THE KINGDOM OF THAILAND

FEASIBILITY STUDY ON SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

FINAL REPORT

SUMMARY

NOVEMBER, 1992

JAPAN INTERNATIONAL COOPERATION AGENCY
ELECTRIC POWER DEVELOPMENT CO., LTD.

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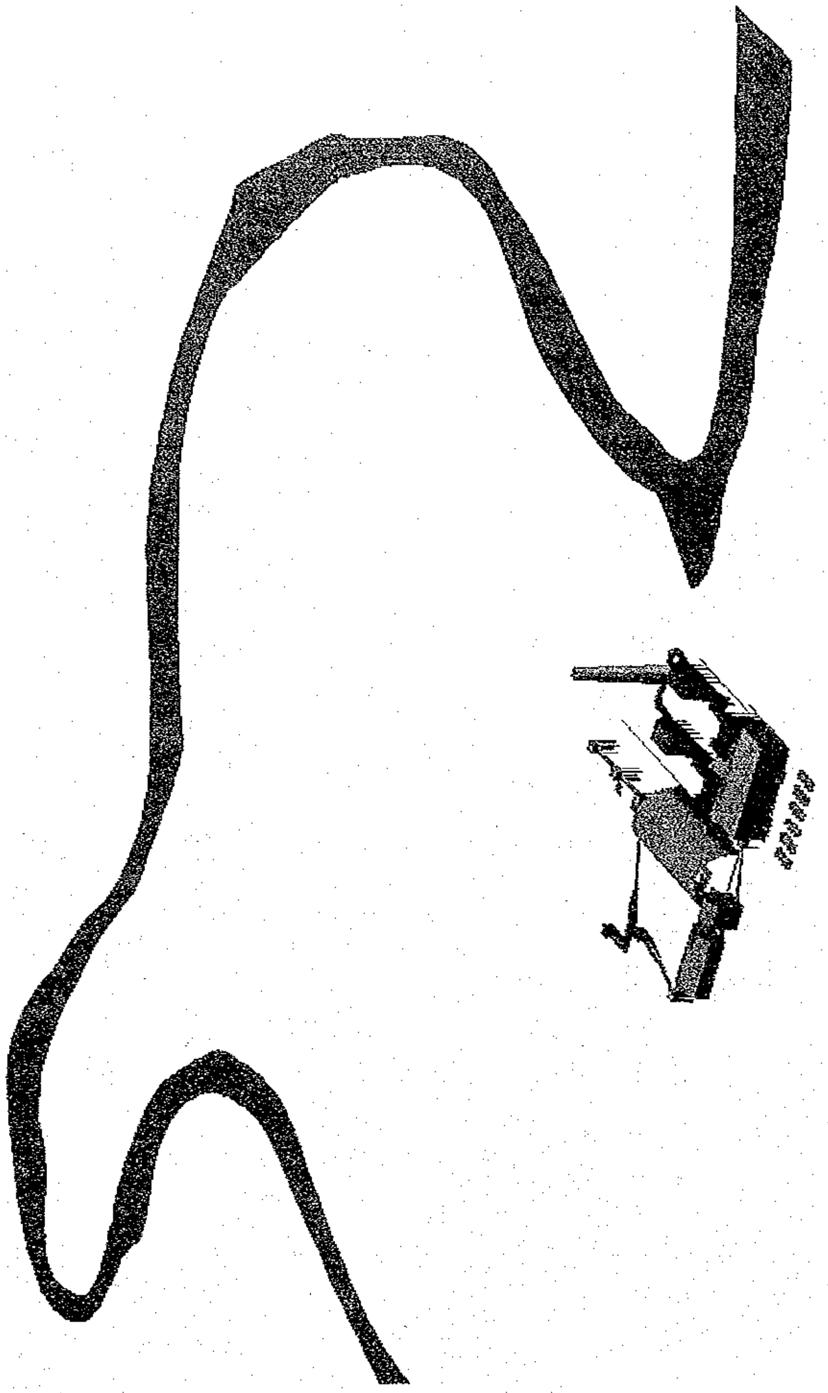
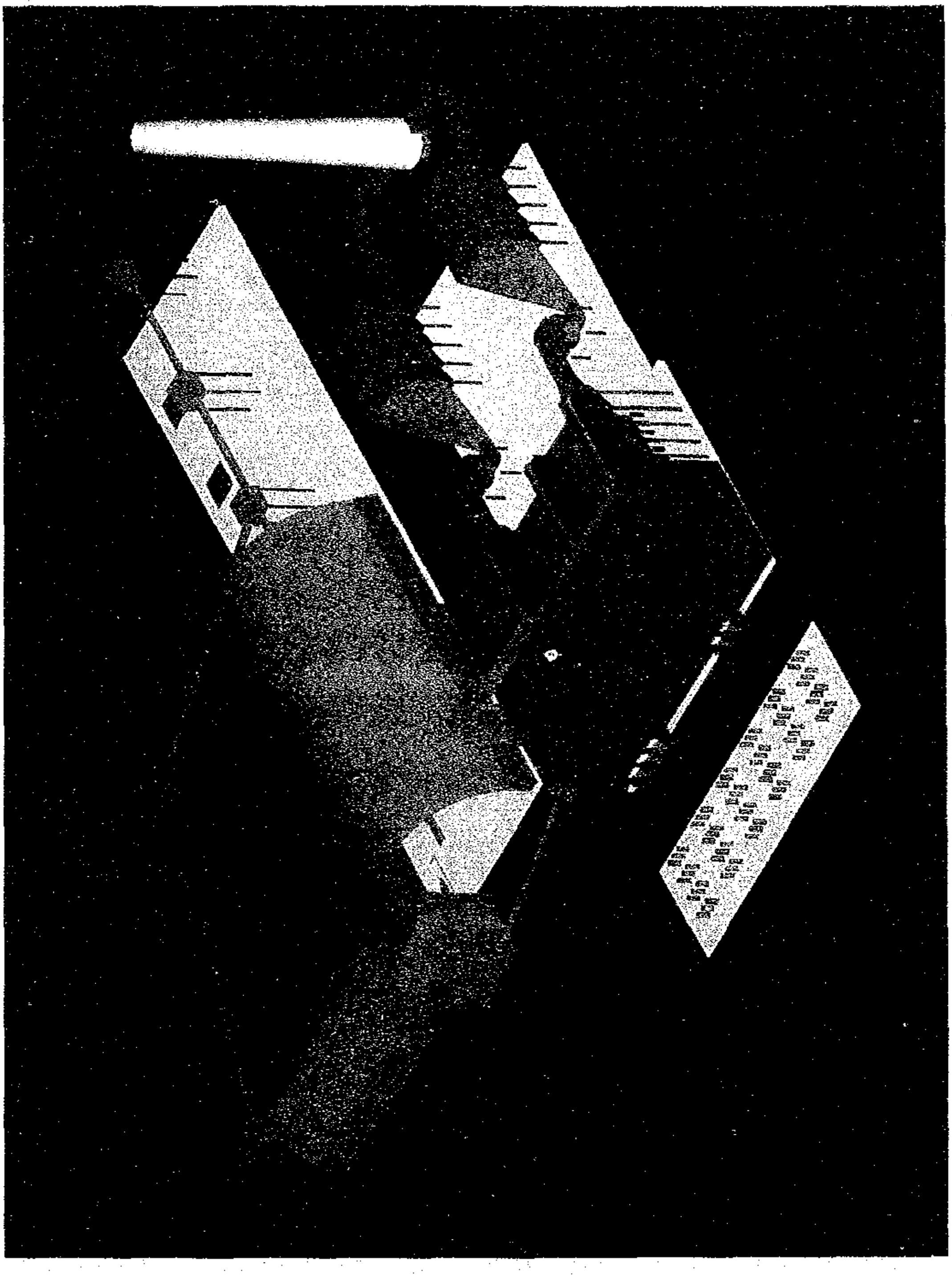
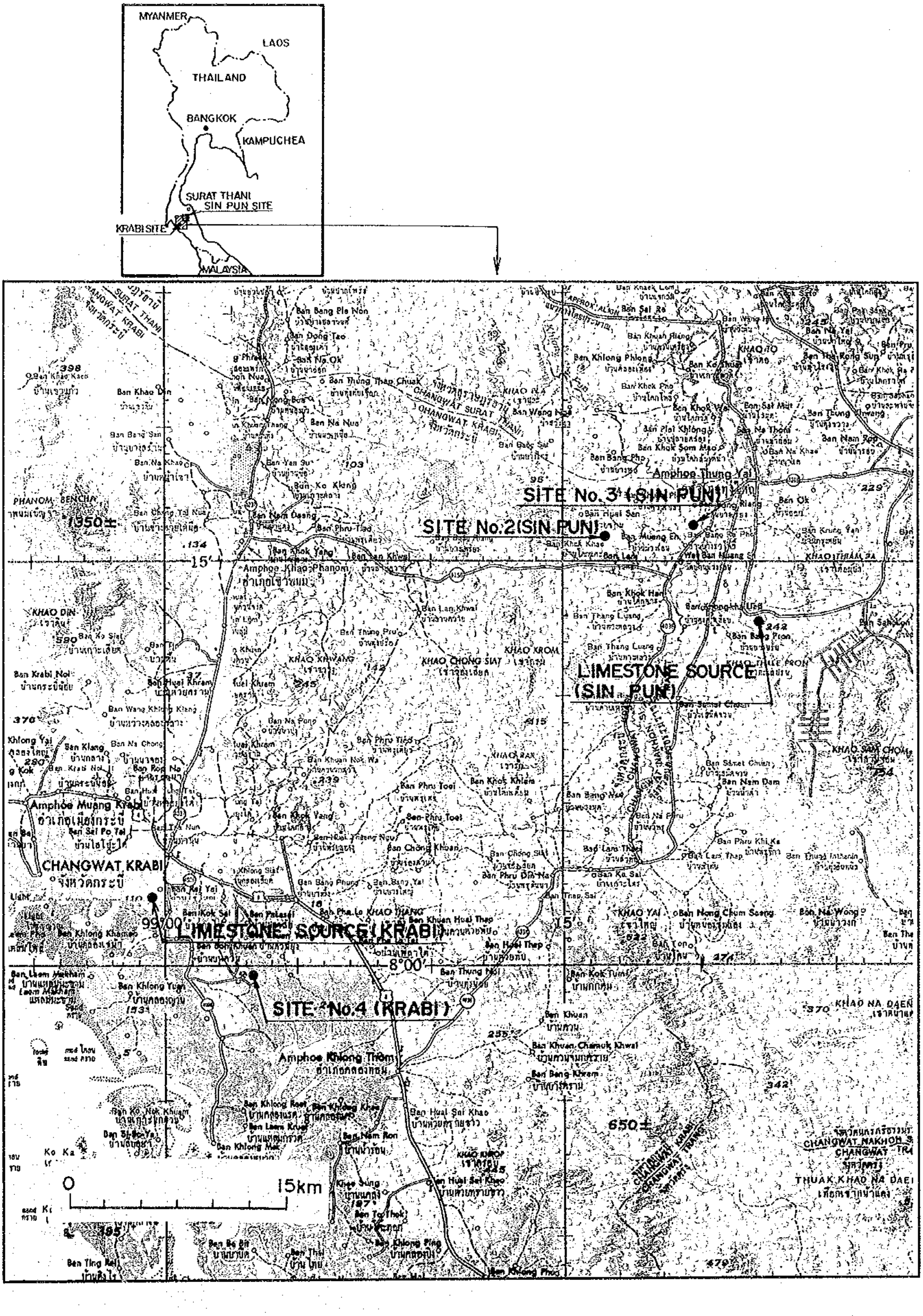
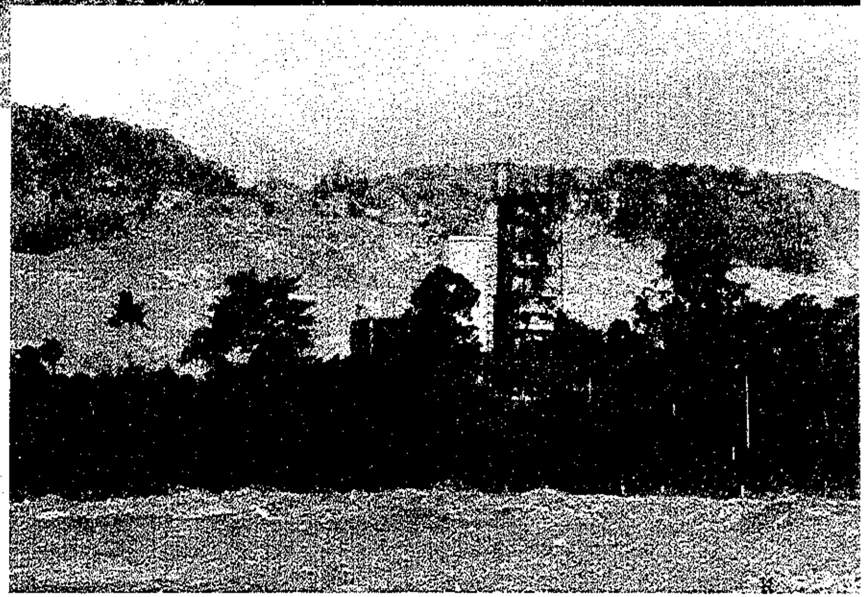





MYANMER
LAOS
THAILAND
BANGKOK
KAMPUCHEA
SURAT THANI
SIN PUN SITE
KRABI SITE
MALAYSIA
SITE No.3 (SIN PUN)
SITE No.2 (SIN PUN)
LIMESTONE SOURCE (SIN PUN)
LIMESTONE SOURCE (KRABI)
SITE No.4 (KRABI)
CHANGWAT KRABI
Amphoe Muang Krabi
Amphoe Khao Phanom
Amphoe Thung Yai
Amphoe Khlong Thom
CHANGWAT SURAT THANI
PHANOM BENCHA
KHAO DIN
KHAO KHWANG
KHAO CHONG SIAT
KHAO KROM
KHAO YAI
KHAO NA DAEN
KHAO SAM CHOM
99°00'
8°00'
15'
0
15km

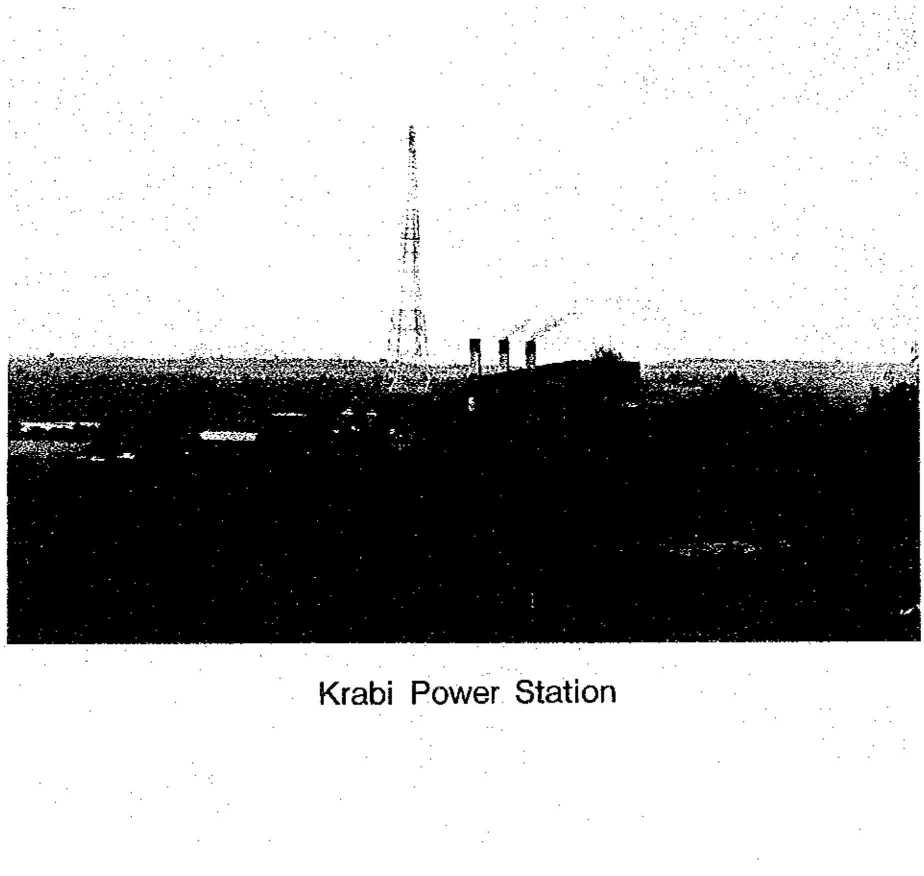
Krabi Site : View From Existing Ash Pond

Limestone Quarry in Sin Pun area

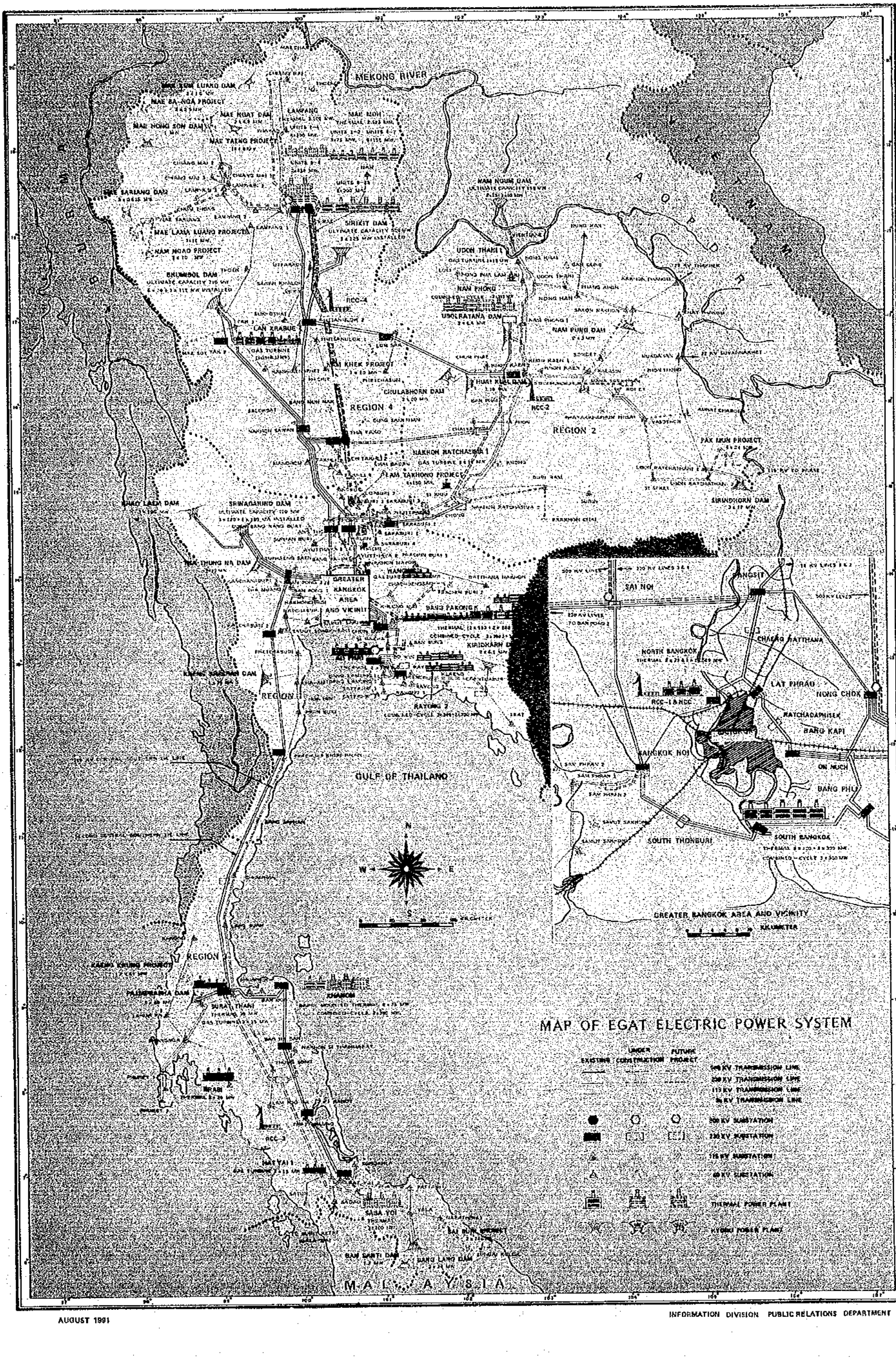


Cement Factory in Thung Song
(50 km from Sin Pun)

Krabi Lignite Mine

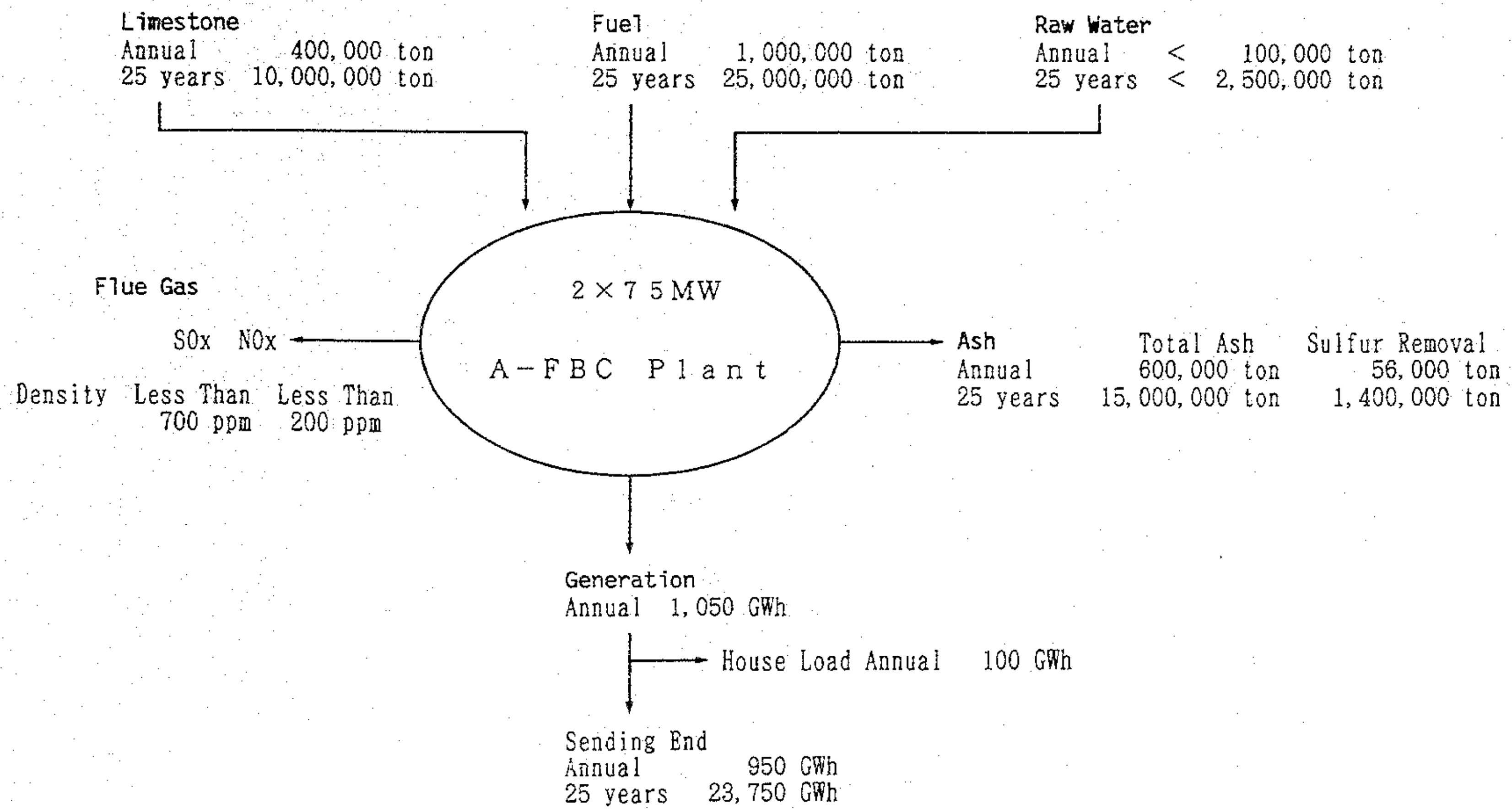


Krabi Power Station

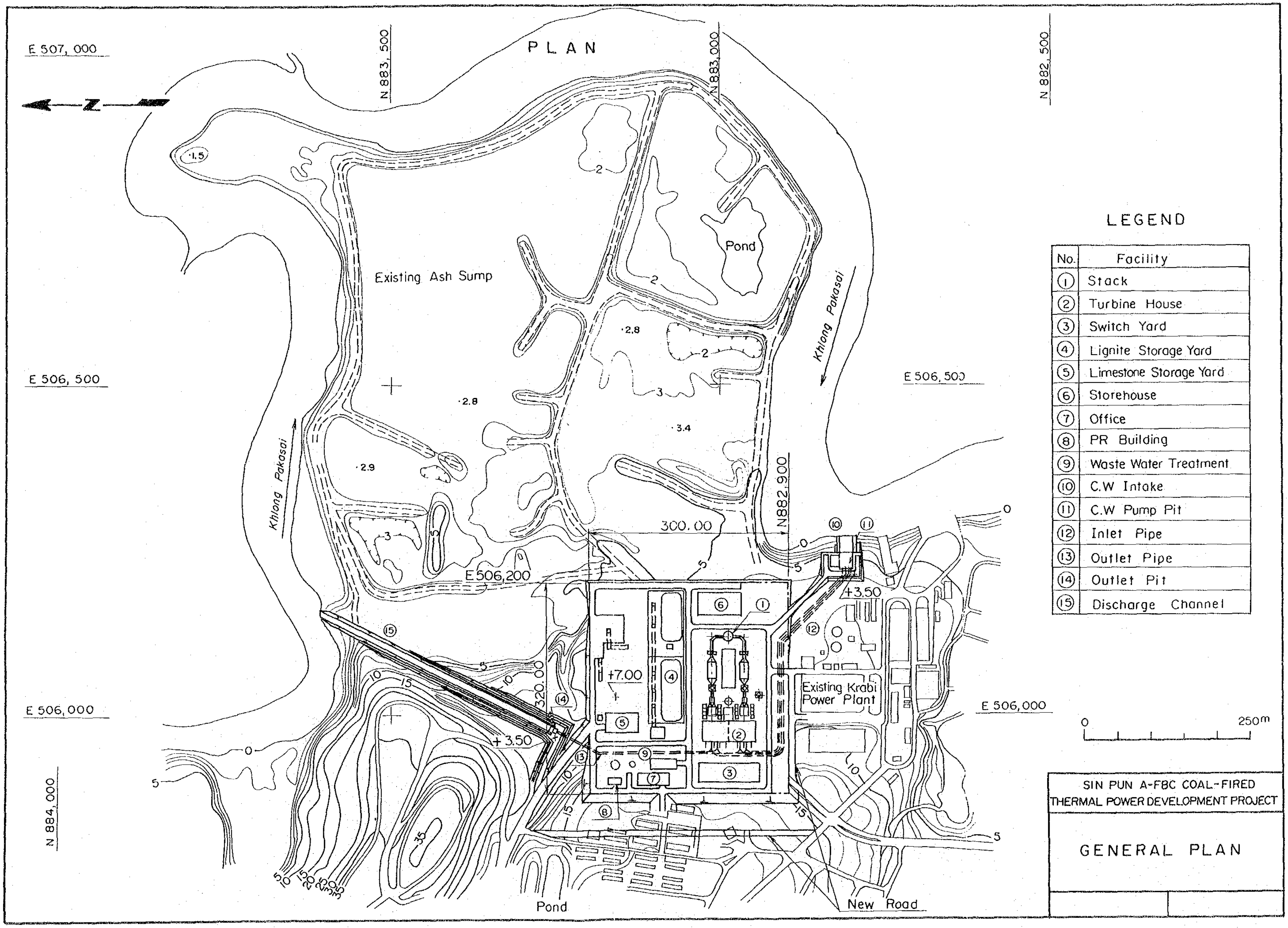


AUGUST 1991

INFORMATION DIVISION PUBLIC RELATIONS DEPARTMENT



Material Balance of Sin Pun A-FBC Generating Scheme
(Sin Pun + Krabi Lignite Case)


PLAN
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N 882, 500
N882,900
N 884,000
300.00
320.00
Existing Ash Sump
Pond
Khlong Pakasai
+7.00
+3.50
Existing Krabi Power Plant
New Road
LEGEND
No. Facility
1 Stack
2 Turbine House
3 Switch Yard
4 Lignite Storage Yard
5 Limestone Storage Yard
6 Storehouse
7 Office
8 PR Building
9 Waste Water Treatment
10 C.W Intake
11 C.W Pump Pit
12 Inlet Pipe
13 Outlet Pipe
14 Outlet Pit
15 Discharge Channel
0 250m
SIN PUN A-FBC COAL-FIRED
THERMAL POWER DEVELOPMENT PROJECT
GENERAL PLAN

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1. INTRODUCTION

1.1 Circumstances

Thailand's economic growth rate in 1989 was marked at 12%, being prominent among Asian developing nations. Particularly, the growth of its industrial sector was significant.

The rates of average annual increase of EGAT's power and energy generation for the five years from 1986 to 1990 were 12.9% and 13.2% respectively. The rates increased in 1990 by 13.8% and 18.5% respectively.

The Thai Government has a policy of utilizing indigenous energy sources such as natural gas, lignite, hydropower etc., while suppressing the increase of oil importation as much as possible.

On the other hand, there is a plan to construct the imported low sulfur coal fired power plant in order to cover the rapid increase of the electric power demand. However as a recent worldwide program for the environmental protection on the SOx emission, the imported low sulfur coal price will rise up gradually, and this tendency will keep the high necessity to apply the indigenous lignite together with the application of the imported coal in Thailand.

In the view of the policy situation mentioned above, EGAT is planning to construct lignite thermal power plants in the southern region of Thailand since the only prominent indigenous energy sources in this region.

Furthermore, following this worldwide tendency for the environmental protection, EGAT has also been pursuing the low polluted emission to keep the environmental resource for humanity, and has been developing its environmental programs which are considered as leading body in the Thailand.

To satisfy the above necessity, EGAT made a preliminary study on the Fluidized-Bed Combustion (FBC) boilered power plant pursuing the following capabilities;

i) Economical design of the boiler for the low SOx and less NOx emission compared with PCF and DeSOx plant

ii) Wider range of coal utilization from the lower grade of the lignite to the high grade of the coal

The study concluded that FBC plant is most feasible boiler for the wider range of the lignite utilization and the low polluted emission boiler.

Following the above preliminary study, the Government of the Kingdom of Thailand requested the Government of Japan to implement the Feasibility Study on Sin Pun A-FBC (Atmosphere-Fluidized Bed Combustion) Coal-Fired Thermal Power Development Project with the capacity of 2 x 75 MW as of November 8, 1990.

1.2 Objective and Scope of the Study

The main objective of the Study is to formulate the optimum development scheme of the Sin Pun A-FBC Coal-Fired Thermal Power Development Project and to assess technical, environmental, financial and economic feasibility of the project.

JICA started the study following the Scope of work on March 1991. Consequently, JICA dispatched to study team in Thailand for the field survey and submitted the reports as follows;

3rd March ~ 23rd March 1991	First Field Survey
March 1991	Inception Report
24th September ~ 8th October 1991	Second Field Survey
September 1991	First Progress Report
19th January ~ 2nd February 1992	Meeting for Interim Report
January 1992	Interim Report
8th July ~ 22nd July 1992	Third Progress Report
July 1992	Second Progress Report
16th September ~ 30th September 1992	Meeting for Final Draft Report
September 1992	Final Draft Report

During this period, JICA term and EGAT carried out the field survey, the sampling and the tests as follows;

(1)	Geological Survey		
	Simple Seismic Prospecting	3 points	30 m
(2)	Sampling		
	Sampling for Bench Scale Combustion Test	Lignite	600 kg
		Limestone	720 kg
	Sampling for Pilot Scale Combustion Test	Lignite	20 ton
		Limestone	10 ton

(3) Test

Analysis of Samples for Bench Scale Combustion Test	19th August ~ 15th September 1991
Analysis of Sample for Pilot Scale Combustion Test	February 1992 (before dispatching) 6th May ~ 20th Mary 1992 (After dispatching)
Bench Scale Combustion Test	2nd September ~ 19th November 1991
Pilot Scale Combustion Test	12th May ~ 23rd May 1992
Ash Sampling Analysis	15th May ~ 15th June 1992

1.3 Characteristics of Project

Sin Pun A-FBC Coal-Fired Thermal Power Development Project has a characteristics for the environmental protected power development plan by the atmospheric fluidized bed boiler with using the high sulfur low heat valve lignite in Sin Pun on Southern Thailand.

Since Sin Pun Lignite involves high sulfur content up to 7% and has low heat value, the fine gas emits the SO_x with the density up to 10,000 ppm. Furthermore, the project can not be expected the scale merit on the equipment because the economical mining resources reserves 20 million tons in Sin Pun mine and 5 million tons in Krabi mine only and these amounts are just enough for the generation plant 2 x 75 MW scale.

However, since the lignite is a prominent resources in Southern Thailand as mentioned above and the Krabi power station (3 x 20 MW) would retire 1995, the alternate power source is required in these area using Sin Pun and Krabi lignite. It is also required to develop the generation plant as early as possible with keeping the natural resources because the site is located nearby the Krabi terminal which is the center of developing area in the southern Thailand, and also nearby the resort area such as the Phuket island and Krabi. Furthermore, Thailand are going to set the emission regulation on the major air polluted items such as SO_x and NO_x (SO_x 700 ppm, NO_x 1,000 mg/Nm^3 in Southern Thailand) and the environmental protected power plant is inevitably necessary.

In Thailand, the labour wages are increased rapidly and consequently, rase up the mine development cost which is occupied with the large amount by the labor cost, so that the early mining development is required.

These mining and power plant development will also contributes to accelerate the economic development in this area.

2. Study Result of Data

2.1 Optimum Power Developing Plan

(1) Electric Demand in Thailand

In addition to the favorable economy and rapid industrialization in Thailand, the electric power situation, as mentioned above, has recently shown wide increases due to inroads of foreign enterprises.

Whole the power generation capacity of Southern Thailand (Region 3) is 610 MW as of 1991. It consists of 312 MW by hydraulic generation, 214 MW by thermal generation, and 84 MW by gas-turbine.

The peak demand and generated energy of this district in 1991 reached 608 MW, and 3,922 GWh respectively and there is no reserve power at this moment. Furthermore, the generated energy was short more than 1,000 GWh in this year.

Even though the grid system in this region is connected to the whole Tai system, the trunk interconnect line is 500 Km and it is preferable to ballance the demand and supply in this region for the less loss of transmission line and the better operating management.

(2) Optimum Power Developing Plan for Region III

In order to prepare the optimum power developing planning, EGAT has already introduced the least cost developing planning program package. This software package also provides developing schemes which can provide adequate system reliability corresponding with the target value given by a planner.

JICA Team simulate the power system of the assumption that the power system consists of two power network, one is the Region III and another one is the main power grid including Region I of greater Bangkok and resulted for the most economical commissioning date to be 1998. However, taking into account of the constant power flow from the central Thai to the region III, it is preferable to implement this project as soon as possible. From this point, it is judged that the optimum commissioning date of the project is 1997 as earliest case.

2.2 Site Selection

Following points are considered in feasibility study of candidate sites for 2 x 75 MW A-FBC coal-fired power plant which are economical generating scale for the mining and generation.

i) Area should have good topographical and geological condition.
ii) Area should be available the coal and limestone with reasonable cost.
iii) Cooling water and fresh water must be available in vicinity.
iv) Sufficient area should be available with reasonable cost and easy to acquire.
v) Area must be available for large volume of ash disposal in vicinity.
vi) Transmission line route should be selected with minimum cost.
vii) Area must be convenient for securing labors, equipment and materials.
viii) Area must have minimum environmental problems.

ix) Area must be easy to transport large scale equipment with reasonable cost.

The evaluation applies the net present value with discount rate of 10%.

Evaluation result of the study team is summarized as follows;

- The land reclamation does not make the big cost difference among those candidate sites since there are no big difference on the topographic condition and geological condition between Sin Pun sites and Krabi site.

- The highway routes also run around the candidate sites in vicinity and there are no big cost difference among those sites for the construction of the access road.

- The cost difference for the lignite transportation is prominently big among two Sin Pun sites and Krabi site because of the long travel of the Sin Pun coal to Krabi site. The cost calculation is assumed that 20 million tons of lignite are travelling from Sin Pun mine to Krabi site and 5 million tons of them comes from Krabi mine for the site No. 4. This cost difference is only negative to the site No. 4.

- The cost difference of the limestone procurement comes from the travelling cost and the difference of required amount of limestone since the sulfur content of Krabi lignite is lower than that of Sin Pun lignite. The impact of the cost difference for the transportation is not big but the cost difference due to the different amount is relatively big.

- The cost difference of the cooling water supply system and operation is relatively big because of the different system. The Sin Pun sites apply the cooling tower system due to the shortage of cooling water for the one through cooling system while the Krabi site applies the one-through cooling system from the Phakasai River. Main reason of the cost difference is due to the difference of the power consumption of each system and the cooling tower installation cost.

- The cost difference of the ash disposal is due to the sheet pile because Sin Pun sites request the sheet pile for the ash disposal area to prevent an environmental pollution of ground water, while Krabi site does not

request the sheet pile because none of residents utilize the well water as their drinking water. The impact of this cost difference is relatively big.

- The cost difference of transmission line and switch yard cost is coming from the cost difference of transmission line between Sin Pun Sites and the existing network system. Since there is no transmission line running above Sin Pun sites, the new sets of transmission line are requested for the power transmission of 150 MW (2 x 75 MW). On the other side, Krabi site does not request the new set of the transmission lines because of the utilization of the existing lines. The impact of this cost difference is relatively big.

- The cost difference of the equipment transportation is due to the inland transportation for Sin Pun sites. The impact of this cost difference is not big.

- There are no cost difference on the environmental mitigations because the same emission level is applied to each site.

- The land acquisition of Krabi site is not a problem because the site is located in the existing power station while Sin Pun site has no view on the land acquisition for the power station.

- The accommodation facilities for the staff in the power station are available in Krabi site with using the existing Krabi power station while the accommodation facilities have to be prepared in Sin Pun site.

As a whole, there are small cost benefit on Krabi site within the amount of 3% of the investment as shown in below. In addition to the above cost benefit, Krabi site is selected by EGAT because of the following reasons.

(1) Sin Pun site has unforeseen difficulty and no programmed schedule of the land acquisition, while the Krabi site has land already in the existing power station.

(2) The water pollution in the ash disposal area may effect to the drinking water of the well with the long term period.

	No.2 (Sin Pun)	No.3 (Sin Pun)	No.4 (Krabi)
Cost difference at 1992 Discount Rate 10%	+149	+191	Base

2.3 Mining Development

JICA team studied three documents prepared by EGAT. Based on those EGAT studies, JICA team has set up and evaluated the mine development plan. The conception of the plan is interpreted by the fact that 800 thousand tons of lignite from Sin Pun area and 200 thousand tons of the lignite from Krabi area are supplied yearly to the A-FBC 150MW power plant.

The conclusion is as follows:

(1) The basins of Sin Pun and Krabi have enough reserves of lignite to supply to the A-FBC 150MW power plant for 25 years.

(2) The quality of the lignite is not so stable. Considering the characteristics of the FBC boiler, the quality variation in the run-of-mine product will be acceptable. However a blending system is recommended for minimizing the quality variation because the lignite is usually supplied from three deposits: two pits in Sin Pun and one in Krabi.

(3) EGAT used computers for the purpose of analyzing the geological data in detail to study economic and technical matters and selected three economic deposits (Bang Sai, North Khuan Klang and South Klang Klang) among the five deposits in the Sin Pun Basin. JICA team reviewed the study of EGAT and confirmed its suitability.

(4) JICA team recommended the most rational and economic mining sequence for supplying lignite to the 150 MW power plant. This recommendation has been accepted by EGAT.

(5) Considering the geological condition, special mining methods or huge mining equipment are not necessary. A shovel and truck operation is the recommendable mining method in most of Sin Pun Area. From a

viewpoint of the hydrogeological study, the planned dewatering activities prior to mining are presumed to be effective.

(6) Criteria used for the mining plan are based on the experience of EGAT and regarded as realistic.

(7) In this Economic evaluation based on the 15% of contingency and 10% of discount rate, Levelized Unit Cost is estimated about US$20 per ton while Average Cost is about US$18 per ton. As Operation Cost is calculated for the lengthy period of 25 years, Levelized Unit Cost will be astringent to the certain figure (US$20). Economic Ratio is lower than US$10 per Gcal. These evaluations are carried out with estimated parameters for 150 MW on the basis of the 100 MW case.

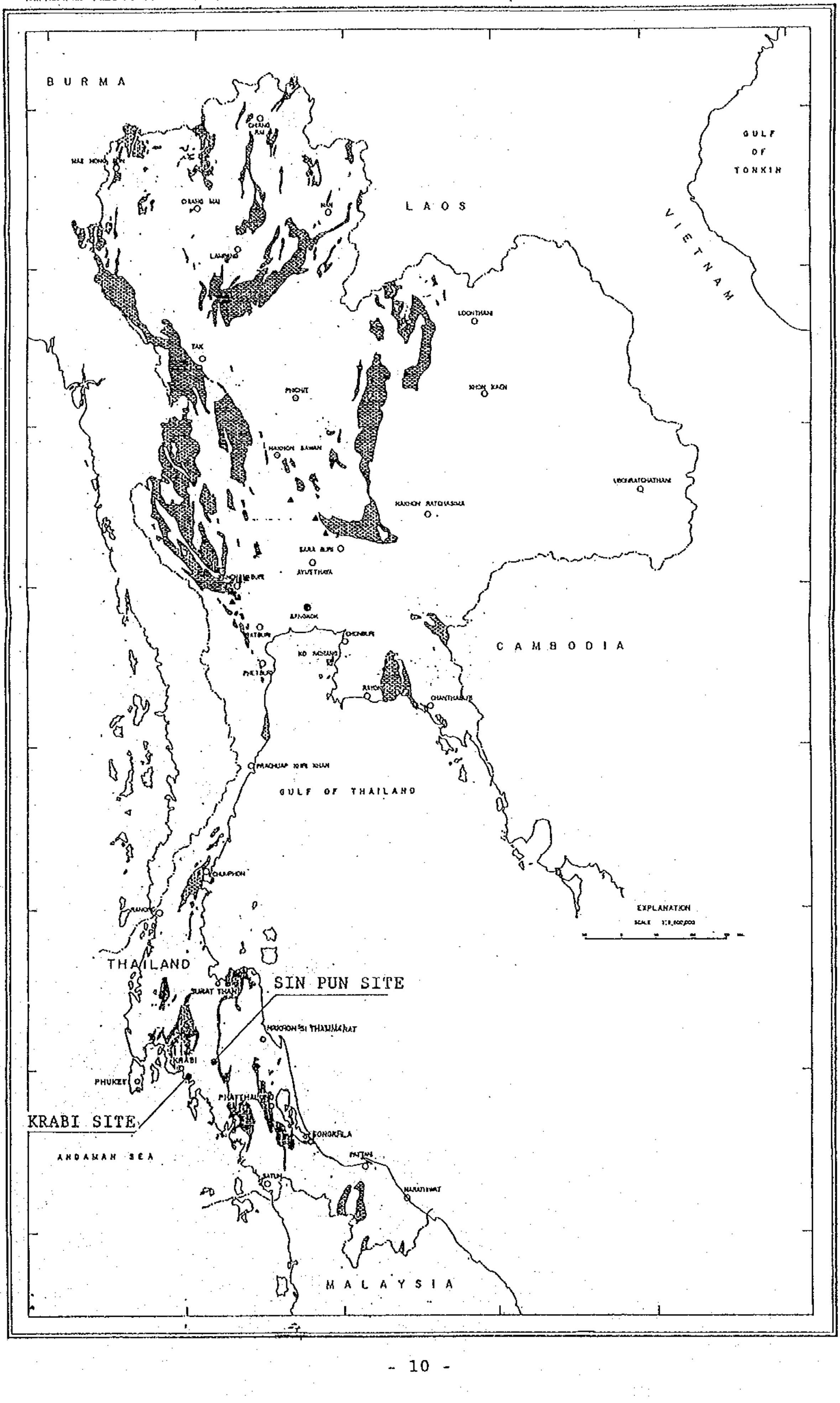
2.4 Limestone Market

Thailand is everywhere affluent in limestone. Especially around the planned plant site are many limestone quarry candidates.

In 1990, the total annual production of limestone in Thailand was about 19 million tons. Cement plants concentrate in the central area of Thailand because of the large demand for cement there, and 1.6 million tons of cement, slightly more than 8% of total production, is produced in the southern area.

The projected 2 x 75 MW class FBC boiler will consume limestone at the rate of 0.4 million tons/year, the limestone market will go through some problem times in the Southern Thailand and users will suffer from price appreciation and the imposition of severer purchase terms. It is recommended that new limestone mines exclusively intended for producing desulfurizer be developed near the planned plant site.

The limestone price is considered 145 Baht/t with the raw material as the market price involving the transportation cost, and it is estimated that the course limestone (3 mm under particle size) for the bubbling type A-FBC is cost about half price of the fine limestone (325 mesh: 40 μm) for the wet type desulfurized facilities.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GULF OF TONKIN
LAOS
VIETNAM
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MALAYSIA
EXPLANATION
PHUKET
SURAT THANI
NAKHON SI THAMMARAT
SONGKHLA
CHUMPHON
PRACHUAP KHIRI KHAN
AYUTTHAYA
TAK
KRABI
PHATTHALUNG

2.5. Combustion Test Result

Thailand Sin Pun and Krabi lignite have a particular of the high sulfur lignite involving the sulfur content 15 times by heat value compared with the coal utilized in the imported coal fired power plant in Japan as shown in the following table.

	Sin Pun lignite	Krabi Lignite	Imported coal in Japan applied by Utility
Heat Value (LHV: kcal/kg)	2787	1600	around 6000
Moisture Content (%)	32.7	26.1	around 10
Ash Content (%)	21.1	36.4	around 10
Sulfur Content (%)	7.0	1.8	around 1
Fuel Ratio	0.34	0.43	around 2

The limestone nearby Sin Pun area has high purity up to 90% of the lime. The reduction ratio, which indicates the particle size reserving of the limestone in the fluidized bed and is a key indication for the bubbling type fluidized bed combustion, is in the applicable range experienced during the demonstration test in Japan, and consequently is judged suitable for the desulfurizer for the bubbling type fluidized combustion. Furthermore, since the decarbonized temperature, over which the limestone transfers to the quick lime with the decarbonization, is low as 750°C, it is recognized by the sample analysis that Thailand limestone has high activation as the desulfurizer in the fluidized bed.

The combustion test was carried out with two stages using two brands of lignite and the limestones acquired nearby Sin Pun.

Test	Purpose
Bench scale combustion test	Test furnace: Diameter 100 mm Height 2 m Combustion characteristics is grasped under the various operating conditions with using the small amount of the lignite and limestone.
Pilot scale combustion test	Test furnace: Surface 500 mm x 500 mm Height 7m The combustion furnace is simulated with the actual boiler and can combust the actual particle size of lignites and limestone. Based on the combustion characteristics, the F/S level design is carried out and the data for the economical analysis is obtained.

From the above two combustion tests, the confirmed items are as follows;

(1) Environmental Characteristics

(a) Desulfurization Performance

(i) The suitable operating conditions for the desulfurization of Sin Pun, Krabi lignite in the fluidized combustion is within the operating range confirmed by the demonstration test in Japan. (Fluidized Bed Temperature 830 or 850°C, Space Velocity 1.5 ~ 2.0 m/s, Air Ratio above 1.2)

(ii) Desulfurized efficiency was increased by applying the recycle system of the fly ash, and could achieve 94% with the calcium-sulfur molar ratio 2 (Ca/S molar ratio 2). This achieves 600 ppm emission which is below the Thailand proposed regulation 700 ppm.

(iii) 30% of unreacted desulfurizer is involved in the ash from the atmospheric fluidized bed boiler and could be utilized as the desulfurizer again for the future development of the

emission regulation. In Japan, there are two kind of the desulfurized system applying the desulfurizer with the ash.

The one is the simplified desulfurized system using the bag filter and the other is the spray dryer system. The demonstration test results of the above could be reflected on this project for the future development of the environmental regulation in Thailand with the detail economical evaluation.

(b) NO_x Emission Performance

(i) The bubbling type fluidized bed boiler applied Sin Pun Krabi lignite can be operated with the NO_x emission 200 ppm under while the Thailand proposed emission regulation is below 1,000 mg/Nm^3 (500 ppm for NO_2)

(ii) Even further development of the emission regulation in future, the additional facilities are not requested in terms of NO_x emission, therefore the boiler is economical design for the NO_x emission.

(2) Combustion Characteristics

(a) Fludized Characteristics

The trouble of the fluidized action by the lumpy ash and the agglomeration of the ash are not recognized during the test. Even through the troubles of the lumpy ash shall be confirmed with the thousands hours operation record, it is confirmed by the non-agglomeration during the test period that the troubles are avoided by extracting the fluidized bed ash continuously.

(b) Combustion Efficiency

(i) 98% over combustion efficiency was confirmed even applying the simplified fuel feeding method i.e. the lignite spreader.

(ii) The combustion efficiency 99 ~ 99.5% is achieved by applying the ash recycle system.

(iii) It is confirmed that the economical boiler can be designed because of the high combustion efficiency more than 99% and the non-necessity of the additional facilities for the combustion efficiency such as the unburn carbon burn up cell.

(3) Material balance

(a) The over flow bed material is amounted up to 45% of the total ash with the condition of the limestone particle size 3 mm under and CA/S molar ratio 2.

(b) It is confirmed under the ash recycle condition that the over flow bed material can be reduced by applying the small particle of the limestone which also increase the desulfurized efficiency.

(4) Other Particular

The bag filter is applied for the second stage dust collector. It is confirmed that the emission value of SO_x was reduced up to about 100 ppm at the outlet of the bag filter. It is assumed that the unreacted desulfurizer collected in the bag of the bag filter captures the SO_x in the low velocity flue gas.

It is recommendable to proceed the detail design by getting the test result of the simplified desulfurized equipment using the bag filter which is carried out in Japan.

2.6 Environmental Prediction

The environmental prediction for the ambient air was carried out on SO_x and NO_x which are major issues for the generation plan. From the prediction, the maximum ground level density (24 hours value) for SO_x is 128 $\mu g/m^3$ and that (1 hour value) for NO_x is 83 $\mu g/m^3$.

Item	2 x 75 MW A-FBC Emission Condition	Thailand Proposed Emission Regulation
1. SO_x emission	285 g/sec (667 ppm)	700 ppm under (Bangkok 400 ppm below)
2. NO_x emission	113.8 g/sec (350 ppm NO conversion)	1,000 mg/Nm^3 under
3. Stack hight	80 m	(NO conversion 750 ppm NO_2 conversion 500 ppm)
4. Flue gas temperature	130°C	
5. Flue gas velocity	27.3 m/Sec	
6. Diameter of inner stack	2.5 m	
7. Diameter of common stack	3.54 m	

As shown in the table below, the prediction value for the Sin Pun generation project is for below to the proposed regulation in Thailand

	2 x 75 MW Environmental Prediction	Thailand Proposed Emission Regulation
SO_x 24 hours regulation	128 $\mu g/m^3$	300 $\mu g/m^3$
NO_x 1 hour regulation	83 $\mu g/m^3$	320 $\mu g/m^3$

Furthermore, since the other environmental issues are also cleared as shown in below, the project is feasible environmentally also.

- Waste Water from Power Station — Waste water treatment facility is installed in the project and restricted the waste water from the power station within the standard value.

- Penetration of Waste Water in the Ash Disposal Area — The existing mining pit is used as the ash disposal area. The area is located in the existing power station and no inhabitant is living the area. There are no pollution problem occurred in future due to the water penetration to the well water.

- Coal Dust

The lignite from Sin Pun is transported to Krabi by 30 trucks 4 cycle with the distance 66 km.

Since the loading trucks are passing every 8 minutes, the coal dust pollution may be considered. Therefore, the truck shall equip the cover door on the cargo and transport the lignite after water spreading to the lignite for the prevention of flying powder lignite.

3 Outline of Optimum Development Plan

3.1 Basic Items

The following items are applied for the design.

Generator Output : 2 x 75 MW
Boiler Type : Atmospheric Bubbling Type Fluidized Bed Combustion Boiler
Annual Load Factor : 80%
Life Time : 25 years
Annual Mean Heat Rate (L.H.V.):
2,365kcal/kWh (36.4%)
(Bo. Eff. 91.7% x Tb Eff. 41.5% x Ge Eff. 98.5%)x0.97
Main Steam Pressure : 127 kg/cm^2 g
Steam Temperature : 538 °C/538 °C
Flue Gas : SOx 700ppm, NOx 1,000mg/Nm^3
Dust 500mg/Nm^3
Limestone Consumption (Ca/S Mol Ratio): 2.0
Lignite

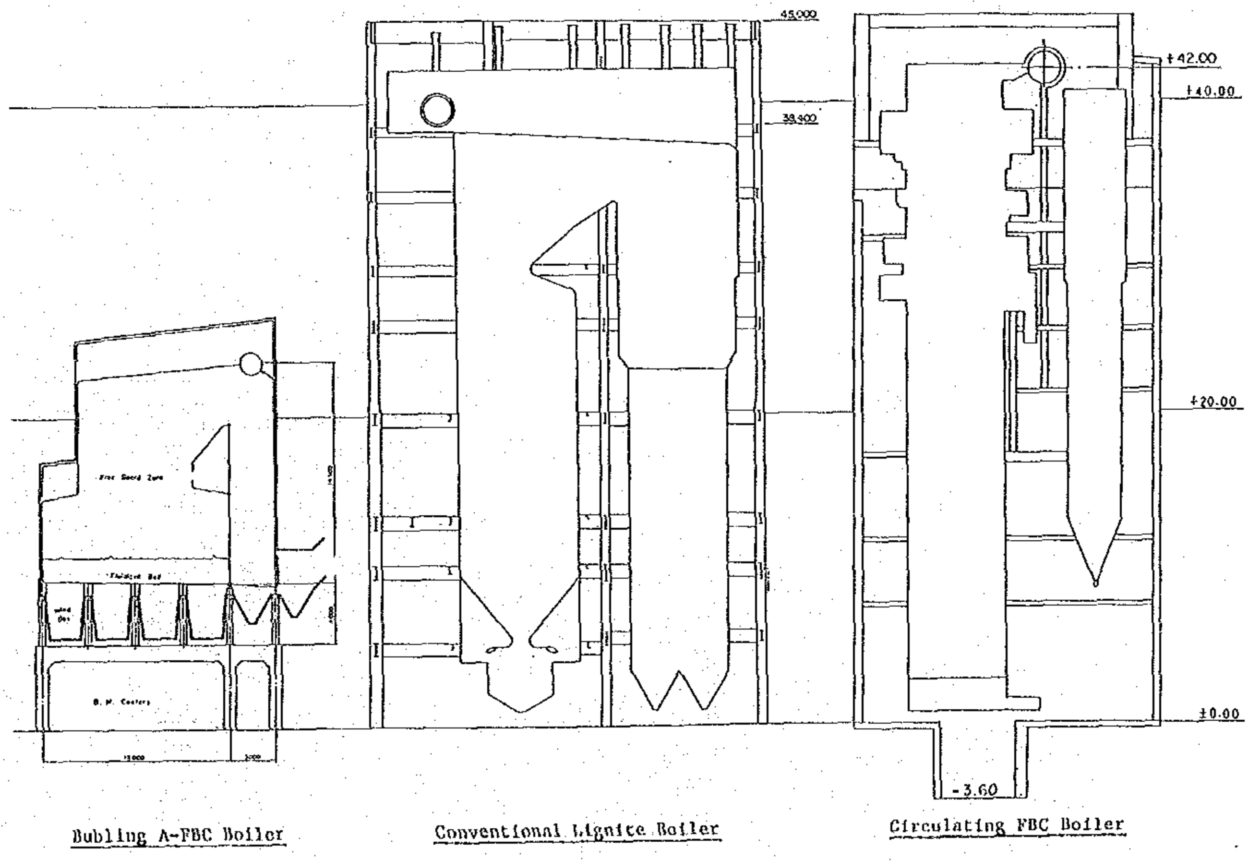
	Sin Pun Lignite	Krabi Lignite
Heat Value (LHV) (kcal/kg)	2,795	1,600
Total Moisture (%)	32.7	26.1
Ash Content (%)	21.1	36.4
Sulfur Content (%)	7.0	1.8

Lignite Consumption : 1,000,000 ton/year
(Sin Pun 4, Krabi 1)

Limestone Consumption	:	400,000 t/year
Ash Generation	:	600,000 t/year
Schedule	:	1996 12 Unit 1 Commissioning
		1997 6 Unit 2 Commissioning
Sea Water Temp.	:	32 °C
Ambient Temp.	:	34 °C (Max) 27°C (Mean Value)
Wind Velocity Max.	:	30 m/s
Lateral Force	:	V = 0.07 W

3.2 Outline of Scheme

It is confirmed by the combustion test that the atomospheric bubbling type fluidized bed boiler can conbust the Thailand Sin Pun lignite with the high efficiency and can be designed with the compact and economical boiler. It is also confirmed that the environmental characteristics of this boiler is well friendly in terms of SO_x, NO_x and so on. In the study, it is confirmed that the bubbling type A-FBC can be designed most economical boiler compared with the other type of boiler.



Outline of 75 MW Boiler

The outline of the scheme is shown as follows;

3.2.1 Land Preparation

(1) Site Area

Plant yard		:	10 ha
Pump pit and discharge channel		:	3 ha
Ash disposal area	No. 1 area	:	49 ha
	No. 2 area	:	37 ha
Total		:	99 ha

(2) Site Format Level : DL. +7.00 m

(3) Land Preparation Work : Excavation approx. 300,000 m^3
: Filling approx. 20,000 m^3

3.2.2 Lignite and Limestone Preparation System

(1) Lignite Receiving Facility
1) Lignite Receiving Hopper
2) Lignite Receiving Conveyor
No. 1 Conveyor (BC1) : 300 T/H
No. 2 Conveyor (BC2) : 300 T/H
No. 3 Conveyor (BC3) : 300 T/H
No. 4 Conveyor (BC4) : 300 T/H

(2) Lignite Dispatching Facility
1) Lignite Dispatching Hopper
2) Lignite Dispatching Feeder : 300 T/H
3) Lignite Dispatching Conveyor
No. 5 Conveyor (BC5) : 300 T/H
No. 6 Conveyor (BC6) : 300 T/H

(3) Limestone Receiving Facility
1) Limestone Receiving Hopper
2) Limestone Receiving Conveyor
No. 1 Conveyor (LBC1) : 150 T/H
No. 2 Conveyor (LBC2) : 150 T/H

	No. 3 Conveyor (LBC3)	: 150 T/H

(4) Limestone Dispatching Facility

1) Limestone Dispatching Hopper
2) Limestone Dispatching Feeder : 150 T/H
3) Limestone Dispatching Conveyor No. 4 Conveyor (LBC4) : 150 T/H

(5) Lignite Limestone Crushing Facility

1) Lignite Bucket Elevator : 300 T/H
2) Lignite Distribution Hopper
3) Lignite Feeder : 150 T/H
4) Lignite Crusher : Double Roll Type : 150 T/H x 2
5) Lignite Conveyor (LLBC1) : 300 T/H
6) Limestone Bucket Conveyor : 150 T/H
7) Limestone Crusher : Hammer Crusher Type : 75 T\H x 2
8) Limestone Conveyor (LLBC2) : 150 T/H
9) Lignite-Limestone Conveyor (LLBC3) : 500 T/H
10) Lignite-Limestone Bucket Conveyor : 500 T/H

3.2.3 Oil Storage Tank : 80 m^3

3.2.4 Raw Water Supply System

(1) Quantity : Max. 300 m^3/day

(2) Water Source : R1 and R2 Reservoir

(3) Intake Pipe Line Length : approx. 500 m (R1)
approx. 1,500 m (R2)

(4) Fresh Water Tank : 1,000 m^3

(5) Demineralized Water Tank : 500 m^3

(6) Demineralization Plant : 24 m^3/hr

3.2.5 FBC Boiler (Per Unit of 75 MW)

(1) Boiler

1) Furnace : Membrane structure
Width : 15 m, Depth : 12 m,
Height: 15 m

Lignite Feeding System Over spreading system
Draft System : Balance Draft System
Desulfurized Material : Limestone
Height of Bed : 1.2 m
Bed Load : 1.2 x 10^6 kcal/m^2h
Heat Exchanger Tube : Economizer, Evaporator, Super, Hater, Re-Heater

2) Boiler Auxiliary
Drum
Super Heater Spray
Re-Heater Spray
Boiler Circulation Pump: 400 t/h
Safety Valves and Silencer
Drum Level Gauge

3) Air Heater
Type : Rotative Regeneration Type
Air Side : 270,00 Nm^3/h
47°C Inlet, 277°C Outlet
Gas Side : 310,000 Nm^3/h
330°C Inlet, 130°C Outlet

4) Soot Blower Type : Remote-Auto Control Steam Atomizing Type

5) Continuous Blow Out Facility : Flushing Tank

6) Steel Structure, Boiler Casing Platform and Footstep

7) Cast

(2) Lignite Firing Facility

1) Lignite Bunker : 150 ton/Hopper (12 hours)

2) Lignite Measuring : 20 t/h (Ca/S Mol Ratio 4, 20% Margin)

3) Lignite Spreader : 20 t/h x 8

4) Auxiliary : Lignite Shoot, Rotary Valve, Screw Conveyor, Gate

(3) Oil Firing Facility

1) Hot Wind Furnace : Light Oil 2,000 kg/h, 550°C

2) Light Oil Pump : 4,000 kg/h

3) Light Oil Intermediate Tank : 20 m^3

4) Strainer Piping and Valves

(4) Air-Gas Draft System

1) Forced Draft Fun : 5,520 m^3/min at 27°C, 2,560 mmH_2O

2) Induced Draft Fan : 8,510 m^2/min at 130°C
600 mmH_2O

3) Wind Duct

4) Gas Duct

(5) Mechanical Cyclone Ash Collecting System

1) Mechanical Cyclone : 312,600 Nm^3/h, 340°C

2) Recycle Blower : 300 m^3/min, 2,650 mmH_2O, 220 kW

3) M/C Ash Storage Hopper : 50 m^3 (3 hours)

4) Auxiliaries
Screw Conveyor
Rotary Valves
Pipes and Valves

(6) Bed Material Handling System

1) B.M. Extraction Valves : 8 per unit

2) B.M. Cooler

3) Auxiliaries
B.M. Shoot

(7) Bag House : 300,000 Nm^3/H Dry 130°C -300 mmH_2O
Inlet Dust 20 g/Nm^3, Outlet Dust 0.5 g/Nm^3
Difference Pressure 100 mmH_2O

(8) Piping and Valves : Main Steam Pipes, Hot Reheat Pipes, Cold Reheat Pipes, High Pressure Turbine Bypass Valves, Low Pressure Turbine Bypass Valves, Main Feed Water Pipes, Spray Pipes, Auxiliary Steam Pipes, Blowdown Pipes, Drain Pipes, Cooling Water Pipes, Chemical Dosing Pipes,

Sampling Pipes, Air Pipes, Flush Tank, B l o w down Tank, Other Necessary Pipes and Valves

(9) Miscellaneous Equipment

1) Station Air Compressor : 7 kg/cm^2g x 12 m^3/min

2) Chemical Dosing System

3) Sampling Equipment

(10) Control and Instrumentation

1) APC

2) Local Control System

3) Boiler Auxiliary Sequence Control

4) Boiler monitoring System
Boiler Inspection T.V., Drum Level Monitoring T.V., O_2 Monitoring Equipment in Flue Gas, Necessary Transmitter, Indicator and Recorder

5) Instrument Compressor : 7 kg/cm^2g x 10 m^3/min

(11) Electrical : Motors, Cable and Cabling, Earthling

3.2.6 Turbine (Per unit of 75 MW)

(1) Turbine

1) Steam Turbine

Type	:	Tandem Reheat Regeneration Extraction condensing Type
Number	:	1
Rated Output	:	75 MW

Rotation	:	3,000 rpm
Steam Condition		
Main Steam (Inlet of MSV)	:	128 kg/cm^2 538°C
Reheat Steam (Inlet of RSV)	:	30 kg/cm^2 538°C
Number of Extraction Steam	:	5
Turbine Efficiency	:	41.5%
Vacuum	:	-693 mmAg
Cooling Water	:	32°C, Sea Water

2) Main Stop valve

3) Reheat Stop Valve

4) Turbine Speed Control Equipment

5) Lubricant Oil Equipment

6) Turning Equipment

7) Grand Steam Pressure Control Equipment

8) Safety and Monitoring Facility

9) Turbine Supervisory Equipment

(2) Condensing Equipment

1) Condenser

Design Vacuum	:	-693 mmAg
Purity Factor	:	75%
Water Velocity in Tube	:	2.0 m/s
Temperature Difference	:	7°C
Electric Cathodic Protection		
Sponge Ball Cleaning Facility		

2) Circulation Water Pump : 6,900 m^3/h, 200 kW

3) Condenser Pump : 220 m3/h x 2 (1 for stand-by), 6.7 kg/cm^2

4) Condenser Booster Pump : 220 m^3/h 2 (1 for stand-by)

(3) Feed Water Heater

1) L.P. No. 1 Heater : 53 kg/s Inlet 90.5°C, Outlet 128°C

2) L.P. No. 2 Heater : 53 kg/s Inlet 44.5°C, Outlet 90.5°C

3) H.P. No. 1 Heater : 64.5 kg/s Inlet 198°C, Outlet 238°C

4) H.P. NO. 2 Heater : 64.5 kg/s Inlet 163.5°C, Outlet 198°C

5) Deareator : Resolving Oxygen under 0.005 cc/ℓ
Storage 60 m^3, 64.5 kg/s
Inlet 128°C, Outlet 161°C

6) Make-up Pump : 80 m^3/h

(4) Boiler Feedwater Pump

1) Motor Derived Type BFP : 250 m^3/h x 2 (1 for stand-by), 3,000 rpm

2) BFP Motor : 1,500 kW x 2 (1 for stand-by), 3,000 rpm

3) BFP Boost up Pump : 250 m^3/h x 2 (1 for stand-by), 3kg/cm^2, 1,500 rpm

(5) Miscellaneous Equipment

1) Auxiliary Cooling Water Pump : 800 m^3/h x 2 (1 for stand-by), 50 m, 1,500 rpm

2) Cooling Water Cooler

3) Auxiliary Cooling Water Stand Pipe and Temperature Control Valve

4) Sailing Crane : Maximum Capacity 40 ton

3.2.7 Cooling Water Facilities

(1) Intake Pump Pit

(2) Inlet Pipe Line 4 lines x 410 m/2 units

(3) Outlet Pipe Line 2 lines x 150 m/2 units

(4) Outlet Pit

(5) Discharge Channel

3.2.8 Electrical Facility

(1) Generator

1) Generator : 88.3 MVA
11 kV
4,635 kA
50 Hz, 3,000 rpm
p.f. 0.85

Cooling Method
Rotor : Air Direct Cooling
Starter : Air Indirect Cooling
Short Circuit Ratio: 0.45
Exciter : Brushless Exciter

2) Exciter Equipment

3) Automatic Voltage Regulator

4) Nutoral Grounding Resister

5) Electrical Interlock Equipment

6) Isolated Phase Busduct (I.P.B.)

(2) Transformer

1)	Main Transformer	:	ONAF, 85 MVA, 115 kV/11 kV
2)	House Transformer	:	ONAF, 10 MVA, 11 kV/6.6 kV
3)	Starting Transformer	:	ONAF, 10 MVA, 115 kV/6.6 kV

(4) Switch Yard Facility

1)	115 kV Switch	:	Air Circuit Breaker 800 A, 2,000 MVA, 120 kV x 6
2)	115 kV Line Switch	:	Air Drive L.S. 800 A, 115 kV x 18
3)	C.T.	:	800/5A x 3 x 100 VA x 18
4)	P.T and P.D	:	110 kV/ $\sqrt{3}$, 500 VA x 18
5)	Earth Switch		
6)	Line Arrester		
7)	Bus		

(5) House Load Facility

1)	M/C Circuit Beaker	:	6.6 kV A/C
2)	P/C Circuit Beaker	:	380 V A/C

3) C/C Circuit Beaker: 380 V A/C

4) Distribution Board

5) Direct Current C/C

6) Transformer

Unit P/C Transformer

7) Direct Current Power Supply System

8) Cable and Cabling/Grounding

(6) Control and Instrumentation

1) Central Control and Supervisory Panel

2) Boiler Turbine Generator Control Panel

3) B.T.G Auxiliary Panel

4) Relay Panels

5) Input/Output Panels

6) Steam Turbine and Generator Control Panel

7) All Necessary Sensors

8) Local Control Panels

9) Control CVCF

10) Control Cable and Cabling/Piping

11) Data Acquisition System (Computer)

(7) Emergency Power : 300 kVA

3.2.9 Ash Handling System

(1) FBC, B.M. Transportation Facility: 50 T/H x 2 (Alternate Control)

(2) FBC B.M. Ash Silo : 600 T

(3) FBC, B.M. Transportation Blower

(4) M.C. Transportation Facility

(5) M.C. Ash Silo : 600 T

(6) Bag House Ash Transportation Facility

(7) Bag Ash Silo : 120 T

(8) M.C. Ash, Bag Ash Transportation Blower

3.2.10 Power House

Ground floor area: 2,900 m^2, Building volume: 79,000 m^3, Height: 28 m

3.2.11 Stack

(1) Foundation : Reinforced concrete mat

(2) Outer Tube : Reinforced concrete
Height: 80 m
Diameter Top: 8.0 m
Bottom: 13.0 m

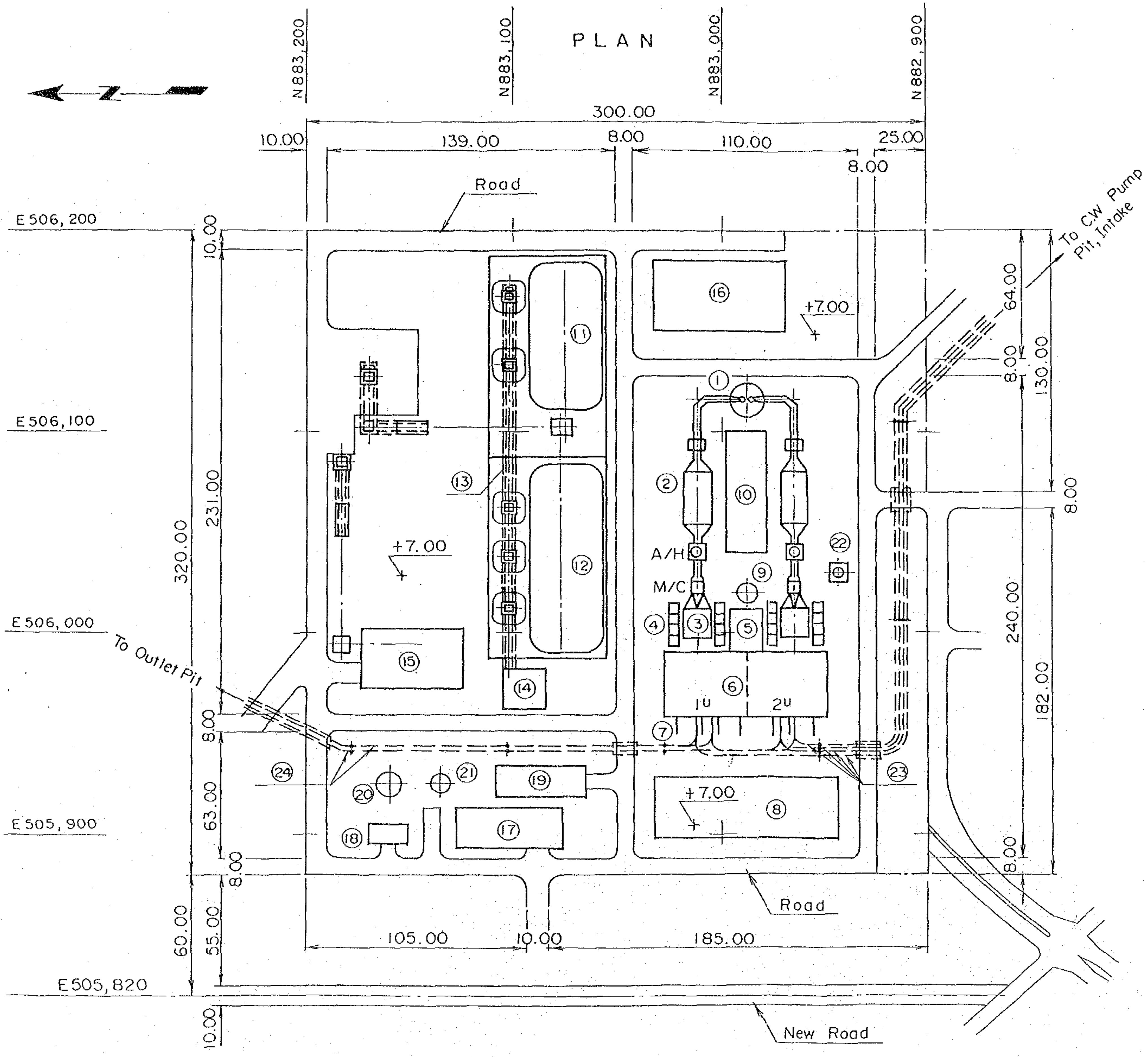
(3) Inner Tube : Steel construction
Height: 80 m
Diameter Top: 2.5 m
Mean: 3.5 m

3.2.12 Ancillary Building

(1) Administration Building : Reinforced concrete construction
4 floor 4,000 m^2

(2) Warehouse : Reinforced concrete construction
1 floor 2,300 m^2

(3) Limestone storehouse : Reinforced concrete construction
1 floor 1,500 m^2



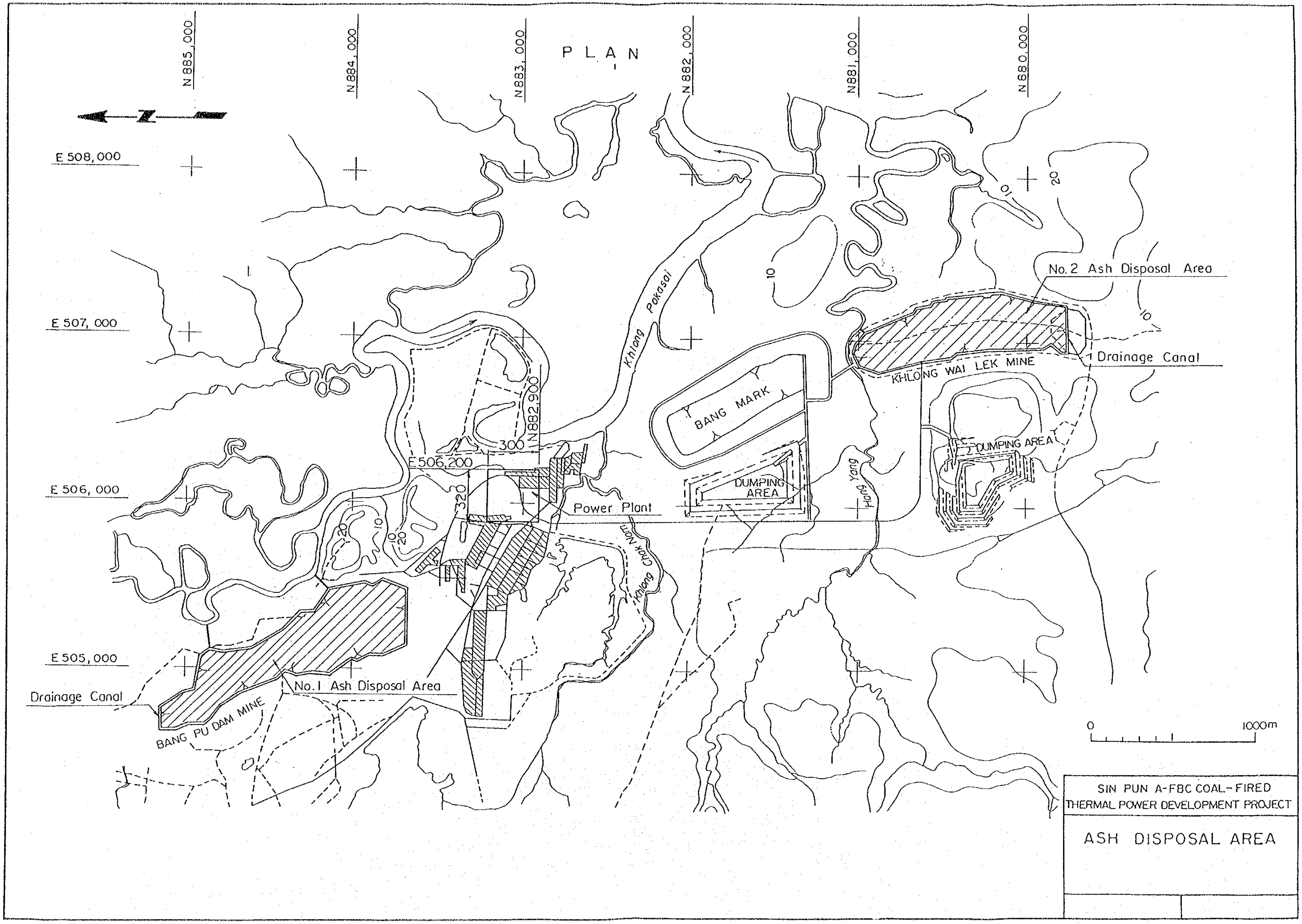
LEGEND

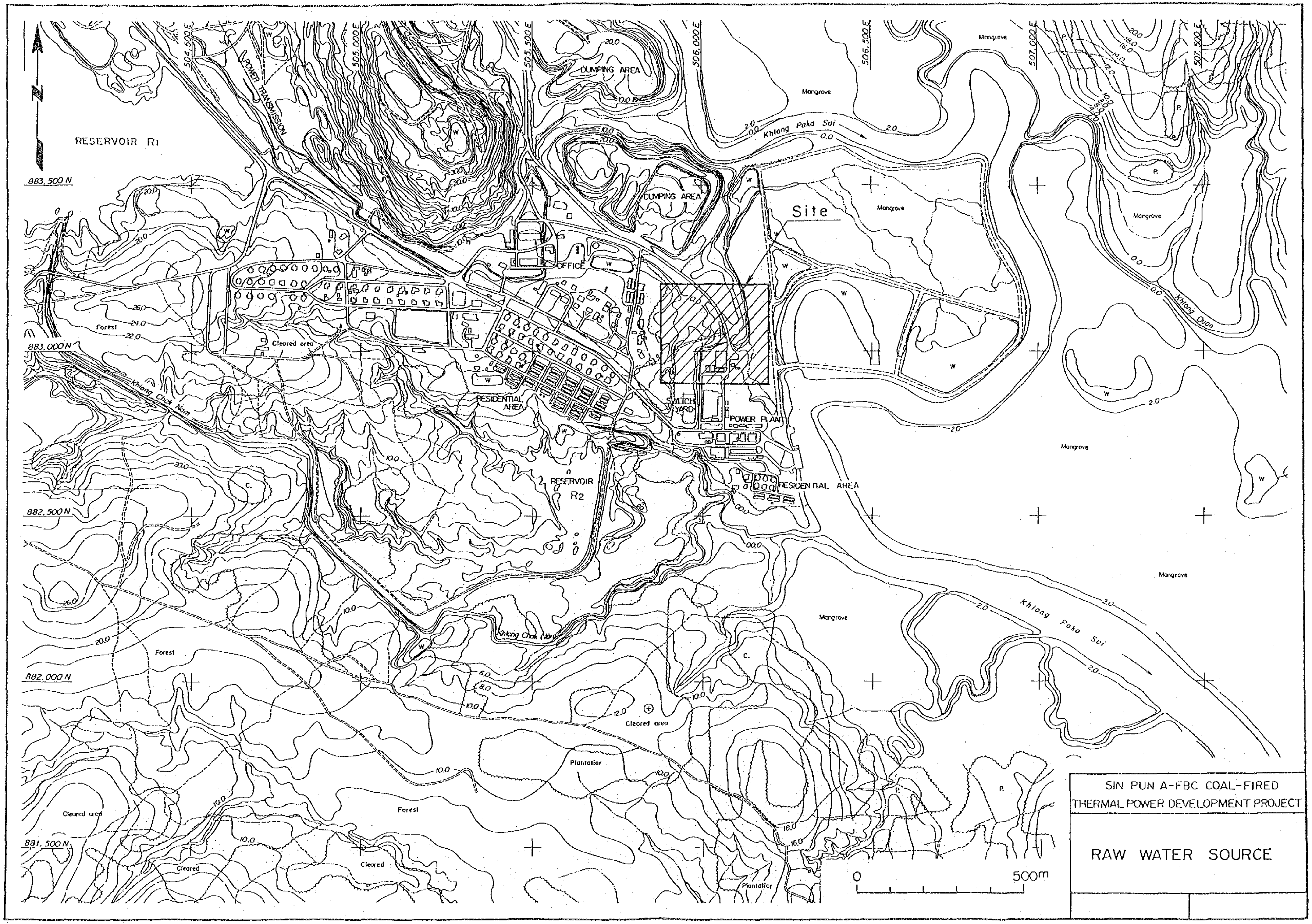
No.	Facilities	Size (m)
①	Stack	
②	Bag House	15 x 26
③	F.B.C Boiler	15 x 15
④	Coal Bunker	5 x 5
⑤	Control House	16 x 23
⑥	Turbine House	32 x 81
⑦	Transformer	
⑧	Switch Yard	30 x 90
⑨	B.M Silo	10D, (400m³)
⑩	Ash Handling Equipment	20 x 60
⑪	Roofed Lignite Storage Yard	55 x 100
⑫	Open Air Lignite Storage Yard	55 x 100
⑬	Underground Conveyer	4.2 x 3.9
⑭	Lignite Limestone Preparation House	20 x 20
⑮	Limestone Storage House	30 x 50
⑯	Storehouse	35 x 65
⑰	Office	20 x 50
⑱	PR Building	10 x 20
⑲	Waste Water Treatment	16 x 42
⑳	Raw Water Tank	12D, (1,000m³)
㉑	Demineralized Water Tank	9D, (500m³)
㉒	Light Oil Tank	5D, (80kℓ)
㉓	Inlet Pipe	ø1100mm x4 line
㉔	Outlet Pipe	ø1600mm x2 line

0 100m

SIN PUN A-FBC COAL-FIRED THERMAL POWER DEVELOPMENT PROJECT

GENERAL ARRANGEMENT OF EQUIPMENT


PLAN
N885,000
N884,000
N883,000
N882,000
N881,000
N880,000
E508,000
E507,000
E506,000
E505,000
Khlong Pokasai
No.2 Ash Disposal Area
Drainage Canal
KHLONG WAI LEK MINE
BANG MARK
DUMPING AREA
DUMPING AREA
Hang Yang
N882,900
300
E506,200
320
Power Plant
Khlong Chak Nam
No.1 Ash Disposal Area
Drainage Canal
BANG PU DAM MINE
0
1000m
SIN PUN A-FBC COAL-FIRED
THERMAL POWER DEVELOPMENT PROJECT
ASH DISPOSAL AREA


RESERVOIR R1
POWER TRANSMISSION
DUMPING AREA
DUMPING AREA
Site
OFFICE
RESIDENTIAL AREA
SWITCH YARD
POWER PLANT
RESERVOIR R2
RESIDENTIAL AREA
Khlong Paka Sai
Khlong Paka Sai
Khlong Chak Nam
Khlong Chak Nam
Khlong Duan
Mangrove
Forest
Cleared area
Plantation
504,500 E
505,000 E
505,500 E
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883,500 N
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0
500m
SIN PUN A-FBC COAL-FIRED
THERMAL POWER DEVELOPMENT PROJECT
RAW WATER SOURCE

3.2.13 Environmental Facilities

(1) Flue gas Treatment System

1) Desulfurization System : Non (because of in-situ desulfurization)

2) Denitrization System : Non (because of low NOx combustion in the boiler)

(2) Waste Water Treatment System

Capacity : 10 m^3/h

Storage Capacity : 700 m^3

4. Construction Schedule and Construction Cost

4.1 Construction Schedule

The lignite production cost is deeply depend on the salary of staffs and the rapid increase of the salary may cause the inflation of the lignite production cost and consequently cause the increase of the power generation cost. Therefore, it is preferable to implement the project as soon as possible. Furthermore, the power demand in the region III would over balance the stable power supply in 1997, therefore the commissioning of the generation plant is set as follows;

Unit 1 End of Dec. 1996

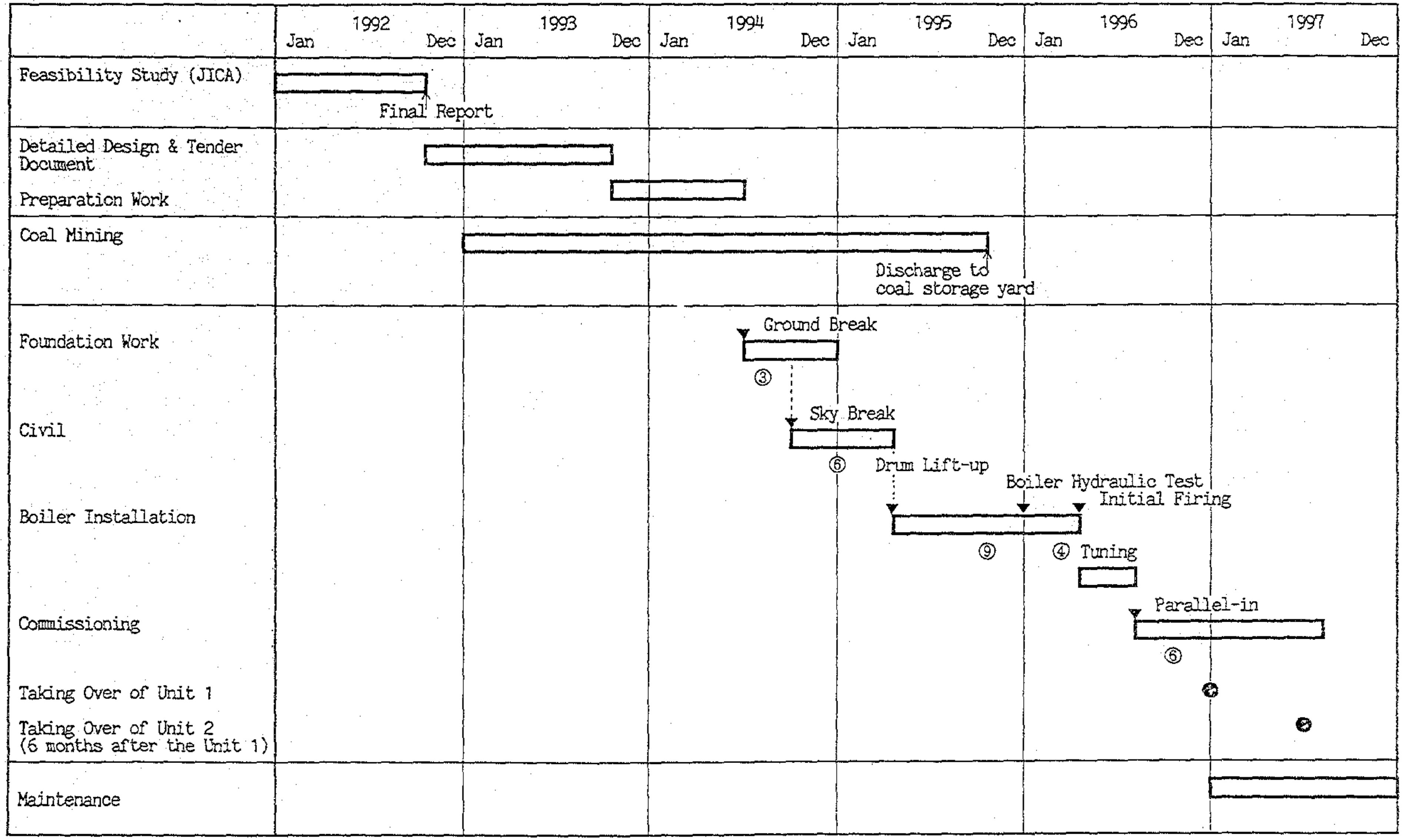
Unit 2 End of June 1997

Since Krabi site is located in the existing power station, the lead time is not requested for the land acquisition. This project has already considered for the environmental reservation. With the above reasons, the project can be implemented earlier than the other project.

4.2 Construction Cost

The construction cost is based on the product in Japan. The light load steel structure is estimated based on the local material cost to optimize the 3construction cost.

Development schedule of Sin Pun FBC



The total construction cost is shown in the following table.

(Million Baht)

	Foreign	Local	Total
Civil & Structure	145.8	910.2	1,056
Boiler	1,363	466.7	1,829.7
Turbine	1,305	318.7	1,623.7
Miscellaneous	547	312.9	859.9
Administration	0	380.0	380.0
Sub Total	3,360.8	2,388.5	5,749.3 (5,317.3)
Import Duty	0	183	183
Sub Total	3,360.8	2,758.5	6,119.3
IDC	515.3	454.7	970
TOTAL	3,876.1	3,026.2	6,902.3

Note: ( ) shows the subtotal without contingency.

5. Economical Analysis and Financial Analysis

5.1 Economical Analysis

(1) The economical analysis of this project applied the alternate equipment aproach method. The comparison is carried out between the economical cost of this proejct (construction cost, fuel cost, limestone cost and operation & maintenance cost) and the economical cost for the alternate thermal power plant which can supply the same service with this proejct involving the evironmental aspect.

(2) In detail, the cost for this project is taken as the cost, and that for the alternate thermal power station is ttaken as the benefit with the condition of the same generation, same fuel and same emission level for the case of the lignite pulverized power plant and FDG, and also with the condition of the same generation, same emission level for the case of the oil power plant.

The compared items are as follows;

(1) Benefit and Cost Ratio (B/C)

(2) Net Present Value [or Benefit Cost difference (B-C)]

(3) As a result, the project was found the economical feasibility as compared with pulverized coal fired plant as follows;

(1)	B/C	with pulverized coal fired plant	: 1.10
		with oil fired plant	: 0.96
(2)	NPV	with pulverized coal fired plant	: 885 Million Baht
		with oil fired plant	: -380 Million Baht

5.2 Financial Analysis

(1) The financial analysis is carried out with the comparison between the financial cost requested in this project and the financial benefit come out from the electricity tariff in terms of the financial internal rate of return. As a result, the FIRR of 0% is achieved by using the current tariff of 1.21 B/kWh. This come from the fact that the current tariff does not include any cost for environmental countermeasure.

(2) EGAT applies the levelized cost method for the comparison between the project and alternate scheme. With this method, this project is found more beneficial than the pluverized coal fired plant.

6. Conclusion

This project is 2 x 75 MW Sin Pun fluidized bed combustion coal fired power development project with the environmental protected type generation facilities by the fluidized bed combustion boiler using Sin Pun lignite and Krabi lignite in the southern Thailand. The study team carried out the feasibility study with the field survey and the combustion test using two lignite from Sin Pun and Krabi mine, and the limestone nearby the respective candidate site. As a result, the project found the feasibility in terms of the technical, the economical and the environmental aspects.

The following is the content of result.

i) The power demand and supply in Thailand is very tight because of the rapid growth of the economy. Furthermore in Region III, the power generation was short and received the electric power from the central Thailand with the amount of 1,000 GWh in 1991. JICA team carried out the optimum power developing planning and resulted that the most economical developing year of this project is 1998. However, taking into account of that the region III received the electric power from the central Thailand all the time, it is preperable to start this project as soon as possible and it is judged that the optimum date of the completion of commissioning of the project is 1997 as earliest case.

ii) Sin Pun Lignite involves the high sulfur content and emits the SO_x with the density up to 10,000 ppm which would affect strongly on environmental resources. Therefore, the environmental protected power plant is inevitable necessary in this project.

iii) The existing Krabi power station which operated long term as power source in this area is scheduled to retire in 1995 and the alternate power plant is required in these area.

iv) The generation output study was carried out with the case of 1 x 100 MW and 150 MW (2 x 75 MW) and found that 150 MW (2 x 75 MW) case is more economical with the total evaluation of the generation and mining development project.

v) The site selection is carried out among three sites, i.e. two sites for Sin Pun area and one site in the existing Krabi power station. The economical comparison result among three sites shows that there is no big difference among these sites. However, from the unforesean cost in Sin Pun sites for the land acquisition and the mitigation of the affection to the drinking water by the drain in the ash disposal area, the site was decided to Krabi.

vi) The lignite resources of Sin Pun and Krabi is just enough for 2 x 75 MW 25 years and the more consumption of the lignite would exceed the economical ratio of EGAT for the mining.

vii) From the combustion test using Sin Pun and Krabi lignite with the limestone in vicinity of the site, it is confirmed the extremely high combustion characteristics (combustion efficiency 99% above) and environmental characteristics (desulfurized efficiency 94% SO_x emission density 600 ppm, NO_x emission density 200 ppm below).

From the above points, the project is feasible technically.

viii) Compared with the conventional wet $DeSO_x$ facility and the pulverized lignite boiler using Sin Pun lignite and Krabi lignite under the same environmental conditions, the atmospheric bubbling type fluidized bed combustion boiler is more economical due to the compact boiler design which can achieve the high combustion efficiency for the lignite.

Therefore, the atmospheric fluidized boiler is feasible economically also.

ix) This project can be operated within the emission value of the flue gas proposed emission regulation (SO_x 700 ppm under, NO_x 1,000 mg/Nm^3 ≒ 500 ppm NO_2). The current environmental regulation also maintained as shown in the following table. And also the other environmental standard is kept within the value. Therefore the environmental resources are reserved.

	2 x 75 MW Environmental Prediction	Thailand Proposed Emission Regulation
SO_x 24 hours regulation	128 $\mu g/m^3$	300 $\mu g/m^3$
NO_x 1 hour regulation	84 $\mu g/m^3$	320 $\mu g/m^3$

x) The construction cost is estimated based on the available technical design, construction method, material and product in June 1996. The cost is based on the Japanese product cost and the local materials and estimates the import duty and IDC. The construction cost is 19.4 billion yen for the foreign portion and 3.02 billion Baht (equivalent about 15.1 billion yen), totally 34.5 billion yen.

xi) The output of this project 2 x 75 MW is relatively small in the grid of EGAT and does not have a scale merit. Furthermore, due to the additional desulfurizer cost and the additional facility for the environmental protection, the financial feasibility is achieved on the condition of the generating cost above 1.67 Baht/kWh.

xii) This project has several indirect benefits as shown in below. Considering the total economical effect involving the indirect benefits, this project shall be promoted.

- The project will promote the development of new energy sources alternating oil.

- The project will promote the defusion and spread of the bubbling A-FBC technology in the south east asia since the project is the first unit in this area.

- The project will contribute to the development of the project area which is located in the Krabi developing terminal.

- The project will contribute in increasing the quality and reliability of the electricity supply in the region III.

- The project can be implemented earlier than the other project since the site is located in the existing Krabi power station which is scheduled to retire in 1995.

- The project will save the cost related to employment by the utilization of man power in the existing power station to the new power station.

- The project will make the image of the resort area such as Krabi and Phuket better all the more because of the new environmental facility.

7. Recommendation

Sin Pun fluidized bed combustion coal fired generation project is feasible in technically and economically.

However, the labour cost occupies 30% of the lignite mine developing and the recent rapid increase of the labour cost in Thailand may induce the increase of the lignite mine developing cost when the mine development is delayed and consequently make the generation cost increase. In addition to the above factor, the stable electric supply in southern Thailand would short for the demand in 1997.

With the above points, the project is recommendable to start as soon as possible.

To implement this project with the commissioning date end of 1996 for unit 4, the following items shall be undertaken.

i) To start the detail design at the end of 1992, and to prepare the bid document and other necessary preparation work for the construction in 1993.

ii) To carry out the environmental monitoring and to prepare document for the environmental assessment as soon as possible.

iii) To undertake the mining development project as soon as possible.

iv) To take care of the coal dust pollution on road caused by the damp truck transportation of lignite with applying the cover door on the cargo.

JICA