ISLAMIC REPUBLIC OF PAKISTAN

FEASIBILITY REPORT

FOR

LAKHRA COAL MINING AND POWER STATION PROJECT

FEBRUARY, 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request of the Government of the Islamic Republic of Pakistan, the Japanese Government decided to conduct a survey on the Lakhra Coal Field and Power Station Project and entrusted the Japan International Cooperation Agency with the survey.

The Japan International Cooperation Agency sent to Pakistan a 13-man survey team headed by Mr. Shohachi Uchida from May 19 to December 5, 1979 for the purpose of drilling and exploratory work. Based on the findings of the survey, another 16-man survey team was dispatched from May 27 to July 10, 1980 for studies concerning development of mine and design of coal-fired power station.

The survey teams exchanged views with the officials concerned of the Government of Pakistan and conducted a field survey (in Lakhra Coal Field, Sind State). After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the team.

February, 1981

Keisuke Arita
President
Japan International Cooperation Agency

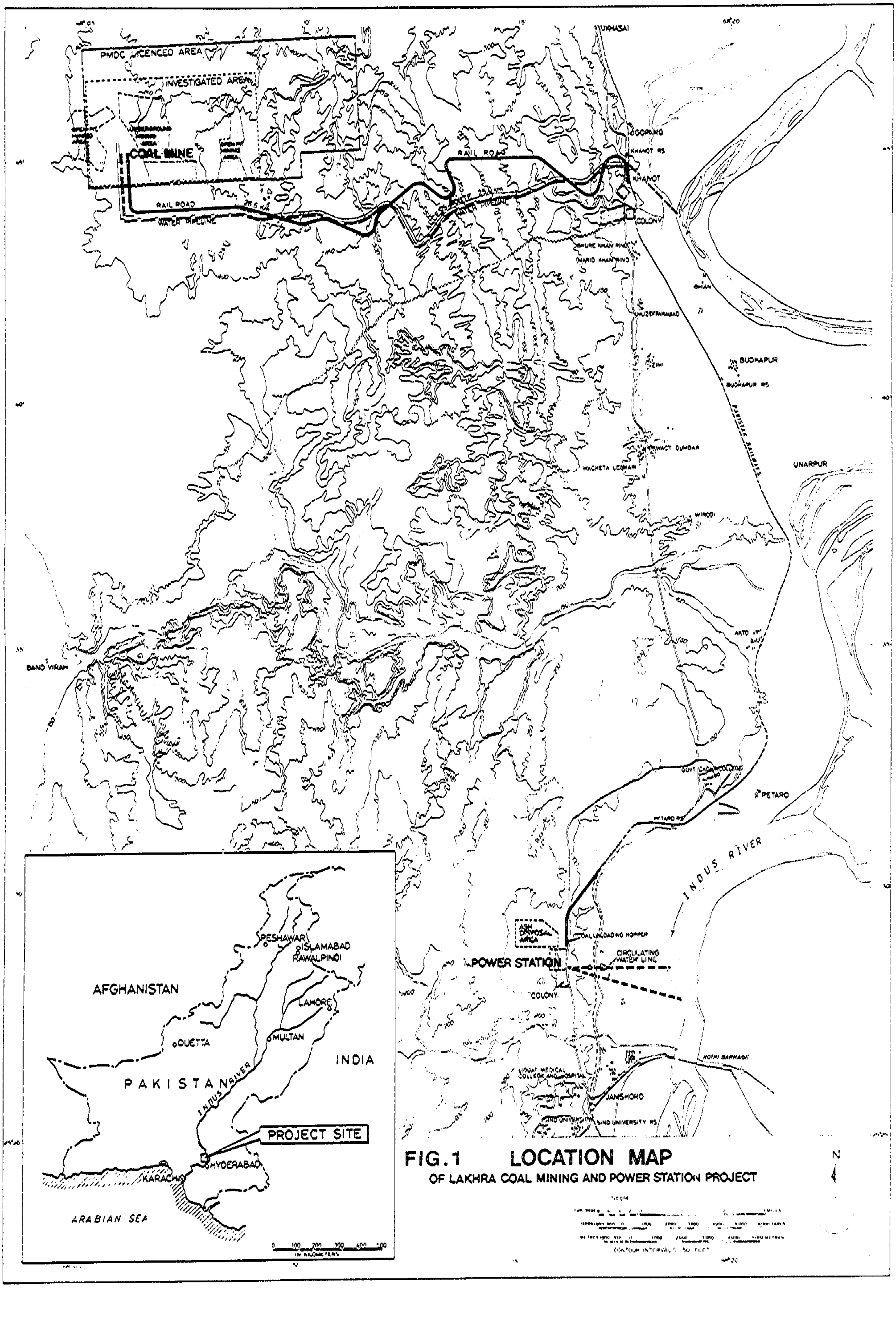

FIG. 1 LOCATION MAP
OF LAKHRA COAL MINING AND POWER STATION PROJECT

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PART I SUMMARY

PART I SUMMARY

CHAPTER 1 INTRODUCTION

1-1 Purpose of Study

This study is to investigate a technical and economical feasibility of constructing a coal-fired thermal power station which will use lignite to be produced at Lakhra Coal Mine situated approximately 230 km northeast of Karachi City in order to meet the growing power demand in the southern part of the Islamic Republic of Pakistan. A request was made by the Government of the Islamic Republic of Pakistan to the Government of Japan for the performance of the study stated above. The Government of Japan entrusted to Japan International Cooperation Agency (JICA) to undertake a feasibility study of development of a coal mine and coal-fired thermal power station in response to the request from the Government of the Islamic Republic of Pakistan. The study is to be performed at two phases; at Phase I, drilling and exploratory works are to be conducted to determine geologic conditions, quality and quantities of coal, etc., whereas at Phase II, the first-hand data and information are to be collected through the performance of site surveys required for studies in the fields of coal mining and construction of a coal-fired thermal power station. These studies are also to be conducted by reference to the results of observation of the facilities of the existing coal mines and power stations thereby making preliminary designs and calculating estimated construction costs of the coal mine and coal-fired thermal power station.

1-2 Background

(1) West Pakistan Industrial Development Corporation commenced and arranged various studies to determine large quantities of coal from Lakhra Coal Mine and to look into possibilities of constructing a coal-fired thermal power station around 1967.

(2) After many turns and twists following the progress of studies, an area to be drilled and explorated was finally selected by Pakistan Mineral Development Corporation (PMDC) in 1974. The block of PMDC licences covers land with an area of approximately 52 square kilometres that lies 10 kilometres from east to west and around 5 kilometres, respectively from the central point of Lakhra coal field. Drilling works were conducted at 19 points in the said block, and a report incorporating the results of such drilling work was forwarded to the Government of the Islamic Republic of Pakistan.

(3) At the request of Water and Power Development Authority (WAPDA), the Canadian International Development Agency (CIDA) prepared a report entitled "Reconnaissance Study and Evaluation of Lakhra Lignite Deposited and Associated Thermal Power Station, Hyderabad, Lower Sind, Pakistan". In this report CIDA recommended on the necessity of further drilling and described coal reserves.

(4) PMDC submitted the PC-1 scheme of Lakhra Coal Mining Project in 1976, and WAPDA submitted PC-1 scheme of 250 MW power station which will use Lakhra coal in 1976.

The schemes were discussed with the Government of Pakistan, and it was decided to arrange feasbility study of the integrated Lakhra Coal Mining and Power Station Project for further consideration and approval. Following that a Working Committee was constituted and WAPDA was assigned the Project as the executing agency.

(5) In March 1978, a Technical Co-operation Mission of JICA/MITI visited Pakistan to look into the possibilities of Japanese assistance to the Government of Pakistan in the Project. In the meetings with the Government of Pakistan and WAPDA, the Mission was requested for deputing a team for feasibility studies, and financial and technical assistance for development of coal mines and setting up a coal fired power plant.

(6) Following the above-mentioned visit, JCI Mission visited Pakistan. The Mission had consulted the available literature, and they were of the opinion that the data in respect of mining conditions, and quality and quantity of coal were not sufficient to plan development scheme. This view was confirmed after visiting the site. So they suggested that the feasibility study shall be undertaken in two stages;

1) Detailed exploration including drilling in the western part of the block of PMDC licences to determine the geological and mining conditions, and to confirm the reported coal reserves.

2) Feasiblity studies for coal mining and power plant provided the exploration during the first stage proves coal reserves suitable for power generation.

(7) The Government of the Islamic Republic of Pakistan requested the Government of Japan to undertake a feasibility study of the Lakhra Coal Mining and Coal-fired Thermal Power Station Project on a Government-to-Government basis in 1978. In compliance with this request, a preliminary mission composed of five persons visited Pakistan during the period from November 17 to December 1, 1978 for the purpose of deciding on the general terms and conditions of performing the study.

This mission explained to officials of the authorities concerned of Pakistan a Japanese plan of operation regarding the performance of drilling and exploratory work at Phase I and that of a feasibility study of coal mining and coal-fired thermal power station on the basis of the results of the studies conducted at Phase I. The Mission also prepared the Minutes of Meeting incorporating details of drilling and exploratory work which would be done during the period of Phase I.

(8) In accordance with the Minutes agreed upon between the Government of the Islamic Republic of Pakistan and the preliminary mission, JICA organized a survey team composed of 13 experts for Phase I and sent it to Pakistan for a period of six and a half months from May 19 to December 5, 1979 to have them undertake drilling and exploratory work as well as geologic investigations and surveying. The tentative results of their workin Pakistan were reported to the Government of the Islamic Republic of Pakistan prior to their return to Tokyo.

(9) A survey team composed of 16 experts was organized by JICA for the purpose of carrying out studies on coal mining and coal-fired thermal power station. They visited Pakistan for a period of one and a half months from May 27 to July 10, 1980. The survey

team forwarded papers incorporating the tentative results of their field studies before their departure from Pakistan.

(10) The survey team for Phase I submitted to JICA an interim report on drilling and exploratory works of Lakhra Mine which was prepared after they returned home to Tokyo. The said interim report was also forwarded to the Government of the Islamic Republic of Pakistan.

(11) The survey team for Phase II (Survey Team for Feasibility Study of Lakhra Coal Mining and Coal-fired Thermal Power Station Project) briefed to JICA the tentative results of their field studies conducted on coal mining and coal-fired thermal power station in Pakistan after their return to Tokyo. In addition, the Pakistani delegation to Japan composed of the representatives from Ministry of Water and Power, WAPDA and PMDC visited Tokyo at the invitation of JICA for a period of 9 days from November 8, 1980. They discussed the basic requirements of design on the coal mine and coal-fired thermal power station and also the implementing schedule for this Project in detail with members of the survey team.

The survey team has prepared estimated construction costs and construction schedule following design on facilities for the coal mine and coal-fired thermal power station, based on the Minutes incorporating items and requirements agreed upon between the Pakistani delegation and the survey team. In amalgamation of the results of studies in both components, the Project implementation schedule as well as total construction costs and economic and financial analyses have respectively been prepared.

(12) The survey team is to forward to JICA and to the Government of the Islamic Republic of Pakistan a report on feasibility study on Coal Mining and Coal-fired Thermal Power Station Project consolidating the reports for Phases I and II.

1-3 Scope of Work

1-3-1 Studies for Phase I

(1) Drilling

PMDC's block measuring about 52 square kilometres was drilled already at 22 localities by PMDC at 19 and Geological Survey of Pakistan (GSP) at 3 points. Since the present work is aimed at determining the geological and mining conditions, continuity and classification of coal seams; and to analyze the geologic structure and to confirm the reserves, 50 drill-holes with an average depth of about 100 m are to be executed at close spacing in the western part of the block.

(2) Geologic Investigations

Location, size and shape of coal seams along with lithology of overburden and host rock are to be studied. Geologic structure in the area is to be analyzed and the quality of coal is to be established. Also the coal reserves are to be estimated and mining conditions determined for planning mine development and undertaking mining feasibility.

(3) Surveying

Drilling sites and grid intersection points are to be plotted and their heights with respect to mean-sea-level are to be determined through surveying. Also the sketch topographic map of western part of the area are to be prepared.

1-3-2 Studies for Phase II

(1) General Study

The general study referred to as herein is to determine the "Services and Facilities" including provision of data and information which will be furnished by WAPDA and the requirements of the studies to enable the survey team to conduct their field studies in Pakistan smoothly and effectively. During their stay in Pakistan, the survey team is to discuss with officials of WAPDA and associated government agencies the scope of work, principles and manner of execution of studies, schedule for the performance of field studies, etc.

(2) Mine Development Study

Field surveys are to be conducted in connection with the surface of open pit and underground mine areas, locational conditions of surface facilities for mine, transportation routes of coal, etc. And visual observation is to be also made on the existing mines for collection of data and information useful for the performance of the studies. The survey team is to make efforts to further collect and gather detailed data and information from WAPDA and associated government agencies based upon data and information to be obtained through the performance of the field surveys stated above thereby facilitating the execution of studies in Japan.

After their return to Tokyo, the survey team is to study the following subjects based on the data and information obtained in Pakistan; system of mining, coal production scale, mining area, layout of surface facilities, coal transportation system, etc., which provide a framework of coal mine development. They are also expected to undertake a mechanical study of rock bearing thereby making design of the coal mine. Through the performance of a series of work, the survey team is to prepare the estimates of capital expenditure, coal production, estimated costs of coal, quality control of coal, countermeasures against spontaneous combustion, construction schedule, etc.

(3) Study on Coal-fired Thermal Power Station

The survey team is to conduct field surveys on locational conditions of possible sites in which the power station will be constructed, transportation routes of coal and visit the existing power stations and substations as well as load centers for collection of data and information. The survey team is to make further efforts to collect and gather detailed data and information which will be needed for work in Japan from WAPDA and associated government agencies based upon the results of their field surveys.

After their return to Tokyo, the survey team is to undertake forecast on electric power demand, selection of the most appropriate site for construction of the coal-fired thermal power station, studies on adaptability of coal quality to boiler, determination of power station scale, layout, electric power analysis, etc.

The survey team is also to conduct preliminary design on facilities of the power station, calculate estimated construction costs and prepare construction schedules.

1-4 Composition of Survey Team

1-4-1 Survey Team for Phase I

The survey team was composed of the following personnel.

Member	Employer	Duty as Member of Team
Shohachi Uchida	Mitsui Mining Overseas Co., Ltd.	Leader
Mitsuharu Masui	"	Assistant Leader
Masaru Tateishi	Japan International Cooperation Agency	Coordinator
Akiyoshi Tsuchiya	Mitsui Mining Overseas Co., Ltd.	Geologist
Shigeru Mori	"	Surveyor
Masanori Hanada	"	Senior Drilling Engineer
Takemitsu Meike	"	Drilling Engineer
Yoshihiko Kodani	"	Drilling Engineer
Kazuo Shoji	"	Drilling Engineer
Kazufumi Shibi	"	Drilling Engineer
Yoshiaki Hirakawa	"	Drilling Engineer
Bunichi Sato	"	Drilling Engineer
Azuma Yasuda	"	Drilling Engineer

1-4-2 Survey Team for Phase II

The survey team was composed of the following personnel.

Member	Employer	Duty as member of Team
Shohachi Uchida	Mitsui Mining Overseas Co., Ltd.	Leader
Masashi Mikuni	Electric Power Development Co., Ltd.	Assistant Leader
Masaru Tateishi	Japan International Cooperation Agency	Coordinator
Takehiko Koguchi	Mitsui Mining Overseas Co., Ltd.	Mining Engineer (Open pit)
Takuya Abe	"	Electrical Engineer
Hiroaki Hirasawa	"	Mining Engineer (Underground)
Takio Yagi	"	Mechanical Engineer
Katsuhisa Honda	"	Civil Engineer
Minoru Goda	"	Coal Preparation Engineer
Kiyotaka Hidehira	"	Mine Economist
Tetsuya Fukuda	Electric Power Development Co., Ltd.	Power Economist
Mitsuhiro Omori	"	Power System Engineer
Minoru Ikeda	"	Thermal Power Engineer (Mechanical)
Tatsuya Yoshioka	"	" " (Electrical)
Shoki Horigome	"	" " (Civil)
Koji Fukami	"	" " (Structural)

1-5 Period of Field Study

The period of the field studies for Phases I & II is as given hereunder.

(1) Field Study for Phase I

Member	Period		Days	Remarks
	From	To		
S. Uchida	19 th May	29th June, 1979	41	General Management
M. Masui	4th June	5th Dec., 1979	185	Management and Geologic Survey
M. Tateishi	4th June	13th June, 1979	10	Coordination
A. Tsuchiya	9th June	5th Dec., 1979	180	Geologic Survey
S. Mori	31th Aug.	29th Sept., 1979	30	Survey
M. Hanada	4th June	5th Dec., 1979	185	Drilling
T. Meike	9th June	5th Dec., 1979	180	Drilling
Y. Kodani	9th June	5th Dec., 1979	180	Drilling
K. Shoji	9th June	5th Dec., 1979	180	Drilling
K. Shibi	9th June	5th Dec., 1979	180	Drilling
Y. Hirakawa	9th June	5th Dec., 1979	180	Drilling
B. Sato	9th June	5th Dec., 1979	180	Drilling
A. Yasuda	9th June	5th Dec., 1979	180	Drilling

(2) Field Study for Phase II

Member	Period		Days	Remarks
	From	To		
S. Uchida	27th May	10th July, 1980	45	General Management
M. Mikuni	27th May	10th July, 1980	45	Management and Power generation study
M. Tateishi	29th May	8th June, 1980	11	Coordination
T. Koguchi	27th May	10th July, 1980	45	Mining study
T. Abe	27th May	10th July, 1980	45	Mining study
H. Hirasawa	10th June	10th July, 1980	31	Mining study
T. Yagi	10th June	10th July, 1980	31	Mining study
K. Honda	10th June	10th July, 1980	31	Mining study
M. Goda	10th June	10th July, 1980	31	Mining study
K. Hidehira	26th June	10th July, 1980	15	Mining study
T. Fukuda	27th May	10th July, 1980	45	Power generation study
M. Omori	27th May	10th July, 1980	45	Power generation study
M. Ikeda	10th June	10th July, 1980	31	Power generation study
T. Yoshioka	10th June	10th July, 1980	31	Power generation study
S. Horigome	10th June	10th July, 1980	31	Power generation study
K. Fukami	10th June	10th July, 1980	31	Power generation study

1-6 Location, Access and Topography

Lakhra coal field lies to the northwest of Hyderabad in Dadu district, Sind, Pakistan. The field is about 50 km in north-south and 12 km in east-west directions. Block of PMDC licences measuring about 52km² is almost in the center of the field. It extends about 10km in east-west and 5 km in north-south directions.

The area investigated in the present work covers about 26 km² in the western part of the block. Its extent is about 6 km in east-west and 4 km in north-south directions. It lies 16 km to the west of Khanot, which is the nearest railway station along the Indus Highway. By road, the area is 217 km from Karachi and 80 km from Hyderabad. It is accessible by metalled roads up to Khanot from where non-metalled roads, taking about an hour in four-wheel driven vehicles, lead to the area.

The area consists mostly of flat limestone cap-rock truncated and eroded in the south-eastern part by non-perennial streams exposing older rock formations. Western part of the area is comparatively flat and gently rolled, while eastern part is fairly dissected by Kath Butthi Stream and shows some relief.

The Jamshoro area where construction of a 300 MW coal-fired thermal power station is proposed is located on the right-hand bank of the River Indus. It is about 170 km to the east-northeast of Karachi. Access is made to the proposed power station site in the Jamshoro area by passing the Super Highway, National Highway and National Road. There is an existing railway between Karachi and Dadu.

The proposed site in Jamshoro is a slope descending slowly to the east or southeast. Although there exist some hills, the proposed site has relatively gentle relief. The said site is approximately 10 m higher than the flood level of the River Indus.

Refer to Location Map of this Project (Fig. 1-1)

CHAPTER 2 CONCLUSIONS AND RECOMMENDATIONS

2-1 Conclusions

2-1-1 General Descriptions

As a result of a Feasibility Study carried out over a two-year period of 1979–1980, the JICA Survey Team has drawn the conclusions below regarding a project for developing a coal mine at Lakhra, Islamic Republic of Pakistan, and developing a thermal power station utilizing the lignite produced at the coal mine.

(1) The result of geologic investigations carried out by the JICA Survey Team from May to December 1979, confirm the feasibility of extracting 35,602,000 tonnes of coal (sulfur content approximately 6%) on an as-received basis and 29,538,000 tonnes on an air-dried basis at the mine through both open pit and underground mining from the Lakhra Coal Field covering an area of 26 km^2.

(2) The above-mentioned coal has a calorific value of 4,613 kcal/kg (air-dried basis), and when used as a fuel for electric power generation, it will be possible to develop a thermal power station of thermal efficiency of 37% and installed capacity of 300 MW with a plant factor of 70%.

(3) The preparatory period before commencing with the Project has been set as 24 months in accordance with the strong wishes of the Pakistani authorities, and the start of construction will be in April 1983 making it possible for relatively full coal productron from January 1987 and commercial operation of the power station from March of the same year.

(4) The approximate construction cost is estimated to be a total of 7,023 million Rupees (1 Rupee = 22 Yen) consisting of 2,146 million Rupees for coal mine and railway facilities and 4,877 million Rupees for the thermal power station in terms of construction costs not including interest during construction and at June 1980 values. Of this total, the costs in the foreign currency portion amount to 3,918 million Rupees and those in the local currency portion 3,105 million Rupees.

However, if commodity price escalations hereafter are tentatively assumed as being 7% annually for the foreign currency portion and 9% annually for the domestic currency portion, the abovementioned construction cost without the amount of interest during construction will be increased to a total of 9,958 million Rupees, 5,333 million Rupees for the foreign currency portion and 4,625 million Rupees for the local currency portion.

(5) In the case of this Project, the costs required for construction, operation and maintenance of the coal mine and railway facilities would be directly converted to the fuel cost of the thermal power station. In case this Project is compared with an oil-fired thermal power station of equal generating output in consideration of difference in station service, the "benefit-cost ratio (B/C)" will be as indicated below.

(a) Case of Discount Rate 10%

		B/C
o	Heavy oil price annual average escalation rate 4.5%:	1
o	Heavy oil price annual average escalation rate 8.0%:	1.62

(b) Case of Discount Rate 13%

o	Heavy oil price annual average escalation rate 4.95%:	1
o	Heavy oil price annual average escalation rate 8.0%:	1.45

From 1974 until the present, the basic price of crude oil of the Organization of Petroleum Exporting Countries (OPEC) has greatly increased at an annual average rate of 17% (12% or more in real terms even when considering the relative decline in the purchasing power of the dollar), and when it is considered that the future trend will be unpredictable, the economic advantageousness of this Project will be proven by the above-mentioned figures. Further, through implementation of this Project, it will be possible for natural gas used in Pakistan exclusively as a power generation fuel to be conserved by approximately 530 million m^3 (in case of a plant factor of 70%), and this may be applied as material for a gas-chemical industrial activity of high added value.

(6) The construction cost taking into account the commodity price escalation above, when procured under the conditions of interest per annum of 8.75% and repayment period of 25 years for the foreign currency portion, and interest per annum of 12.5% and repayment period of 20 years for the local currency portion, will be in terms of total construction cost including interest during construction 12,008 million Rupees (including a foreign currency portion of 5,333 million Rupees and a local currency portion of 6,675 million Rupees) consisting of 3,360 million Rupees for coal mine and railway facilities and 8,648 million Rupees for the thermal power station.

Based on this total construction cost, the coal supply cost and electric power supply cost as of 1987/1988 will be as indicated below.

a) Coal Supply Cost

o Air-dried basis 983 Rs/ton
(0.50 Rs/kWh)

b) Electric Power Supply Cost

o At sending end 1.44 Rs/kWh

(Case of escalation not considered, as of June, 0.93 Rs/kWh)

A fuel cost for an oil-fired thermal power station with a gross thermal efficiency of 37% is calculated to be 0.54 Rs/kWh as of escalation rate of 8% per annum, it will reach 0.93 Rupees/kWh in 1987/88. The said price is about twice as costly as the fuel cost of lignite from Lakhra Coal Mine.

The above points, considered together with increases in employment opportunities accompanying development of the coal mine, and regional redistribution of income, show that this

Project is of extremely high feasibility, and it is desirable for the Project to be realized at an early stage.

2-1-2 Exploration Study

(1) General Description of Exploration Work

Geological survey team consisting of 13 members was deputed to Pakistan. The team stayed there from May 19th to December 5th, 1979 and carried out geological studies, executed 50 drill holes and undertook surveying.

Various arrangements had to be made after reaching the site, and drilling could be commenced from 27th, June by using 3 wire-line drilling machines brought from Japan. 50 drill holes with a composite depth of 5203.06 m had been executed by November 22nd. Depth of holes ranged from 71.14 m to 143.25 m with an average of 104.06 m.

Drilling had been conducted non-coring by using tricone bit through the limestone, and core drilling was extended to the coal measure by using NQ bit adopting wire-line method. Drilling cores were logged at the sites and columnar sections of lithologic units and coal seams, and cross-sections of lithologic units and coal seams, and cross-sections were prepared. Their section were used for preliminary correlation of coal seams and determining the geologic structure. Samples of all the coal seams and representative rock units were collected for analyses and tests in the laboratories in Japan.

Co-ordinates and heights of drill holes had been determined and supplementary topographic survey undertaken.

After returning back, the team has remained pre-occupied with the works discussed below.

Arrangements for and drawing of columnar sections of lithologic units, coal seams and cross-sections; correlation of coal seams, determination of stratigraphic succession and geologic structure, etc. Investigations have been carried out to fix the workable thicknesses of coal seams and stripping ratios. The coal samples have been subjected to proximate and ultimate analyses. Their calorific value, sulphur content, specific gravity, ash fusion temperature, ash components and Hardgrove grindability index have been determined. Float and sink tests, and spontaneous combustibility tests have also been undertaken. For rock samples, weight of the unit cubic volume (specific gravity), supersonic velocity, uniaxial compressive strength, tensile strength, coefficient of water absorption, effective porosity, stability test for aggregate and Poisson's ratio have been measured and determined.

Based on the data contour maps of coal seams, iso-grade maps, iso-stripping ratio maps, iso-pach maps, etc., are drawn by computer, and both theoretical and recoverable coal reserves have been estimated.

Topographic base map has been revised by incorporating the supplementary survey data.

(2) Results of Exploration Work

1) General Geology

Stratigraphic succession has been determined on the basis of investigations stated above. Exposed rocks in the area consist of Ranikot and Laki groups, which at places are overlain by Manchar formation unconformably.

Laki group is sub-divided into Laki limestone and Basal Laki laterite. Ranikot group consists of Lower and Upper Ranikot formations.

The Upper Ranikot in the present report is referred to as Upper Shell Beds as its strata contain fossil shells. The Lower Ranikot formation has been sub-divided into Upper Coal-bearing Beds, Lower Shell Beds and Lower Coal-bearing Beds. Upper and Lower Shell Beds consist of predominant sandstones alternating with sub-ordinate siltstones and intercalated claystones and shales. They contain abundant fossil shells. Siltstones contain characteristic sandstone and siderite nodules.

The Lower Coal Beds also constitute by alternating sandstones, siltstones and claystones contain three coal zones, which are mostly thin and insignificant from economic poinf view.

Barren areas devoid of coal or containing very thin coal seams occur in the southwestern and northern parts of the investigated area. Red zone comprising of variegated rock facies occurs in the upper part of Ranikot group. It spreads almost all over the area. In the areas devoid of coal, it extends to Upper Coal-bearing Beds.

2) Characteristics of Rocks

The measured values of rock tests vary considerably. For example, the uniaxial compressive strength of limestone ranges from 122.5 to 957.3, sandstone from 5.2 to 323, and in case of siltstone/claystone from 9.2 to 312.6 kg/cm^2. Certain types of sandstone, particularly the so-called silica sandstone is so soft and loose that its core could not be obtained. This sandstone when in roof of coal seam would not permit underground mining for reasons of safety.

3) Geologic structure (Fig. 2-1)

The investigated area falls mostly in the western limb of the Lakhra anticline. As the dips of strata are very gentle and the eastern limb was beyond the scope of the present work, the axis of the anticline has not been confirmed. The strata and the coal seams dip at 2 degrees and appear to be gently rolled.

Three faults have been noted in the middle of the southern part of investigated area. Western fault referred as fault A strikes northeast. Its throw is 25 metres to the east. Central fault B1 trends northsouth to northwest. The eastern fault referred as fault B2 branches out from the central fault and strikes in northeast direction. Blocks to the west of both the faults are downthrown. Threw near the junction of faults is 30 m. Displacements of the faults decrease northwards and they die-out in the investigated area. They are pivotal faults. The investigated area is divided into western, central and eastern blocks based on these faults, and the barren areas mentioned already.

4) Economic Geology

(a) Coal Zones

The Upper Coal-bearing Beds contain five coal zones – No. 1 to No. 5 in ascending order. The Lower Coal-bearing Beds bear three coal zones – L1 to L3 in descending order. Each zone contains from one to more than one seams. No. 1 zone is 0.2 to 0.7 m thick. It persists throughout except the barren areas. No. 2 zone ranging in thickness from 0.1 to 8.0 m is as persistent as the zone No. 1. Towards east, however, it merges with zone No. 1. Zone No. 3, 0.05 to 4 m in thickness, also spreads over the area like No.1 and No.2 zones. These three are the main zones containing workable seams in the investigated area.

No. 4 and No. 5 zones are up to 2.0 m and 1.2 m thick respectively. They are impersistent. In the eastern part they are generally thin and fish out at places. Both the zones are therefore workable only locally.

The coal zones in the Lower Coal-bearing Beds, L1, L2 and L3 are up to 3.0, 4.0 and 5.0 m thick respectively. However, they are generally thin and their continuity could not be established in the present work. Consequently, they have not been evaluated.

(b) Quality of Coal

Coal in each zone in the investigated area is lignite in rank. Rarely it grades into sub-bituminous. It contains about 30% moisture when fresh (PMDC, 1976). It loses most of the moisture on exposure to surface and easily crumbles. It is liable to spontaneous combustion. The coal contains abundant pyrite grains and thin gypsum veins at places. Sand and clay are also included in pipe-like, lensoid or scattered pattern.

It has been determined that the moisture content of coal is 5.5 to 14.6%, calorific value ranges from 3,500 to 5,860 kcal/kg (6,300 to 10,550 BTU) and total sulphur from 3.3 to 18.1% on air dried basis. Proportion of inorganic to organic sulphur content is 66 to 34.

Ultimate analyses of ash and moisture free samples show carbon – 58.5 to 72.4%, hydrogen – 4.5 to 5.8%, oxygen – 14.4 to 22.3%, nitrogen – 0.9 to 1.4% and sulphur ranging from 2.4 to 16.7%. Ash fusion temperature has been determined as follows – deformation 1,250 to 1,425°C, hemisphere 1,300 to 1,450°C, flow 1,350 to 1,450°C or more. Hardgrove grindability index varies from 59 to 88. Ash consists of SiO_2 – 8.0 to 44.42%, Al_2O_3 – 9.49 to 28.8%, Fe_2O_3 – 17.3 to 70.76%, SO_3 – 1.93 to 17.47%. These values show considerable variation. The coal is known to be non-coking and non-caking.

From the results of analyses and tests, it is concluded that the coal is suitable for use as fuel in thermal power generation through the variation of each analytic value is high.

Washability (float and sink) tests have also been carried out. The tests indicate that the coal can be up-graded and partially desulphurised, for example, when floated in solution with 1.8 specific gravity the ash decreases from 19.7 to 12.0% and sulphur from 6.84 to 4.2%.

(c) Coal Reserves

In the present work coal reserves are estimated on the basis of following factors and assumptions:

a) Reserves over 2.353 km^2 in the western and 6.87 km^2 in the eastern parts of the investigated area have been calculated from the point of view of open pit mining due to suitable stripping ratio up to 15/1.

b) Minimum thickness of coal seams taken into account for estimating reserves is 0.5 m for open pit and 0.75 m for underground mining.

c) Minimum thickness of coal seams taken into account for estimating reserves is 0.5 m for open pit and 0.75 m for underground mining.

d) Seams with calorific value under 3,500 kcal/kg on air-dried basis are not taken into account.

e) Specific gravity of coal for open-cut and underground mining has been determined at 1.5 and 1.45 respectively. The difference is because comparatively better grade coal would be won in the underground mining as the coal seams underlying loose sand would be left out, and workable thickness has been taken considerably less than the actual for the sake of mine safety.

f) Geologic safety factor and recoverable factor would be determined depending on the mining method to be selected. For the sake of present calculations for recoverable reserves it has been assumed that the geologic factor would be 80% for open cut and 70% for underground mining; and the recoverable factor would be 90 and 65% respectively for open cut and underground mining. Based on the above factors and assumptions, the theoretical and recoverable reserves in raw coal have been estimated as follows;-

Unit: million tonnes

Mining Area	Theoretical Reserves	Recoverable Reserves
Open Pit	65.50	47.16
Underground	14.28	6.50
Total	79.78	53.66

2-1-3 Mine Development Study

(1) General Description of Study

The feasibility study has been divided into four main separate studies.

- Mine planning study
- Surface facilities study
- Coal preparation study
- Railway study

The report presented herein represents the study of the mining plan which has been based upon the development of mine plan inclusive of support facilities capable of sustaining an annual production rate of 1.2 million tonnes of clean steaming coal (as received base) for a period of 30 years on the basis of the geological exploration study, site survey, and study in Japan.

The mining plan developed in this report involves the extraction of 36,780,000 tonnes of raw coal from No. 1, 2, 3 and 5 seams.

The major considerations for the development of this plan were as follows.

The coal reserves area for this study has been divided into 3 blocks as shown in the geological report, and three mines i,e, an underground mine provided with longwalling in central block, and two open pits provided with truck-shovel method in ewest and east block.

The annual average coal production (as receied base) of clean coal for a period of 30 years will be 1,170,000 tonnes of which 220,000 tonnes of coal will be produced at an underground mine and 950,000 tonnes at open pits. The average value of clean coal is estimated at 3,827 kcal/kg, and its sulphur content is estimated at 5.9 %. The layout of the underground mine will be developed by inclined shaft system provided with the longwall mining method. The open pits will be developed by the average stripping ratio of 11/1.

Office buildings, factory buildings, and factories, etc., as the support facilities on the surface inclusive of service and welfare facilities will be provided. In order to reduce a part of sulphur content and ash content, coal preparation plant provided with a picking belt of the capacity of 400 t/h will be planned.

The railway of 27.5 km between mine site and Khanot, and also spur track of five km from existing railway to plant will be laid to meet the main purpose of coal transportation and also commuting train from colony in Khanot to mine.

The operating employee requirements will be 1,824 during the main production period, and average employee requirements will be 1,689 for a period of 30 years.

Total mine productivity exclusive of railway will be 2.3 tonnes per man per shift.

Preproduction schedule has been made by a request in response to the Pakistani delegation in Tokyo, November 1980, and so construction work will commence in April 1983. However, in order to achieve this start-date it will be necessary to perform certain pre-engineering and procurement activities, and preparation work inclusive of detailed drilling.

The production schedule indicates longwalling production commencing in 1986, and total production inclusive of open pit production will be 733,000 tonnes in 1986.

The total capital costs calculated for this study inclusive of railway amount to 2,146,000,000 Rupees based on June 1980 price levels. But interest during construction and escalation have not been included.

The average operating costs with freight will be estimated at 381 Rupees per clean coal tonne based on June 1980 price levels. But escalation has not been included.

(2) Layout of Mining Plan

1) Mining Area and Production Scale

The investigated area of about 26 square kilometers has been divided into three blocks; namely central, western, and eastern defined by foldings and fault zones at boundary.

In central block, only two seams of No. 1 seam and No. 3 seam are considered mineable. No. 1 seam which covers main part of production, lies at a depth of 85 m to 123 m. Therefore, open cut method will be uneconomical due to the high stripping ratio which indicates more than 15/1, an underground mining method will be applicable for this block.

In western block, five coal seams are considered minable, and No. 1 seam, bottom seam, lies 33 m to 85 m deep which is shallower compared with eastern block. Accordingly, stripping ratio has been calculated at 8.6/1 and west pit will be planned to cover the half part of production for total production.

In eastern block, three seams are considered mineable, and the bottom seam lies 45 m to 91 m deep and in this block there exists loose sand on the direct roof of No. 1 & No. 2 coal seams. Therefore an underground mining method is not applicable. And also even in open cut system the stripping ratio will be calculated at 18/1, so coal reserves will be fundamentally estimated uneconomical at the present time. However coal production has been calculated by both mines with the consideration of average stripping ratio keeping to 11/1 or below.

The geological mineable reserve figure as calculated in geological report is approximately 6,500,000 tonnes raw coal (air dried base) in central block, approximately 15,000,000 tonnes raw coal (air dried base) in western block, and approximately 32,000,000 tonnes raw coal (air dried base) in eastern block.

The annual coal production rate has been calculated at 200,000 tonnes of clean coal (air dried base) in central block and 500,000 tonnes of clean coal (air dried base) in western block based on a period of 30 years of power station life.

In eastern block as abovementioned there are not economical reserves. However, by diluting the high stripping ratio with the low stripping ratio in western block so as to reduce the total stripping ratio of 11/1 annual coal production will be calculated at the 300,000 tonnes of clean coal (air dried base).

2) Underground Mine

The underground mining plan developed involves the extraction of 6,589,000 tonnes of clean coal as received base. Major access between the mining areas and surface will be via two inclined shafts in rock. No. 1 inclined shaft will be used for coal transportation, personnel and materials transportation, and intake airway, while No. 2 inclined shaft will be used for return airway only.

The portal of No. 1 inclined shaft is located at 2152590 E of X axis and 900685 N of Y axis in. co-ordinates, and No. 2 shaft will be driven on 50 m centres.

The inclined shaft will terminate at the point of intersection with No. 1 seam which is on the centre of this mining block. Both shafts will be driven at minus 12 degrees of gradient. Two parallel headings which are intended for use as main intake airway and main transportation roadways provided with 11.2 m^2 of effective sectional area will be driven from north to south in the central part of block via access in-seam entry from shaft bottom to east. The panel entry will be driven on 120 m centres. Longwall face will be installed in this section. The main entries and inclined shafts will be driven conventionally blasting, side-tipping loaders, and mine car system with arch support, and other entries will be driven blasting, gate-end-loader, and mine car system with square set support. The developing rate has been calculated at 2.7 m/day at maximum.

Mining area will be divided into eleven blocks for the purpose of preventing loss of coal reserves due to spontaneous combustion, and each block will be sealed off after completion of extraction of coal. Pillars will be left along amin entries, gob areas and faults, and 50–100 m in length between panels.

Retreating longwall method of 120 m long with caving is selected. Coal will be won conventionally using blasting, hand loading to a double chain conveyor in the face supported with the hydraulic steel prop and link bar. The packing in gob side of gate entry will be done with flyash in order to re-use the gate entry for return entry. This method is very advisable for both prevention of spontaneous combustion and increasing the recovery percentage. Coal winning will be operated by increasing the recovery percentage. Coal winning will be operated by two shift system and one shift will be used for preparation and maintenance of face. The coal production from longwall face has been calculated at 400 tonnes/day, manpower required inclusive of foremen will be 129, and average productivity will be calculated at 3.1 tonnes per man per shift in face operation. In areas which cannot be worked by systematic mining, room and pillar method will be planned.

Mine car transportation system has been selected to handle coal produced, waste rock, and materials transportation. To sustain this mine car transportation underground, the two types of battery locomotives of 8 and 10 are selected. The winding machine with the capacity of 200 kW in inclined shaft will be installed.

Drainage equipment with capacity of 50 kW, 180 m head, 1.4 m^3/min will be installed at the bottom for rainy season. And also small capacity supply water pump and drainage pump are provided.

The total consumption of compressed air has been calculated at approximately 90 m^3/min. To cover this demand the compressor with a capacity of 2 set of 240 kW and 1 set of 75 kW will be installed on the surface.

The centralized ventilation system has been selected to meet this mining plan, main fan of 300 kW will be installed at the entrance to No. 2 inclined shaft. The fan will be capable of 5,000 m^3 at 200 mm water gauge.

Site work for portal will be completed in a three month period to permit the inclined shafts. Mine development will require a total time of 24 months, including 7 months for inclined shafts, 8 months for main entries, 9 months for panel entry and preparation for longwalling.

3) Open Pit

A shovel and truck system in both pits to remove the overburden has been selected with the consideration of multi-seam mining, early production, and techniques of workers. The shape in bench represents the multi-bench system, and the bench is designed at 14.0 m high, maximum 60 m wide, and at an angle of 45 degrees from a rock stability points of view. Truck road is designed at 14 m wide with the maximum inclination of 8 degrees.

The total steps of bench will be 3 to 4 benches to reach the upper most coal seam due to the deep mine.

Overburden is drilled with the two sets of drills of electric drive type of 9-7/8" in diameter in both pits, and drilling operation will be done by two shift system in a day. Three units of bulldozer will be arranged for cleaning the surface of bench and treating the soil.

Spacing of drill holes is designed for 7 m x 8 m, and penetrating speed is designed at 23.3 m/h. Ammonium Nitrate Fuel Oil is used for blasting the overburden, and powder factor is designed at 0.44 kg/m^3.

After blasting the overburden, loose overburden is loaded by two units of electric power shovel with a dipper capacity of 11.5 m^3 in each pit, and a bulldozer for a shovel aids in cleaning the surface. Mechanical efficiency of shovel is estimated at 75%.

Loosed overburden is removed by 120 t trucks provided 9 no.s in each pit and/or dumped into the space from where the coal had been mined out. The truck speed in pit area is designed at 13 km/h, and in up grade road is designed at 10 km/h, and in flat and good condition road is designed at 30 km/h. The combined operation between truck haulage and shovel operation is designed by simulation method of computer system.

The parting rock between coal seams is drilled by rotary type drilling machine of 80 mm in diameter, and also for the loading and transportation, bulldozer, wheel loader, scraper, and 46 ton trucks are provided. This operation will be done after coal mining and before stripping work. The rock blasted is removed in trucks or dumped in mined area by bulldozer and/or scraper. A bulldozer is used for discharging the rock from the highwall to mined out space and cleaning the surface of coal before mining. A scraper is used for loading and hauling the parting rock and cleaning the surface of coal.

Coal seams are usually broken by the aid of ripper of bulldozer, but in hard coal seam blasting will be done. Coal is loaded by hydraulic excavator using a 6 m^3 dipper and is transported by a 46 t truck.

In pit service and road maintenance road grader, bulldozer, crusher, water tank, and truck crane, etc. are provided.

Dewatering equipment is equipped with the pump capacity of 2 units of 22 kW capable of 30 m head and 2 m^3/min of water volume during rainy season.

Rock desert area spread in the surface, and so damage due to pollution need not be considered, but some extent of reclamation work will be necessary. In cleaning the mined out area one unit of wheel loader with bucket capacity of 5.6 m^3, one unit of scraper with the capacity of 24 m^3, two unit of bulldozer, and a 46t dump truck will be provided.

Layout of pit is designed at 40 m wide, and 300 m to 1,000 m long based on geological factor of 80% and mining recovery of 90%.

The clean coal production in open pit has been calculated at 29,013,500 tonnes with the stripping volumes of 330,112,900 m^3 in solid for a period of 30 years, and stripping ratio will be 11/1 which will be 9/1 in west pit and 14/1 to one in east pit respectively. Productivity in open pit is estimated at 5.7 tonnes per man per shift.

The open pit planning study provides for a continuing intensive coal development schedule. In order for this to be reliably achieved, it is necessary for certain preparation work to be performed prior to the commencement of the project.

The total volume of bank overburden to be removed will be 5,000,000 m^3 in 1983, 7,780,000 m^3 in 1984, 8,958,000 m^3 in 1985 and 1986, approximately 10,000,000 m^3 after 1987.

The coal production will be planned at 123,000 tonnes in 1984, 301,000 tonnes in 1985, 602,000 tonnes in 1986, 732,000 tonnes in 1987, full production in 1988.

Stripping work in the west pit will commence at the line connecting the drill hole JT16, JT7, JT9, and PS19. Bench cut will be developed to west. The total volume of bank overburden to be removed will involve of 11,938,000 m^3 from 1983 to 1985. In east pit stripping work will commence at JT50 of drill hole. The stripe type of bench cut will be provided from east to west, and mining procedure will be developed to north with a constant angle of highwall and width of bench. The total volume of bank overburden to be removed will be 9,799,900 m^3 from 1983 to 1985.

4) Surface Facilities

Integrated surface layout system bas been selected and the buildings and factories are located at the surface of barren area between west block and central block with no influence on mining operation.

In the central part of surface lay-out, mine office, air compressor house, winding machine house, work allocation room, safety lamp room, mine substation, mechanical and electrical workshops and store house, etc. will be provided. In west side of this block, head office, heavy vehicle maintenance shop, etc. will be provided. In the south side, preparation plant and emergency stock yard near railway station will be provided.

Coal transportation from mine to power station and commuting service from colony in Khanot to mine will be done by railway. Both railway and road will be utilized for the transportation of materials and equipment, etc.

The water near surface in the River Indus will be delivered by in-take pump to sediment pond, and purified. This purified water will be utilized for industrial and living water.

Site work for the area of building inclusive of supporting area will be provided for approximately 210,000 m^2, and for railway inside mine and road outside mine of 43 kilometres long will be provided for approximately 470,000 m^2. Total of 680,000 m^2 for site work will be provided. Other civil work including foundation work of mine substation, and construction of oil tank, protective fence around mine, and embankment work for explosive magazine, and construction work of sewage treatment plant will be provided. Road construction work of 6 kilometres long with 14 m wide for dump truck and other road work of 33 km long with 7.5 m wide will be provided.

Structural work for production facilities consisting of mine substation, emergency power house, air compressor house, and work allocation room, etc. will be provided for approximately 2,700 m^2 in area. These are structural reinforced concrete or brick buildings of single story. Head office building, open pit office building, and underground office building will be provided for approximately 4,140 m^2 in area. These are structural reinforced concrete or brick buildings. Head office building will only be constructed as two storied building. The workshops consisting of heavy vehicle shop, mechanical and electrical shops for underground mine, etc. will be provided by structural reinforced concrete and steel building with the total area of approximately 12,200 m^2 and also with one story building. Other building will be provided with powder magazine, and powder handling house.

The industrial and living water required for the mine site and colonial area will be delivered from the River Indus to two sand basins in Khanot with each capacity of 240 m^3 by means of two water intake pumps provided with the capacity of 36 kW and 2.93 m^3/min. with the head of 90 m. The water will be purified at the purification stations in Khanot, and conveyed to the distributing reservoir in colonial area and in mine site respectively, and also distributed by the distributing pump from the reservoir to the consumer. The water conveyance pump to the mine site is provided with the capacity of 37 kW and 0.75 m^3/min. with the head of 180 m. The water conveyance pumps of two units to colonial area are provided with the capacity of 10 kW and 2.18 m^3/min. with the head of 30 m. The pipes used for will be 150 mm, 200 mm an 250 mm in diameter of cast iron pipes for water delivery and conveyance. Especially galvanized steel pipes is used for water distribution. The septic tanks will be provided for the sewage treatment of administration office and other major surface facilities.

The mine substation is provided for receiving the required power from WAPDA at 33 kW and distribute it to all areas at 33 kW and/or 3.3 kV. The total installed motor capacity within the mine has been calculated at approximately 7,000 kW and, excluding the open pit supplied at 33 kV, the total capacity to be supplied at 3.3 kV is estimated at 3,480 kW. Therefore, the required transformer capacity to be installed will be 4,000 kVA.

Two units of emergency diesel generator with the capacity of 500 kVA at 3.3 kV in three phase will also be provided for supplying the power only to safety facilities in case of the power failure. For the communication system within the colliery a private telephone system will be provided. The other major facilities for the mine are two sets of drilling machines, vehicles, a computer, and a hospital.

5) Coal Preparation Plant

The plant feed coal is screened at 50 mm in size and 50 mm oversize waste with 75% ash content, 4% of total raw coal, will be removed by hand picking.

The quality of clean coal delivered at the power station will be estimated at total moisture of 25%, ash content of 19.7%, volatile matter of 27.8%, total sulphur of 5.9%, calorific value of 3,840 kcal/kg, and plant yield of 96% on as received basis.

The quality indicates inherent moisture of 9.3% and calorific value of 4,640 kcal/kg on air dried basis, ash fusion temperature is more than 1,300°C, and Hardgrove grindability index is 70, and these characteristics are favourable for steaming coal. The electric resistance of ash is 3.5×10^{13} ohm-cm at 130°C, and it is fairly high for the maximum limit of 1×10^{13} ohm-cm, accordingly some considerations are required for the design of a electric dust collector.

The anticipated operating schedule of plant is established at a rate of 16 hours on 2 shift system per day, 300 days per year and availability of 80% and average plant feed is designed on 400 tonnes of raw coal per hour. The main process is provided for removal of over 50 mm waste in size by hand picking system, and the main plant facilities are as follows:

A 100 t dump hopper and a 1,500 t raw coal bin is included in the raw coal receiving and stocking equipment, and over 300 mm wastes in size are removed at this section.

Raw coal from the underground mine is stored in the above mentioned raw coal bin through a tippler and a raw coal conveyor. Raw coal drawn out from the raw coal bin is fed to the raw coal screen through the plant feed conveyor to be screened at 50 mm in size.

Over 50 mm raw coal is conveyed onto hand picking conveyor at a rate of 40 t/h, while 50 mm undersize of the screen is stored in the clean coal silos through the clean coal conveyors at a rate of 384 t/h.

Over 50 mm waste is delivered to a rock bin through rock belt conveyors and dumped on to a waste area by truck. Over 50 mm coal is crushed by a single roll crusher and stored in the clean coal silos.

The clean coal storage and loading equipment is provided with two 2,000 t clean coal silos, a 20,000 t emergency clean coal stockpile, clean coal reclaiming system, a 110 t loading hopper and a railway track scale.

Reinforced concrete structure will be built for a raw coal dump hopper, a raw coal bine and clean coal silos, and a rock bin and a loading hopper will be constructed with steel structure, and the housing of the hand picking and electric room will be provided with steel structure.

The total capacity of the motors in the plant will be provided with 460 kW, and power will be supplied with 3 kV and 3 phase from the mine substation.

The open-air stockpiling system of the Lakhra coal will be recommendable by the following methods to prevent spontaneous combustion.

The compacted stockpiling should be less than a week in storage period and under 3 m in height. In order to build and keep a safe stockpile, the stockpile must be compacted perfectly at every layer of piles by bulldozer or loaded truck, and the height of each layer should be kept at 40–50 cm, and the final stockpile will be built and piled up by repeating of the above methods.

6) Railway Transportation

In order to supply the coal tonnages required for power station of approximately 1,200,000 tonnes per annum i.e. 4,000 tonnes per day the railway system between mine site and power station will be provided for the distance of 64.5 km. For this purpose, the new railway of 27.5 km long having the same gauge with existing Pakistan National Railway from preparation plant to Khanot will be constructed and connected with the existing one at Khanot, and new spur track of 5 km long near power station site will be provided.

Equipment of 3 units of diesel electric locomotives, 50 wagons, 4 passenger cars, tracks of 32.5 km long, and all support facilities inclusive of loading and unloading facilities, and also repair shop will be provided. However operation and management will be left to the Pakistan National Railway.

The freight charge will be estimated at 26 Rs/t. In this case, the freight charge of existing railway is estimated at 5 Rs/t, and total of depreciation cost, amortization cost, and interest is calculated at 9 Rs/t.

Coal is loaded from clean coal silo to wagon through vibration feeder. A train comprised of 24 wagons loaded with the 840 tonnes of coal is pulled by the locomotive with the capacity of 2 units of 825 kW motor and the ownweight of 84 tonnes.

The time required for round trip between mine and power station will be approximately 202 minutes. Two formation of trains and five round trips per day will be scheduled.

Commuting train between Khanot and mine will be scheduled at four round trips in a day, and other materials will be mainly transported by road, and railway transportation of materials will be available at slack time in middle of the night.

7) Mine Development Schedule

The mining plan development schedule indicates the commencement of the stripping work of open pit and construction work of road, etc. after the date of approval of the project. In order to achieve this starting date it will be necessary to perform detailed drilling, ground investigation, topographic survey, repairing a part of road, preparation work near initial box cut, and certain pre-construction and procurement activities prior to the date of commencement.

The construction work will commence in April 1983. Site work, road construction work, preparatory work, and construction work of mine substation and heavy vehicle maintenance shop in the surface facilities will commence in April and be completed at the end of 1983, and other surface facilities will be completed by the end of 1984.

Construction work of railway will commence in April 1983, and be completed in June 1986.

Construction work of coal preparation plant will commence in October 1983, and be completed at the end of 1985.

Construction work of portal in underground mine will commence in October 1983, and development work in underground commence in the beginning of 1984, and one longwall face will be prepared at the end of 1985. Another face will be prepared one year later.

Stripping work by the heavy machines will commence in April 1983. Full production of coal scheduled will commence in 1988.

8) Manpower requirements and organization

The operating manpower requirements for this project are planned upon modification of manpower and organization commonly observed in Japan and also the world, and also in prevailing coal mines controlled by PMDC and in PC-1 Form for Lakhra project submitted by PMDC in 1976.

The total numbers of officers and wage workers represent the jobs and/or positions to be filled each day, and to not include persons not working due to sickness, accident or any other reason. Costs associated with a 20% level of absenteeism for underground wage workers have been included in the plant.

The manpower requirements will be 662 men inclusive of 47 officers and 615 wage workers during the main production period in underground mine.

The manpower requirements in open pit will be 410 men inclusive of 50 officers and 360 wage workers during the main production period.

The manpower requirements in surface facilities will be 629 men inclusive of 111 officers and 518 wage workers.

In preparation plant the manpower requirements will be 123 men inclusive of 10 officers and 113 wage workers.

The total will be 1,824 men inclusive of 218 officers and 1,606 wage workers during the main production period. The average number will be 1,689 for a period of 30 years.

Organization for this project is planned on the basis of prevailing system of coal mines in Japan and Pakistan. The new and special sections of safety, training and system which are not organized in Pakistani coal mine will be added.

Productivity has been calculated at 1.3 t/man/shift in underground mine, 7.8 t/man/shift in open pit, and 2.3 t/man/shift in overall mine.

9) Capital Costs

The capital costs in this study are based on June 1980 values. The total capital costs calculated for this study amount to Rs. 2,522,000,000 inclusive of interest during construction for the first three years of the project. The total capital costs are composed of direct costs and indirect costs.

The direct costs have been estimated at 1,555 million Rupees inclusive of 1,290 million Rupees for mine development, 191 million Rupees for railway construction, and 74 million Rupees for a 4% contingency to direct costs.

The indirect costs have been estimated at 591 million Rupees, inclusive of 425 million Rupees, for import duty of 40% on C & F price of equipment, materials and supplies, 77 million Rupees for engineering fees of 5% to direct costs, and 62 million Rupees for administration cost of 4% to direct costs. Interest during construction is calculated at 376 million Rupees.

The total currency will be divided into 1,245 million Rupees for the foreign currency portion and 1,277 million Rupees for the local currency portion. Escalation has not been included.

The capital costs include the following:

Production facilities –

- o site work, and construction cost of road, factory buildings and preparation plant.
- o mechanical and electrical equipment purchased and installation costs applicable to the mine operation.
- o machines and materials for mine development and installation cost applicable to the mine operation.
- o maintenance and power cost during the initial 36 months of the project.
- o all miscellaneous costs during the initial 36 months of the project.

Ancillary facilities –

- o construction cost of office buildings and furniture etc.

Service & welfare facilities –

- o officer's salaries and worker's wages during the initial 36 months of the project.

Railway –

- o construction of tracks, and mechanical and electrical equipment purchased and installation cost.
- o loading and unloading facilities.

The capital cost for development of open pit will be calculated at maximum expenditure of 67% in total capital costs and secondly railway of 12%, inclusive of import duty but exclusive of contingencies.

10) Operating Costs

The operating costs have been calculated as follows:

- Depreciation cost calculated at the average 30 years life of equipment and installation cost with the consideration of residual value of 10%.

- Interest is based on 12.5% for local currency and 8.75% for foreign currency. Interest for local currency will be paid for 5 years, and for foreign currency will be paid for 10 years according to repayment schedule. All these calculations are based on PC-1 Form submitted by PMDC.

- Salaries and Wages are based one PMDC PC-1 Form and escalation is added to the 1976 base cost.

- Power costs calculated at Ps. 49 per kWH based on WAPDA's Tariff C-3 for bulk supply at 33 kV.

- Replacement and improvement costs of equipment calculated on the basis of life of machine.

- Materials and supplies include explosives, mine timbers, oils, fuel oils, cables, etc.

- Maintenance cost calculated maintenance costs of equipment and buildings. The maintenance costs of machine are estimated at less than 10% of machine to be used.

- Administration costs are estimated at 3 Rs/t for outside service, management fee of head office, travelling fee, etc.

- A wage personnel absenteeism rate of 20% has been used in the study. Equivalent additional wage workers will have to be employed to counteract the effect of this absenteeism rate, in order to ensure that all the jobs are manned in underground workers.

- Freight charge will be estimated at 17 Rs/t inclusive of 5 Rs/t in existing freight charge.

- Coal preparation costs calculated for 7 Rs/t.

ESTIMATED CAPITAL COST

(In Million Rapees)

Description	Foreign Currency	Local Currency	Total
Production Facilities	1,022	221	1,243
Ancillary Facilities	3	20	23
Service, Welfare Facilities	–	24	24
Sub-Total	1,025	265	1,290
Railway Facilities	106	85	191
Contingency	56	18	74
Sub-Total	162	103	265
Direct Cost Total	1,187	368	1,555
Import Duty	–	452	452
Engineering Fee	58	19	77
Administration Cost	–	62	62
Indirect Cost Total	58	533	591
Total	1,245	901	2,146
Interest During Construction F.C.	–	188	376
Interest During Construction L.C.	–	188	
Grand Total	1,245	1,277	2,522

Freight, taxes and duty included.
The estimates reflect June 1980 values.
No escalation.

ESTIMATED CAPITAL COST BY FACILITIES

(In Million Rupees)

Description	Foreign Currency	Local Currency	Total	%
Underground Mine	85	49	134	7
Open Pit	803	493	1,296	67
Surface Facilities	71	80	151	8
Preparation Plant	66	52	118	6
Sub-Total	1,025	674	1,699	88
Railway	106	128	234	12
Grand Total	1,131	802	1,933	100

Freight, taxes and duty included.
Contingency in direct cost not included.
The estimates reflect June 1980 values.
No escalation.

ESTIMATED OPERATING COST

(Rupees per clean tonne)

Description	Foreign Currency	Local Currency	Total
Salaries	–	9	9
Wages	–	3	3
Power	–	5	5
Replacement and Improvement	46	20	66
Materials and Supplies	45	91	136
Maintenance	28	14	42
Administration	–	3	3
Sub-Total	119	145	264
Depreciation	–	32	32
Amortization	–	27	27
Interest	–	36	36
Mine Total	119	240	359
Freight	2	15	17
Depreciation	–	3	3
Amortization	–	2	2
Interest	–	4	4
Railway Total	2	24	26
Deduction	–	Δ4	Δ4
Grand-Total	121	260	381
Underground Mine	8	21	29
Open Pit	108	111	219
Preparation Plant	1	6	7
Surface	2	7	9
Total	119	145	264

The estimate reflect June 1980 values.
No escalation.

2.1.4 Coal-fired Power Station Study

(1) Electric Power Demand Forecast and Electric Power Development Scheme

1) Electric Power Demand Forecast

In making a long-range forecast for the future with the past record of electric power demand as the background, the JICA Survey Team adopted two approaches. One was a technique of analysis by category whereby a forecast is made based on the past records of customers by category and the estimations of future population increase and electrification. The other is a comprehensive, statistical technique where a forecast is made using a performance statistics model of electric power demand and a gross national product model, with the purpose of augmenting the result obtained by the former category-by-category analysis technique. In making a prediction of the annual maximum power demand from the annual energy consumptions obtained by the above-mentioned techniques, the two hypotheses below were set up.

a) The overall transmission and distribution losses

Date	June 1980	June 1984	June 1990
Loss	31%	27%	25%

b) The annual load factor is estimated under the following equation

$$Alf = 62.96 - 0.558x$$

Alf: Annual load factor

x: Number of years on the assumption of zero at the end of June 1980

Accordingly, the annual maximum power demand and annual average growth rate for the period 1980–1990 with were forecast by the JICA Survey Team, based on the above energy consumptions, transmission and distribution losses and annual load factors in comparison with the studies made by WAPDA are as shown below.

Calendar Year	Method by JICA Survey Team (A) (MW)	WAPDA (B) (MW)	(B) / (A)
1980	2,443	2,421	0.991
1985	3,808	3,841	1.009
1990	5,842	5,775	0.989
Growth Rate (% per annum)			
1980 to 85	9.3	9.7	
1980 to 90	8.9	8.5	

As seen from the above, there is hardly difference in the figures of the maximum power demand between the JICA Survey Team and WAPDA. Accordingly, the figure of the maximum power demand forecast by WAPDA is to be adopted in this Report.

It is planned for the KESC System to be merged with the WAPDA System in July 1984. The maximum power demand figures and the annual average growth rate for the KESC System are forecast to be 789 MW – 1,353 MW (1984–1990) and 9.4%, respectively, and the maximum power demand and annual average growth rate of the WAPDA System after absorption of the KESC System will be 4,183 MW – 6,920 MW (1984–1990) and 8.8%, respectively.

2) Electric Power Development Scheme

The existing installed capacity of the WAPDA System was 2,685 MW as of July 1980, of which hydro power generating facilities comprised 1,567 MW or approximately 60%, while thermal power generating facilities comprised 1,118 MW or approximately 40%. However, the total effective installed capacity is reduced approximately 5% due to generating facilities which have become anticipated to be about 2,553 MW.

The electric power system of WAPDA is geographically divided into four power markets, with a feature being that the hydro generating facilities making up approximately 60% of the supply capability exist one-sidedly in the Northern power market in the north with the remaining 40% comprising thermal generating facilities existing in the three other power markets. Further, the hydro supply capability is influenced not only by the seasonal variations in river runoffs, but also to a great extent by operation of irrigation water facilities since water resources are used with priority for irrigation, so that there is also a feature of seasonal variations being severe.

The 4 power markets presently interconnected by 132 kV transmission lines and partially by 220 kV transmission lines together with KESC-owned power system are to be interconnected by 220 kV and 500 kV transmission lines in the future.

It will be possible to interchange power effectively between the North and South through strengthening these transmission line networks. The development programs prepared by WAPDA indicate that the incremental capacity of hydro power stations including Tarbela, Mangla and Warsak will be 3,010 MW in total in the 1980's. In addition, if 300 MW of Lakhra Coal-fired Thermal Power Station is developed, the total installed capacity of WAPDA-owned thermal power station is scheduled to reach 2,495 MW.

The demand and supply balance considered from the generating capability of the WAPDA Electric Power System, the maximum demand and the maximum unit capacity will be as described below.

The capability margin will be 30% to 60% in the high-water season (in September) and 7 to 9% in the low-water season (in May) except for the years of 1987 and 1988. The supply capability is below the maximum demand in the low-water season during the period from 1980 to 1985.

The power installed capacity of the system is relatively bigger, compared with the maximum demand. In spite of this fact, there will be serious shortage of power in the low-water season. The ratio of the size of the largest unit in the system to the maximum demand within the sphere of the system is 6 to 8%. The margin capability corresponding to more than 15% of the maximum demand would be required in consideration of possible stopping of the capacity of two biggest units.

(2) Electric Power System

1) Method of Power Transmission of Lakhra Coal-fired Thermal Power Station

There will be two methods of transmission of power from the Lakhra Coal-fired Thermal Power Station through 132 kV and 220 kV transmission lines.

The economic comparisons of construction costs of transmission lines of the two voltages have proved that the former will be more economical than the latter. Accordingly, it is considered advisable that power from the above-mentioned power station be transmitted to 500 kV Jamshoro Substation adjacent to Lakhra Coal-fired Thermal Power Station.

2) System Analysis

With the peak load hours in the low water season in 1987 when Lakhra Coal-fired Thermal

Power Station with a capacity of 300 MW is to be commissioned as the times for studies, the power flows and stability of the WAPDA System were examined.

a) Power Flow

Electric power on 500 kV transmission lines will flow from Multan and Guddu Thermal Power Stations in the central part of Pakistan to the North and South of the country. Since the power flow will be relatively light, there will be a tendency for the 500 kV bus voltages of the various 500 kV substation to rise.

It will be necessary that the capacity of 220/132 kV transformers at 500 kV Jamshoro Substation and the 132 kV transmission lines to connect the existing 500 kV Substation with 132 kV Jamshoro Grid Station be designed so as to adequately meet power demands to arise in Hyderabad area.

b) Stability

As a result of transient stability calculations, it has proved that the power system will be unstable and will hardly discharge its functions should three-phase ground faulting take place at the end closest to Jamshoro of the 500 kV transmission lines between Dadu and Jamshoro.

However, in the event that the 500 kV transmission lines should be designed as double circuit lines, the system will be quite stable even if faults occur on one circuit of the 500 kV transmission lines.

(3) Location of Coal-fired Thermal Power Station

For selection of the location of the Coal-fired Thermal Power Station, studies were made based on conditions of location of candidate sites at Jamshoro, Khanot and Lakhra. It is judged that the Jamshoro site is the most promising as a result of overall comparison of the physical conditions, availability of condenser cooling water, transportation of fuel and materials, necessity for a transmission line, approximate construction cost, etc.

The outline of the 3 sites of Jamshoro, Khanot, and Lakhra are as described below.

1) Jamshoro Site

The greatest advantages of the Jamshoro site are that condenser cooling water can be taken from the River Indus throughout the year, and further, that if the Coal-fired Thermal Power Station is constructed adjacent to the 500-kV Jamshoro Substation, construction of a transmission line will not be necessary. Other than these, a pipeline for natural gas to be used as one of the supplementary fuels runs at a distance of 3.5 km from this site and this pipeline can readily be extended, while for transportation of materials and equipment for construction and maintenance, a railway and roads can be readily used. Further, the infrastructure for maintaining daily livelihood such as educational facilities, hospitals, government agencies, etc. is more or less complete. In comparisons of approximate construction costs also, Jamshoro is cheaper than the others.

The disadvantage of this site is that it is approximately 30 km distant from Lakhra Coal Mine and the coal hauling distance would be the longest and the transportation cost the highest. Also, there is concern about the effect on residents nearby due to air pollution from firing lignite of high sulfur content.

2) Khanot Site

The drawback of the Khanot site is that it will be difficult to select the intake site for condenser cooling water because of variations in the center line of the River Indus and it is impossible to secure a large quantity of cooling water throughout the year. Consequently, cooling towers will have to be adopted for the condenser cooling system, and this will result in increase in construction cost and reduction in plant thermal efficiency. It will be necessary for new construction of a 220 kV, 2 circuit lines of distance of approximately 35 km from the Coal-fired Thermal Power Station to the 500 kV Jamshoro Substation. In the comparison of the approximate construction costs also Khanot is costlier than the Jamshoro site. Other than these points, this site is approximately 18 km distant from Lakhra Coal Mine and since transportation of coal would be by the railway to be newly built the transportation costs would be high. Also, an infrastructure is practically non-existent at this site and it would be necessary for a colony to be constructed at an early date to build up the living environment.

The favorable conditions of this site are that for access and transportation of materials and equipment, a railway and a road from Karachi can be utilized, and also since there are practically no residents in the vicinity, considerations about air pollution will not be necessary,

3) Lakhra Site

Disadvantageous conditions of the Lakhra site are the same as for the Khanot site with regard to securing condenser cooling water, in addition to which water pump-up for a length of approximately 15 km and height of approximately 140 m will be needed to Lakhra. Regarding new construction of a transmission line, similarly to Khanot, a length of approximately 48 km, 220 kV, 2 circuit will be needed to the 500 kV Jamshoro Substation. The approximate construction cost will also be the highest. Other than the above, with respect to access and transportation of materials and equipment, they will be the same as for the Khanot site up to Khanot, while a road must be newly constructed from Khanot to Lakhra. The infrastructure is not complete as in the case of the Khanot site, and it will be necessary to build up a colony at an early date.

The greatest advantage of this site is that it is adjacent to Lakhra Coal Mine so that hauling of coal can be done directly by truck and the transportation cost will thus be the cheapest. Furthermore this site is a barren plateau with practically no residents, and it will not be necessary for special considerations to be given regarding air pollution.

(4) Power Station Scale and Unit Size

It is quite natural that the scale of Lakhra Coal-fired Thermal Power Station should be determined according to annual production of coal from the possible mine site at Lakhra. The study of mine development has proved that coal production of one million tonnes per annum will be possible on an air dried basis consecutively for 30 years. On the assumption that the annual production of coal is to reach one million tonnes as stated above, it is possible to determine the scale of this power station as 300 MW in consideration of annual plant factor and thermal efficiency, etc.

There are two alternatives such as employment of two units of 150 MW each and of a single unit of 300 MW. It is advisable to employ the alternative of adopting a single unit of 300 MW for the reasons listed below.

1) In case comparisons are made on capital costs of the alternative of 300 MW x 1 unit and that of 150 MX x 2 units, the former will be cheaper than the latter by around 10%, the former is also more advantageous in respect of operating costs in view of decrease in lignite consumption because of improvement of thermal efficiency. In other words, the alternative of employment of a single unit of 300 MW will provide scale-merit and is considered to be economically favorable.

2) According to WAPDA, Tarbela with a capacity of 406 MW x 5 units and Mid Country with a capacity of 400 MW will have already been commissioned in WAPDA System prior to the commissioning of 300 MW Lakhra Thermal Power Station.

(5) Outline of Facilities of Coal-fired Thermal Power Station

1)	Location	Jamshoro, District Dadu, Hyderabad Division, Sind Province
2)	Power Station Compound Area	397,000 m² (incl. space for extension, excl. ash disposal site)
	Colony Compound Area	378,000 m² (incl. space for extension)
	Total	775,000 m²
3)	Building Area	19,540 m²
4)	Installed Capacity	300 MW (300 MW x 1 unit)
5)	Equipment Outline	

(a) Boiler

Type	Single drum, natural circulation, outdoor type (Burner, coal bunker will be covered.)
Evaporation	980 t/hr (at max. continuous rating)
Steam Conditions	173 kg/cm²g x 541°C (at superheater outlet)
	36 kg/cm²g x 541°C (at reheater outlet)
Fuel	Lignite

(b) Turbine

Type	Tandem compound, two-cylinder, double-flow reheat turbine

Rated Output	300,000 kW
Steam Condition	169 kg/cm^2 g x 538°C (at main stop valve inlet)
Speed	3,000 rpm
Number of Extractions	7
Vacuum	700 mmHg

(c) Generator

Type	Horizontal, rotating field, closed hydrogen-cooled, explosion-proof type
Rated Capacity	353,000 kVA (at rated hydrogen pressure 3.2 kg/cm^2 g)
Power Factor	0.85 (lagging)
Voltage	18 kV
Current	11,323 A

(d) Main Transformer

Type	3-phase, forced-oil, forced-air-cooled, outdoor type
Rated Capacity	333,000 kVA
Primary Voltage	18 kV
Secondary Voltage	132 kV ± 10%

6) Countermeasures against Corrosion of Boiler due to Combustion of Lignite with High Sulfur Contents

SO_3 contained in flue gas produces sulfuric acid at a temperature of dew point thereby corroding metals in which the said sufluric acid is made. Accordingly, the following measures should be taken.

(a) Countermeasures against Corrosion of Air Preheater

a) The temperature of gas at an exit of the air preheater should be kept at a temperature of 130°C so that the temperature of metals of air preheater can be maintained at a temperature of more than 85°C.

b) It should be arranged that the air temperature at an entrance of air preheater can be risen up to 70°C by means of steam air preheater in winter and during low load hours.

c) The materials of low-temperatured elements should be of acid-proof ceramic.

(b) Flue Gas Duct

The materials of flue gas duct is to be completely kept warm by wrapping the said duct by means of insulators lest the temperature of flue gas should fall.

(c) Stack

Inner lining materials are to be of acid-proof bricks.

(d) Countermeasures against Closure of Air Preheater Elements

a) Closure of air preheater elements is to be prevented beforehand by rise in the temperature and drying of elements, providing bypass lines of cold air in the air preheater.

b) Closure of elements is to be prevented beforehand by means of removing ash, using steam type soots blower to be furnished with air preheater, in case ash should adhere to elements.

c) In case elements are closed, closure is to be removed by washing such elements with pressurized flush warm water.

(6) Possibility of Operation of Turbine-generator as Synchronous Condenser

It is considered technically possible for a turbine-generator to be operated as synchronous condenser within the limits of the generating capability curve.

When a turbine-generator is operated as synchronous condenser, it must be separated from a steam-turbine. Several ways of "start-up" are conceivable. The start-up system by means of a synchronous induction motor would be realistic among said ways since it is most economical and has been used for a turbine-generator of small capacity.

In the event that a turbine-generator should be manufactured so that operation of a synchronous condenser can be made within the limits of generating capability curve, incremental costs of auxiliary equipment and start-up apparatus could be estimated at around 73 million Rupees. While installation of a synchronous condenser with the same capacity as that of reactive power of generator and installation of static condenser and shunt reactor will cost approximately 130 million Rupees and 135 million Rupees, respectively. Accordingly, operation of a turbine-generator as synchronous condenser would be more economical.

As described above, there exist actual records of having used turbine-generators of small capacity as synchronous condenser in the past.

However, the proposed turbine-generator will have a capacity of 300 MW for the Project. Unfortunately, no actual records of having used such a big scaled turbine-generator as synchronous condenser have been observed. Therefore, it will be essential that WAPDA conduct careful and strict examinations prior to their finalization of employment of the turbine generator as synchronous condenser.

(7) Estimated Construction Costs

The construction costs of the coal-fired thermal power station have been calculated in the foreign and local currency portions, based on prices prevailing as of June 1980.

The contingency given in Item G of the following table was calculated to be 5% of the sub-total shown in Item F comprising Item A through E. Import Duty (Item I) quoted in the local currency portion has been estimated at 40% of C & F prices of materials. Equipment and supplies included in Item A through D of the table. The Engineering Fee shown in Item J has been estimated at 5% of the Total Direct Cost of Item H. The Administration Cost (Item K) corresponding to be 4% of the Total Direct Cost (Item H) in both currency portions has been assumed to be incurred in the local currency portion.

The amount of interest during construction given in N has been calculated at a rate of 8.75% per annum for the foreign currency portion and at a rate of 12.5% for the local currency portion, respectively.

Thus, the construction costs have been calculated to be 6,225 million Rupees in total. Of this amount, 2,673 million Rupees correspond to the amount of costs to be incurred in the foreign currency portion while 3,552 million Rupees are estimated to be incurred in the local currency portion. However, escalation in prices due to inflation is not considered.

Estimated Construction Costs of Coal-fired
Thermal Power Station

(In Million Rupees)

Item \ Category	Construction costs: Foreign Currency	Construction costs: Local Currency	Construction costs: Total
A. Equipment	1,727	–	1,727
B. Civil work	295	300	595
C. Building work	144	266	410
D. F.G.D. plant	109	84	193
E. Installation	130	415	545
F. Sub-total	2,405	1,065	3,470
G. Contingency	121	53	174
H. Total direct cost	2,526	1,118	3,644
I. Import duty	–	905	905
J. Engineering Fee	147	35	182
K. Administration cost	–	146	146
L. Total indirect cost	147	1,086	1,233
M. Total	2,673	2,204	4,877
N. Interest during construction F.C.	–	620	1,348
construction L.C.	–	728	
O. Total construction cost	2,673	3,552	6,225

(8) Considerations Regarding Environmental Problem

1) Air Pollution Countermeasures

Substances influencing air pollution produced as a result of firing the lignite at the Coal-fired Thermal Power Station will mainly be soot and dust, and sulfur oxides.

a) Soot and Dust Countermeasure

The ash content of the lignite is approximately 24% and relatively high, and approximately 80% of ash produced in combustion of the lignite will be scattered in the atmosphere as fine-particled fly ash to contribute to air pollution. As the measure to prevent this, high-efficiency electrostatic precipitators are to be installed to collect the fly ash. Further, since the apparent electric resistance of the ash is high, duct collection is to be efficiently maintained by means of increasing in the capacity of EP (electric precipitator) and of selection of dischrage terminals to obtain effective corona current and through strengthening of capability.

b) Smoke and Soot Countermeasure

In the Islamic Republic of Pakistan, environmental standards desirable to be maintained to protect the health of people and secure the living environment have not been established. However, since the sulfur content of the lignite is of a comparatively high value at approximately 7%, it is expected that the concentration of sulfuric oxides in flue gas will be high. As a countermeasure, a concentration of sulfuric oxide is to be maintained at less than 0.14 ppm as set forth in U.S. Federal by treating half of flue gas at a desulfurization plant (under the Limestone/Gypsum Recovery Process Method) from the economical standpoints.

2) Drainage Countermeasures

Oil separation, settling and filtering and neutralization treatment will be provided drainage to be discharged from the Coal-fired Thermal Power Station according to the properties of the waste water so that the environment will not be affected.

a) Domestic Waste Water

Waste water from privies are to be conducted to septic tanks for purification, while drainage from hot water supply rooms is to be subjected to filtering and settling treatment after which it is to be discharged.

b) Waste Water from Apparatus

Waste water from water treatment apparatus and the chemical analysis laboratory is to be conducted to a waste water neutralizing tank where it is to be neutralized and then discharged. Washing water from electrostatic dust precipitators, electric preheaters and chimneys, and waste water from chemical cleaning of boilers will be produced irregularly and are to be subjected to neutralization treatment at a temporary pond and then discharged into the ash disposal lot. Drainage from around the coal yard is to be settled and filtered, and then discharged.

c) Waste Water with Oil Content

Waste water containing oil such as drainage from bulldozer garage and drains from various equipment are to be subjected to oil separation and then discharged.

(9) Construction Schedule of Coal-fired Thermal Power Station

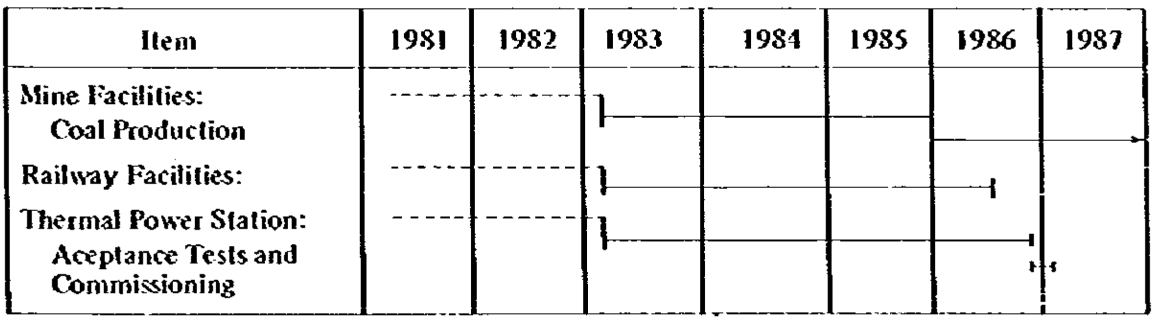
It was estimated various schedules prior to the start of construction such as investigation work necessary for definite design, preparation of bid documents, bidding, award of contract, etc. would require approximately 24 months. The subsequent construction schedule including design and manufacture of equipment to be done by the contractor, transportation, civil and building construction, installation and erection of equipment and facilities, acceptance tests, etc. was set taking into account the annual coal production projected for Lakhra Coal Mine. As a result, it was considered that construction of the 300 MW coal-fired thermal power station would require approximately 47 months. Accordingly, the total period of time for implementing construction of the coal-fired thermal power station will be 71 months comprising 24 months and 47 months.

In consideration of the above, the coal-fired thermal power station will be commissioned in March 1987.

2-1-5 Implementation Schedule

The period required for investigation works for the definite design including negotiations for arrangements for funds, definite design, preparation of bid documents, bidding, contract execution, etc., was set at 24 months at the strong request of the Pakistani authorities. As a result, the schedule to be carried out by the Contractor consisting of design and fabrication of materials and equipment, transportation, civil and building works, equipment installation, and trial operation will be 47 months for the thermal power station, and 39 months for the railway facilities. The start of commercial operation of the thermal power station is scheduled to be in March 1987, while completion of the railway facilities is scheduled to be at the end of June 1986. The coal mine facilities would be completed in 1985.

Implementation Schedule for Lakhra Coal Mining and Coal-fired Thermal Power Station Project



2-1-6 Estimated Construction Costs

Making computations based on prices as of June 1980 assuming contingency costs to be 5% of civil costs, building costs, equipment and installation costs, and administration costs and engineering fees as 4% and 5%, respectively, of direct construction costs, the construction costs without the amounts of interest during construction are estimated to be 2,146 million Rupees for coal mine and railway facilities, 4,877 million Rupees for the thermal power station, a total of 7,023 million Rupees (including 3,912 million Rupees for the foreign currency portion and 3,105 million Rupees for the local currency portion). However, the actual fund procurement must be done considering the commodity price escalation to occur hereafter.

Referring to the long-range forecast made by the World Bank regarding future construction costs, and considering the commodity price escalation performances and economic cooling-down trends in the future in Japan, the U.S.A., West Germany, France, etc., it is thought appropriate for commodity price escalation rates of about 7% per annum for the foreign currency portion and about 9% per annum for the domestic currency portion to be assumed.

Based on the above-mentioned commodity price escalation rates, the construction costs without the amounts of interest during construction trial-calculated according to the prices as of the year of commissioning will be increased to 2,870 million Rupees for coal mine and railway facilities, and 7,088 million Rupees for the thermal power station, a total of 9,958 million Rupees (including a foreign currency portion of 5,333 million Rupees and a local currency portion of 4,625 million Rupees). When funds to cover these construction costs are procured under the conditions of interest rates of 8.75% for the foreign currency portion and 12.5% for the local currency portion, the total construction costs for the entire project will be 12,008 million Rupees (cosisting of 5,333 million Rupees for the foreign currency portion and 6,675 million Rupees for the local currency portion).

Estimated Construction Costs of Lakhra Coal Mining and Coal-fired Thermal Power Station Project

(In Million Rupees)

Item	Coal-fired Thermal Power Station	Coal Mine and Railway Facilities	Total
Costs as of June 1980			
Foreign currency portion	2,673	1,245	3,918
Local currency portion	2,204	901	3,105
Total	4,877	2,146	7,023
Costs of Anticipated Year of Project Completion			
Foreign currency portion	3,722	1,611	5,333
Local currency portion	3,366	1,259	4,625
Total	7,088	2,870	9,958
Total Construction Cost			
Foreign currency portion	3,722 (4,216)	1,611 (1,848)	5,333 (6,064)
Local currency portion	4,926 (4,432)	1,749 (1,512)	6,675 (5,944)
Total	8,648	3,360	12,008

2-1-7 Economic Analysis

The domestic energy resources of Pakistan are made up mostly of water power and natural gas, and at present, the thermal power stations use natural gas solely as fuel, but as a policy of the country, natural gas is to be preserved as long as possible in reserve, while with regard to its use, rather than burning it simply as a primary energy source, the emphasis is being shifted to utilization as a raw material for the gas-chemical industry (fertilizer industry, etc.) of higher added value. Meanwhile, should the present development scheme make progress, the natural gas consumption of the thermal power station group of WAPDA will reach approximately 2.6 billion m^3 at an average equipment utility factor of 40%. This would correspond to more than half the annual natural gas production at the present time. Consequently, it is thought that in the not too distant future a time will come when the domestic production of natural gas will become incapable of completely satisfying the requirement for fuel for electric power generation. In such case, the fuel cost of the power station will become the cost of the alternative fuel, or heavy oil. Therefore, Lakhra Coal-fired Thermal Power Station would need to have its economic nature evaluated by a comparison with an oil-fired thermal power station as the alternative.

As the method of economic analysis, the total costs of the Lakhra Coal Mining and Coal-fired Thermal Power Station Project (the entire construction costs of the power station, coal mine and railway facilities plus the operation and maintenance costs throughout the entire service lives) taking into consideration commodity price escalations and the total cost of the alternative oil-fired thermal power station are respectively converted to present values as of the beginning of the years when funds were first expended (1981), the two are compared and the economy of the Project is indicated in terms of the "benefit-cost ratio (B/C)."

Assuming the plant factors of the power stations to be 50 to 70%, the following conclusions would be obtained as results of analyses:

a) The oil-fired thermal power station will not be able to compete with the Lakhra Coal-fired Thermal Power Station Project unless the future escalation rate of heavy oil is held below 4.5–5.5% annually in case of a discount rate of 10% and 4.9–6.1% in case of a discount rate of 13%. Such low escalation rates cannot be expected in reality.

b) Even if it were to be tentatively assumed that the future rate of escalation in the price of heavy oil stops at a level of about 8% annually (the average escalation rate value of wholesale prices of manufactured goods in the principal industrial countries), the "benefit-cost ratio" of the Lakhra Coal Mining and Coal-fired Thermal Power Station Project will show high Benefit/Cost ratios of 1.39–1.62 in case of a discount rate of 10% and 1.24–1.45 in case of a discount rate of 13%.

c) In addition to the economically advantageous nature described above, it will be possible to conserve 380 to 530 million cubic meters of precious natural gas annually through implementation of this project.

2-1-8 Financial Analysis

Assuming interest rates to be 8.75% for the foreign currency portion and 12.5% for the local currency portion, the JICA Survey Team estimates the total construction costs including interest during construction to be 12,008 million Rupees of which 3,360 million Rupees will be for coal mine and railway facilities and 8,648 million Rupees for the thermal power station, and considering the periods of repayment to be 25 years for the foregin currency portion and 20 years for the local currency portion, the following conclusions may be drawn as results of analyses:

a) Regarding the Lakhra Coal Mine and coal transport railway components, the cost of supplying coal as of 1987/88 was computed to be 983 Rs/t (0.50 Rs/kWh), with subsequent price escalation rates being 4.7% annually during the first 20 years, 6.8% annually during the following 5 years, and 7.7% annually druing the final 5 years.

   When supplied at cost not including any profit in sales, the cumulative balance of the cash flow will show a deficit from the year 2003/4, but if the price were to be raised by 1.7% prior to this, the cash flow will not go into the red. The internal rate of return (ratio of sum of net profit and interest paid to the cumulative balance of working assets) in this case will be 11.9%.

b) Regarding the thermal power station utilizing the above-mentioned coal the supply cost per kWh as of 1987/88 is calculated to be Rs 1.44 (Rs 0.935 as of June 1980) at the sending end with subsequent escalation rates for successive 5-year periods being 1.6%, 2.0%, 2.6%, 3.4%, 5.6% and 7.3% annually to indicate gradual increases.

   The present unit electricity sales price of WAPDA is approximately 0.3 Rs/kWh, while the proportion of electric power income attributed to the power generation sector is considered to be 40% of income, so that in order for the electric power sector to pay for future development projects by itself, it will be necessary for large adjustments in the present electricity tariff to be made on a "cost basis" in the future.

2.2 Recommendations

(1) Preparation of Documents for Financial Arrangements

It is recommended that WAPDA make financial arrangements in haste for materialization of the Project. In this context, it will be necessary for WAPDA to make an approach through the Government of Pakistan to appropriate overseas financial source(s) to secure the necessary funds in the foreign currency portion.

It is also believed necessary for budgets to be compiled for appropriation of costs incurred in the local currency portion. A series of documents required for approaches to the authorities concerned and financing agencies at home and abroad shsould be prepared without any delay in order that a loan agreement can be concluded not later than October, 1981.

(2) Materialization of Project

It is suggested that WAPDA coordinate with PMDC and associated governmental agencies smoothly and effectively in the materialization of this Project in order that WAPDA and PMDC may fulfill their respective functions and fully utilize their valuable experience in development of power facilities and coal mines.

(3) Training of Personnel

Since WAPDA will go into the performance of definite studies, construction supervision, maintenance and operation, etc. of such a large-scaled project as the Lakhra Coal Mining and Coal-fired Thermal Power Station Project, it is recommended that WAPDA as the implementing agency of the said Project train personnel who will be engaged in the aforementioned work and related assignments in advance to fully meet the requirements of the Project.

(4) Investigation of Open Pit Mining Area

It is judged necessary that prior to overburden stripping, detailed surveys — together with drilling work be conducted by WAPDA on its own responsibility. In this context, it is recommended that WAPDA take prompt action for the performance of the said work. It should also be borne in mind that the first priority should be placed upon drilling of the western blocks of Lakhra Coal Mine.

(5) Measurements of Surface Moisture and Size Distribution of Coal

There still exist vague points to be clarified regarding surface moisture of raw coal from Lakhra Coal Mine. In this regard it is considered necessary that re-measurements be made as soon as possible.

(6) Geological Surveys and Preparation of Topographic Maps

It is recommended that in view of the urgency of the Project implementation, WAPDA undertake geological surveys on the proposed Project sites and prepare topographic maps thereof which will be needed for definite studies for the Project. It is advisable for WAPDA to take prompt action for this purpose.

STRUCTURE CONTOUR MAP. NO.1 SEAM (FLOOR)

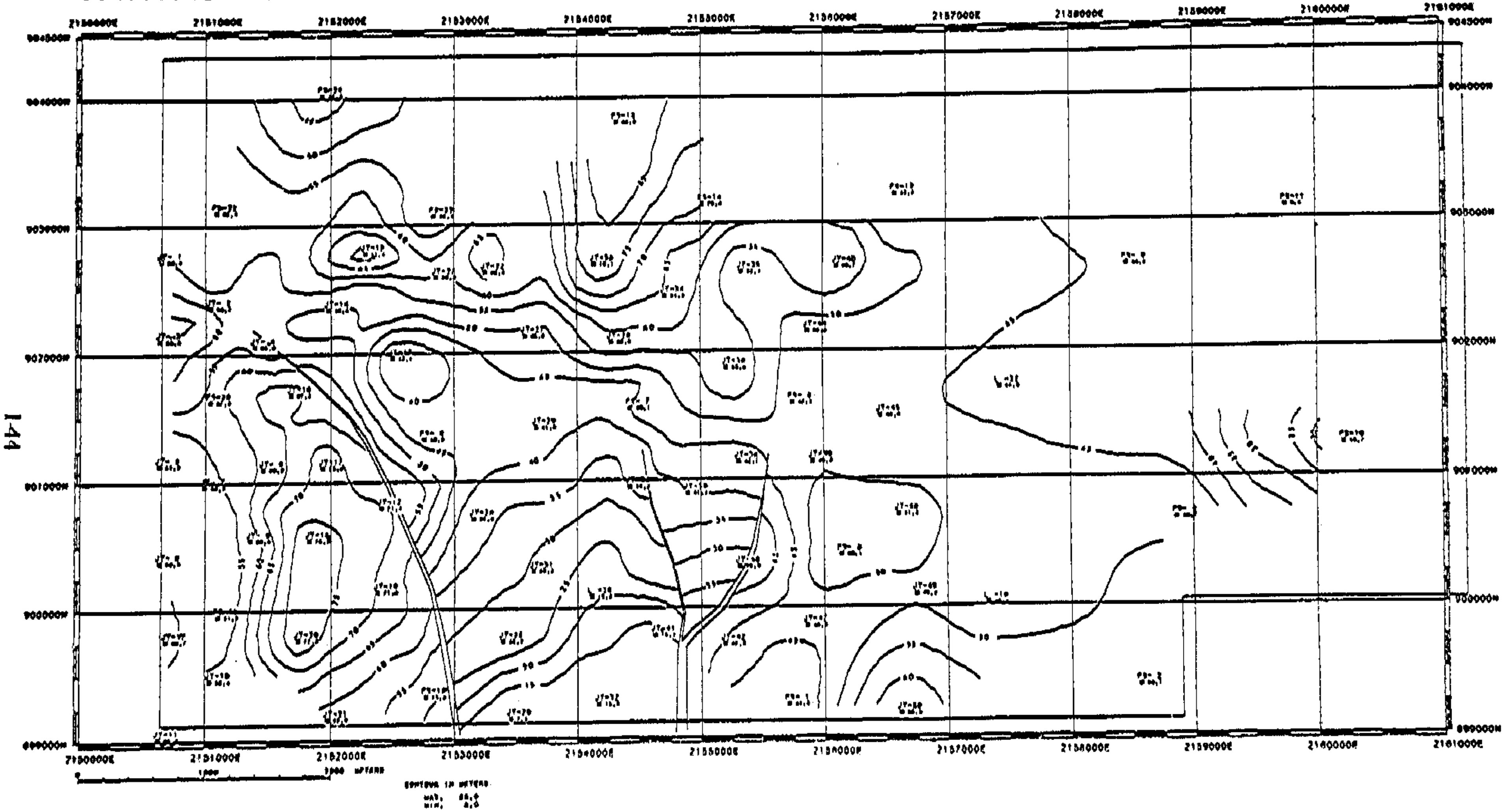


FIGURE 2-1 STRUCTURE CONTOUR MAP OF NO.1 COAL SEAM (FLOOR), THE LOWEST MINEABLE SEAM

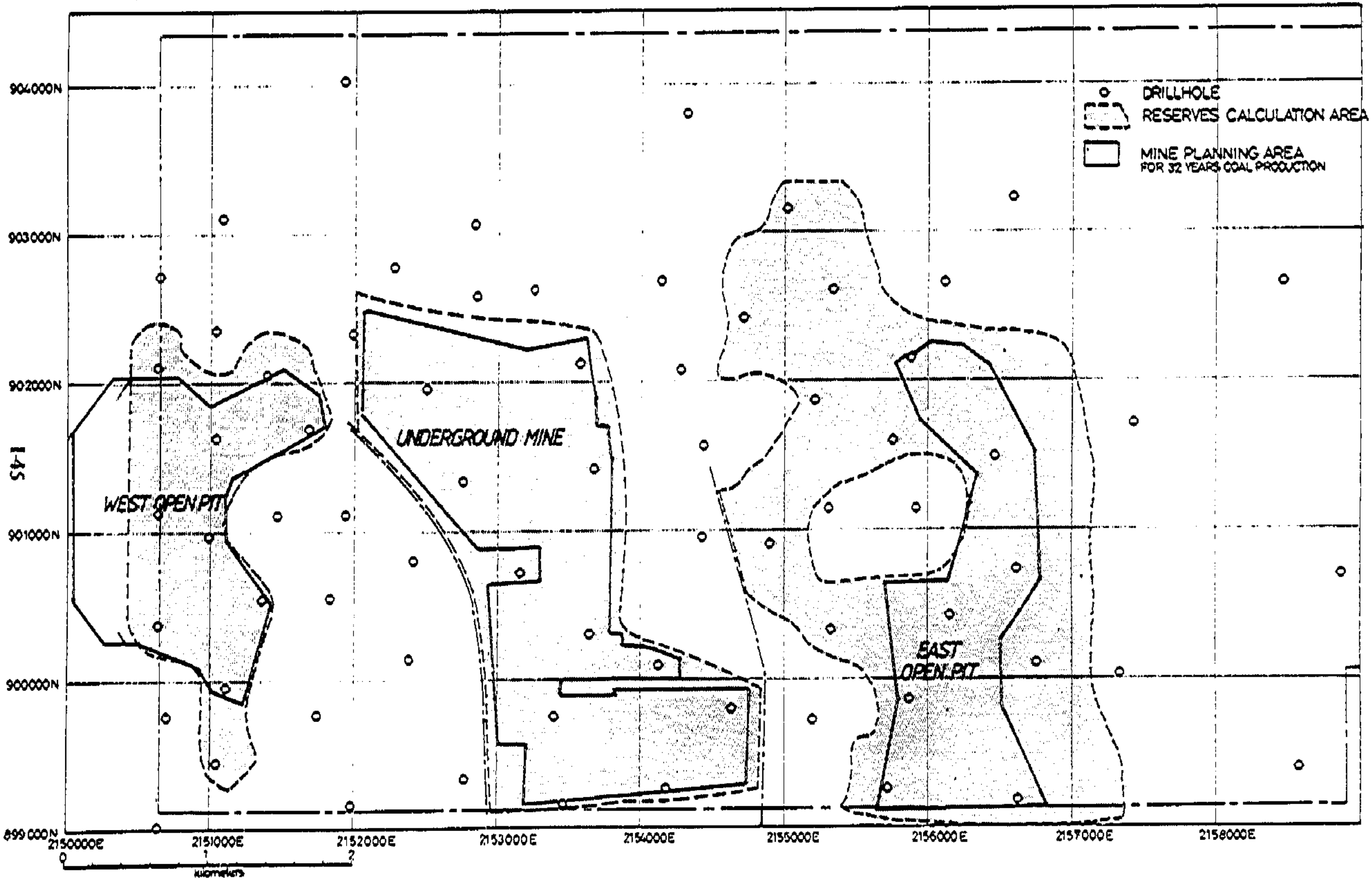


FIGURE 2-2 MINE PLANNING AREA

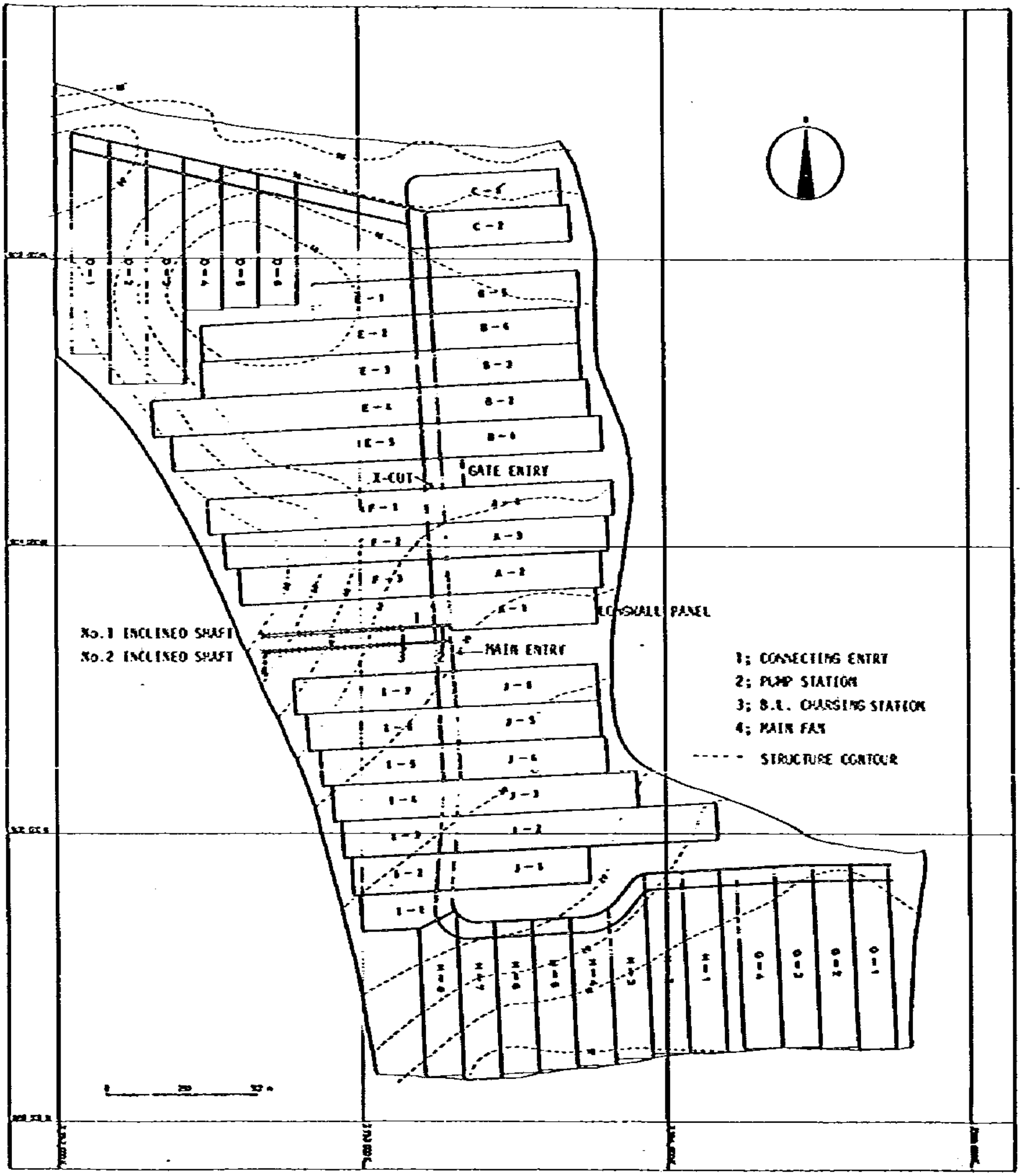


FIGURE 2-3 No.1 SEAM MINING LAYOUT

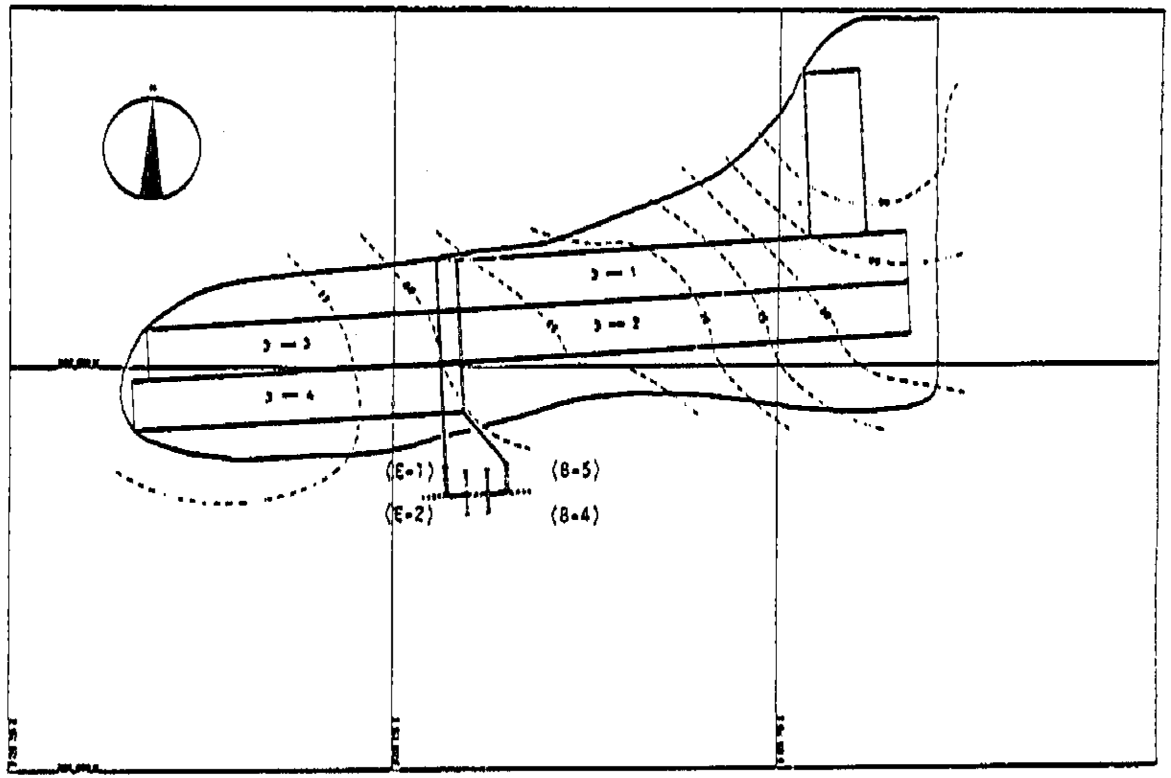


FIGURE 2 - 4 No. 3 SEAM MINING LAYOUT

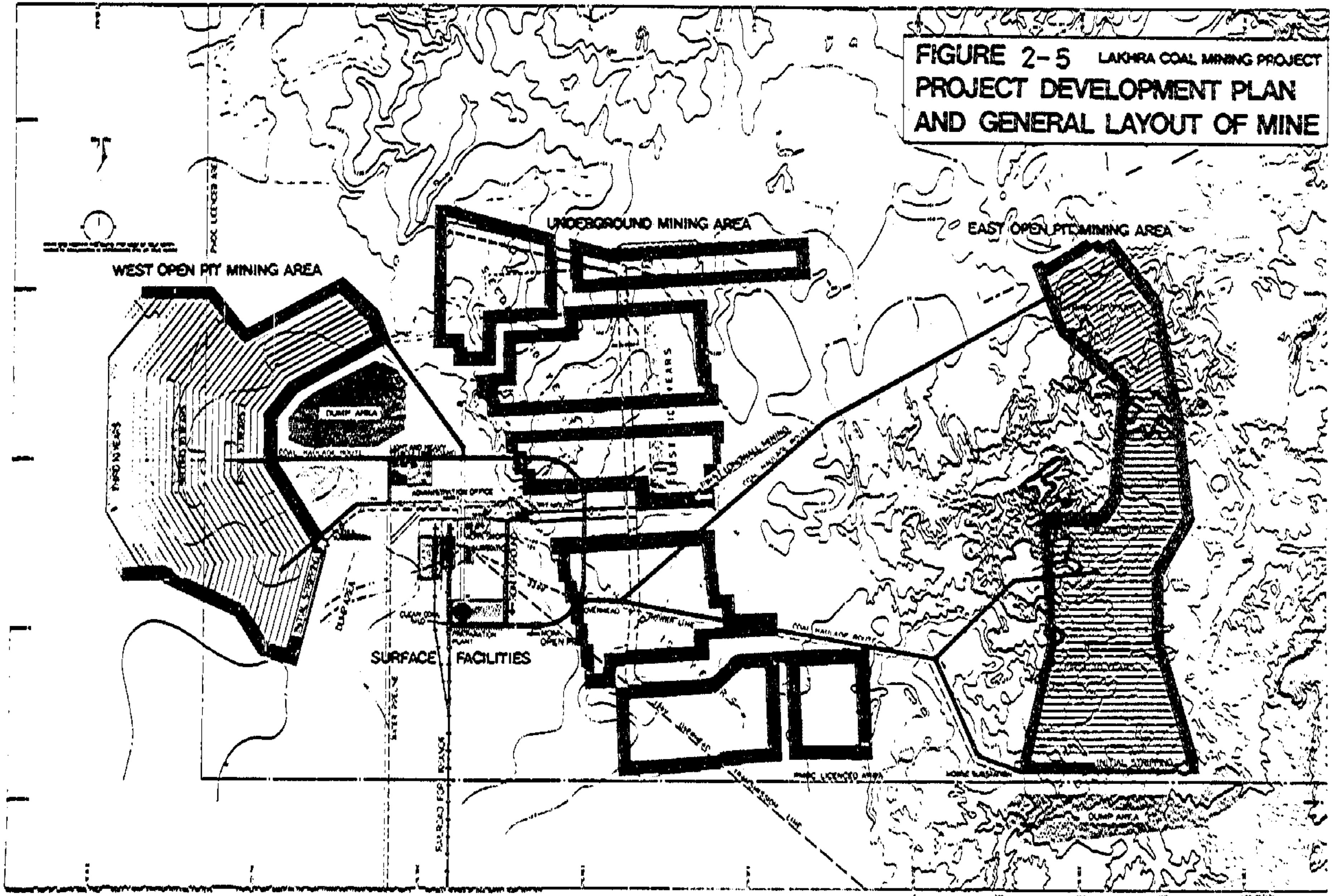


FIGURE 2-5 LAKHRA COAL MINING PROJECT
PROJECT DEVELOPMENT PLAN
AND GENERAL LAYOUT OF MINE
WEST OPEN PIT MINING AREA
UNDERGROUND MINING AREA
EAST OPEN PIT MINING AREA
SURFACE FACILITIES
DUMP AREA
ADMINISTRATION OFFICE
COAL HAULAGE ROUTE
POWER LINE
TRANSMISSION LINE
PMDC LICENCED AREA
INITIAL STRIPPING

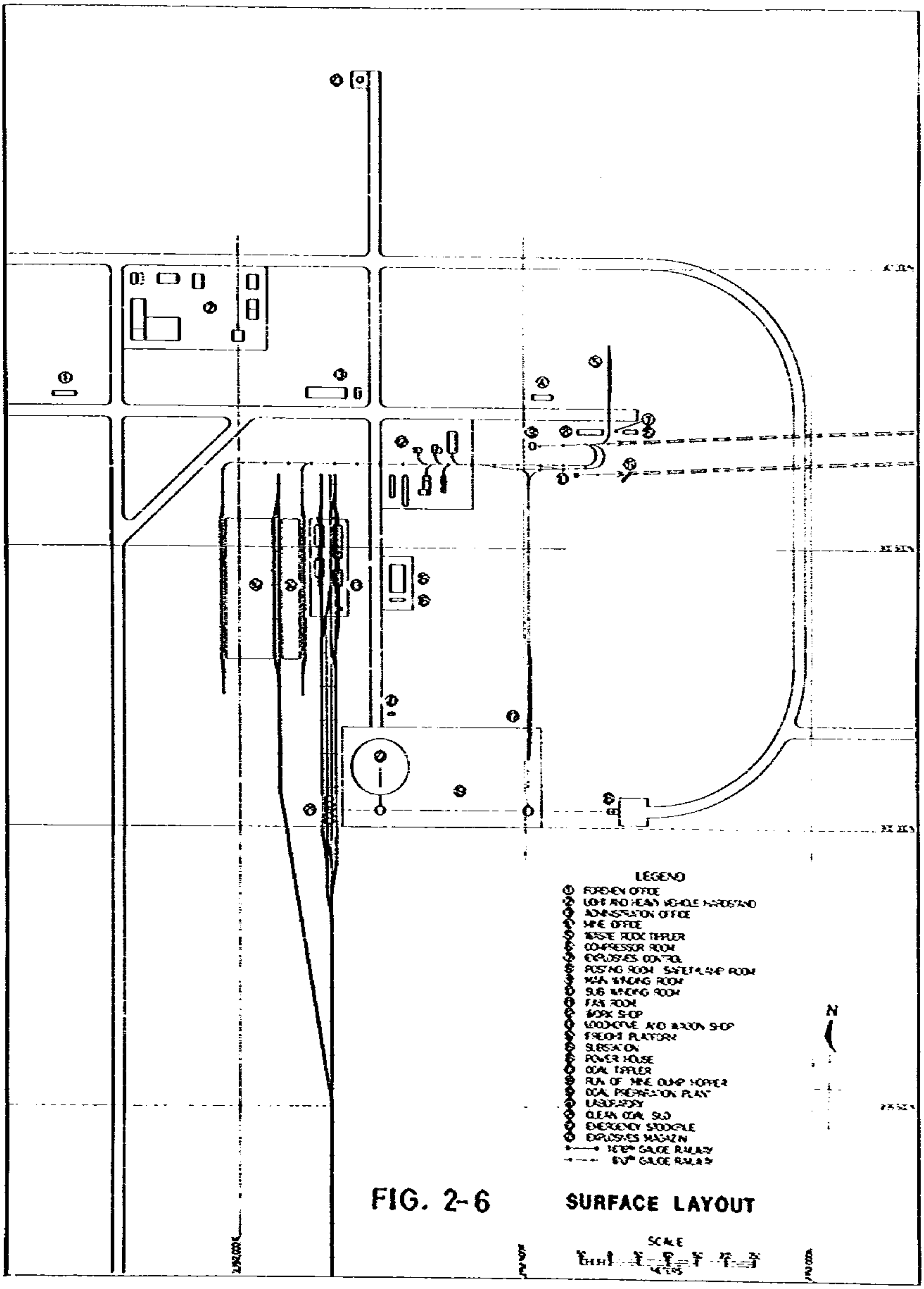


FIG. 2-6 SURFACE LAYOUT

Fig 2-7 GENERAL PLAN (300 MW)

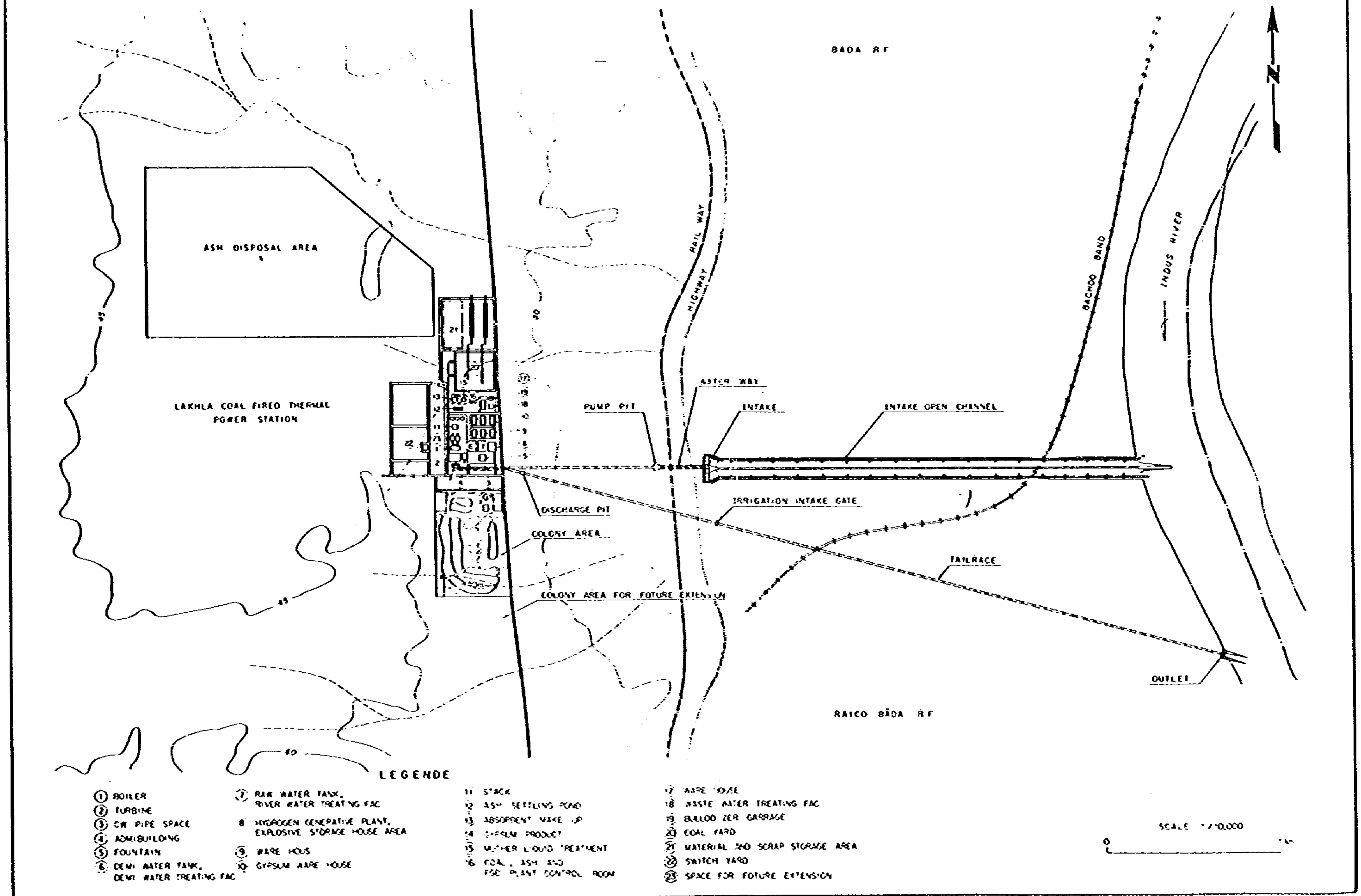


Fig. 2 - 8 LAYOUT OF LAKHRA COAL FIRED THERMAL POWER STATION (300 MW)

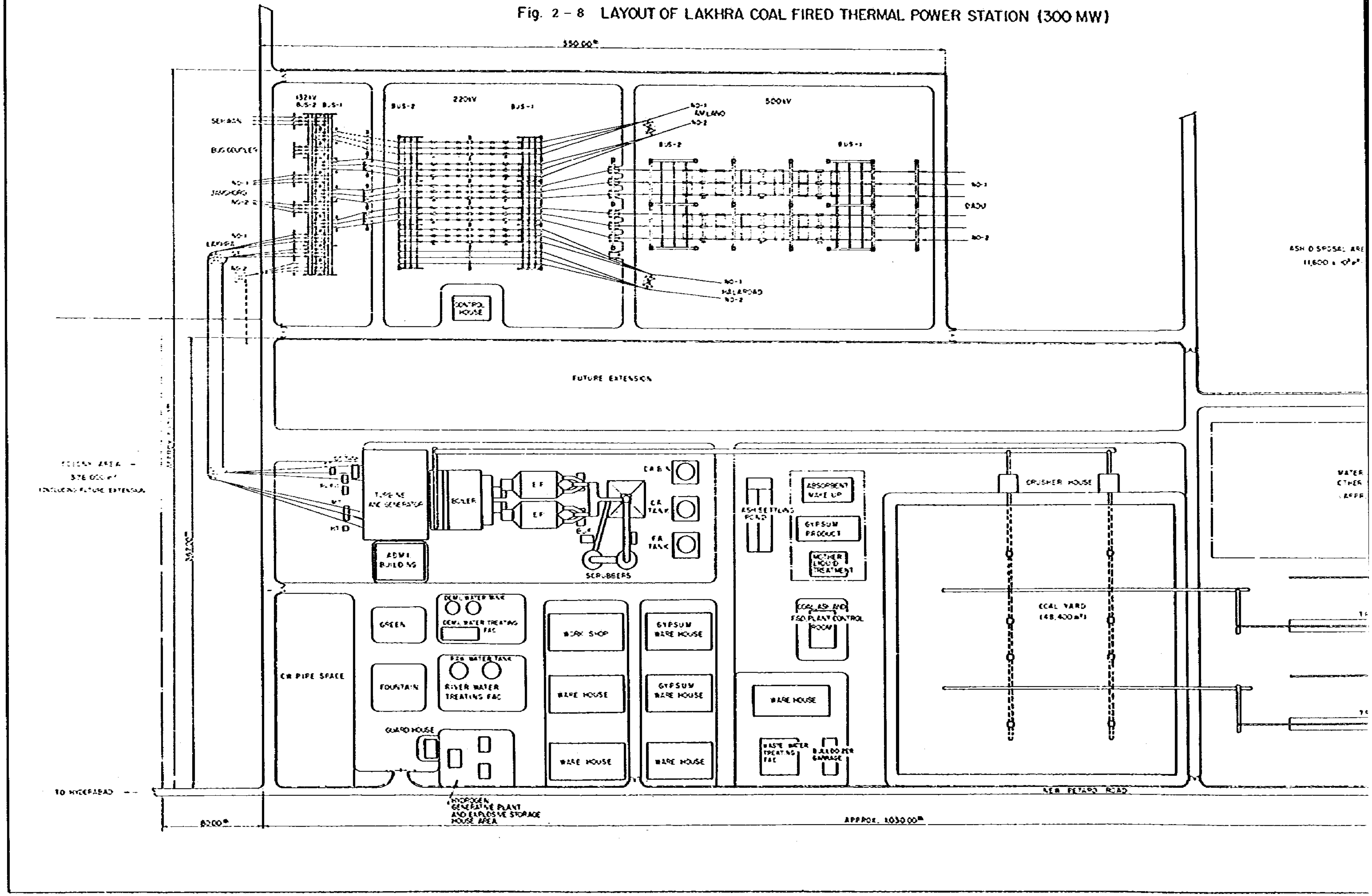
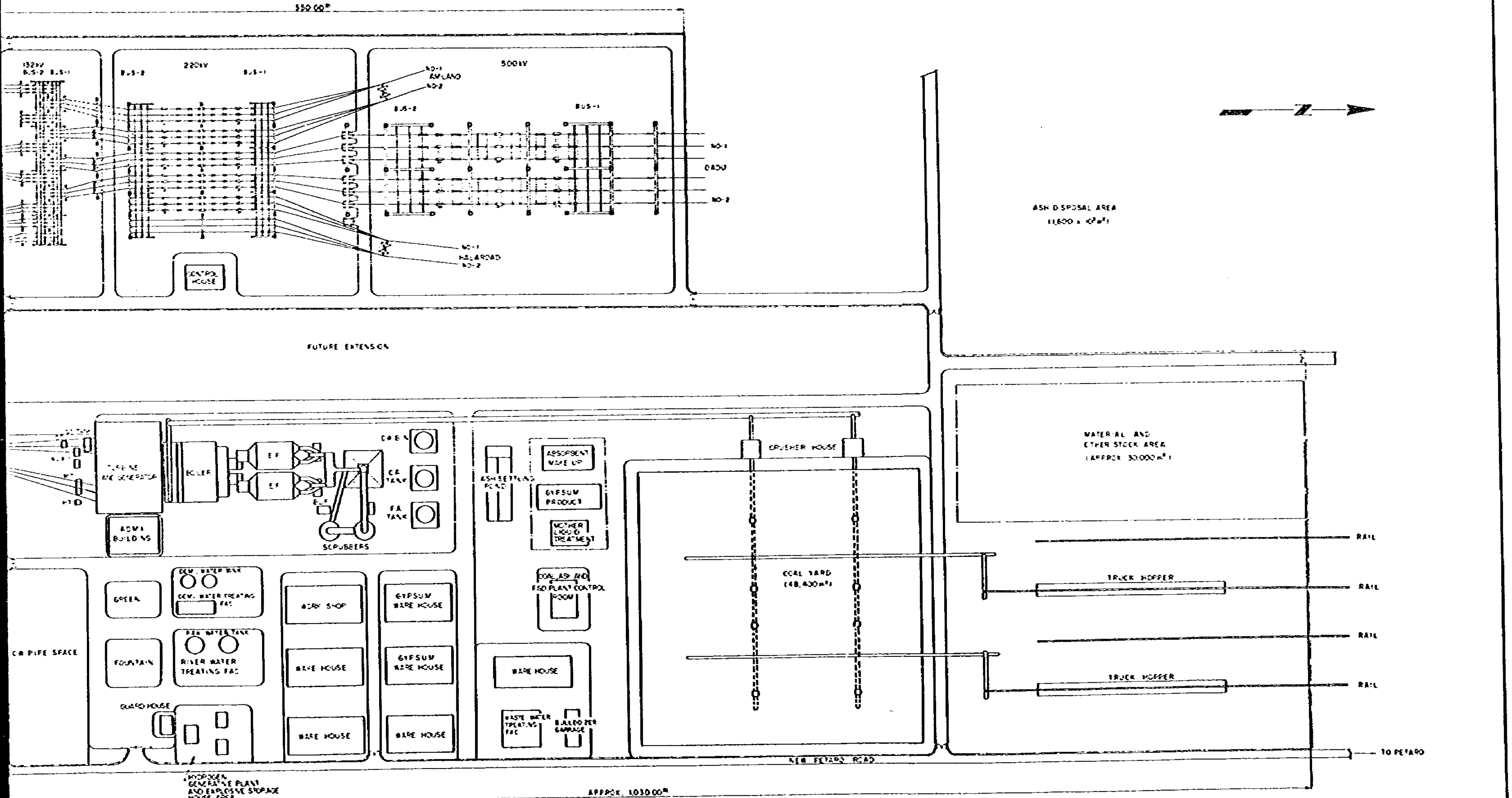


Fig. 2 - 8 LAYOUT OF LAKHRA COAL FIRED THERMAL POWER STATION (300 MW)



Implementation Schedule for Construction of Lakhra Coal Mine and Therm

	Description	Months
Major* Event	Preparation of Tender Documents & Issure	12.0
	Receipt and Evaluation of Bids	6.0
	Award of Contract	5.0
	Appointment of Consultants for Construction	4.0
	Opening of L/C for Construction	5.0
Coal Mine	Detailed Survey & Drilling	(27.0
	Preparatory Work	9.0
	Road & Railroad	48.0
	Preparation Plant	27.0
	Other Surface Facilities	33.0
	Underground Mine	27.0 12.0
	Open Pit	57.0
Power Station	Preparatory Work	9.0
	Water Intake & Discharge	29.0
	Building & Houses	30.0
	Equipment	19.0
	Coal Handling	19.0
	Genenrating Unit 300 MW	42.0
Consultancy Service		Years $5\frac{11}{12}$

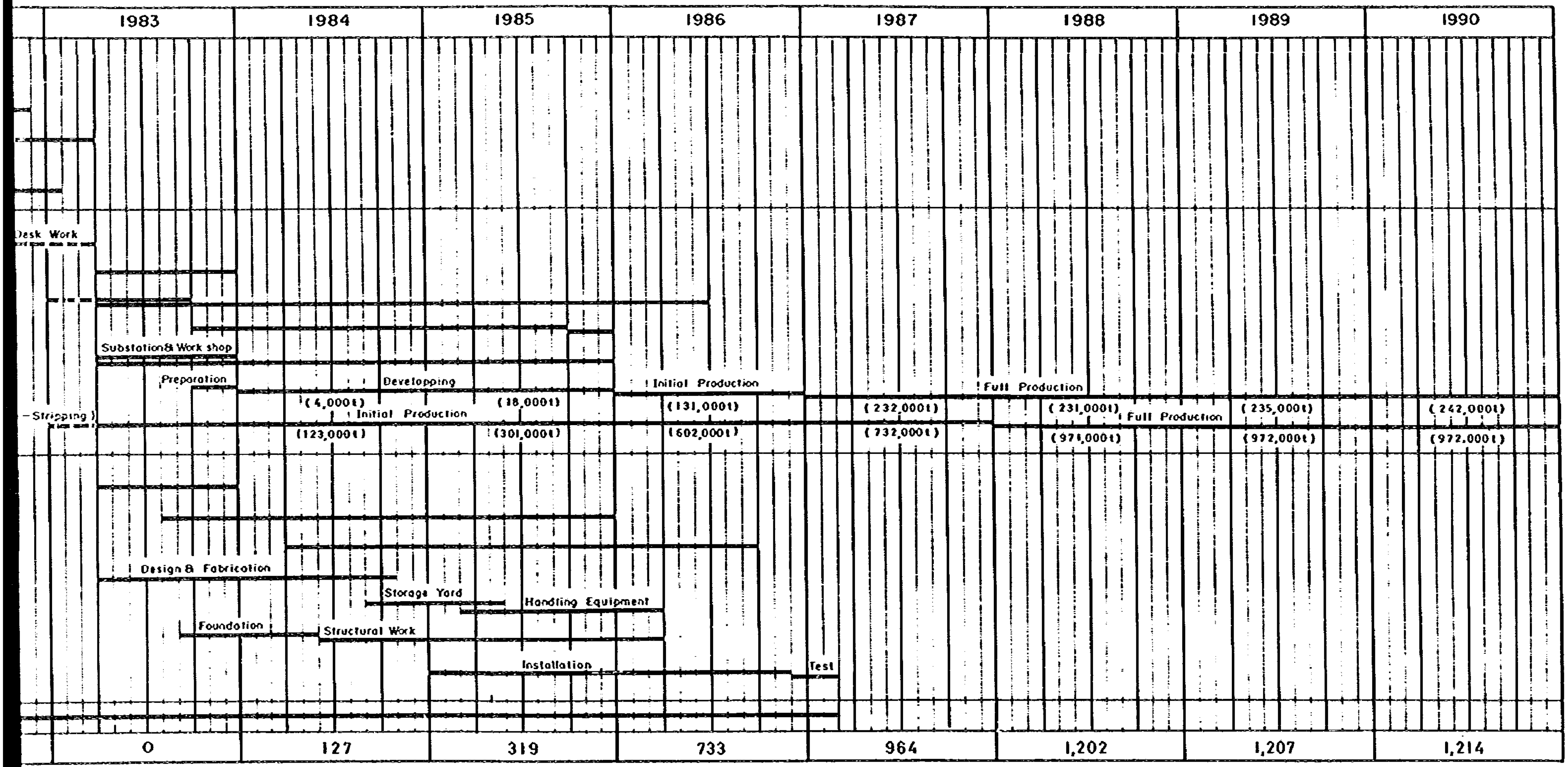
Detailed Survey & Drilling	Survey; Drilling; Desk Work
Other Surface Facilities	Substation & Work shop
Underground Mine	Preparation; Developping; (4,000t); (18,000t); Initial Production; (131,000t)
Open Pit	(Pre-Stripping); Initial Production; (123,000t); (301,000t); (602,000t)
Equipment	Design & Fabrication
Coal Handling	Storage Yard; Handling Equipment
Genenrating Unit 300 MW	Foundation; Structural Work; Installation

Year	1981	1982	1983	1984	1985	1986
Coal Production (As Received Base) '000 MT			0	127	319	733

* The pre-production schedule has been prepared in response to a request made by the Pakistani delegation at a meeting held in Tokyo in November, 1980.

FIGURE 2-9

dule for Construction of Lakhra Coal Mine and Thermal Power Station



SUMMARY OF RAW COAL RESERVES

(in metric ton)

Coal Reserves for Open Cut Mining

Unit x 10^3 Specific Gravity 1.5

STRIP RATIO	THE WEST		THE CENTRAL		THE EAST		TOTAL	
	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable
1:10 and less for the West	16,487	11,871					16,487	11,871
1:12 and less for the East					21,139	15,220	21,139	15,220
1:10 to 1:15 for the West, 1:12 to 1:15 for the East	4,660	3,355			23,212	16,713	27,872	20,062
1:17 and less for the Central			11,990	8,633			11,990	8,633
1:17 to 1:20 for the Central, 1:15 to 1:20 for the East			6,270	4,514	16,536	11,906	22,806	16,420
Total	21,147	15,226	18,260	13,147	60,887	43,839	100,294	72,212
Average Total Thickness	5.93		4.08		4.12		4.40	
Average Calorific Value	4550 (4950)* Kcal/Kg		4660 (5070)* Kcal/Kg		4760 (5350)* Kcal/Kg			
Average Total Sulphur	7.59 (8.25)* %		7.25 (7.86)* %		6.49 (7.17)* %			

Coal Reserves for Underground Mining

Unit x 10^3 Specific Gravity 1.45

	THE CENTRAL		THE EAST		TOTAL		SOUTHERN PART OF THE CENTRAL	
	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable
1.5 or more	10,728	4,881	11,424	5,197	22,152	10,078	4,712	2,145
1.5 to 1.0	2,340	1,065	3,445	1,568	5,785	2,633	2,067	930
1.0 to 0.75	1,216	553	368	168	1,584	721	158	72
0.75 to 0.50	199	90	80	37	279	127	58	26
Total	14,483	6,589	15,318	6,970	29,801	13,559	6,995	3,185
Average Calorific Value	4850 (5380)* Kcal/Kg		4930 (5570)* Kcal/Kg					
Average Total Sulphur	7.11 (7.83) %		6.35 (7.14) %					

Calorific Value and Total Sulphur: air dry basis
* ( ): dry basis

PART II GEOLOGICAL INVESTIGATION

PART II GEOLOGICAL INVESTIGATIOH

CHAPTER 1 CONCLUSIONS AND RECOMMENDATIONS

1-1 Summary of Work (Fig. 2, Table 1)

Geological survey team consisting of 13 members was deputed to Pakistan. The team stayed there from May 19th to December 5th, 1979 and carried out geological studies, executed 50 drill holes and undertook surveying.

Various arrangements had to be made after reaching the site, and drilling could be commenced from 27th, June by using 3 wire-line drilling machines brought from Japan. 50 drill-holes (Fig. 2, Table 1) with a composite depth of 5203.06 metres had been executed by November 22nd. Depth of holes ranged from 71.14 metres to 143. 25 metres with an average of 104.06meters.

Drilling had been conducted non-coring by using tricone bit through the limestone, and core drilling was extended to the coal measure by using NQ bit adopting wire-line method. Drilling cores were logged at the sites and columnar sections of lithologic units and coal seams, and cross-sections of lithologic units and coal seams, and cross-sections were prepared. Their section were used for preliminary correlation of coal seams and determining the geologic structure. Samples of all the coal seams and representative rock units were collected for analyses and tests in the laboratories in Japan.

Co-ordinates and heights of drill-holes had been determined and supplementary topographic survey undertaken.

After returning back, the team has remained pre-occupied with the works discussed below.

Arrangements for and drawing of columnar sections of lithologic units, coal seams and crosssections; correlation of coal seams, determination of stratigraphic succession and geologic structure, etc. Investigations have been carried out to fix the workable thicknesses of coal seams and stripping ratios. The coal samples have been subjected to proximate and ultimate analyses. Their calorific value, sulphur content, specific gravity, ash fusion temperature, ash components and Hardgrove grindability index have been determined. Float and sink tests, and spontaneous combustibility tests have also been undertaken. For rock samples, weight of the unit cubic volume (specific gravity), supersonic velocity, uniaxial compressive strength, tensile strength, coefficient of water absorption, effective porosity, stability test for aggregate and Poisson's ratio have been measured/determined.

Based on the data contour, maps of coal seams, iso-grade maps, iso-stripping ratio maps, iso-pach maps, etc., are drawn by computer, and both theoretical and recoverable coal reserves have been estimated.

Topographic base map has been revised by incorporating the supplementary survey data.

LOCALITY MAP OF DRILL HOLES

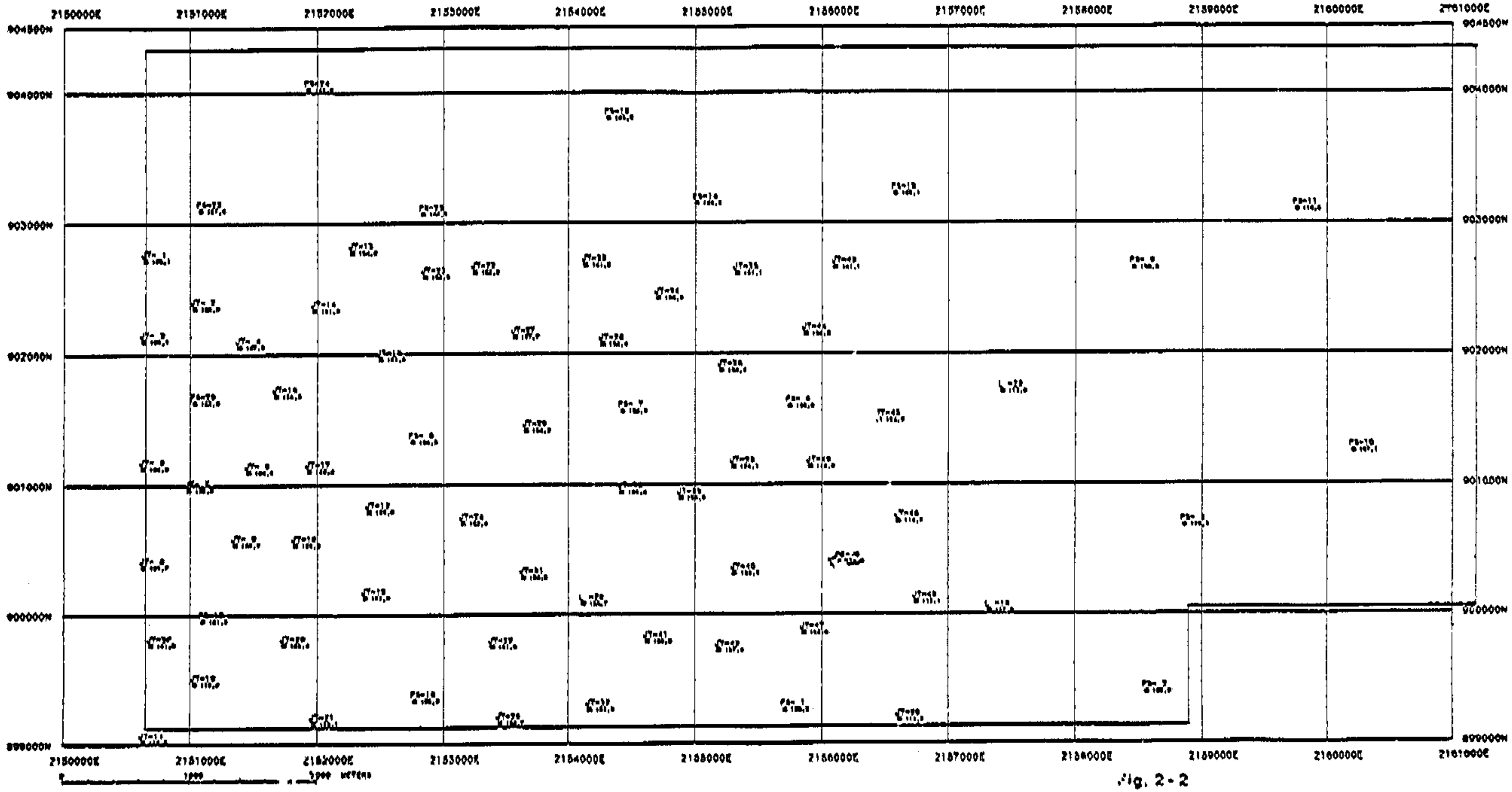


Fig. 2-2

Table 1-1

DATA LIST OF DRILL HOLES

DRILL HOLE NO.	GRID COORDINATES (m) Easting	Northing	HEIGHT (Reduced Level)(m)	DEPTH (m)	HEIGHTS OF DRILL HOLE BOTTOM (m)	BEGGINING OF CORING (m) Depth	Heights	CORE RECOVERY Drill Metres	Core Metres	Recovery (%)
JT- 1	2,150,648.000	902,726.000	+126.130	75.50	+50.63	6.20	+119.93	69.30	54.76	79.00
JT- 2	2,151,035.000	902,360.000	+126.609	90.40	+36.21	24.00	+102.61	66.40	56.43	85.00
JT- 3	2,150,634.000	902,108.000	+126.085	90.80	+35.29	18.00	+108.09	72.80	60.32	82.90
JT- 4	2,151,387.000	902,060.000	+127.280	83.15	+44.13	25.00	+102.28	58.15	48.62	83.60
JT- 5	2,150,632.172	901,136.937	+124.280	83.15	+41.13	33.10	+ 91.18	50.05	45.69	91.30
JT- 6	2,151,459.000	901,305.000	+124.207	101.00	+23.21	16.61	+107.60	84.50	55.30	65.40
JT- 7	2,150,990.000	900,970.000	+123.520	80.25	+43.27	19.50	+104.02	60.75	56.88	93.60
JT- 8	2,150,635.000	900,380.000	+121.680	74.10	+47.58	28.50	+ 93.18	45.60	37.25	81.70
JT- 9	2,151,354.000	900,550.000	+123.155	83.25	+39.31	15.00	+108.16	68.25	45.31	66.40
JT-10	2,151,035.000	899,465.000	+119.400	71.15	+48.25	28.35	+ 91.05	42.80	33.41	78.10
JT-11	2,150,631.860	899,021.938	+119.250	120.00	- 0.75	28.35	+ 90.90	91.65	53.89	58.80
JT-12	2,152,410.749	900,797.145	+125.634	116.30	+ 9.33	30.00	+ 95.63	86.30	52.55	60.90
JT-13	2,152,278.400	902,779.410	+134.800	131.10	+ 3.70	28.30	+106.50	102.80	66.82	65.00
JT-14	2,151,978.000	902,340.000	+131.521	92.15	+39.37	33.15	+ 98.37	59.00	45.72	77.50
JT-15	2,152,500.000	901,965.000	+133.530	105.30	+28.23	36.00	+ 97.53	69.30	55.12	79.50
JT-16	2,151,678.000	901,684.000	+126.514	71.15	+55.36	15.30	+111.21	55.85	50.36	90.20
JT-17	2,151,936.000	901,113.000	+125.448	85.00	+40.45	27.00	+ 98.45	58.00	46.98	81.00
JT-18	2,151,827.000	900,547.000	+123.552	95.25	+28.30	4.00	+119.55	91.25	61.63	67.50
JT-19	2,152,377.000	900,137.000	+123.888	80.15	+43.74	22.35	+101.54	57.80	33.64	58.20
JT-20	2,151,738.000	899,769.000	+123.400	94.65	+28.75	20.55	+102.85	74.10	55.51	74.90
JT-21	2,151,972.000	899,160.000	+123.084	75.65	+47.43	22.35	+100.73	53.30	45.90	86.10
JT-22	2,153,252.075	902,625.516	+135.540	111.35	+24.19	25.35	+110.19	64.95	34.59	53.30
JT-23	2,152,854.000	902,592.000	+133.270	109.90	+23.37	28.30	+104.97	81.60	47.23	57.90
JT-24	2,153,156.000	900,709.000	+133.380	113.25	+20.13	12.00	+121.38	101.25	65.20	65.40
JT-25	2,153,391.000	899,750.000	+131.322	112.00	+19.32	28.35	+102.97	83.65	66.10	79.00
JT-26	2,153,455.000	899,160.000	+129.669	134.15	- 4.48	33.35	+ 96.32	100.60	80.68	80.00
JT-27	2,153,575.854	902,130.092	+137.719	98.15	+39.57	37.25	+100.47	60.90	56.69	93.10
JT-28	2,154,274.000	902,077.000	+138.443	123.81	+14.63	0.00	+138.44	115.84	86.23	74.40
JT-29	2,153,665.000	901,419.000	+134.330	109.45	+24.88	32.62	+101.71	76.83	58.99	76.80
JT-30	2,154,425.000	900,945.000	+133.395	117.25	+16.15	25.52	+107.88	91.73	69.01	75.20
JT-31	2,153,641.000	900,234.000	+130.801	125.00	+ 5.80	15.00	+115.80	110.00	66.04	60.00
JT-32	2,154,169.000	899,264.000	+133.284	119.15	+14.13	34.35	+ 98.93	84.80	63.25	74.60
JT-33	2,154,138.491	902,682.986	+141.530	118.65	+22.88	26.25	+115.28	92.40	61.57	66.60
JT-34	2,154,710.000	902,430.000	+133.046	83.00	+50.05	18.10	+119.95	69.90	49.59	70.90
JT-35	2,155,331.000	902,615.000	+137.150	98.10	+39.05	23.10	+114.05	75.00	49.32	65.80
JT-36	2,155,207.876	901,872.244	+136.435	99.60	+36.84	25.30	+111.14	74.30	27.35	36.80
JT-37	2,150,692.836	899,770.187	+121.260	118.50	+ 2.76	15.00	+106.26	103.50	79.61	76.90
JT-38	2,155,304.000	901,140.000	+128.087	101.40	+26.69	18.00	+110.09	83.40	52.11	62.50
JT-39	2,154,830.607	900,898.658	+121.324	143.25	-18.93	21.00	+103.32	122.25	89.68	73.40
JT-40	2,155,311.000	900,323.000	+135.238	122.15	+13.09	28.35	+106.89	93.80	73.38	78.20
JT-41	2,154,623.000	899,792.000	+135.954	134.15	+ 1.80	33.00	+102.95	101.15	72.56	71.70
JT-42	2,155,189.000	899,720.000	+127.217	107.15	+20.07	28.35	+ 98.87	78.80	52.49	66.60
JT-43	2,156,111.000	902,662.000	+141.116	95.10	+45.02	30.00	+111.12	65.10	51.84	79.60
JT-44	2,155,871.000	902,153.000	+139.571	127.90	+11.60	4.00	+135.57	123.90	79.76	64.40
JT-45	2,156,457.167	901,489.000	+124.471	140.00	-15.53	15.00	+109.47	125.00	88.82	71.10
JT-46	2,155,907.000	901,140.389	+116.882	112.40	+ 4.43	12.00	+104.88	100.40	68.23	68.00
JT-47	2,155,856.639	899,856.000	+125.639	101.15	+24.49	29.15	+ 96.49	72.00	41.16	57.20
JT-48	2,156,604.000	900,722.000	+114.535	90.35	+24.19	15.00	+ 99.54	75.35	39.96	53.00
JT-49	2,156,747.000	900,038.000	+112.692	113.15	- 1.06	28.35	+ 83.74	84.80	47.45	56.00
JT-50	2,156,612.000	899,180.000	+118.172	119.15	- 0.98	28.35	+ 89.82	90.80	49.11	54.10

Table 1 - 2 DATA LIST OF DRILL HOLES (2)

DRILL HOLE NO.	GRID COORDINATES		HEIGHT (Reduced level) (m)	DEPTH (m)	HEIGHT OF DRILL HOLE BOTTOM (m)	BEGGINING OF CORING	
	Easting (m)	Northing (m)				Depth (m)	Height (m)
PS- 1	2,155,705.276	899,258.045	+120.180	79.78	+40.40	2.92	+117.26
PS- 2	2,158,558.279	899,388.036	+126.880	100.98	+25.90	21.19	+105.69
PS- 4	2,158,862.462	900,681.860	+115.330	82.29	+33.04	18.29	+ 97.04
PS- 5	2,156,140.753	900,412.051	+116.630	70.10	+46.53	16.75	+ 99.88
PS- 6	2,152,755.969	901,334.680	+134.350	105.37	+28.98	16.67	+117.68
PS- 7	2,154,429.587	901,563.486	+134.920	108.51	+26.41	2.95	+131.97
PS- 8	2,155,746.848	901,597.947	+132.860	103.63	+29.23	3.02	+129.84
PS- 9	2,158,459.713	902,653.661	+139.780	108.81	+30.97	3.04	+136.74
PS-10	2,106,212.611	901,250.029	+107.070	108.61	- 1.54	44.38	+ 62.69
PS-11	2,159,755.224	903,099.094	+116.790	111.25	+ 5.54	2.92	+113.87
PS-13	2,156,579.241	903,227.902	+143.150	115.14	+28.01	2.92	+140.23
PS-14	2,155,011.258	903,155.588	+142.170	96.01	+46.61	3.05	+139.12
PS-15	2,154,315.326	903,809.788	+143.490	109.01	+34.48	27.73	+115.76
PS-18	2,152,769.418	899,334.511	+126.900	88.95	+37.95	62.46	+ 64.44
PS-19	2,151,102.502	899,960.272	+121.340	83.82	+37.52	27.42	+ 93.92
PS-20	2,151,037.709	901,636.141	+125.880	83.82	+42.06	12.39	+113.49
PS-22	2,151,083.248	903,107.379	+127.160	80.06	+47.10	35.19	+ 91.97
PS-23	2,152,837.461	903,071.786	+138.110	103.63	+34.48	3.05	+135.06
PS-24	2,151,930.218	904,031.920	+132.800	105.20	+27.60	9.14	+123.66
L -18	2,157,326.622	900,024.168	+117.040	79.55	+37.49		
L -22	2,157,427.293	901,707.167	+115.600	86.87	+28.73		
L -28	2,154,115.879	900,090.222	+133.670	167.94	-34.27		

N.B. PS = denotes drill holes executed by PMDC

L = denotes drill holes executed by GSP

1-2 Conclusion

1-2-1 General Geology

Stratigraphic succession detailed in Table 2 has been determined on the basis of investigations stated above. Exposed rocks in the area consist of Ranikot and Laki groups, which at places are overlain by Manchar formation unconformably.

Laki group is sub-divided into Laki limestone and Basal Laki laterite. Ranikot group consists of Lower and Upper Ranikot formations.

The Upper Ranikot in the present report is referred to as Upper Shell Beds as its strata contain fossil shells. The Lower Ranikot formation has been sub-divided into Upper Coal-bearing beds, Lower Shell Beds and Lower Coal-bearing Beds. Upper and Lower Shell Beds consist of predominant sandstones alternating with sub-ordinate siltstones and intercalated claystones and shales. They contain abundant fossil shells. Siltstones contain characteristic sandstone and siderite nodules.

Upper Coal Beds are impregnated with five coal zones and consist of alternating beds of sandstone, silstone, and claystone. Siltstones and claystones are predominant adjacent to the coal seams. The Beds are the most important coal measure in the investigated area.

The Lower Coal Beds also constituted by alternating sandstones, siltstones and claystones contain three coal zones, which are mostly thin and insignificant from economic point of view.

Barren areas devoid of coal or containing very thin coal seams occur in the southwestern and northern parts of the investigated area. Red zone comprising of variegated rock facies occurs in the upper part of Ranikot group. It spreads almost all over the area. In the areas devoid of coal, it extends to Upper Coal-bearing Beds.

1-2-2 Characteristics of Rocks

The measured values of rock tests vary considerably. For example, the uniaxial compressive strength of limestone ranges from 122.5 to 957.3 kg/cm^2, sandstone from 5.2 to 323 kg/cm^2, and in case of siltstone/claystone from 9.2 to 312.6 kg/cm^2. Certain types of sandstone particularly the socalled silica sandstone is so soft and loose that its core could not be obtained. This sandstone when in roof of coal seam would not permit underground mining for reasons of safety.

1-2-3 Geologic Structure

The investigated area falls mostly in the western limb of the Lakhra anticline. As the dips of strata are very gentle and the eastern limb was beyond the scope of the present work, the axis of the anticline has not been confirmed. The strata and the coal seams dip at 2 degrees and appear to be gently rolled (Fig. 3)

Three faults have been noted in the middle of the southern part of investigated area. Western fault referred as fault A strikes northeast. Its throw is 25 meters to the east. Central fault B1 trends northsouth to northwest. The eastern fault referred as fault B2 branches out from the central fault and strikes in northeast direction. Blocks to the west of both the faults are

Table 2. STANDARD STRATIGRAPHIC SUCCESSION OF THE INVESTIGATED AREA

EPOCH	GROUP	FORMATION		THICKNESS (m)	COAL ZONE NAME	COAL ZONE THICKNESS (m)	LITHOLOGY
Eocene	Laki	Laki Limestone		0 - 54	-	-	Limestones, Foraminifera limestones, Sandy limestones, Marls, Chalks, with subordinate shales and sandstones
		Basal Laki Laterite		0 - 14	-	-	Intermingled lateritic clays, sandstones and gypsiferous shale with pocket of sands. Unfossiliferous
							(Unconformity)
Palaeocene	Ranikot	Upper Ranikot	Upper Shell Beds	9 - 70+	-	-	Predominant sandstones interbedded with siltstones. Fossil shells abundant. Siltstones contain sideritic or sandy nodules.
		Lower Ranikot	Upper Coal-bearing Beds	20 - 56	No.5	tr. - 1.2	Thinning or trace to east. Locally workable
					No.5 to No.4	3 - 27	Predominant sandstones interbedded with siltstones, fossil shells occasional.
					No.4	tr. - 2	Thinning or trace to east.
					No.4 to No.3	1 - 10	Sandstones and/or siltstones, claystones
					No.3	0.05 - 4.5	Workable
					No.3 to No.2	1 - 21	Dominantly silica sandstones in the east, sandstones and/or siltstones, claystones
					No.2	0.1 - 8	Workable
					No.2 to No.1	0 - 13.5	Sandstones and/or siltstones, claystones
					No.1	0.2 - 7	Workable
							To the east, No.1 and No.2 seams approach and merge in one coal group
			Lower Shell Beds	20 - 40	-	-	Predominant sandstones interbedded with siltstones. Fossil Shells abundant, siltstones contain sideritic or sandy nodules
			Lower Coal-bearing Beds	30+	L.1	tr. - 3	Mostly thin seams
					L.1 to L.2	5 - 20	Sandstones interbedded with siltstones, claystones
					L.2	tr. - 4	Mostly thin seams
					L.2 to L.3	5 - 23	Sandstones interbedded with siltstones, claystones
					L.3	tr. - 5	Mostly thin seams
							Sandstones interbedded with siltstones, claystones

(tr. = trace)

downthrown. Throw near the junction of faults is 30 meters. Displacements of the faults decrease northwards and they die-out in the investigated area. They are pivotal faults. The investigated area is divided into western, central and eastern blocks based on these faults, and the barren areas mentioned already (Fig. 4).

1-2-4 Economic Geology

(1) Coal Zones

The Upper Coal-bearing Beds contain five coal zones – No. 1 to No. 5 in ascending order. The Lower Coal-bearing Beds bear three coal zones – L1 to L3 in descending order. Each zone contains from one to more than one seams. No. 1 zone is 0.2 to 7 metres thick. It persists throughout except the barren areas. No. 2 zone ranging in thickness from 0.1 to 8.0 metres is as persistent as the zone No. 1. Towards east, however, it merges with zone No. 1. Zone No. 3, 0.05 to 4.5 metres in thickness, also spreads over the area like No. 1 and No. 2 zones. These three are the main zones containing workable seams in the investigated area.

No. 4 and No. 5 zones are up to 2.0 metres and 1.2 metres thick respectively. They are impersistent. In the eastern part they are generally thin and fish out at places. Both the zones are therefore workable only locally.

The coal zones in the Lower Coal-bearing Beds, L1, L2 and L3 are up to 3.0, 4.0 and 5.0 metres thick respectively. However, they are generally thin and their continuity could not be established in the present work. Consequently, they have not been evaluated.

(2) Quality of Coal

Coal in each zone in the investigated area is lignite in rank. Rarely it grades into subbituminous. It contains about 30 percent moisture when fresh (PMDC, 1976). It loses most of the moisture on exposure to surface and easily crumbles. It is liable to spontaneous combustion. The coal contains abundant pyrite grains and thin gypsum veins at places. Sand and clay are also included in pipe-like, lensoid or scattered pattern.

It has been determined that the moisture content of coal is 5.5 to 14.6 percent, calorific value ranges from 3,500 to 5,860 kcal/kg (6,300 to 10,550 BTU) and total sulphur from 3.3 to 18.1 percent on air dried basis. Proportion of inorganic to organic sulphur content is 66 to 34.

Ultimate analyses of ash and moisture free samples show carbon – 58.5 to 72.4 percent, hydrogen – 4.5 to 5.8 percent, oxygen – 14.4 to 22.3 percent, nitrogen – 0.9 to 1.4 percent and sulphur ranging from 2.4 to 16.7 percent. Ash fusion temperature has been determined as follows – deformation 1,250 to 1,425°C, hemisphere 1,300 to 1,450°C, flow 1,350 to 1,450°C or more. Hardgrove grindability index varies from 59 to 88. Ash consists of SiO_2 – 8.0 to 44.42 percent, Al_2O_3 – 9.49 to 28.8 percent, Fe_2O_3 – 17.3 to 70.76 percent, SO_3 – 1.93 to 17.47 percent. These values show considerable variation. The coal is known to be non-coking and non-caking.

From the results of analyses and test detailed in Table 10, 11 and 12 it is concluded that the coal is suitable for use as fuel in thermal power generation though the variation of each analytic value is high.

STRUCTURE CONTOUR MAP, NO.1 SEAM (FLOOR)

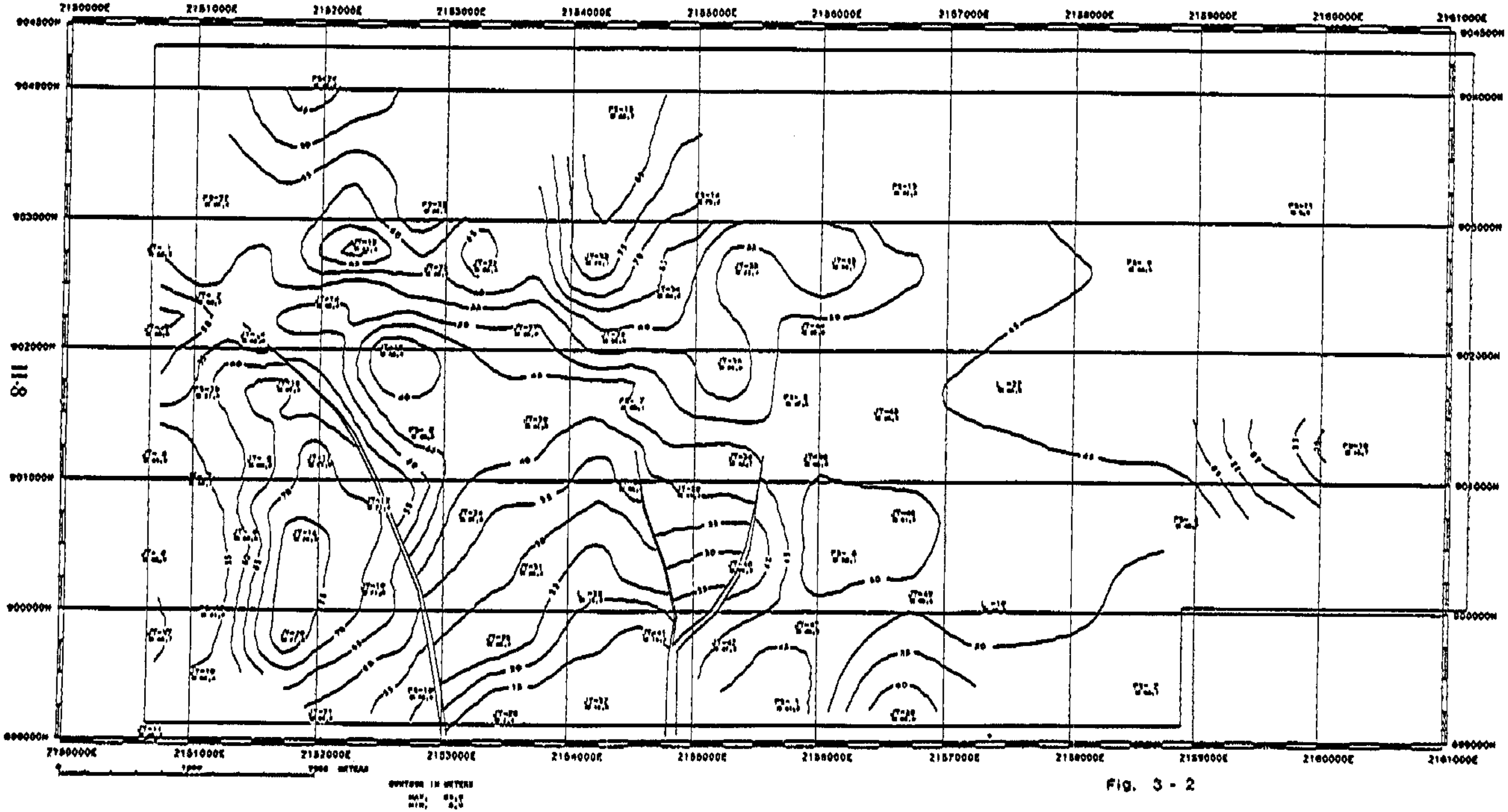


Fig. 3 - 2

DIVISION OF MINING AREA

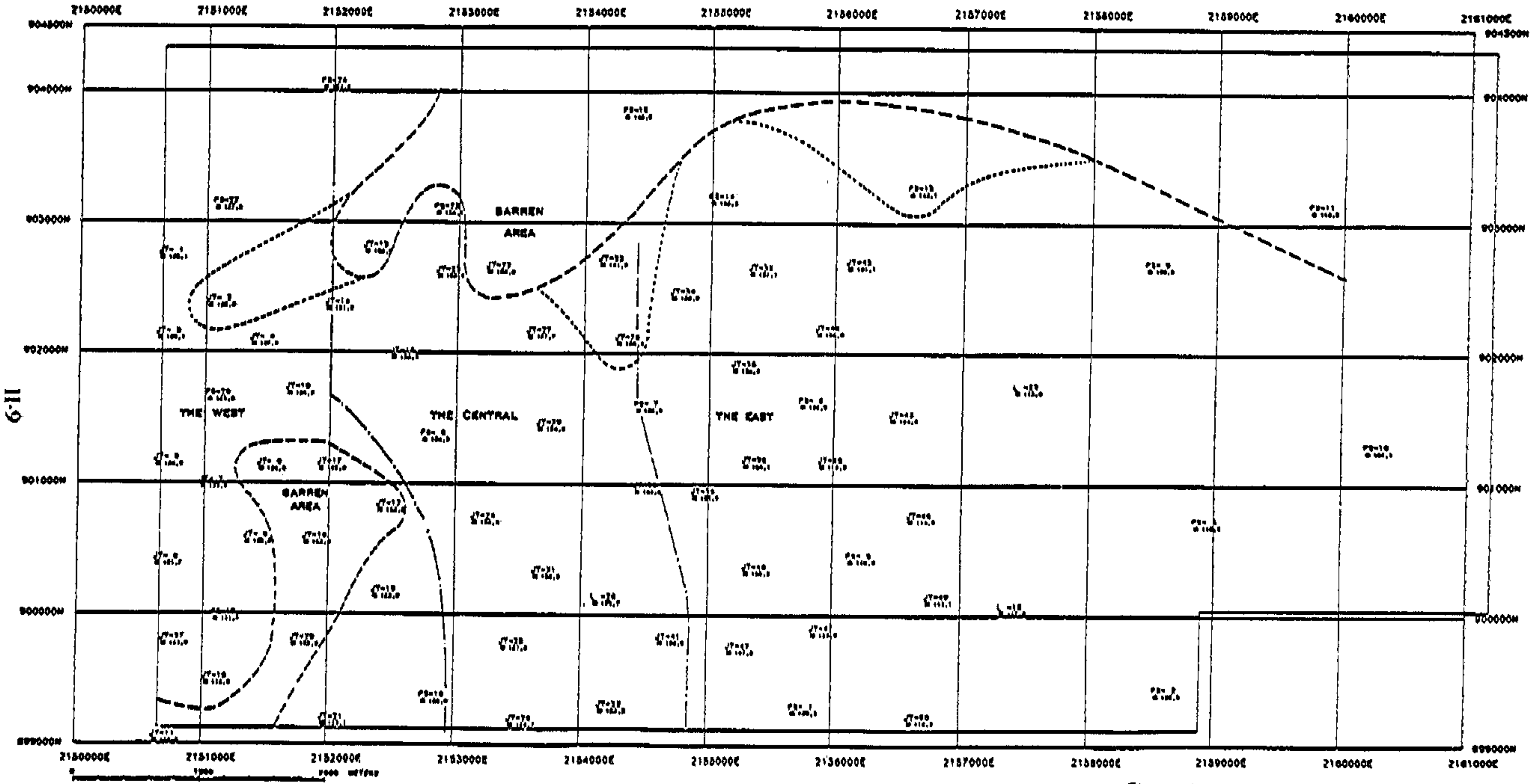


Fig. 4-2

Washability (float and sink) tests have also been carried out. The tests indicate that the coal can be up-graded and partially desulphurised, for example, when floated in solution with 1.8 specific gravity the ash decreases from 19.7 to 12.0 percent and sulphur from 6.84 to 4.2 percent.

(3) Coal Reserves (Table 3)

In the present work coal reserves are estimated on the basis of following factors and assumptions:–

a) Reserves over 2.353 square kilometres in the western and 6.87 square kilometres in the eastern parts of the investigated area have been calculated from the point of view of open cut mining due to suitable stripping ratio up to 1:15.

b) In the central part where the stripping ratio is more than 1:15 and the roof condition is favourable, the reserves have been calculated for underground mining.

c) Minimum thickness of coal seams taken into account for estimating reserves is 0.5 metre for open cut and 0.75 metre for underground mining.

d) Seams with calorific value under 3,500 kcal/kg on air-dried basis are not taken into account.

e) Specific gravity of coal for open cut and underground mining has been determined at 1.5 and 1.45 respectively. The difference is because comparatively better grade coal would be won in the underground mining as the coal seams underlying loose sand would be left out, and workable thickness has been taken considerably less than the actual for the sake of mine safety.

f) Geologic safety factor and recoverable factor would be determined depending on the mining method to be selected. For the sake of present calculations for recoverable reserves it has been assumed that the geologic factor would be 80 percent for open cut and 70 percent for underground mining; and the recoverable factor would be 90 and 65 percent respectively for open cut and underground mining. Based on the above factors and assumptions, the theoretical and recoverable reserves in raw coal have been estimated as follows;–

Unit: million tonnes

Mining Area	Theoretical Reserves	Recoverable Reserves
Open Pit	65.50	47.16
Underground	14.28	6.5
Total	79.78	53.66

1-3 Recommendations

From the results of present investigations it is concluded that workable coal seams persist over greater part of the investigated area measuring 26 square kilometres of Lakhra coal field. Quantity of coal appears to be sufficient and quality suitable for meeting the requirements of a coal fired power plant of 300 megawatt capacity.

The plant under discussion is in the plans of the Government of Pakistan, which desired its materialization at an early date. Therefore, the following recommendations will be made in connection with the mine development in near future;–

(1) It is expected that the coal seams located in western part would persist with workable thickness beyond the western boundary of the area. As addition of recoverable reserves would contribute towards long term planning and feasibility of the project, it is suggested that detailed geological investigations including drilling at an interval of 500 metres may be carried out to evaluate coal potential in this prospective area adjacent to the western boundary.

(2) Consistent production by mechanised mining can be achieved and maintained only when the geologic structure, pattern and continuity of coal seams, and mining conditions are thoroughly studied and interpreted. Depending on the present investigations it is possible to correlate coal zone No. I in the area. However, due to frequent facies changes and repetition of coal seams it is difficult to correlate individual seams. Therefore, detailed drilling at a spacing of 200 metres appears to be necessary throughout the investigated area to confirm the continuity of coal seams and mining conditions. The recommended drilling is suggested to be commenced from the site to be developed during the first stage and then extended to the remaining area as per priorities to be fixed by mining feasibility study.

(3) Results of tests and analyses show that the deviations in the values of coal quality including ash and sulphur content are considerably large. Therefore, coal preparation system and its capacity may be examined alongwith the feasibility of the Project.

Table 3. **SUMMARY OF RAW COAL RESERVES**

(in metric ton)

Coal Reserves for Open Cut Mining

Unit x 10^3 Specific Gravity 1.5

STRIP RATIO	THE WEST		THE CENTRAL		THE EAST		TOTAL	
	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable
1:10 and less for the West	16,487	11,871					16,487	11,871
1:12 and less for the East					21,139	15,220	21,139	15,220
1:10 to 1:15 for the West, 1:12 to 1:15 for the East	4,660	3,355			23,212	16,713	27,872	20,062
1:17 and less for the Central			11,990	8,633			11,990	8,633
1:17 to 1:20 for the Central, 1:15 to 1:20 for the East			6,270	4,514	16,536	11,906	22,806	16,420
Total	21,147	15,226	18,260	13,147	60,887	43,839	100,294	72,212
Average Total Thickness	5.99		4.08		4.12		4.40	
Average Calorific Value	4550 (4960)* Kcal/Kg		4660 (5070)* Kcal/Kg		4760 (5350)* Kcal/Kg			
Average Total Sulphur	7.59 (8.25)* %		7.25 (7.86)* %		6.40 (7.17)* %			

Coal Reserves for Underground Mining

Unit x 10^3 Specific Gravity 1.45

	THE CENTRAL		THE EAST		TOTAL		SOUTHERN PART OF THE CENTRAL	
	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable	Theoretical	Recoverable
1.5 or more	10,728	4,881	11,424	5,197	22,152	10,078	4,712	2,145
1.5 to 1.0	2,340	1,065	3,446	1,568	5,786	2,633	2,067	940
1.0 to 0.75	1,216	553	368	168	1,584	721	158	72
0.75 to 0.50	199	90	80	37	279	127	58	26
Total	14,483	6,589	15,318	6,970	29,801	13,559	6,995	3,186
Average Calorific Value	4860 (5380)* Kcal/Kg		4930 (5570)* Kcal/Kg					
Average Total Sulphur	7.11 (7.83) %		6.35 (7.14) %					

Calorific Value and Total Sulphur: air dry basis
* ( ): dry basis