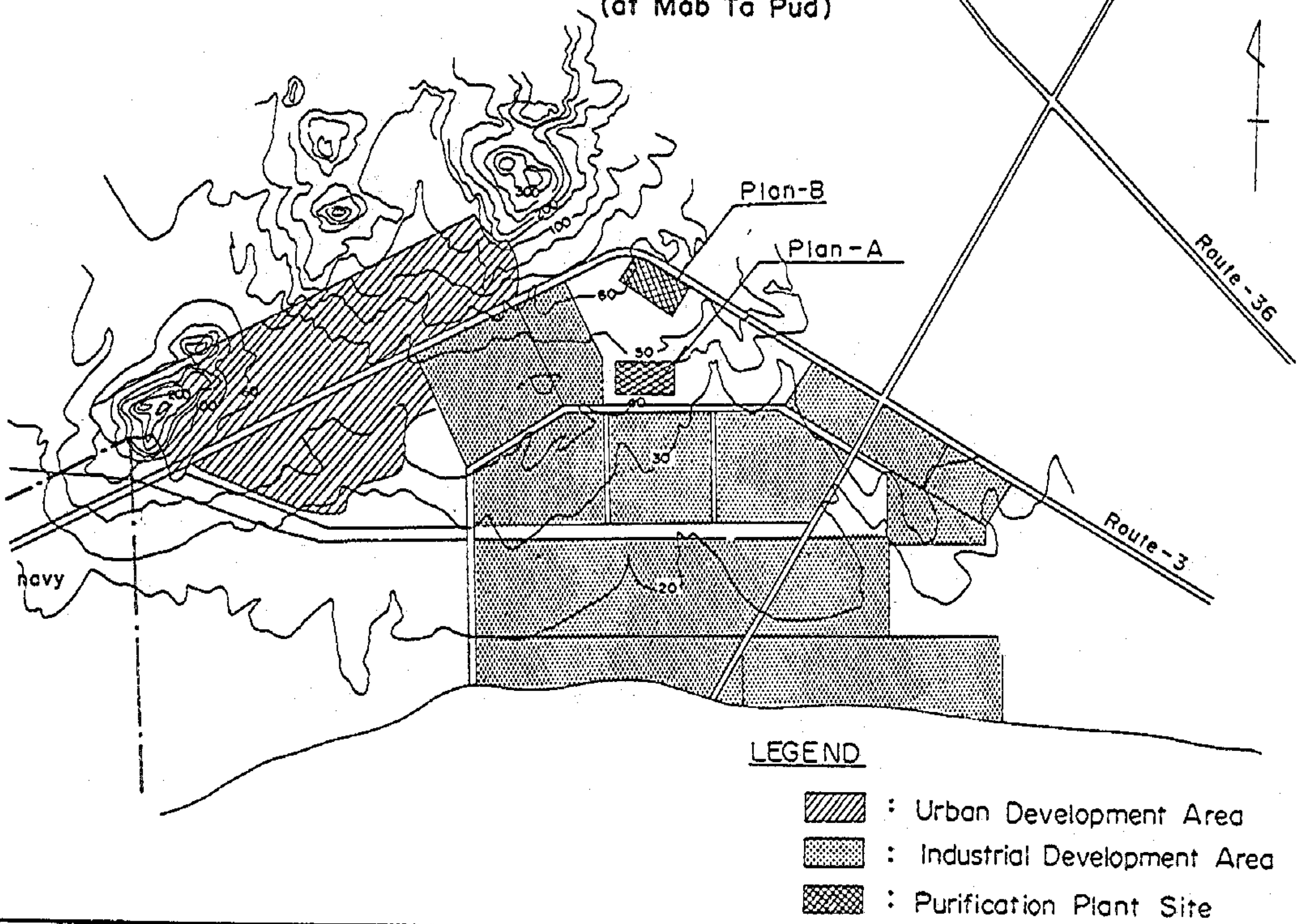


Fig. 3-10 General Plan of Water Supply System

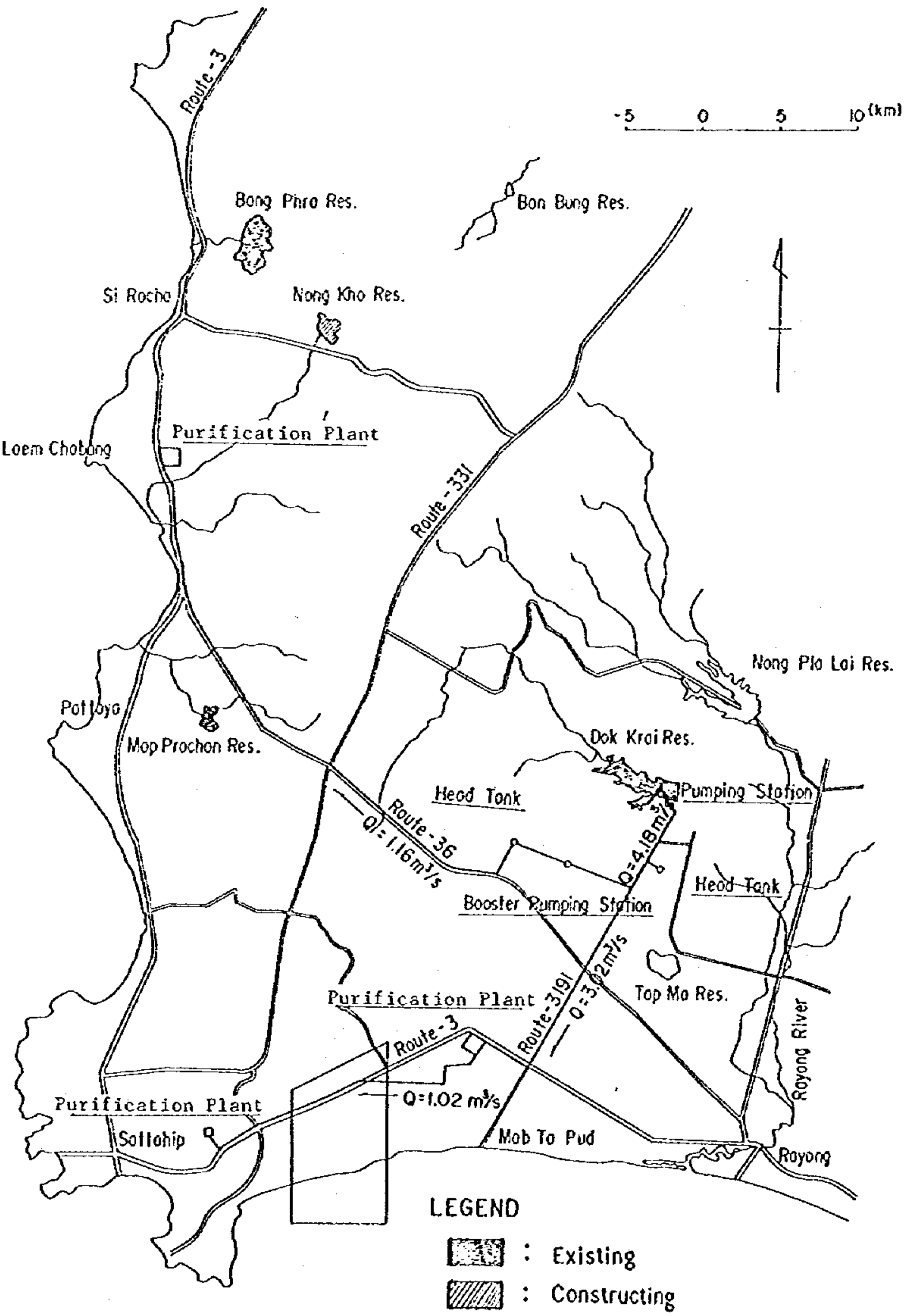


Fig. 3-11 General Plan of Pipeline from Dok Krai to Mab Ta Pud

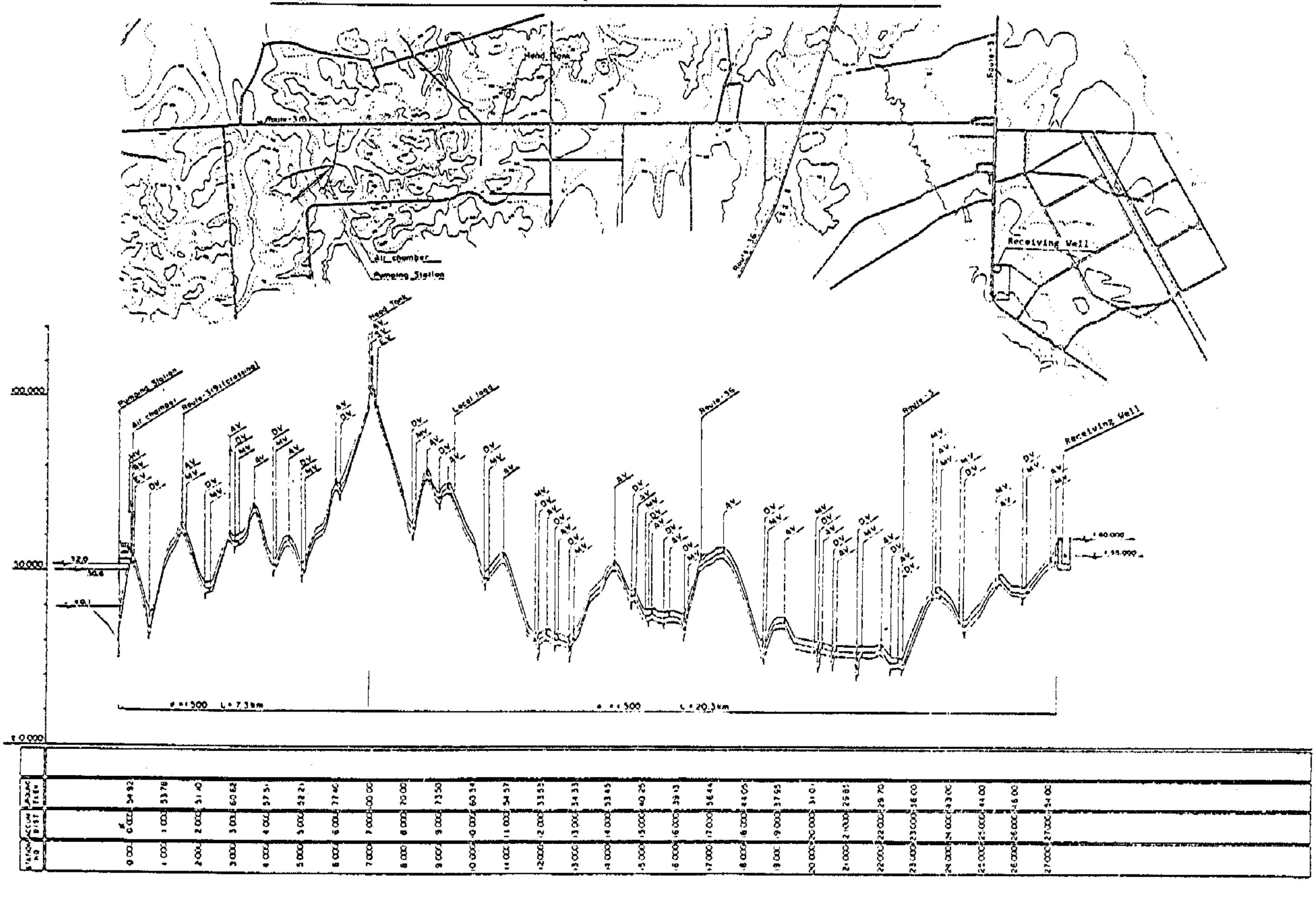


Fig. 3-12 General Plan of Pipeline from Mab Ta Pud to Sattahip

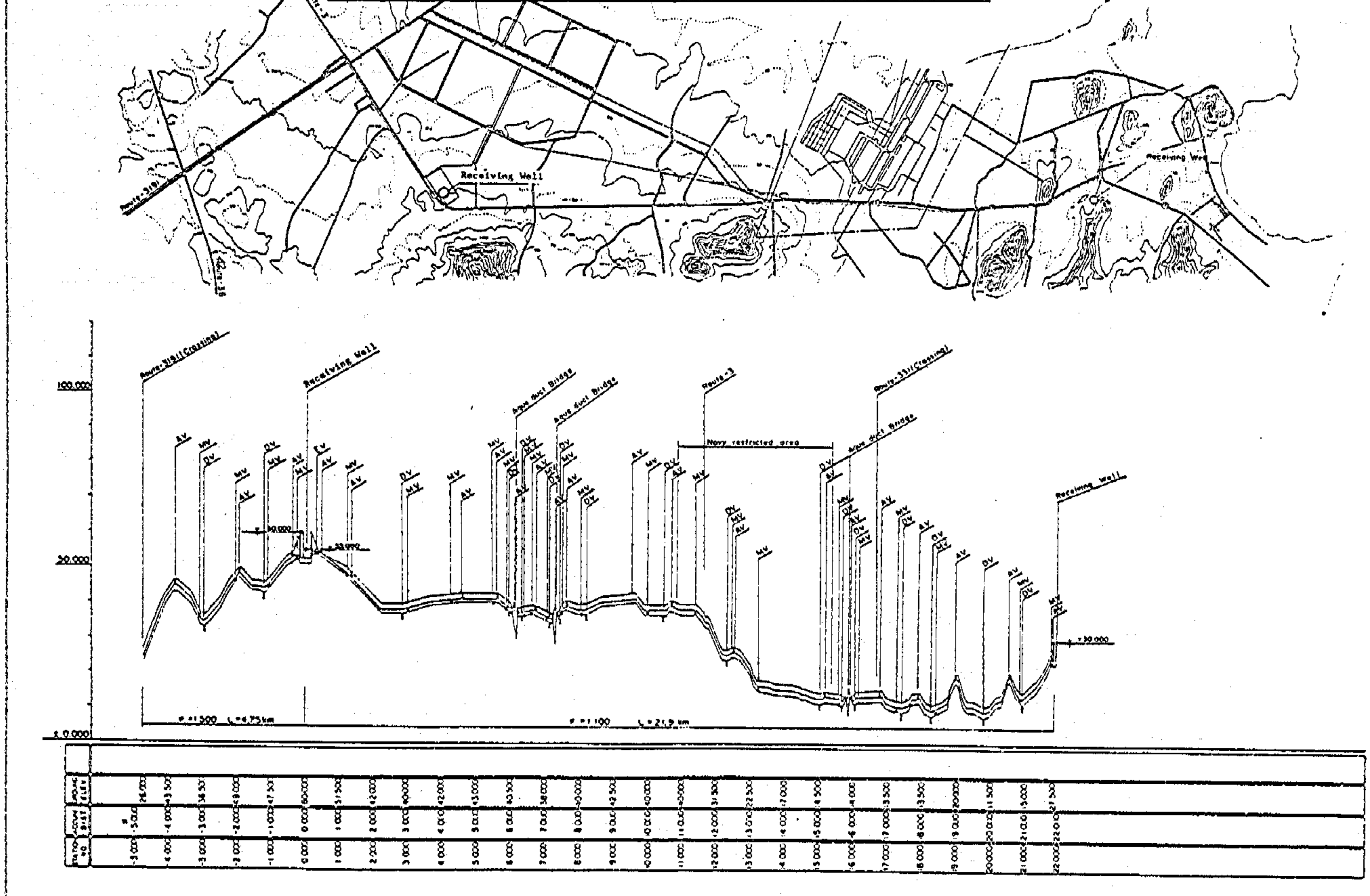


Fig. 3-13 General Plan of Pipeline from Dok Krai to Laem Chabang

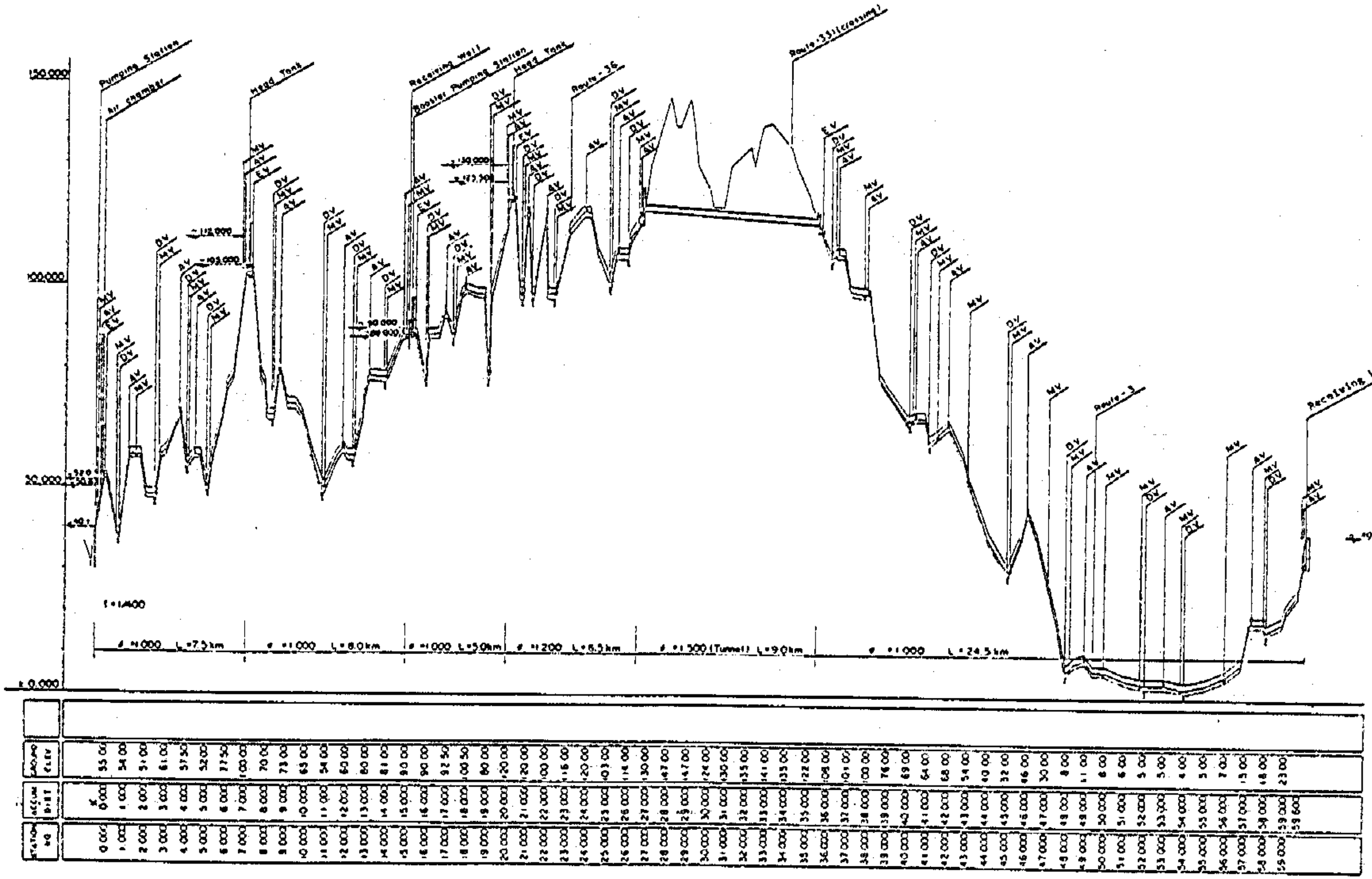


Fig.4-1 Geological Profile of Dok Krai Dam Axies

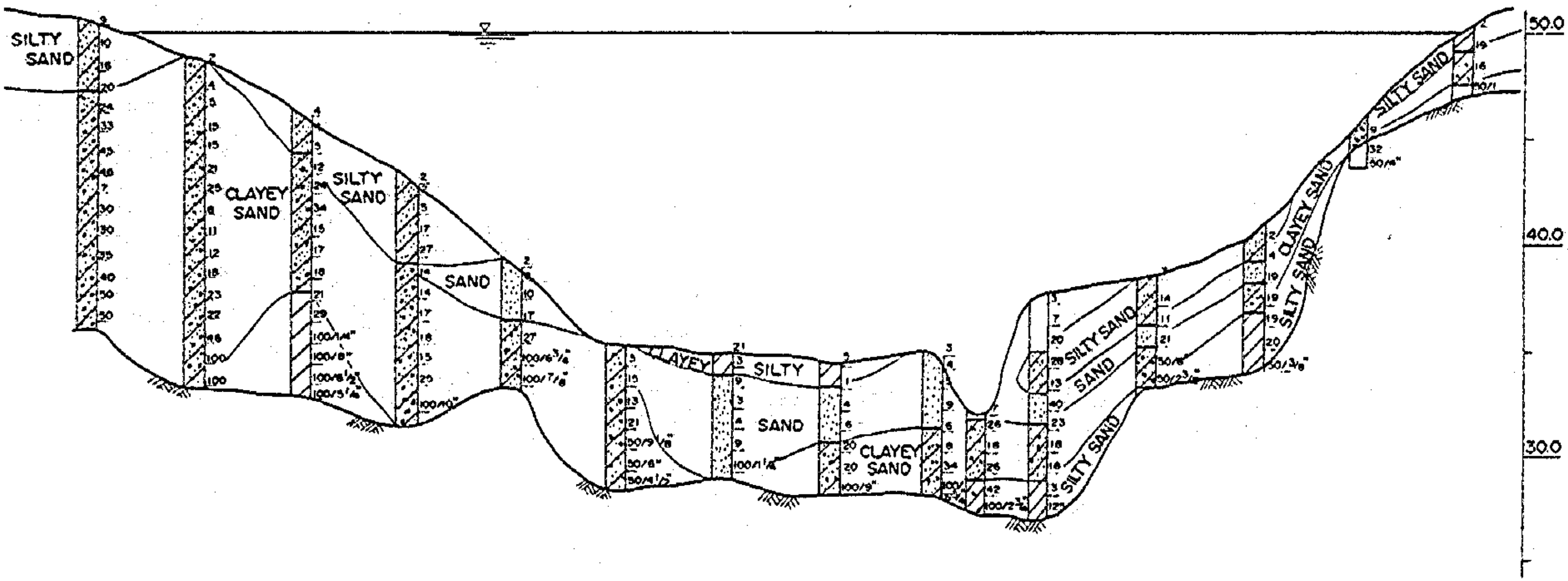


Fig.4-2 Location Map of The Pumping Station

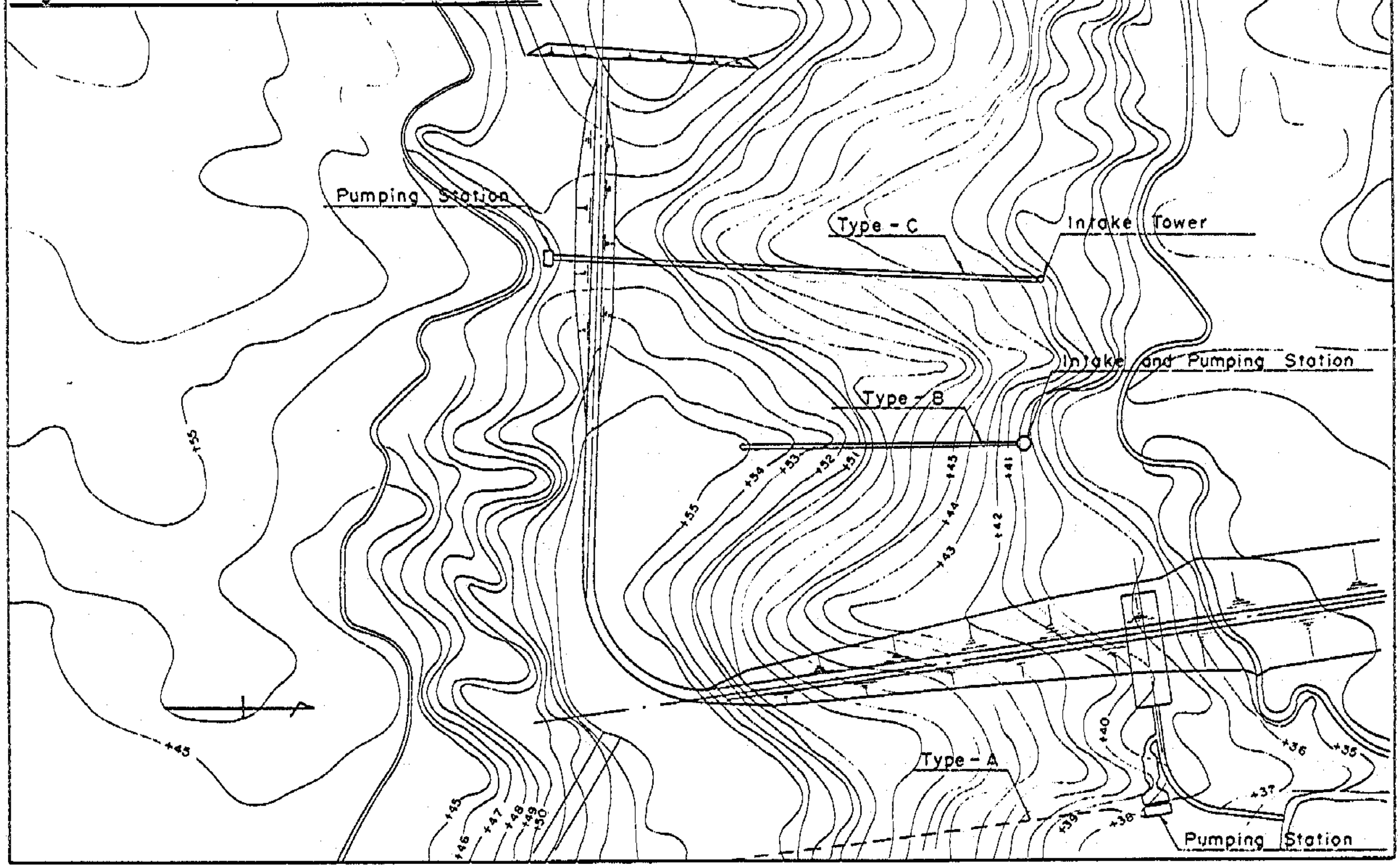


Fig. 4-3 Profile of Pumping Station and Discharge Pipe of Type - A

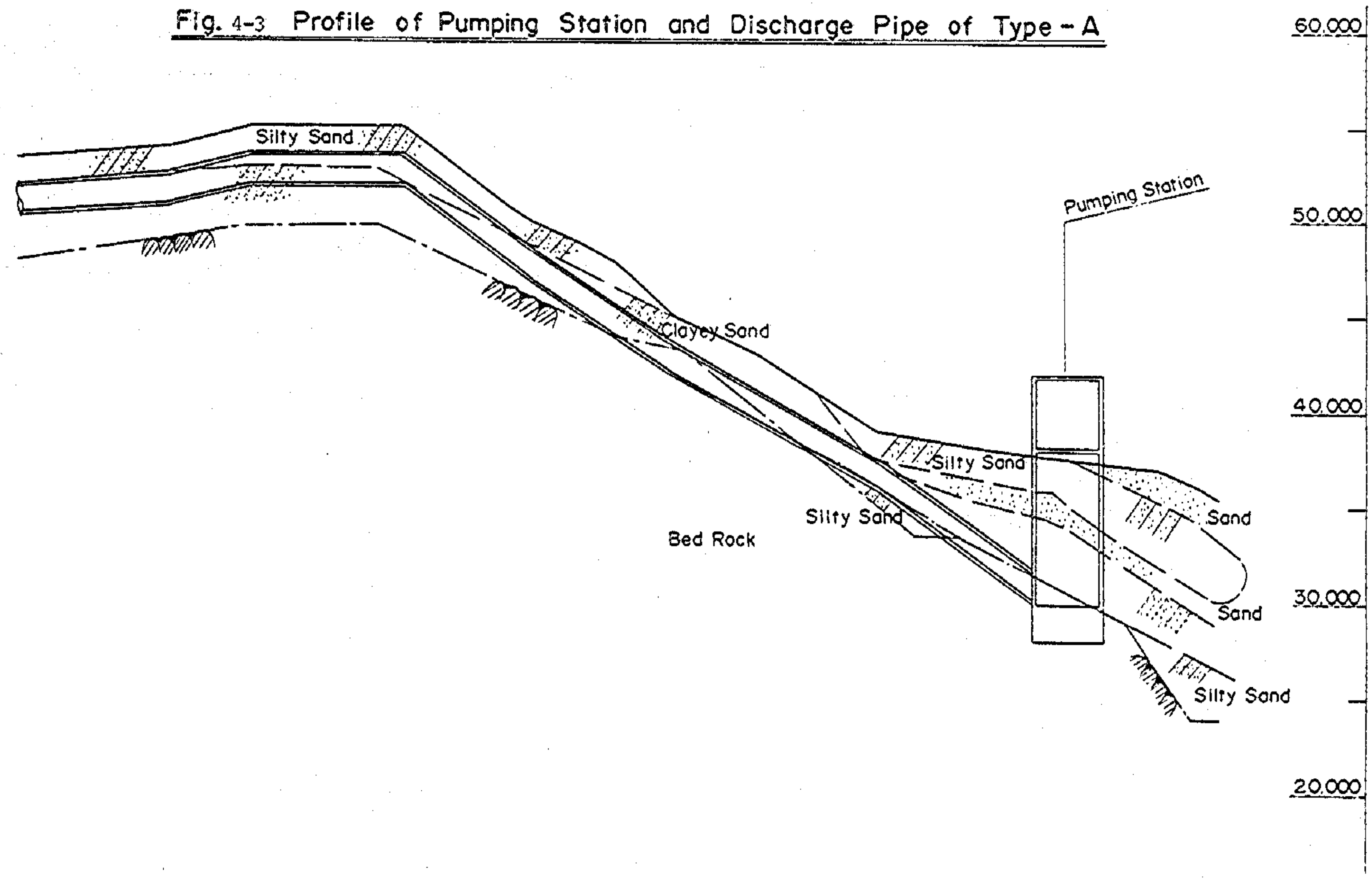


Fig. 4-4 General Plan of Pumping Station of Type-A1

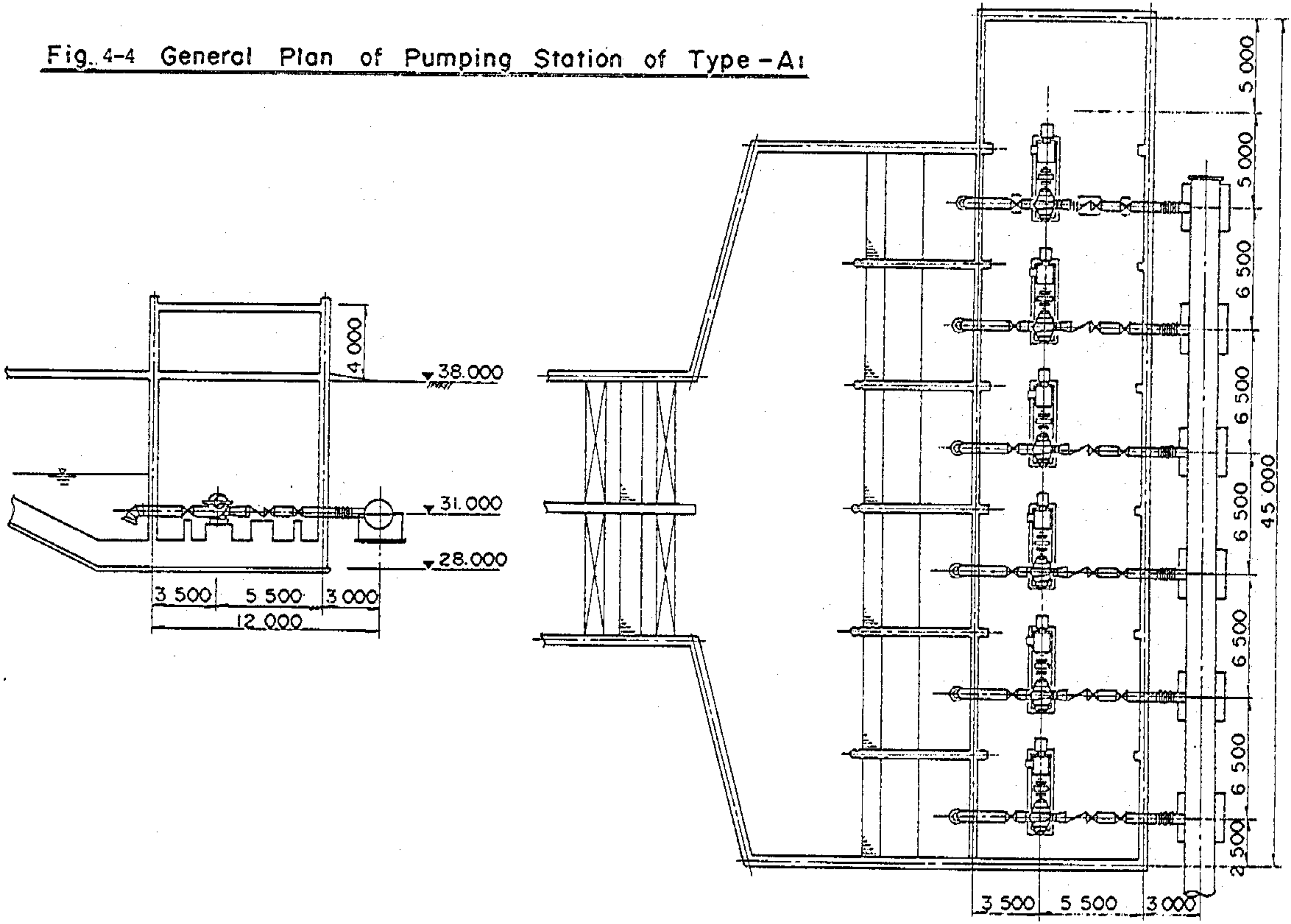


Fig. 4-5 General Plan of Pumping Station of Type-A2

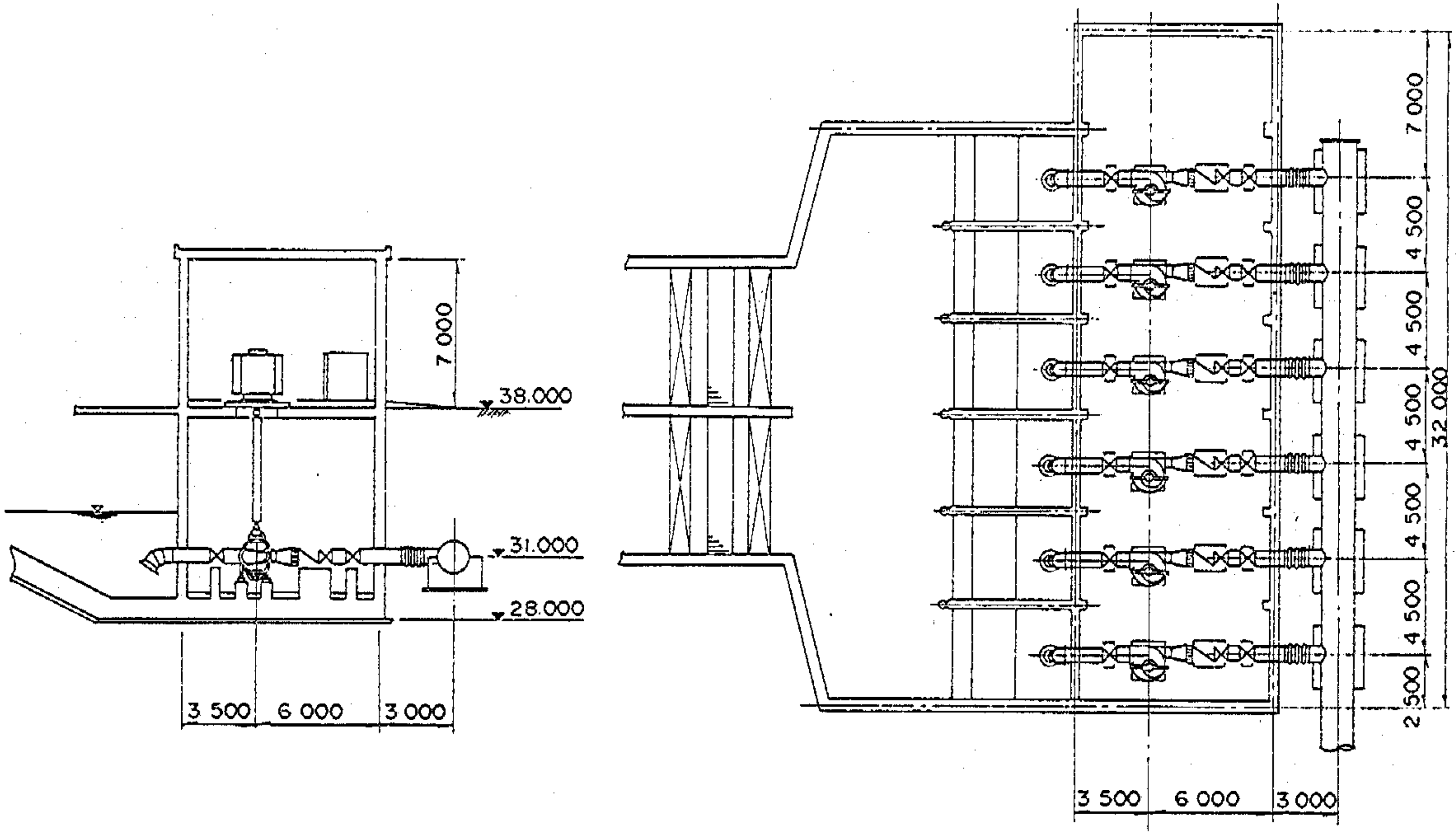
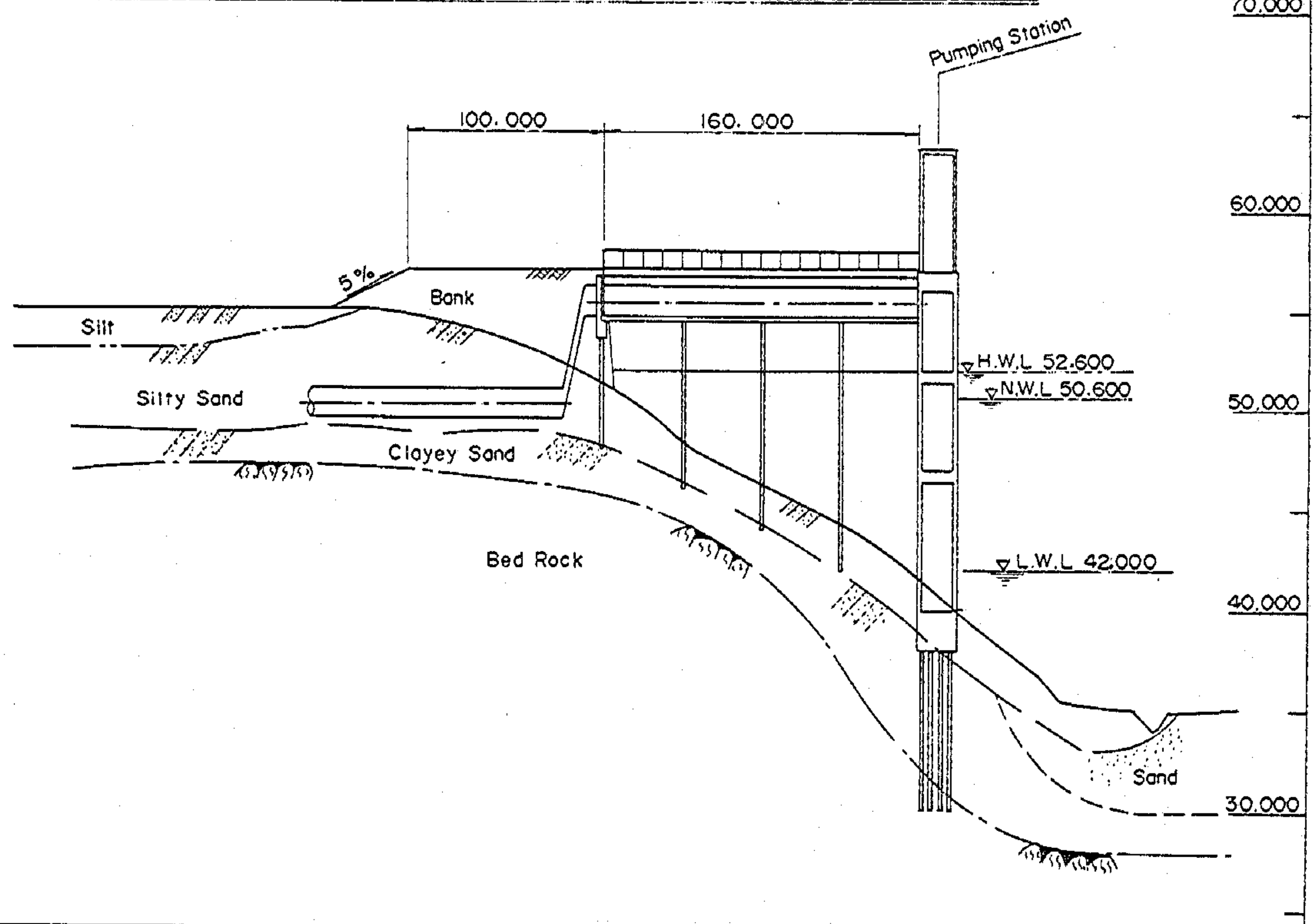


Fig. 4-6 Profile of Pumping Station and Discharge Pipe of Type - B



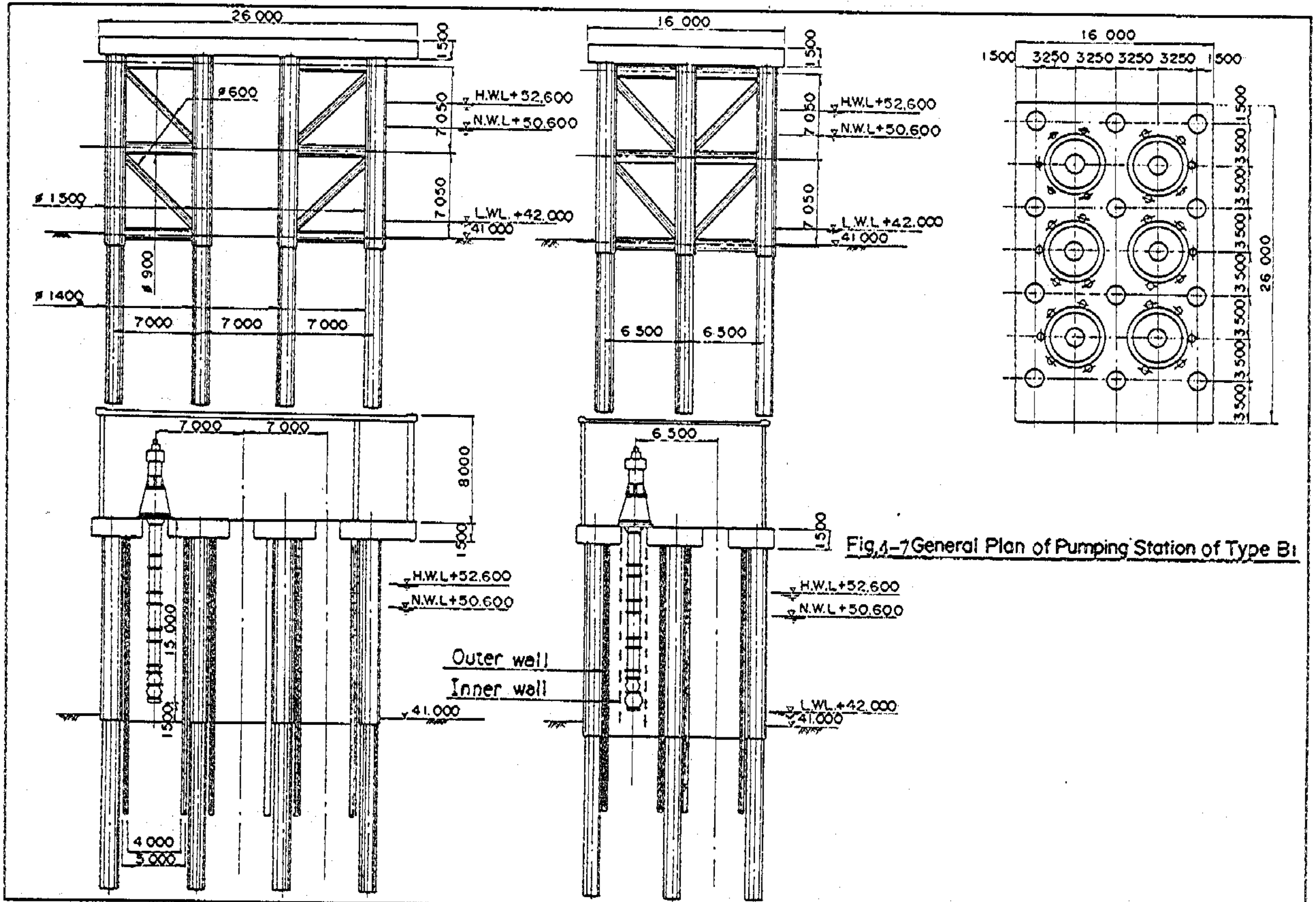


Fig.4-7 General Plan of Pumping Station of Type B1