The Islamic Republic of Pakistan

GENCO Holding Company Limited

Preparatory Survey on Lakhra Coal Fired Thermal Power Plant Construction Project in Pakistan

FINAL REPORT

October 2016

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Nippon Koei Co., Ltd
Mitsui Consultants Co., Ltd.

4R
CR(5)
16-041

FINAL REPORT
for
The Preparatory Survey on Lakhra Coal Fired Thermal Power Plant Construction Project in Pakistan

CONTENTS

Chapter 10 Financial and Economic Analyses

Chapter 11 Environment and Social Considerations

Chapter 12 Review for the F/S on Thar- Matiari Transmission Line

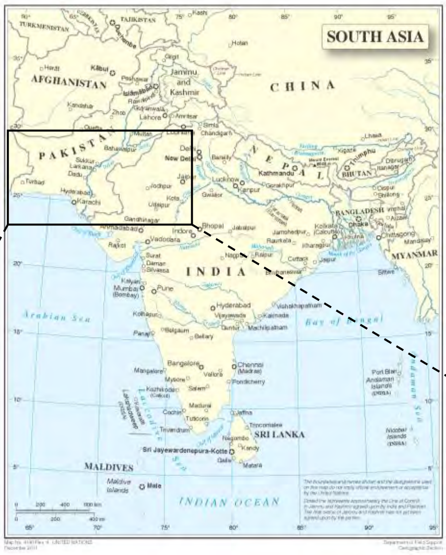
Chapter 13 Conclusion and Recommendation

Tables

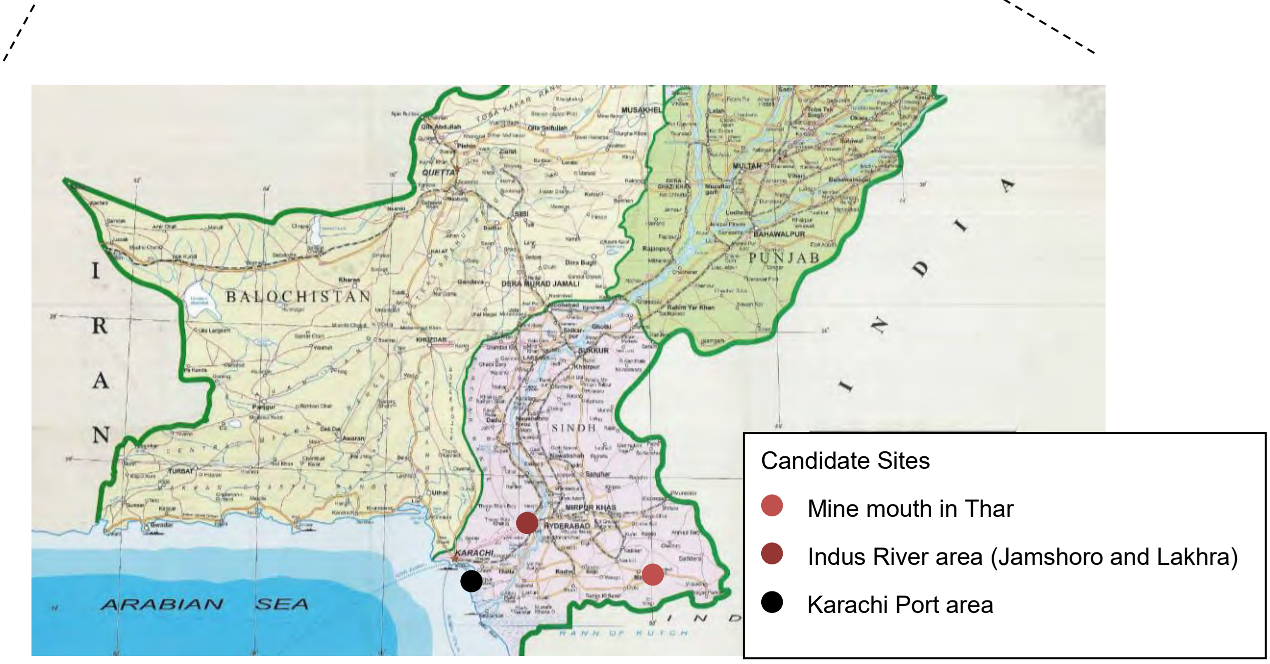
Figures

Photos

Location Map



Source : UNITED NATIONS



Source : Prepared by JICA Survey Team based on Map published by HAQQI BROTHERS

Abbreviations

AAAC	:	All Aluminum Alloy Conductor
AC	:	Alternating Current
ADB	:	Asian Development Bank
AEDB	:	Alternative Energy Development Board
APC	:	Automatic Plant Control system
ASCE	:	American Society for Civil Engineers
ASTM	:	American Society for Testing and Materials
BFPs	:	Boiler Feed Pumps
BG	:	Broad Gauge
BHUs	:	Basic Health Units
BID	:	Background Information Document
BMCR	:	Boiler Maximum Continuous Rating
BOD	:	Biochemical Oxygen Demand
BOT	:	Built Operate Transfer
CAMCE	:	China CAMC Engineering Co., Ltd
C&I	:	Controls and Instrumentation
CAS	:	Compulsory Acquisition Surcharge
CASA	:	Central Asia to South Asia Interconnection
CCCP	:	Central Power Purchasing Agency
CCI	:	Council of Common Interests
CCS	:	Carbon Capture System
Cct	:	Circuit
CDB	:	China Development Bank
CEDD	:	Coal and Energy Development Department
CEO	:	Chief Executive Officer
CFBC	:	Circulating Fluidized Bed Combustion
CFPP	:	Coal Fired Thermal Power Plant
Cl	:	Chloride
COD	:	Chemical Oxygen Demand
COD	:	Commercial Operation Date
COI	:	Corridor of impact
CAFs	:	Cooling Air Fans
CPs	:	Condensate Pumps
CPI	:	Consumer Price Index
CPIH	:	China Power International Holdings
CPP	:	Condensate Polishing Plant
CPPA		Central Power Purchasing Agency
CSA	:	Coal Supply Agreement
CT	:	Cooling Tower
CT	:	Current Transformer
DA	:	Degraded Airshed
DC	:	Deputy Commissioner
DC	:	Direct Current
D/C	:	Double Circuit
DCS	:	Distributed Control System
DD	:	Detail Design
DEC	:	Dongfag Electric Corporation
D-EHC	:	Digital Electro-Hydraulic Control
DHQ	:	District Head Quarter Hospital
DISCO	:	Distribution Company
DOE		U.S. Department of Energy
DU	:	Double Undulated
EHC	:	Electric Hydraulic Control system for turbine
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return

EMP	:	Environmental Management Plan
ENPV	:	Economic Net Present Value
EOI	:	Expression of Interest
EPA	:	Environmental Protection Agency
EPC	:	Engineering Procurement and Construction
ESIA	:	Environmental and Social Impact Assessment
ESP	:	Electrostatic Precipitator
FBC	:	Fluidized Bed Combustion
FC	:	Foreign Currency
FDFs	:	Forced Draft Fans
FGD	:	Flue Gas Desulfurization system
FIRR	:	Financial Internal Rate of Return
FNPV	:	Financial Net Present Value
FOR	:	Forced Outage Rate
FS	:	Feasibility Study
FY	:	Fiscal Year starting on 1st July ending on 30th June in Pakistan
GENCO	:	Generation Company
GFP	:	Grievance Focal Point
GHCL	:	GENCO Holdings Company Limited
GMBC	:	Generator Main Circuit Breaker
GOP	:	Government of Pakistan
GOS	:	Government of Sindh
GRC	:	Grievance Redress Committee
GRFs	:	Gas Recirculation Fans
HDPE	:	High-Density Polyethylene
HHV	:	High Heating Value
HP	:	High Pressure
HPP	:	Hydro Power Station
HSD		High Speed Diesel Oil
HUBCO	:	Hub Power Company
IA	:	Implementation Agreement
IA	:	Interconnection Agreement
ICB	:	International Competitive Bidding
ICBC	:	Industrial and Commercial Bank of China
ICC	:	International Code Council
IDC	:	Interest during Construction
IDFs	:	Induced Draft Fans
IEE	:	Initial Environmental Examination
IESCO		Islamabad electric supply company
IFC	:	International Finance Corporation
IGCC	:	Integrated Gasification Combined Cycle
IMF	:	International Monetary Fund
IP	:	Intermediate Pressure
IPB	:	Isolated Phase Bus
IPD	:	Irrigation & Power Department, Government of Sindh
IPP	:	Independent Power Producer
IUCN	:	International Union for Conservation Nature
JDA	:	Joint Development Agreement
JICA	:	Japan International Cooperation Agency
JIS	:	Japan Industrial Standards
Jn	:	Junction
JORC	:	Joint Ore Resources Committee
JST	:	JICA Survey Team
JTPS	:	JAmshoro Thermal Power Station
KESC	:	Karachi Electricity Supply Company
LAA	:	Land Acquisition Act
LAC	:	Land Acquisition Collector
LARP	:	Land Acquisition and Resettlement Plan

LBOD	:	Left Bank Outfall Drain
LC	:	Local Currency
LCDC	:	Lakhra Coal Development Company
LCPP	:	600 MW Lakhra Coal Fired Thermal Power Plant
LL-TACSR/AS	:	Low Electrical Power Loss Thermal Resistant Aluminum Alloy Conductor Steel Reinforced / Aluminum-clad Steel Reinforced
LP	:	Low Pressure
LPGCL	:	Lakhra Power Generation Company Limited
MBC	:	Mill and Burner Control system
M-BFP	:	Motor operated Boiler Feedwater Pump
MG	:	Meter Gauge
MMI	:	Man Machine Interface system
MOHW	:	Ministry of House and Works
MOU	:	Memorandum of Understandings
MoWP	:	Ministry of Water and Power
MSP	:	Main Steam Pressure
MST	:	Main Steam Temperature
N-5	:	National Highway No.5
N-55	:	National Highway No.55 (Indus Highway)
NDA	:	Non-Degaraded Airshed
NDP	:	National Drainage Program
NEPRA	:	National Electric Power Regulatory Authority
NESPAK	:	National Engineering Services Pakistan
NEQS	:	National Environmental Quality Standards
NF	:	Notched Flat
NFPA	:	National Fire Protection Association
NGO	:	Non-Government organization
NHA	:	National Highway Authority
NOC	:	No Objection Certificate
NO_x	:	Nitrogen Oxide
NR	:	Natural Resource
NRSP	:	National Rural Support Program
NTDC	:	National Transmission and Dispatch Company
O&M	:	Operation and Maintenance
ODA	:	Official Development Assistance
OFAF	:	Outdoor, Oil Forced Air Cooling System
OLTC	:	On-Load Tap Changer
ONAF	:	Outdoor, Oil Forced Circulation and Forced Air Cooled
ONFA	:	Outdoor, Oil Natural Circulation and Forced Air Cooled
OPGW	:	Optical Fiber Composite Overhead Ground Wire
PAFs	:	Primary Air Fans
PM10	:	Particular Matter 10
PBC	:	Pakistan Building Code
PC-1	:	Planning Commission no.1
PCU	:	Public Complaints Unit
PDWP		Project Development Work Program
PEC	:	Pakistan Engineering Council's core group
PEPA	:	Pakistan Environmental Protection Act
PEPCO	:	Pakistan Electric Power Company
P/S	:	Power Station
PIBT	:	Pakistan International Bulk Terminal
PIL	:	Pakistan Intermodal Limited
PIC	:	Project Implementation Consultant
PIU	:	Project Implementation Unit
PMU	:	Project Management Unit
PPA	:	Power Purchase Agreement
PPIB	:	Private Power Infrastructure Board
PPP	:	Public Private Partnership

PPPMCL	:	Pakistan Power Park Management Company Ltd
PR	:	Pakistan Railway
PRSP	:	Punjab Rural Support Program
PSO	:	Pakistan State Oil
PSQCA	:	Pakistan Standards and Quality Control Authority
PSS	:	Power System Stabilizer
PT	:	Potential Transfer
RBOD	:	Right Bank Outfall Drain
RC	:	Railway Crossing
RE	:	Renewable Energy
RFO	:	Residual Fuel Oil
RFP	:	Request for Proposal
RHC	:	Rural Health Centers
RO	:	Reverse Osmosis Membrane Method
ROE	:	Return on Equity
ROW	:	Right of Way
RPF	:	Resettlement Policy Framework
Rs	:	Rupees
RS	:	Railway Station
RST	:	Reheat Steam Temperature
S/S	:	Switching Station
SC	:	Super Critical
SCA	:	Sindh Coal Authority
SCEL	:	Sindh Carbon Energy Limited
SCF	:	Standard Conversion Factor
SECMC chapter2	:	Sindh Energy and Coal Mining Company
SEPA	:	Sindh Environmental Protection Agency
SEQS	:	Sindh Environmental Quality Standards
SINOMACH	:	China National Machinery Industry Corporation
SINOSURE	:	China Export & Credit Insurance Corporation
SO_x	:	Sulfur Oxide
SOP	:	Standard Operating Procedure
SPM	:	Suspended Particular Matter
SR	:	Silicon Rectifier
SSRL	:	Sino Sindh Resources Ltd
SPS	:	Safeguard Policy Statement
SPV	:	Special Purpose Vehicle
Stn	:	Station
TA	:	Telegraph Act
TDS	:	Total Dissolved Solids
TOR	:	Terms of Reference
TPC	:	Thar Power Company
T-BFP	:	Turbine operated Boiler Feedwater Pump
UBC	:	Unified Building Code
UPS	:	Un-interruptive Power Supply
USC	:	Ultra Super Critical
WACC	:	Weighted Average Cost of Capital
WAPDA	:	Water and Power Developed Authority
WEA	:	WAPDA Engineering Academy
W&SD (GoS)	:	Works and Services Department, Government of Sindh
WWF	:	World Wide Fund for Nature

CHAPTER 1

INTRODUCTION

Chapter 1 Introduction

1.1 Background of the Survey

1.1.1 Deficit of Power Supply

The peak generation power in Pakistan in 2011 was 12,755 MW, while the peak demand was 18,860. This lack of supply capacity is expected to be even severer as the capacity of the existing power plants will degrade over time and electricity demand is forecasted to increase at an annual average rate of around 5.0%[1].

1.1.2 Generation Mix

The distribution of power generated (in kWh) by each energy resource in Pakistan from 2011 to 2012 was 34% oil thermal, 32% hydro, 27% gas turbine, 5% nuclear, and 0.1% coal thermal.[2] Oil thermal generation is the most dependable energy resource, but the cost of oil remains high and vulnerable to the market. Therefore, oil thermal cannot be a stable energy resource.

1.1.3 Government Policy

According to the National Power Policy 2013 published by the Government of Pakistan (GoP) in July 2013, the government is working on developing coal-fired thermal power plants utilizing the coal reserve in the Thar coalfield. This will help meet the demand and diversify Pakistan's energy mix by promoting the use of local energy resources.

1.1.4 JICA Action

Under such condition, the Japan International Cooperation Agency (JICA) implemented the "Data Collection Survey on Thar Coal Field in Pakistan," which recommended the construction of the Thar coal-fired thermal power plant for Pakistan's energy mix and safety. Accordingly, JICA decided to implement the "Preparatory Survey on Lakhra Coal Fired Thermal Power Plant Construction Project" (hereafter referred to as "the Survey").

1.2 Objective of the Survey

The objective of the Survey is to identify the location for the construction of a "new coal-fired thermal power plant and its relevant infrastructure such as water supply and transmission line",

[1] Peak demand forecast summary, NTDC
[2] Power System Statistics 2011-2012, Planning NTDC

hereafter called as "the Project", as well as to conduct a feasibility study. It should be noted that the implementation of the Survey does not imply any decision or commitment by JICA to extend its loan for the Project at this stage.

1.3 Rational of Coal Fired Thermal Generation

Pakistan is going through an acute power shortage. The gap supply-demand represents about one-third of the total demand in National Transmission and Despatch Company (NTDC) system. Chronic power shortages in Pakistan are the most serious constraints to the country's economic growth and job creation.

In addition to increasing the generation capacity, it is essential to lower the generation cost. One possible option is the hydropower. Hydropower despite being the ideal solution has long implementation period and is not attractive for addressing immediate issues. Other solutions are either too costly or have other technical or economic issues. In this background, coal offers a promising option in the medium as well as long-term to provide affordable power and diversify the energy mix. The GoP aims to increase the share of coal-based generation from nearly none now (0.07%) to about 39% in 5 years. This will be achieved through converting existing High Sulfur Fuel Oil (HSFO) generation units, replacing old inefficient units, and constructing new plants. Electricity generated from coal, with long-term fuel supply contracts, will also add stability to the power price.

Generation costs depend on the thermal fuel source, residual fuel oil (RFO), high speed diesel oil (HSD), and RFO mixed with gas (or simply "mixed") are the largest sources for thermal electricity generation. Generation costs are Rs 12/kWh for mixed, Rs 17/kWh for RFO, and Rs 23/kWh for HSD, which the latter is considered tremendously expensive.[3] The dependence for such expensive sources has forced Pakistan to impose electricity rates that are not affordable to the nation and its populace. One the other hand, levelized upfront tariffs for the coal-fired thermal power range from Rs 7.3/kWh to Rs 9.4/kWh, depending on the size of unit capacity (200 MW, 600 MW, or 1,000 MW), type of coal (local or import), and financing (local or foreign). Details on upfront tariffs are shown in Table 2.7-2, where rates are affordable to the nation and its populace.

GoP is encouraging new thermal power plant by IPP, however IPPs have been hesitate to invest due to the reasons of such as circular debt.

Large scale hydro power plant, of which generation cost is around Rs.6.5/kWh, is considered

[3] National Power Policy 2013 "3. Challenges", Ministry of Water and Power

an option to compensate the power shortfall. However it cannot be the stable power source urgently installed, because normally it will take more than 10 years for construction, and the generating capacity in dry season will be decreased to 30 to 50% of which in rainy season.

For gas turbine power plant, the generation cost is higher than that of the coal fired thermal plant. On the other hand, solar and wind renewable powers are not stable powers so that cannot be base power generation.

1.4 Survey Area

1) Thar area: Thar Parker, Sindh Province
2) Indus River area: Hyderabad, Thatta and Badin districts, Sindh Province
3) Karachi coastal area: Karachi City Area, Sindh Province

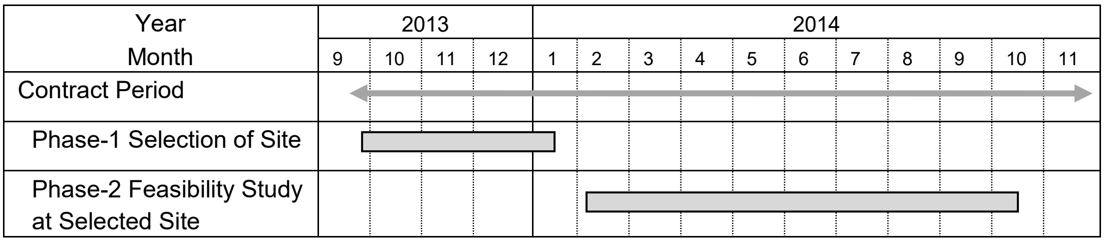
1.5 Scope of the Survey

The scope of the Survey is listed below, and their details are shown in Appendix 1-1.

A. Background and necessity of the Project,
B. Study on the suitable location for constructing a new power plant either in the mine mouth, Indus River, or Karachi Port,
C. Study on power plant types, fuel to be used, and fuel supply plan,
D. Calculation of project cost and estimation of environmental and social impacts,
E. Identification of appropriate project scope,
F. Basic design,
G. Analysis of the power system,
H. Cost estimation,
I. Financial plan,
J. Implementation schedule and action plan,
K. Evaluation of the Project,
L. Examination and preparation of plant for project implementation, operation, and maintenance,
M. Environmental and social considerations,
N. Determination and presentation of the feasibility study report and draft PC-1,
O. Review of the Thar–Matiari transmission line feasibility study prepared by the National Transmission and Dispatch Company (NTDC), and
P. Pre-feasibility study of the railway coal transportation between port Qasim and Lakhra power station.

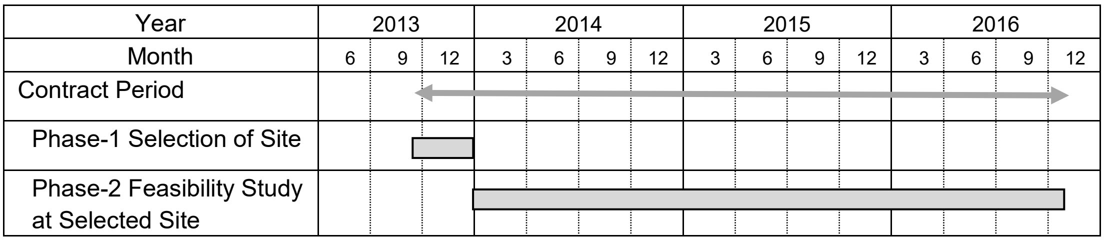
1.6 Schedule of the Survey

The survey period had been from 25 September 2013 to 30 November 2014 originally. Phase-1, which covers the selection of a feasible site for power plant construction, is carried out until the middle of January 2014. Phase-2 which involves the feasibility study on the selected site had scheduled to be completed in October 2014, as shown in Figure 1.6-1. However the pre-FS for railway line for coal transportation from a port to the plant is added in the scope of the Survey, the period of the phase-2 was extended up to October 2016, as shown in Figure 1.6-2.



Source: JICA Survey Team

Figure 1.6-1 Schedule of the Survey



Source: JICA Survey Team

Figure 1.6-2 Revised Schedule of the Survey

CHAPTER 2

BASIC DATA AND INFORMATION

Chapter 2 Basic Data and Information

2.1 National Power Policy 2013

The National Power Policy 2013 was published and uploaded on the website of the Ministry of Water and Power (MoWP) in September 2013. The key points relating to the Survey are summarized in Table 2.1-1.

Some policies directly related to the Project are quoted below. Coal thermal generation is highlighted to secure the inexpensive energy, especially utilizing indigenous resources such as Thar coal.

- <u>Ensure the generation of inexpensive and affordable electricity for domestic, commercial, and industrial use by using indigenous resources such as coal (Thar)</u> and hydroelectricity (hereinafter referred to as "hydel");
- <u>Promote world class efficiency[1] in power generation; and</u>
- <u>Develop coastal energy corridors based on imported coal (then mixed with local coal) and rapid proliferation of coal mining all across the country especially in Thar.</u>

Table 2.1-1 Key Points of the National Power Policy 2013

	Policy
Visions	Pakistan will develop the most efficient and consumer-centric power generation, transmission, and distribution system that meets the needs of its population and boosts its economy in a sustainable and affordable manner.
Challenge	Pakistan's power sector is currently afflicted by the number of challenges that have led to a crisis. 1. The supply-demand gap has continuously grown over the past 5 years, such enormous gap has led to load-shedding of 12-16 hours across the countries. 2. Highly expensive generation cost of electricity Rs 12/kW, due to an increased dependence on expensive thermal fuel sources. 3. Terrible inefficient power transmission and distribution system that currently records losses of 23~25% due to poor infrastructure, mismanagement, and theft of electricity. As aforementioned inefficiencies, theft and high cost of generation are resulting in debilitating level of subsidies and circular debt.
Goals	To achieve the long-term vision of the power sector and overcome its challenges. The Government of Pakistan (GoP) has set the following nine goals. 1. Built power generation capacity that can meet Pakistan's energy needs in a sustainable manner. 2. Create a culture of energy conservation and responsibility.

[1] The plant efficiency of the existing steam turbine power generation owned by GENCO is less than 35%. The planned plant will be more than 35.7% (HHV) for Thar coal and 39.3% (HHV) for imported coal.

	3. Ensure the generation of inexpensive and affordable electricity for domestic, commercial and industrial use by using indigenous resources <u>such as coal (Thar coal)</u> and hydel. 4. Minimise pilferage and adulteration in fuel supply 5. Promote world class efficiency in power generation 6. Create a cutting edge transmission network 7. Minimize inefficiencies in the distribution system 8. Minimize financial losses across the system 9. Align the ministries involved in the energy sector and improve the governance of all related federal and provincial departments as well as regulators. A clear strategy has to be articulated for each of the aforementioned goals in order to actualize the power sector's aspirations.
Targets	Supply Demand Gap: for Goal 1 & 2 Decrease supply and demand gap from 4,500-5,000MW today to 0 by 2017 Affordability: for Goal 3 Decrease cost of generation from 12 USc/kW today to 10USc/kW by 2017 Efficiency: for Goal 4 to 6 Decrease transmission and distribution losses from -23~25% to 16% by 2017 Financial Viability and Collections: for Goal 8 Increase collection from ~85% t o95% by 2017 Governance: for Goal 9 pertains Decrease decision making processing time at the Ministry, related department and regulation from long to short durations.
Policy Principal	The process of policy and strategy is formulated by the "efficiency", "competition"
Strategy	There are 9 strategies to achieve the 9 goals respectively. 1. <u>Supply strategy to meet goal 1</u> Build a power generation capacity that can meet Pakistan's energy needs in a sustainable manner. - Investment can only be encouraged if the sector is made attractive and bankable by eliminating all subsidies to prevent built-up circular dept. - A preference shall be affordable to up-front tariff or feed in tariff which shall set the upper ceiling. (In the short run) - The government has already brought the existing capacity online by retiring the circular dept, which has resulted in an additional supply over 1,700MW. - In tandem, an aggressive rehabilitation and expansion program for the generation company (GENCO)s is underway which would add 1,447MW within a year: rehabilitation projects at Guddu, Jamshoro, and Muzzafargarh will yield 700MW while expansion of Guddu will add 747MW. - Maximum delay limits for payable set for RFO (45~60days) and gas (35~45days) should also apply to hydel Independent power producer (IPP) s and water and power developed authority (WAPDA). - In medium term (In the medium term) - The MoWP will attract new investments and expedite the pipeline projects on a war footing. - A number of projects (5 projects 256MW in total) have reached financial close, one project (100MW) will reach it within 2013. The Uch-II power project (404MW) has reached financial close and it expected to come

	online by end of 2013. - The cumulative 2,726MW of wind electricity (if deemed feasible) could come online in 2016. - 341MW of solar energy project are currently in the feasibility assessment and could come online by 2015 if deemed feasible. - Six project totalling 388MW of hydel power are expected to be completed by February 2015. - Gulpur Hydropower 247MW by December 2017, Neelum-Jhelum HPP by November 2016, fourth and fifth extension totalling 1,919 MW is come online. - **The government is also poised to announce a coal corridor with a capacity to generate 6,000 – 7,000MW in the near future.** (In long run) - Large infrastructure program including the Indus Basin Cascade will be aggressively developed. Detailed engineering design for Dasu 2,160MW, Patan 2,800 MW and Thakot 2,800MW is being carried out and will optimally be constructed using a built operate transfer (BOT) public-private partnership (PPP) method. - Bunji and Diamer-Basha 7,000MW and 4,500MW potential respectively could ensure the energy independence and security of Pakistan. (To achieve its medium and long terms goals) - The government will develop infrastructure and provide incentives to attract greater private sector investment. - The government will set the foundations of energy cities and corridors, and sponsor PPP for coal and run of river projects. - The government will assign "key client managers or relationship managers" at the MoWP who will act as a "one window operation" for investors to ensure the timely completion of investments and projects. 2. Demand Strategy to meet goal 2 Create a culture of conservation and responsibility. 3. Affordable Power Strategy to meet goal 3 Ensure the generation of inexpensive and affordable electricity for domestic, commercial & industrial use. - The strategy focusing on shifting Pakistan's energy mix toward low cost sources such as hydel, gas, coal, nuclear and biomass. - **Development of coastal energy corridors based upon imported coal (mixed later with local coal), rapid proliferation of coal mining all across the country-especially at Thar,** and conversion of expensive RFO based plants to coal are the central tenets of coal policy. - The proposed strategy will change the energy mix of Pakistan in favour of low cost sources and significantly reduce the burden of energy to the end of consumer. 4. Supply - Chain Strategy to meet goal 4 Minimize pilferage and adulteration if fuel supply. - The strategy will focus on redirecting the supply of fuel from inefficient GENCOs to the most efficient IPPs which has the potential of saving Rs 3 billion per month and generation an additional 500MW. - The MoWP will sign performance contracts with GENCOs, Pakistan state oil (PSO), and fuel transporters and hold them accountable for the quality and theft of oil. 5. Generation Strategy to meet goal 5 Promote world class efficiency in power generation. - The strategy focuses on establishing plant efficiency through external heat

	rate testing, building a merit order accordingly, and allocating fuel to the more meritorious plants. - Merit order will privilege fuel allocation on the basis of efficiency and optimize dispatch and payments. - The strategy calls for the privatization or O&M based leasing of GENCOs. 6. Transmission Strategy to meet goal 6 Create a cutting-edge transmission network. 7. Distribution Strategy to meet goal 7 Create a cutting-edge transmission network. 8. Financial Strategy to meet goal 8 Minimize financial losses across the system. 9. Governance Strategy to meet goal 9 Align the ministries involved in the energy sector and improve governance.
Prioritization	To maximize the impact of the various strategic initiatives: (In the short term) - Bring existing capacity online, stop thefts of all from, rationalize the tariff, sign performance contract, and ensure transparency. (In the medium term) - Bring low-cost pipeline projects online, and jump start coal and hydro PPP projects. (In the long term) - Finish large infrastructure hydel projects and retire high cost energy contracts to ensure that Pakistan moves towards cheap electricity generation.
Impact	The successful implementation of this policy will lead to enormous improvement within the power sector. - By 2017, the supply – demand gap could be eradicated completely. - By the end of the current government, power surplus which can then be regionally traded. - By the end of decade Pakistan could be transformed from energy strapped, importer of power to a regional exporter of power. - The cost of power generation will be reduced to an affordable amount. - The efficiency improvements in transmission and distribution will decrease the burden of power to the end consumer. In summary, prosperity and social development will become a reality in a Roshan Pakistan.

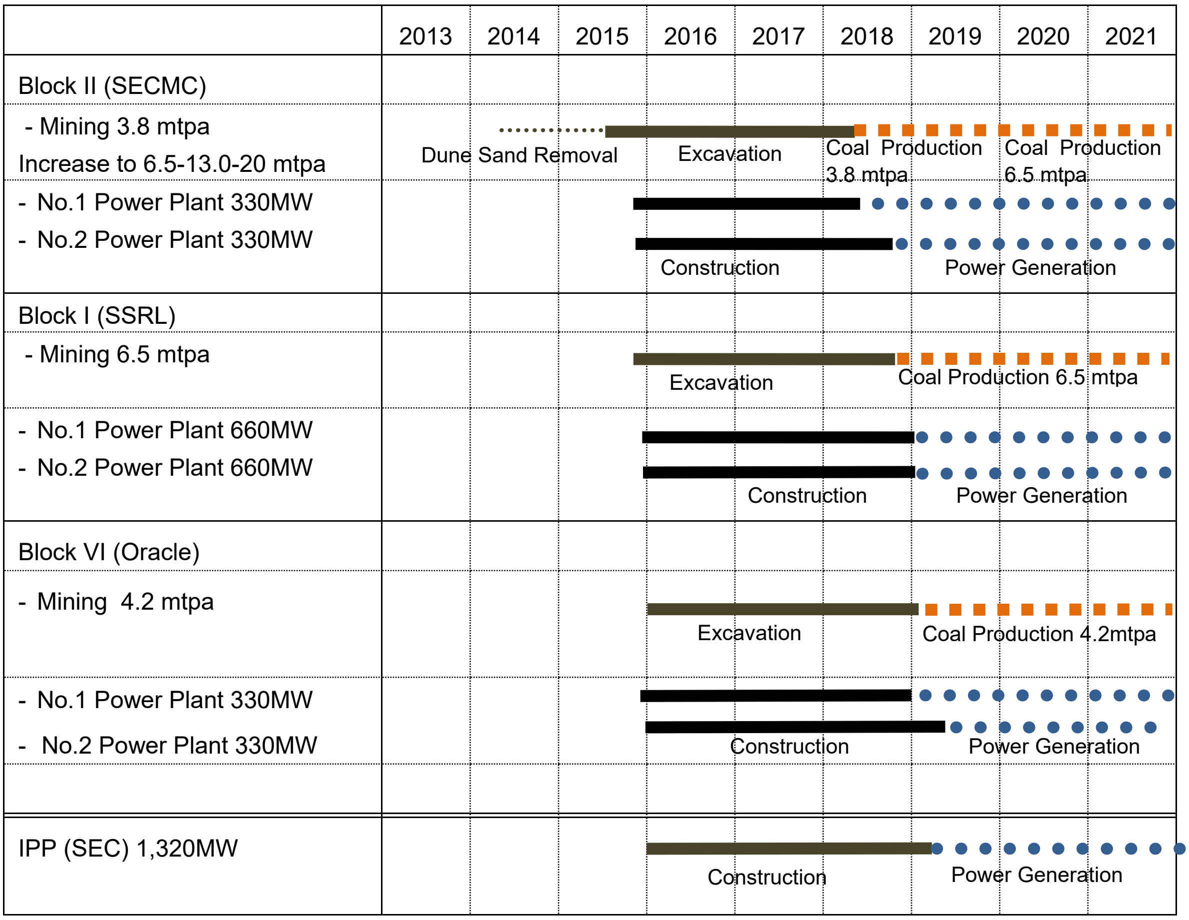
Source: National Power Policy 2013, MoWP

2.2 Development of Thar Coalfield

2.2.1 Summary of the Development Status

Table 2.2-1 shows the development schedule of three out of 12 blocks in Thar coalfield, where mining licences have been released, development plans have been made, and financial sources have been arranged. Block II is owned by the Government of Sindh (GoS) at 51% and Engro & other local investors at 49%. Block I is 100%-owned by Sino Sindh Resource Limited, a subsidiary of Global Mining Company private sector in China. Block IV is owned by Oracle Coalfields PLC (or simply "Oracle") of the United Kingdom. The detailed actions on the development of these blocks are explained below. All three blocks aim to develop both for coal mining and power generation.

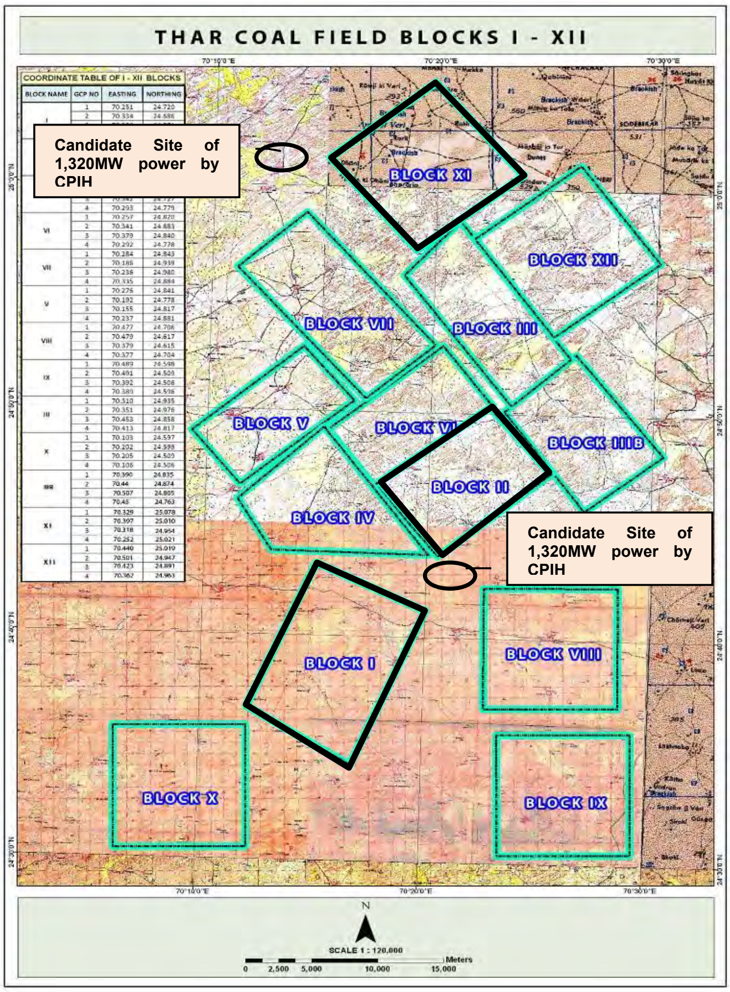
Table 2.2-1 Development Schedule of Three Blocks in Thar Coalfield



Note: Each block is planned to supply coal not only for mine mouth power plant but also for cement factory and coal thermal power plant to be developed by KESC. Schedule for Block I and Block VI are assurance based on the delay of procedure at least 6 months against information obtained by the interviews.

Source: Block II: Letter from SECMC and up-dated interview in December 2014, Block I: Interview with Sino Sindh Resource, Block VI: Oracle Coalfields PLC interview in December 2013 and Annual General Meeting 21 May 2014 in Website of Oracle.

The locations of Blocks I, II, and VI in Thar coalfield are highlighted, and the candidate sites of 1,320 MW IPP will be financed by Shanghai Electric Corporation (SEC) are shown in Figure 2.2-1.



Source: JICA Survey Team, based on the block allocation map prepared by the Thar Coal and Energy Board (TCEB)

Figure 2.2-1 Location of Blocks in Thar Coalfield

The resources and calculated duration of mining are divided by planned maximum mining size for Blocks I, II, and VI are listed in Table 2.2-2.

Table 2.2-2 Calculated Duration of Mining by Planned Mining Size

Block	Investors	Area (km^2)	Total Drill Holes	Resources (million t)				Planned Max. Mining Size (mtpa)	Calculated Duration of Mining (years)
				Measured < 0.4 km	Indicated 0.4-1.2 km	Inferred 1.2-4.8 km	Total		
I	SSRL	150.0	41	620	1,918	1,028	**3,566**	19.5	**183**
II	SECMC	79.6	113	425	1,492	423	**2,240**	6.0	**373**
VI	Oracle	66.1	35	762	893	-	**1,655**	5.0	**331**

Source: JICA Survey Team based on Coal Resource Volume, TCEB

2.2.2 Power Plant Construction Plan in Thar Coalfield

The power plant construction plan in Thar coalfield is summarized in Table 2.2-3.

Table 2.2-3 Power Plant Construction Plan

Area	Planned Power Plant by 2020 (gross)	Total in MW (net)
Block I	1,320 MW (660MW x 2 units) will be installed by 2019	1,200
Block II	660 MW CFBC (330MW x 2 units) will be installed by 2018	600
Block VI	660 MW (330MW x 2 units) will be installed by 2018 to 2019	600
SEH	1,320 MW (660MW x 2 units) will be installed by 2019	1,200
Total		3,600

Source: JICA Survey Team based on the results of interview with Blocks I, II, and VI

2.2.3 Block II (Letter from SECMC and up-dated in December 2014)

1) Financing:

For Mining: Initial mining size will be 3.8 mtpa which needs USD 1,200 million financed under a debt-to-equity ratio of 75:25. Block II had approached a number of international financial institutions but only a Chinese company agreed to finance the mine. Its financing was subject to the Government of Pakistan (GoP) providing sovereign guarantee of USD 630 million for the debt portion of the mine, which made it possible to finance the mine. They had numerous positive discussions with local banks, Sino Sure, ICBC China, and China Exim Bank; and discussions are in the advanced stages for mine financing. As a requirement for providing sovereign guarantee, GoP also insisted to change the shareholding of GoS to Engro from 40:60 to 51:49, i.e., increasing the share of GoS from 40% to 51%; thus, making Sindh ENGRO Coal Mining Company (SECMC) a state company. As for the private share of 49% equity, Engro, HUBCO, Tihel, House of Habib, Habib Bank and China Coal technology and Engineering Group (CCTEG), who is contractor of the mining, are willing to invest. The financial close is expected by end of June 2015. SECMEC's project has been included in the prioritized list of projects being pursed in the Pakistan-China energy Corridor and having GoP's sovereign guarantee, hence, both Chinese and Pakistani banks have in principle agreed to finance the project.

Power Plant: This will be developed under Engro Powergen Thar Limited (EPTL), to which Engro and CMEC will invest 80% and 20% respectively. Estimated project cost is USD 1,980 million for two units of 330MW power plants. This will be financed under a debt-to-equity ratio of 75:25. Chinese banks, especially the Industrial and Commercial Bank of China (ICBC) and China Development Bank (CDB), together with local banks, will to finance this project under the current regime of power purchase agreement (PPA) and implementation agreement (IA).

2) Contract:

As per Pakistan procurement procedures, SECMC had prequalified several Chinese, Indonesian, Australian, and Turkish contractors for the mining project. The requests for proposal were distributed to the prequalified contractors. The contract was awarded to CCTEG.

3) Land acquisition

Block II has identified approximately 6,000 acres required for the first eight years of mining including the site for the power plant. Procurement activities have already completed as of May 2014. The good side of this procurement is that it does not require any relocation. Land area of 1,000 acres shall be acquired for the power plant which is mainly owned by Government.

4) Early start of mining before financial close

The sponsors (GoS and Engro & other investors) had agreed to start the mining activities early without waiting for financial close. This will include procurement of land, removal of initial overburden. Initial overburden removal work (approximately 3 million m^3) had started early in May 2014 by local contractors and equipment, which will also exhibit confidence over the project to its sponsors, as the main mining contractor will mobilize after financial close. As of end August 2015, 3.0 million m^3 of overburden have been removed with 250 labours, 70 trucks and 20 excavators. As total overburden to be removal up to reach the coal seams is estimated at 113 million $m^{3,}$ the removal works by the financial close will be increased.

5) Mine size and usage of coal

Initially, the mine would be developed for 3.8 million t per annum (or mtpa) will be expanded to 6.5 mtpa, and finally to 20 mtpa (equivalent to 3,600 MW). During the initial phase, coal will be supplied to the ETPL power plant (3.0 mtpa) while the rest will be for power plant Jamshoro financed by ADB. After expanded, coal can also be supplied to the plant proposed by SEH in Thar.

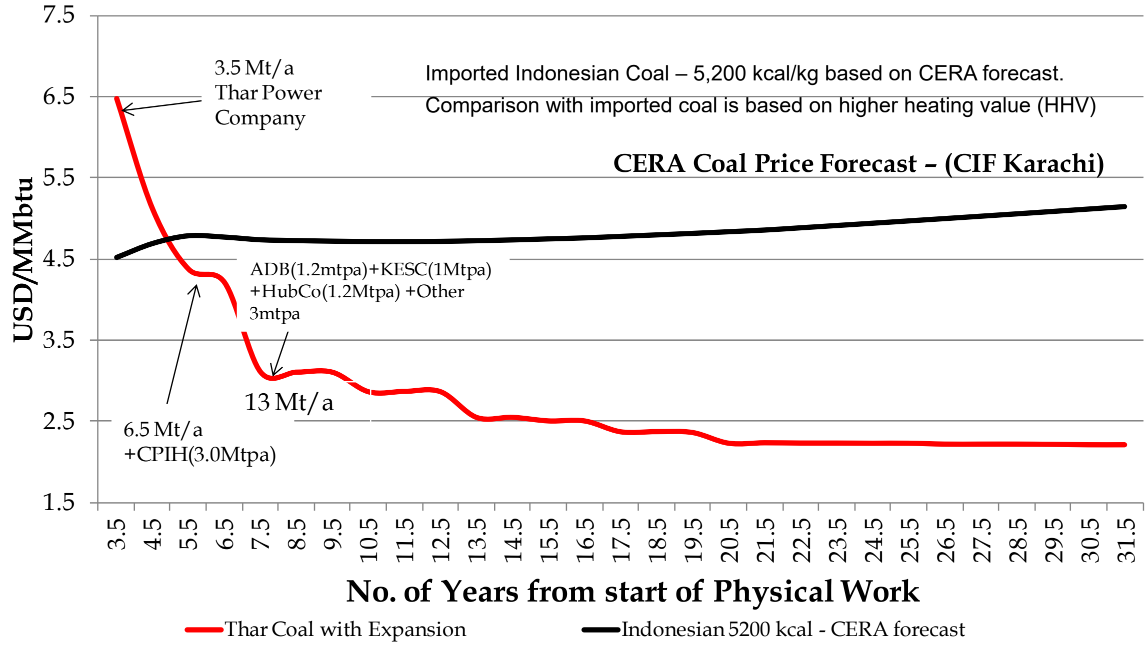
6) Overall schedule

- Financial close: end of 2015
- Power plant (first 330 MW): first half of 2018
- Power plant (second 330 MW): second half of 2018
- Mine completion: first quarter of 2018

7) Coal price

Block II's objective was to make Thar coal price equal or better than the international price. However, with the falling international prices, this objective had become more difficult to achieve. Almost 7-8 months were spent to redesign the mine with the help of the German and Chinese consultants (including equipment selection, overburden sites, timing for the development, initial dune sand removal by local contractors, contracting strategy, and division of work between contractor and owner). Now, through all the efforts, the price of the 1,200 MW power plant equivalent mine, has become slightly lower than the international price. For the ultimate capacity of the mine (equivalent to 3,600 MW), Thar coal price would be lower than the international coal price. This advantage is only available with indigenous coal as its price mechanism is not tied to international prices; rather, it follows a cost-plus pricing.

The Thar coal price forecast compared with imported subbituminous (CIF Karachi) is illustrated in Figure 2.2-2. When mining starts with a production size of 3.5 mtpa, the coal price is assumed at USD 6.5/MMBTU; then, it will be decreased to USD 4.2/MMBTU at 15 mtpa; and in the far future, it will be 2.3 USD/MMBTU. On the other hand, imported coal will be at USD 4.5/MMBTU, then will be increased to USD 5.2/MMBTU.



Source: Thar Coal Project - Key to Pakistan's Energy Security, updated on 4 July 2013, SECMC

Figure 2.2-2 Thar Coal Price Compared with Imported Coal in MMBTU

2.2.4 Block I (Interview as of December 2013 and letter from SECMC in August 2015)

1) Financing

The total mining cost is estimated at USD 1,200 million for a mining size of 6.5 mtpa, of which the debt-to-equity ratio is 20% by Global Mining and 80% by Chinese banks, with the main bank being China Development Bank (CDB). The financial close is expected by 4th quarter of 2015.

2) Contract

China Coal Technology and Engineering Group (CCTEG) was awarded to an engineering, procurement, and construction (EPC) contractor, and the work is expected to commence in 2015. It will then take three years to produce the first coal.

3) Land acquisition

Survey for land use was completed and maps of block I was prepared. The Government award by local authority at Mitihi is being waited.

4) Mine size and usage of coal

The initial feasibility study (FS) was conducted for the installation of two 660 MW power plants in Thar in October 2013. The candidate sites in Thar are outside the concession among Blocks I, II, and VIII, or Vajhiar, where a reservoir will be constructed by GoS.

With a mining size of 6.5 mtpa, coal will be supplied to the coal-fired thermal plants with a total capacity of 1,260 MW, which was planned to be constructed initially by previous contractor.. However, current EPC contractor has been changed to Shanghai Electric Corporation (SEC) and the capacity of power plant is enhanced to 1,320 MW.

5) Other information

Up to November 2013, the staff of Global Mining China have not continuously stayed in Pakistan but only visited on a trip basis. As the project will start soon, two staff will also start to continuously reside in Pakistan.

As for the water to be used for the plant mainly for cooling the generated steam coming from the turbine, SEC has two options: one is the water coming from the Left Bank Outfall Drain Project (LBOD) and the other is through groundwater extraction, anticipating 35 mtpa.

In November 2013, SSRL decided to construct the two 660 MW power plants in Block I, as the sovereign guarantee can be secured only for power generation and not for mining. The CSA with the sovereign guarantee for power plants can guarantee the selling of coal produced by mining.

2.2.5 Block VI (based on letter from Oracle Coalfields as of August 2015))

1) Financing

In September 2014, Oracle Coalfields signed an EPC framework agreement with Shandon

Electric Power Company (SEPCO) for the construction of initially a 600 MW mine mouth power plant and for the development of a 4.2 mtpa open pit to supply the power plant. The cost of developing the above integrated coal mine and power plant (including finance cost) is estimated USD 1,600 million, which will be 30 % funded by equity and the balance 70 % by debt. Thar Electricity Limited, a subsidiary of Oracle Coalfield, as been established that shall build and own the mine-mouth power plant at the block VI site. The integrated project shall be funded by major international institutional investors and strategic investors of Oracle Coalfields.

Work is ongoing to develop this agreement into EPC term sheets for both the mine and the power plant. Oracle Coalfields is working with its advisors, Mott MacDonald UK on the power plant and Turner and Townsend for the mine development.

Oracle has had in place a Joint Development Agreement (JDA) with the K-Electric (KE) since 2012 for the power plants in block VI. In addition, Oracle Coalfields is working with KE to develop a PPA for the entire electricity output of the power plant for 30 years.

2) Contract

EPCs for both the mine and the power plant are being finalized and will be incorporated into EPC term sheets so that finance discussions with Sinosure and equity providers can be progressed prior to signing the EPC contracts.

3) Land acquisition

Work is underway to identify land ownership across block VI under the supervision of Hagler Bailly prior to land acquisition in accordance with the Resettlement Framework Policy of the GoS.

4) Mine size and coal usage

A 4.2 mtpa is being developed to supply a 600 MW (2x300 MW) mine mouth power plant.

5) Other information

Block VI is located in the center of the coalfield and covers and area of 66.1 square kilometres. The site has been extensively drilled and coal samples recovered and tested to international standards and a Joint Ore Reserves Committee (JORC) resource and the results of the geotechnical and hydrological investigations set out the design parameters for the mine and confirmed the viability of constructing and operating a large open pit mine capable of producing 5mtpa. The lignite coal in block VI is relatively low in sulphur content when compared with lignite in Germany and Poland. Although the moisture content is relatively high, it is suitable for a coal-fired electrical power plant. The coal itself lies at150 m depth below the ground surface.

Following the completion of the technical FS by the Sindh Carbon Energy Ltd (SCEL) were granted a mining lease for block VI by the mines and mineral s development department, GoS for first 30 years which can be extended at the end of the period for another 30 years.

Pre-FS by Mott MacDonald UK confirmed the suitability of the coal for thermal power generation and concluded the coal was suitable for either conventional pulverized coal or circulating fluidised bed plans.

The company engaged Wardell Armstrong International and Hagler Bailly of Pakistan to carry out the environmental and social impact assessment for the project and this was completed in May 2013 and approved by SEPA in January 2014. The company submitted its resettlement action plan (RAP) to SEPA in April 2014 as required in the ESIA approval process. The RAP has been drawn up in line with recently published Interim Resettlement Policy Framework by the GoS.

The RAP sets out the policy and procedures that will be employed to facilitate the eventual resettlement of the small local communities who will be affected by the mine and power plant development. This is being done in consultation with the local communities with the support of the TCEB and local government agencies.

Work is underway to establish current and ownership within the block and to identify areas suitable for resettlement within the block I. Some 2,000 people are expected to be resettled within the block VI.

2.3 Existing and Future Planned Generation Capacity

2.3.1 Existing Generation Capacity (except KESC)

As of November 2013, the installed power generation capacity in Pakistan is 20,822 MW, while the derated/dependable capacity is 18,830 MW during summer, which decreases to 14,295 MW in winter due to the decrease in output of hydropower. Details of the installed power generating capacity in Pakistan are shown in Table 2.3-1.

Table 2.3-1 Existing Installed and Derated Capacity as of November 2013

Type of Generation	Installed Capacity (MW)	Derated/ Dependable Capacity (MW)	Availability (MW)	
			Summer	Winter
WAPDA Hydro	6,733	6,660	6,660	2,314
GENCOs Thermal	4,829	3,580	3,580	3,580
Nuclear	665	615	615	615
IPP Hydro	195	195	195	65
IPP Thermal	8,294	7,687	7,687	7,687
Wind Power Plant	106	93	93	35
Total	20,822	18,830	18,830	14,295

Source: Existing Installed Capacity and Capability of X-WAPDA DISCOs System, NTDC

Details on installed and derated capacity for each power station are shown in Attachment 2-1.

2.3.2 Generation (except KESC) in 2011-12

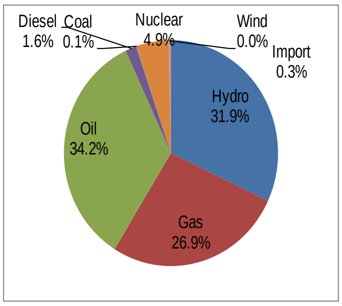
The generated power by fuel type in 2011-12 is shown in Table 2.3-2.

Table 2.3-2 Generation by Fuel Type in 2011-12 (unit: GWh)

Total	Hydro	Gas	Oil	Diesel	Coal	Nuclear	Wind	Import
89,721	28,643	24,161	30,662	1,474	66	4,413	6	296

Source: Power System Statistics 2011-2012 37th Edition, Planning Power NTDC

In 2011-12, the total generated power was 89,721 GWh. Hydropower, gas, and oil dominated at 31.9%, 26.9%, and 34.2% respectively, totaling to 93% of the total generated power. One coal thermal power plant, namely Lakhra, with a capacity of 150 MW (50 MW x 3 units), contributed only 0.1% of the total power, and it was derated to a maximum of 30 MW. Details of power distributed by different sources are shown in Figure 2.3-1.



Source: Power System Statistics 2011-2012 37th Edition, Planning Power NTDC

Figure 2.3-1 Generated Power by Fuel Type

2.3.3 Future Generation Development Plan

Table 2.3-3 shows the future generation development plan prepared by the National Transmission and Despatch Company (NTDC). By the end of fiscal year 2019-2020, an additional 26,296 MW is planned to be installed, of which 8,715 MW will be from hydropower; 1,396 MW from gas; 1,000 MW from solar power; 1,650 MW from wind; 425 MW from oil; 10,320 MW from coal; 1,790MW from nuclear; and 1,000 MW from imported sources.

The name of power plants and their corresponding installed capacities are listed in Attachment 2-2.

Table 2.3-3 Future Generation Development Plan (unit: in MW)

Fiscal Year	Total Capacity	Hydro	Gas	Solar	Wind	Oil	Coal	Nuclear	Import
2013-2014	**475**	130	245	100					
2014-2015	**2,356**		1,151	300	480	425			
2015-2016	**1,250**			600	650				
2016-2017	**3,572**	2,712			520			340	
2017-2018	**10,082**	222					**8,520**	340	1,000
2018-2019	**4,090**	2,290					**1,800**		
2019-2020	**4,474**	3,361						1,110	
Total	**26,269**	8,715	1,396	1,000	1,650	425	**10,320**	1,790	1,000

Source: JICA Survey Team, based on the Annual Summary of Generation Addition as of November 2013, NTDC

The details of the 10,320 MW coal-fired thermal plants are as follows:

2017-18: 8,520 MW in total

Engro Thar Coal Phase-1 with 600 MW; Pakistan Power Park Phase-1 (Gaddani) with 1,320 MW; Pakistan Power Park Phase-2 (Gaddani) with 5,280 MW; and Bin

Qasim Power Plant with 1,320 MW.

2018-19: 1,800 MW in total

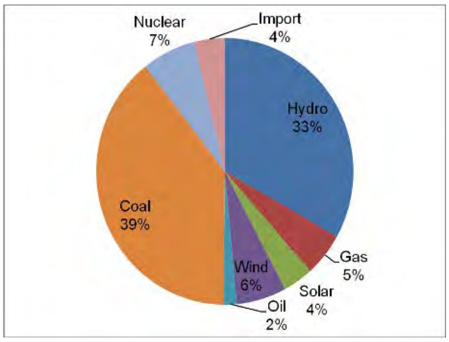
Engro Thar Coal Phase-2 with 600 MW; TPS Jamshoro Phase-1 with 600 MW; and TPS Jamshoro Phase-2 with 600 MW.

The new power plant under the Project is not included in the plan shown in Table 2.3-3.

The coal thermal plants planned to be developed in Thar as discussed in Clause 2.2 are not fully incorporated in the plan summarized by NTDC.

The Pakistan Power Park (Gaddani) plan for 6,600 MW (Phase-1 with 1,320 MW and Phase-2 with 5,280 MW) was established by the new government in the middle of 2013. Details are explained in Clause 2.4.

The energy mix of the planned generation, as shown in Figure 2.3-2, will be incorporated in the power system within seven years, i.e., from fiscal years 2013-14 to 2019-20. The shares of coal and hydropower are 39% and 33%, respectively.



Source: JICA Survey Team based on the data shown in Table 2.3-3

Figure 2.3-2 Energy Mix of the Planned Generation up to 2019-20

2.3.4 Power Demand

Increase in power demand as forecasted by NTDC, except for KESC, namely 660 MW, will be constantly supplied by NTDC, as shown in Table 2.3-4.

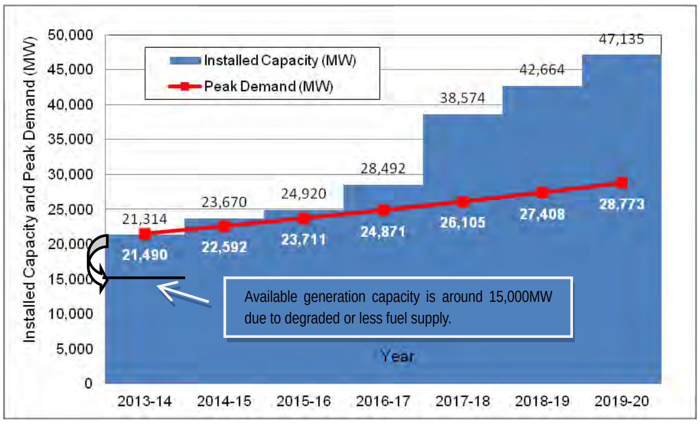
Table 2.3-4 Peak Power Demand Forecast (except KESC)

Year	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Demand (kWh)	21,490	22,592	23,711	24,871	26,105	27,408	28,773
Increase (%)	5.1%	5.0%	4.9%	5.0%	5.0%	5.0%	4.8%

Source: Peak Demand Forecast Summary, NTDC

The calculated average increase in rate of power demand during 2013-14 to 2019-20 is at 5.0%. Details of the forecast are shown in Attachment 2-3

The accumulated installed capacity by year and its corresponding power demand forecast are shown in Figure 2.3-3. Studying the figure, the installed capacity will greatly exceed the power demand. However, the planned installed capacity contains huge generation projects, which do not seem to have any financial background especially for coal, nuclear, and hydropower projects; therefore, the project-sharing finance firm must proceed.



Source: JICA Survey Team based on the data of NTDC

Figure 2.3-3 Demand Forecast and Planned Aaccumulated Installed Capacity

2.3.5 Prioritized projects pushed by the Government other than Gaddani

According to the statement by the Prime Minster on 14 October 2013, the following projects are prioritized by the government:

1) Coal thermal project development of 1,320 MW (660 MW x 2 units) in Port Qasim.
2) Wind energy generation of 1,650 MW by 2016.
3) Central Asia to South Asia Interconnection (CASA) Project (1,000 MW import) by 2017.
4) Tabella-V extension project (1,410 MW increase through hydel) by 2017.
5) Development of a 1,000 MW power project at Quad-e-Azam Solar Park by the Government of Punjab.
6) Neelum-Jhelum (969 MW of hydel), under construction, to be completed by November 2016
7) Nandipur (425 MW using gas-combined) power projects, which is under construction and will be completed by December 2014.
8) Jamshoro Coal Thermal (1,200 MW) to be financed by ADB.

The projects are also listed in Appendix 2-2, Annual Summary of Generation Addition.

2.4 Pakistan Power Park in Gaddani

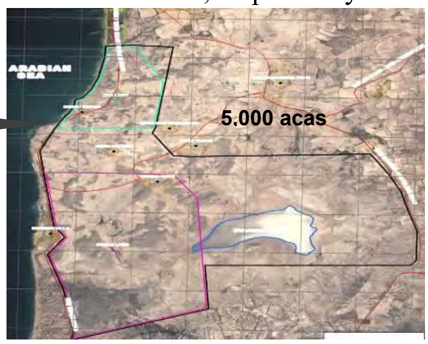
As stated under “7. Supply Strategy” of the National Power Policy 2013, “the government is also poised to announce a coal corridor that has a capacity to generate 6,000–7,000 MW in the near future”. In line with this, the Prime Minister has announced the development of the Pakistan Power Park in Gaddani to house 6,600 MW in blocks of 10 units of 660 MW plants was announced at the end of August 2013. The objective of the development is to facilitate investors in a transparent manner in expediting the following:

a. Developing the site including land acquisition, security, and coal/water infrastructure;
b. Saving time and money of investors by reducing project cost;
c. Installing transmission lines for carrying generated power; and
d. Developing draft agreements, implementation agreements, power purchase agreement, shared facilities agreement, etc.

The location and area of Gaddani are shown in Figure 2.4-1 and 2.4-2, respectively.

Source: JICA Survey Team

Figure 2.4-1 Location of Gaddani



Source: Pakistan Power Park in Gaddani, PPIB

Figure 2.4-2 Land Area in Gaddani

2.4.1 Background of Gaddani

Gaddani has been recommended by three reputable independent consultants, whose FSs are being studied by the current government. They are the following:

a. Shanigan Integ conducted a study for WAPDA in 1986 for 4,000 MW, where Gaddani was listed one of the four recommended sites.
b. Sargent & Lundy conducted a study for Mitsui/Malakoff in 2006 for 1,200 MW in Gaddani.
c. PB Power conducted a study for AES Corp in 2006 for another 1,200 MWs in Gaddani.
d. AES and Mitsui recommended 660 MW, supercritical and pulverized coal platform.

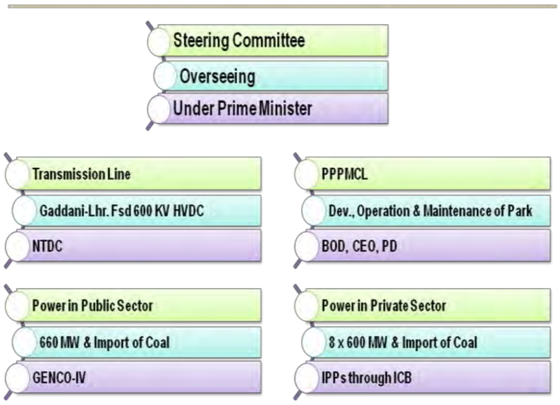
2.4.2 Organization of the Power Park

The steering committee is chaired by the Prime Minister of Pakistan. Among its members are from the federal ministers of relevant ministries and the chief minister of Balochistan Province.

The organization of Pakistan Power Park in Gaddani is shown in Figure 2.4-3.

(Chairman)
- Prime Minister of Pakistan

(Member)
- Federal Finance Minister
- Federal Minister for Water and Power
- Federal Minister for Petroleum and Natural Resources
- Chief Minister of Balochistan Province
- Other three members



Source: Pakistan Power Park in Gaddani, PPIB

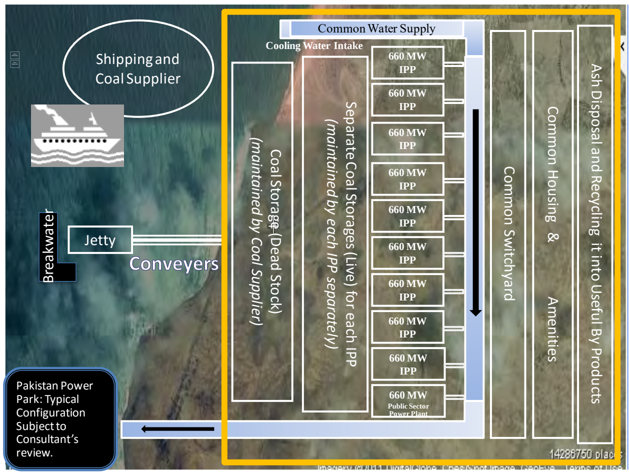
Figure 2.4-3 Organization of Pakistan Power Park in Gaddani

The four main players under the steering committee are the following: 1) NTDC who will construct 600 kVDC transmission lines from Gaddani to Lahore and Faisalabad; 2) Pakistan Power Park Management Company Ltd. (PPPMCL) who will handle the development, operation and maintenance of the park: 3) GENCO who will construct two units of 660 MW coal thermal power plants and import of coal; and 4) IPPs who will construct eight units of 660 MW coal thermal power plants including the import of coal through international competitive bidding (ICB). The organizational chart is illustrated in Figure 2.4-3.

2.4.3 Outline Plan

Imported coal will be carried by Capesize or Panamax vessels, which can carry 130,000 t and 60,000 t of coal, respectively. Then, the coal will be unloaded on the jetty to be constructed 7 km on shore. It will then be carried to the coal yard via a conveyor installed on the 7 km connecting bridge between the land and the jetty.

The conceptual arrangement of the ten power plant units and common facilities, water intake and outlet, coal storage, common switchyard and ash disposal and recycling, common housing, and amenities are illustrated in Figure 2.4-4.



Source: Pakistan Power Park in Gaddani, PPIB

Figure 2.4-4 Overall Plan of Pakistan Power Park in Gaddani

2.4.4 Budget for the Project

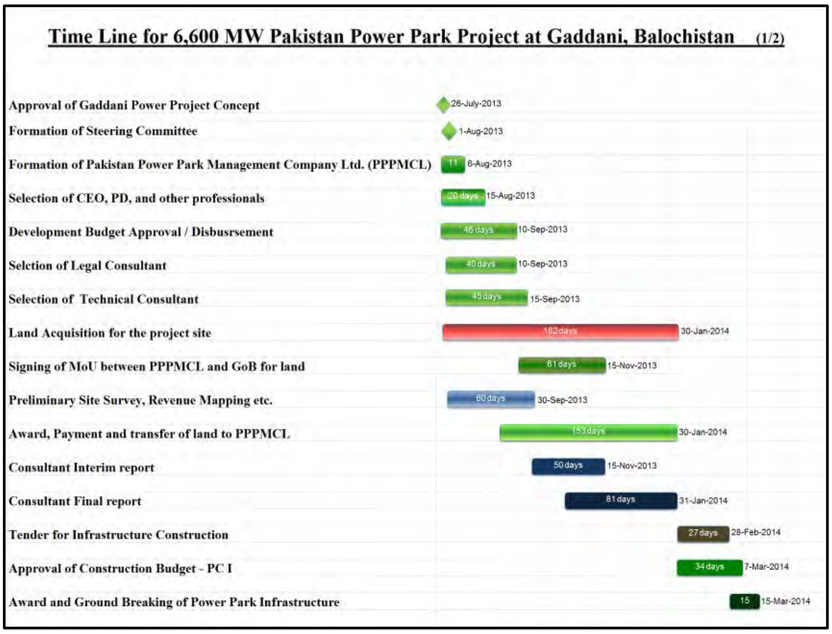
The government roughly estimates the cost at USD 13.8 billion for the whole power park project. Details are shown below.

Items	Cost USD million
Jetty and related marine infrastructure	700
Park's onshore infrastructure	100
Transmission line	4,000
2x660 MW projects in the public sector	1,800
8x660 MW projects in the private sector	7,200
Total	13,800

Note: These are only preliminary and rough estimates, and will change considerably once the design has been finalized and costs have been firmed up.

2.4.5 Preparatory Work Schedule

The schedule for preparatory works for the project, which include land acquisition for the site, selection of legal and technical consultant, consultant design for infrastructures, and approval of Planning Commission No. 1 (PC-1), are formulated as shown in Figure 2.4-5. According to the schedule, the awarding of infrastructure to the contractor and groundbreaking is scheduled to be done in May 2014.



Source: Pakistan Power Park in Gaddani, PPI

Figure 2.4-5 Preparatory Work Schedule for Pakistan Power Park in Gaddani

2.4.6 Transmission Line from Guddani

For carrying the power generated in Pakistan Power Park at Guddani (6,000 MW in net), NTDC plans to install high-voltage direct current (HVDC) transmission lines to connect with the northern power demand centers.

- Two 600 kV HVDC bipole transmission lines to Faisalabad West, 1,200 km
- Two 600 kV HVDC bipole transmission lines to Lahore South, 1,200 km

In addition to the above, 500 kV high-voltage alternating current (HVAC) transmission lines for connecting internal and neighboring countries are planned.

- Two 500 kV HVAC transmission lines to Quetta West through Khuzdar connecting with Iran, 625 km.
- Two 500 kV HVAC transmission lines to Gawadar through Ormara, 550 km
- Other 500 kV HVAC transmission lines to be connected to the east.

The total cost for the abovementioned HVDC and HVAC transmission lines was estimated at USD 4 billion, which GoS cannot afford to finance.

The GoS constitutes a committee on formulating private transmission policy for Pakistan Power Park and electricity import from neighboring countries for the private sector to be able to invest on the construction and operation of the transmission lines. NTDC published new “Guidelines Transmission Line Policy 2015”.

2.5 Oil to Coal Conversion

Karachi Electric Supply Company (KESC) has decided to convert two of its power utility generation units (No. 3 and No. 4[2], 210 MW each) at Bin Qasim Power Station, from oil/gas to coal by leasing them out to Bright Eagle Enterprises[3] for 20 years.

Table 2.5-1 Conversion Plan from the Existing Thermal Plants of Oil or Oil/Gas to Coal Thermal

Owner (Province)	Power Station Total Installed Capacity	Plants to be Converted	Commissioned Year of Existence	Target Year of Conversion	Coal to be Used	Finance
KESC (Sindh)	Bin Qasim-1 1,260 MW	210 MW x 2 oil (total 420MW)	1989, 90	Planning	Imported	K-Energy China

Source: JICA Survey Team

The necessary volume of imported coal (heating value of 5,800 kcal/kg) for the calculated 420 MW as shown above is estimated at 1.62 mtpa.

2.6 Circular Debt

2.6.1 Circular Debt in the Power Sector

Circular debt is the amount of cash shortfall within the Central Power Purchasing Agency (CPPA) that it cannot pay to IPPs. This shortfall is the result of the difference between the actual cost of providing electricity in relation to revenues realized by the power distribution companies (DISCOs), from sales to customers plus subsidies and insufficient payments by the DISCOs to CPPA out of the realized revenue, as they give priority to their own cash flow needs. This revenue shortfall cascades through the entire energy supply chain, from electricity generators to fuel suppliers, refiners, and producers; resulting in a shortage of fuel supply to the public sector thermal generating companies (GENCOs), a reduction in power generated by IPP, and an increases in load shedding. It was said that the circular debt had accumulated to over Rs 500 billion.

2 Bin Qasim has six units of 210 MW oil/gas thermal plants. The boilers for Plant Nos. 1, 2, 5, and 6 were supplied by Hitachi Babcock Japan in 1984, 1984, 1991, and 1997, respectively. Plant Nos. 3 and 4 that will be converted to coal were supplied by Deutsche-Babcock Germany in 1990 and 1991, respectively.

3 Bright Eagle Enterprises, a Hong Kong-based investment company, will lease the plants and convert them from oil/gas to coal. K Energy, a subsidiary of Bright Eagle Enterprises, will make necessary arrangements to ensure the required money for the conversion of the two units to coal. KESC will buy electricity from Bright Eagle Enterprises and will sell it to its consumers.

2.6.2 Clearance of Circular Debt

The new government, established in May 2013, has successfully cleared almost all of its circular debt worth Rs 480 billion to IPPs: 322 billion in June 2013 and 158 billion in July 2013, just a few months after coming to power.

This resulted IPPs to increase power generation by 1,700 MW. The IPPs also accepted the government's demand for converting four thermal power plants (HUBCO 1,200 MW, Lalpir, Pakgen, and Saba) to coal in order to reduce costs within a few years.

This measure had not only resulted in the addition of 1,700 MW in the national grid but also buoyed foreign investors who are now looking forward to investing in the energy sector in Pakistan.

2.7 Upfront Tariff for Coal Thermal Generation

2.7.1 Upfront Tariff[4]

The National Electric Power Regulatory Authority (NEPRA) has issued the document "Determination of NEPRA in the Matter of Upfront Tariff for the Projects on Imported/Local Coal (Other than Thar Coal)" on 6 June 2013. This document states that the tariff for coal-based generation technology consists of two types of charges, which are further divided into items as shown in Table 2.7-1.

Table 2.7-1 Structure of Tariff for Coal-based Generation Technology

A. Energy Purchase Price	B. Capacity Purchase Price
1. Fuel cost	1. Fixed O&M (local)
2. Variable O&M (local)	2. Fixed O&M (foreign)
3. Variable O&M (foreign)	3. Insurance cost
4. Lime stone	4. Working capital
5. Ash disposal	5. Return on equity (ROE)
	6. Debt service

Source: "Determination of NEPRA in the Matter of Upfront Tariff for the Projects on Imported/Local Coal (Other than Thar coal)", NEPRA

NEPRA indicated the set upfront tariff based on 1) the capacity of generation, 2) type of coal, and 3) financing. This tariff ranges from approximately Rs 7/kWh to Rs 9/kWh, although it varies depending on the above categorization.

Table 2.7-2 Upfront Tariff on Coal-based Generation Technology Determined by NEPRA

Capacity	Type of Coal	Financing	Energy Charge (Rs/kWh)	Capacity Charge (Rs/kW/hour) 1-10 yrs	Capacity Charge (Rs/kW/hour) 11-30 yrs	Levelized Tariff (Rs/kWh)

[4] A tariff developed, declared, determined, or approved by the Authority on a petition moved by any relevant agency or in exercise of suo moto powers by the Authority.

200 MW	Local	Local	4.3504	3.8885	1.3620	**9.3651**
		Foreign	4.3504	2.7281	1.2720	**8.0522**
200 MW	Imported	Local	4.3504	3.8648	1.3384	**9.3256**
		Foreign	4.3504	2.7179	1.2619	**8.0353**
600 MW	Local	Local	4.1167	3.7391	1.2987	**8.9324**
		Foreign	4.1167	2.5427	1.1858	**7.5671**
600 MW	Imported	Local	4.1167	3.7136	1.2732	**8.8899**
		Foreign	4.1167	2.5341	1.1772	**7.5528**
1000 MW	Local	Local	4.1167	3.3998	1.1912	**8.5013**
		Foreign	4.1167	2.3225	1.0909	**7.2728**
1000 MW	Imported	Local	4.1167	3.3944	1.1793	**8.4886**
		Foreign	4.1167	3.8729	1.8202	**7.2749**

Source: "Determination of NEPRA in the Matter of Upfront Tariff for the Projects on Imported/Local Coal Other than Thar Coal)", NEPRA

SECMEC is currently negotiating with NEPRA on the upfront tariff for the Thar Coal-fired Power Plant. It has not reached a consensus yet due to the disagreement on several issues.

2.7.2 Operation and Maintenance (O&M) Cost

NEPRA indicates its assumptions on the fixed and variable O&M unit costs based on the capacity of the power plant as a guideline, as shown in Table 2.7-3.

Table 2.7-3 Assumption on Unit Cost of O&M (Unit: Rs/kWh)

Plant Size	Fixed O&M	Variable O&M	Total
200 MW	0.307	0.114	0.421
600 MW	0.287	0.114	0.401
1000 MW	0.266	0.114	0.380

Source: "Determination of NEPRA in the Matter of Upfront Tariff for the Projects on Imported/Local Coal (Other than Thar Coal)", NEPRA

2.8 Power Tariff for Consumer

The GoP stringently follows the structural reforms agreed with the International Monetary Fund (IMF) against the Extended Fund Facility loan amounting to USD 6.67 billion.

Based on the instructions by the GoP, all DISCOs submitted their petition to NEPRA for the increase in tariffs. The tariffs are a little bit different among the 11 distribution companies. The existing and increased tariffs under the assessment of NEPRA, represented by Islamabad Electric Supply Company (IESCO), are shown in the tables hereafter.

As of December 2013, the increased tariffs are not finalized yet. The starting period for applying the revised tariff is unknown.

There are ten categories of tariff, namely, “A1: Residential”,” A2: Commercial”, “B: Industrial”, “C: Bulk Supply”, “D: Agriculture”, “E: Temporary Supply”, “F: Seasonal Industrial Supply”,” G: Public Lighting”, “H: Residential Colonies attached to industrial premise”, and “I: Railway Traction”.

Categories A1, A2, and B are summarized in Table 2.8-1, Table 2.8-2, and Table 2.8-3, respectively.

Table 2.8-1 Power Tariff Increase for Residential Use

Range (kWh/month)	Previous (Rs/kWh)	Revised Proposed by NEPRA (Rs)	Increase (%)
Residential Use A1			
For Peak Load Requirement less than 5 kW			
Up to 50	4.0	8.5	113
1-100	11.0	11.0	same
101-300	14.0	18.0	20
301-700	17.0	21.0	23
Above 700	18.0	24.5	36
For Peak Load Requirement of 5 kW and above			
Time of Day (Peak[5])	18.0	25	50
Time of Day (Off-peak)	12.5	17.0	36

Source: NEPRA, Petition Filed by Islamabad Electric Supply Company (IESCO)

[5] Peak and off peak-hours shall be the following time periods in a day;
Peak: (i) Dec-Feb 5:00 p.m.-9:00 p.m., (ii) Mar-May 6:00 p.m.-10:00 p.m., (iii) June-Aug 7:00 p.m.-11:00 p.m., and (iv) Sep-Nov 6:00 p.m.-10:00 p.m.
Off-peak: Remaining 20 hours of the day.

Table 2.8-2 Power Tariff Increase for Commercial Use

Range (kWh/month)	Previous (Rs)		Revised		Increase (%)
	Fixed	Variable	Fixed	Valuable	Fix/ Vari
Commercial A2					
For Peak Requirement less than 5 kW		18.0		24.0	33
For Peak Requirement of 5 kW and above					
Regular	400	16.0	440	22.0	10/ 38
Time of Day (Peak)	400	18.0	440	25	10/ 39
Time of Day (Off-peak)	400	12.5	440	17.0	10/ 37

Source: NEPRA, Petition Filed by Islamabad Electric Supply Company (IESCO)

Table 2.8-3 Power Tariff Increase for Industrial Use

Range (kWh/month)	Previous (Rs)		Revised 2013 (Rs)		Increase (%)
Industrial B	Fixed	Variable	Fixed	Variable	Fix/Variable
B1 up to 25kW (400/230 V)		14.5		20.0	38
B2(a) exceeding 25-500 kW, 400 V	400	14.0	440	19.0	10/36
B1(b) up to 25 kW (Peak)		18.0		25.0	39
B1(b) up to 25 kW (Off-peak)		12.5		17.4	39
B2(b) TOD (Peak) 400V	400	18.0	440	25.0	10/39
B2(b) TOD (Off-peak) 400V	400	12.3	440	17.3	10/41
B3 TOD (Peak) up to 5,000 kW (11/33 kV)	380	18.0	420	25.0	11/39
B3 TOD (Off-peak) up to 5,000 kW (11/33 kV)	380	12.2	420	17.2	11/41
B4 TOD (Peak) 66/132 kV and above	360	18.0	400	25.0	11/39
B4 TOD (Off-peak) 66/132 kV and above	360	12.1	400	17.1	11/41

Source: NEPRA, Petition Filed by Islamabad Electric Supply Company (IESCO) Note: TOD means "time of day"

2.9 Budget for the Infrastructures of Thar Coalfield

2.9.1 Budget for the Infrastructures allocated by the Government of Sindh

Sihdh Coal Authority (SCA), which is in charge of developing infrastructures in GoS, is pushing the preparation of the infrastructures. The budget for major infrastructures, airport, effluent discharge channel, road and water supply widening and improvement were allocated and approved at Rs 20,158 million. However, after the detailed design, the cost increased to Rs 41,166 million, or about 204% of the originally approved budget, The reasons of the increase were due to: a) price escalation as the estimated costs approved by PC-1 were 2-3 years before, and b) unpredicted matters[6] that were found in the detailed design. Table 2.9-1 shows the originally estimated costs and revised targets costs of the infrastructure for developing the Thar coalfield. According to SCA, the revised costs for "2. Effluent Discharge Channel", "3. Widening Road Phase-1 (200 km)", and "4. Widening Road Phase-2 (135 km)" have already been approved by GoS; while the revised costs for "1. Airport", "5. Water Supply Nabisar to Thar" and "6. Water Supply Left Bank Outfall Drain (LBOD) to Nabisar" are still for approval of the Project Development Work Program (PDWP) of GoS.

Table 2.9-1 Allocated Budget for Infrastructure of the Thar Coalfield

Infrastructures	PC-1 Estimated Cost (Rs million)	Revised Estimated Cost by Detailed Design (Rs million)	Increased Rate (%)	Completion Target
1. Airport	972	1,660	171	June 2016
2. Effluent Discharge Channel	3,673	6,742	184	June 2016
3. Widening Road Phase-1 (200 km)	3,034	8,350	275	December 2016
4. Widening Road Phase-2 (135 km)	3,401	8,189	241	December 2016
5. Water Supply Nabisar to Thar	4,078	17,594	431	December 2016
6. Water Supply LBOD to Nabisar	5,000	12,472	249	December 2016
Sub Total (Major Infrastructure)	**20,158**	**55,007**	**273**	

Source: Provincial Coal and Energy Development Department, GoS, and SCA

2.9.2 Issues on Infrastructure

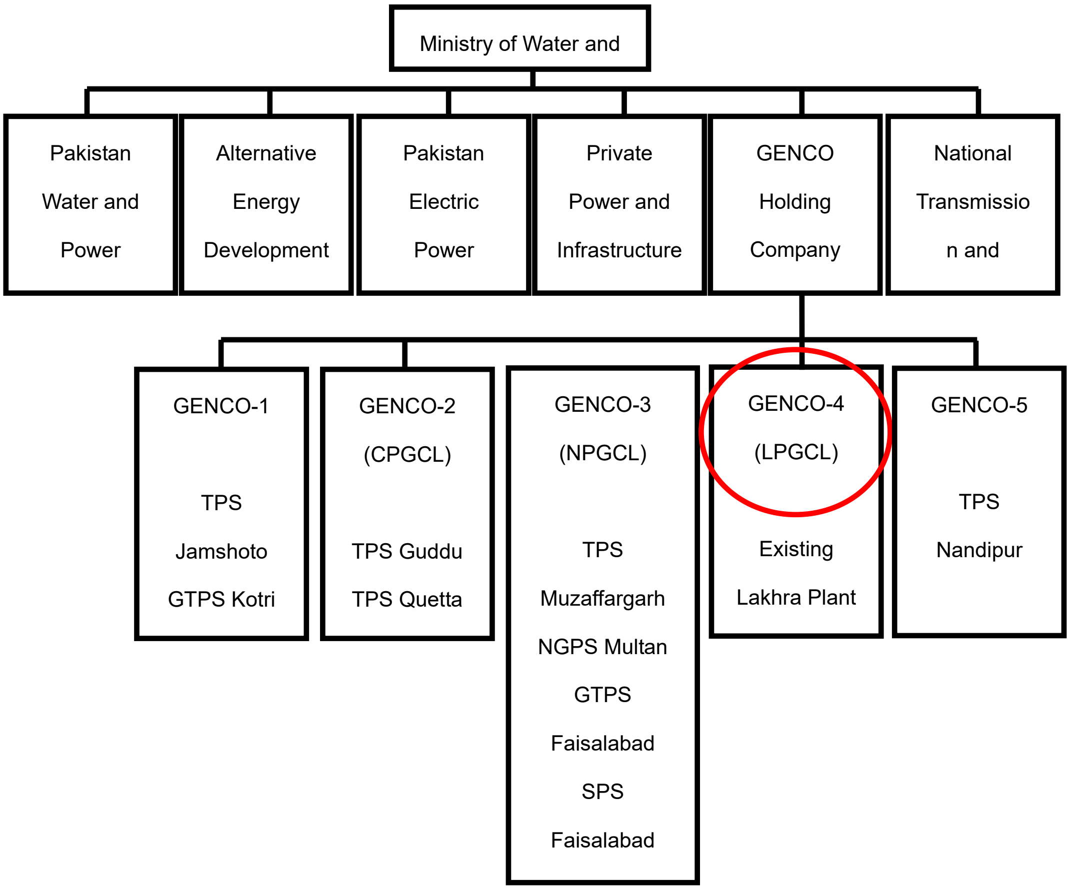
The drain alignment for the effluent discharge channel that will be used for draining groundwater during mining activities has not yet been finalized. This is because the candidate discharge area, which is 40 km south of Block II where the effluent water can be discharged through gravity, was found to be located in a wildlife sanctuary designated by the Forest Wildlife Department of GoS. The detailed design work is still pending as of December 2013.

[6] For example, earth cutting and filling volumes calculated in the detailed design show an increase against the volumes approved by PC-1, which based its calculation of volumes for standard sections.

2.10 Organization of the Power Sector

2.10.1 Power Sector Organization in the Federal Government

The power sector organization in the federal government is shown in Figure 2.10-1



Source: JICA Survey Team based on the websites of each authority

Figure 2.10-1 Federal Organization Chart of the Power Sector in Pakistan

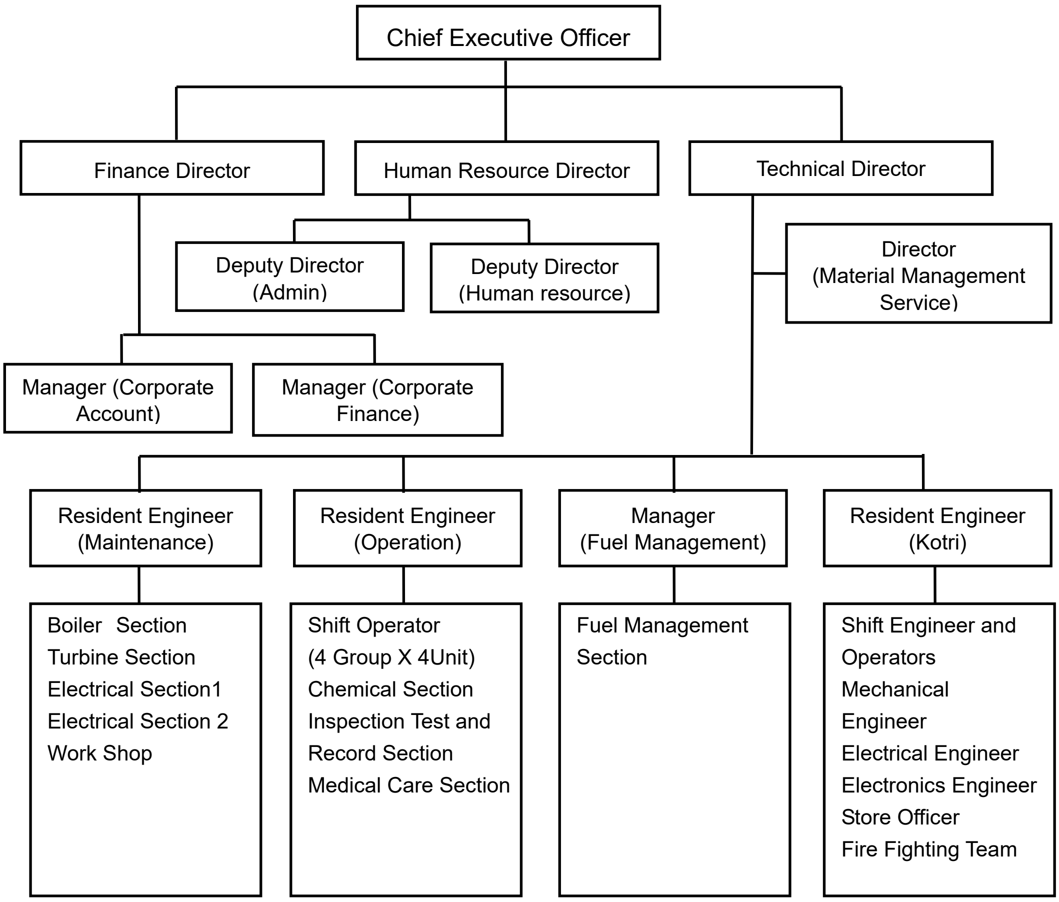
WAPDA has entrusted Pakistan Electric Power Company (PEPCO) to shift from a bureaucratic structure to a corporate, commercially viable, and productive entity. GENCO Holding Company looks after the affairs of four GENCOs. All public thermal power stations have been restructured to four corporatized companies, namely, Jamshoro Power Generation Company Ltd. (GENCO-1), Central Power Generation Company Ltd. (GENCO-2), Northern Power Company Ltd. (GENCO-3), and Lakhra Power Generation Company Ltd. (GENCO-4).

The Private Power and Infrastructure Board (PPIB) was established in 1994 as a "single-window Facilitator" to promote private sector participation in the power sector in Pakistan. PPIB facilitates investors in establishing private power projects and related infrastructure, executes IAs with project sponsors and sovereign guarantees on behalf of the Government of Pakistan.

Three types of organization chart are shown as examples hereinafter; i) Jamshoro power station as public sector, ii) IPP Hubco as private sector and iii) Japanese typical coal termal power plant as reference.

2.10.2 Organization of the Jamshoro Power Station

The organizational chart of the 850 MW Jamshoro Power Station (250 MW oil x 1 unit and 200 MW oil/gas x 3 units) is shown in Figure 2.10-2



Source: JICA Survey Team, based on the interviews with Jamshoro Power Station

Figure 2.10-2 Organizational Chart of Jamshoro Power Station

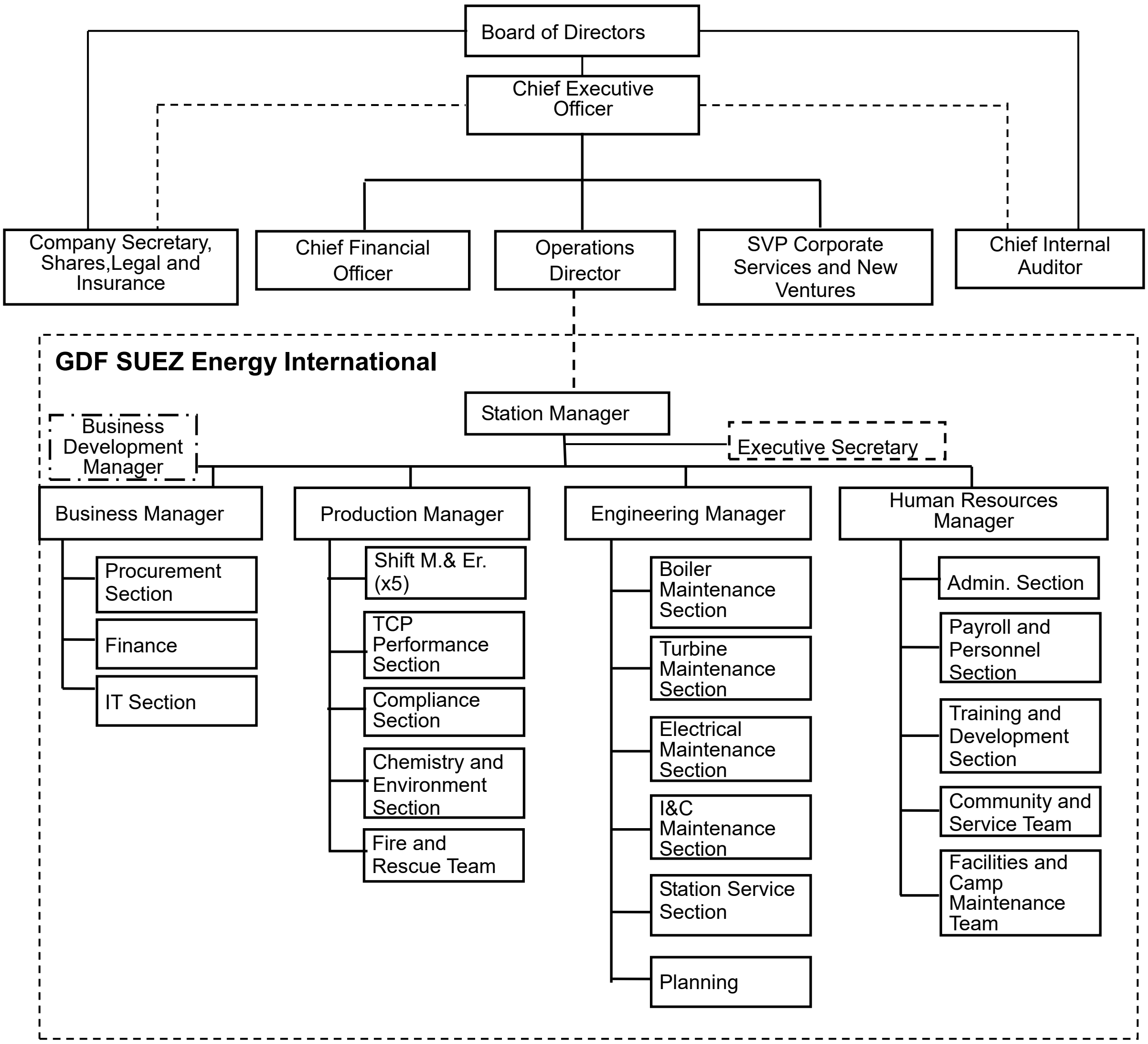
The organization of Jamshoro Power Station is separated into three major divisions, namely, finance, human resources, and technical divisions. The technical division is separated into four departments, namely, operation, maintenance, fuel management, and Kotri management.

The power plant is operated by 15 staff per shift. The operation is done by four shifts, who work eight hours per day, while one shift is on standby.

The operation and maintenance section has a sectionalized hierarchy for each plant unit, such as senior engineer, junior engineer, assistant, foreman, and helper. Therefore, the total number of staff is approximately 1,000, including staff for related services. Moreover, there is some room for a flexible organizational management.

2.10.3 Organization of IPP HUBCO Power Station

The organizational chart of the 1,200 MW Hub Power Station (300 MW oil x 4 units) is shown in Figure 2.10-3.



Source: Presentation prepared by the Hub Power Station

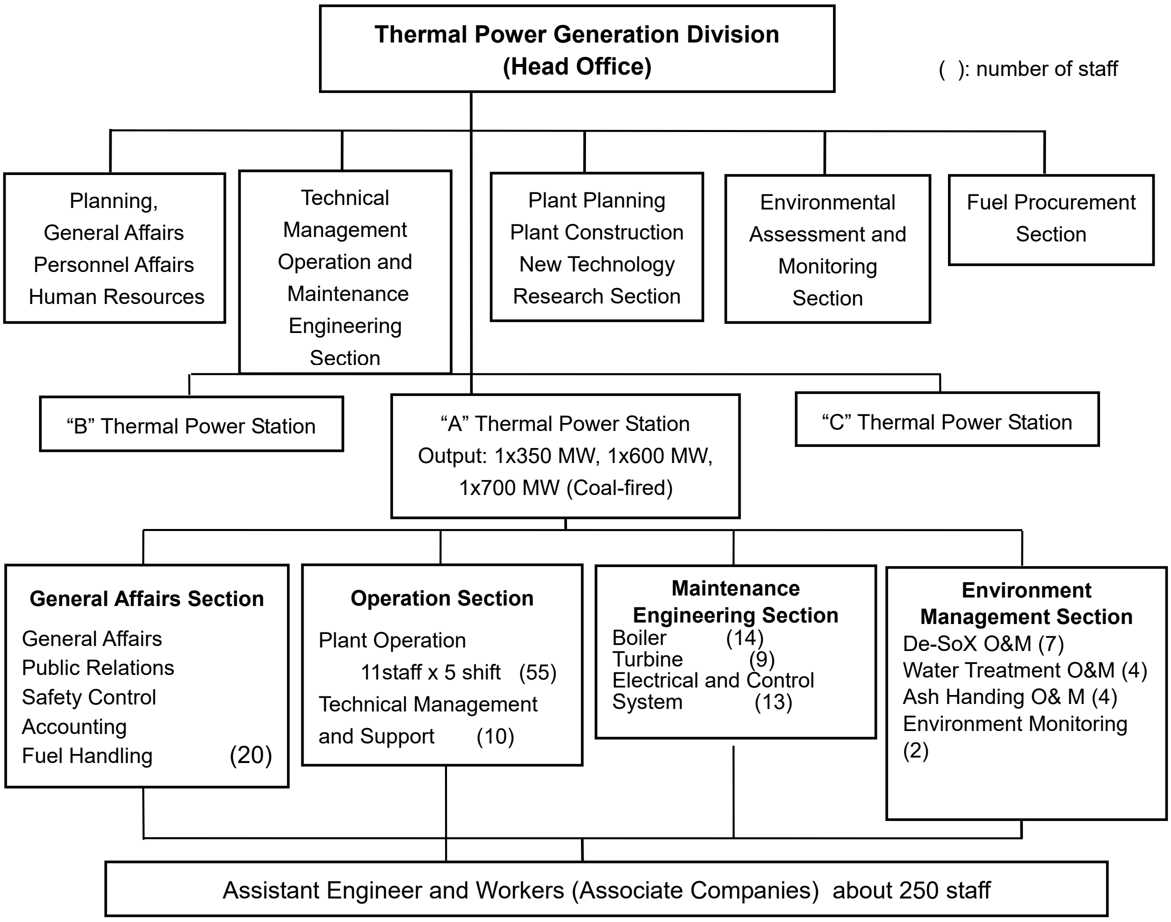
Figure 2.10-3 Organizational Chart of the Hub Power Station

The Hub Power Station, which started its operation in 1997, is the first IPP in Pakistan. GDF SUEZ Energy International operates and maintains the power station under a long-term operation and maintenance agreement after commissioning.

A total of 277 staff are working in the power plant, excluding security staff. The plant is operated in two shifts per day, which changes every twelve hours. Each shift has 13 staff.

2.10.4 Organization of Power Station in Japan

The organizational chart of a typical coal thermal power station in Japan is shown Figure 2.1-4.



Source: JICA Survey Team

Figure 2.10-4 Reference Organizational Chart of the Power Station in Japan

A typical power station in Japan is operated by a simple organization. Each operator is in charge of all facilities (namely, boiler, turbine, and electrical facilities) and should have the knowledge on three different types of plant (350 MW subcritical, 600 MW supercritical, and 700 MW ultra-supercritical). Plant operation requires a high level of skill related to facility control. Therefore, the 11 operators should be flexible in operating all plants.

The maintenance and engineering section has a total of 36 staff. One engineer is in charge of some parts and complements each other to balance work volume.

The engineers are able to carry out similar works for various units with the associate company's staff.

CHAPTER 3
SELECTION OF THE SUITABLE SITE

Chapter 3 Selection of Suitable Site

Site selection had been conducted and the selected site of the Project was agreed between MoWP / GENCO and JICA at the end of 2013. All of relating information in Chapter 3 was as of the end o 2013.

3.1 General

3.1.1 Criteria for Site Selection

There are three candidate sites for constructing the new power plant, namely, the mine mouth in Thar, the Indus River, and Karachi Port.

(1) Mine Mouth in Thar

The Thar coalfield has sufficient land for the construction of a power plant, and it has no major issue for selecting candidate plant construction site. The candidate site is selected as the mine mouth in Thar taking the site development status in account.

(2) Indus River and Karachi Port

As for the Indus River and Karachi Port, the major issues on site selection are securing large land area and environmental impacts since large land for power plant construction is necessary in general and there are a lot of residences in these areas. Consequently, in consideration of such issues, both candidate sites will be selected.

After selecting the candidate sites at each location, the most suitable site for the construction of a new power plant will be selected among the mine mouth in Thar, the Indus River, and Karachi Port according to the criteria shown in Table 3.1-1.

Table 3.1-1 Criteria for Site Selection

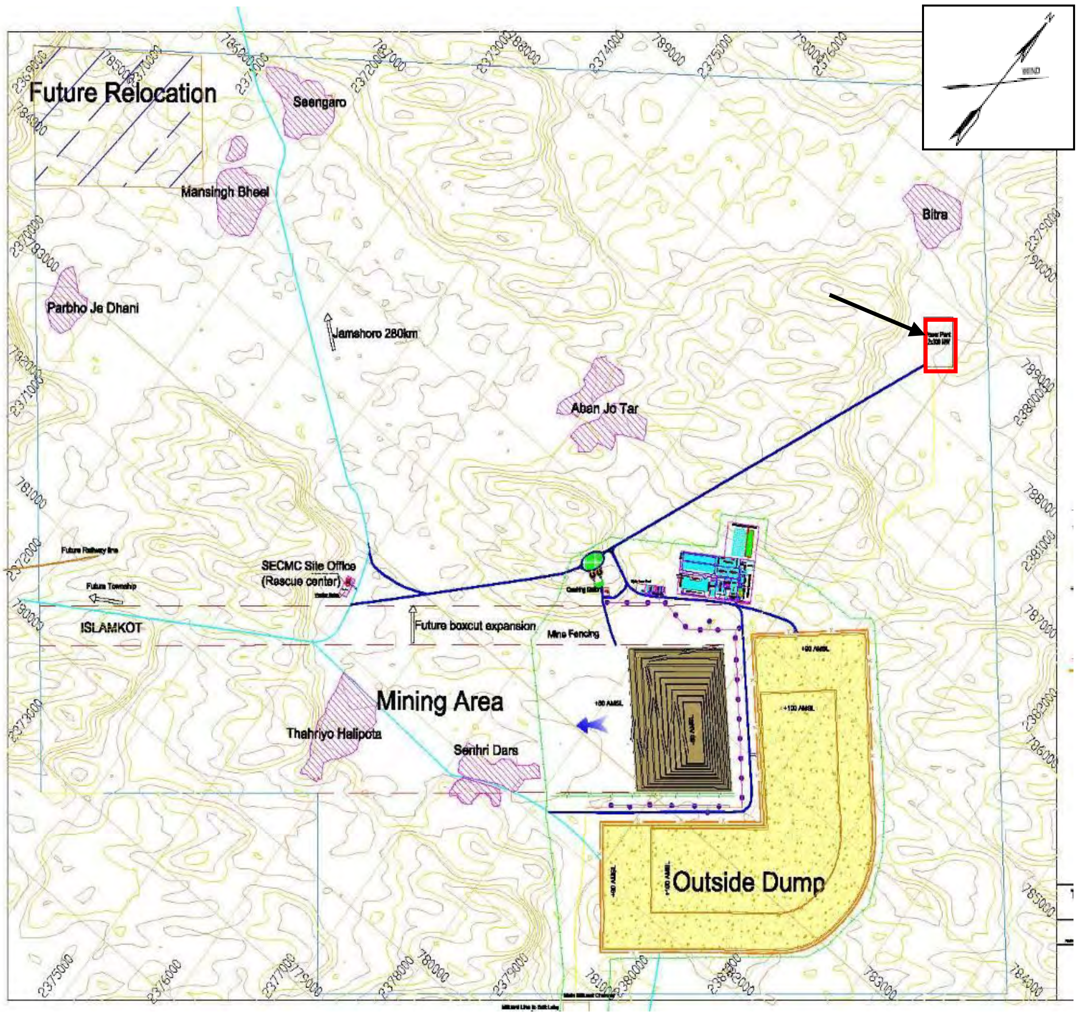
No.	Description	Consideration Items
1	Transportation (Thar coalfield–candidate site, Karachi Port area–candidate site)	- Construction cost - Transportation cost
2	Transmission Line	- Construction cost - System stability
3	Condenser Method (Configuration of facilities)	- Condenser vacuum - Generation efficiency - Cost (initial, operation)
4	Cooling Water, Disposal Water	- Water intake method - Water disposal method - Cost (construction, operation)
5	Land Availability	- Availability of land and cost of land acquisition - Environmental and social considerations - Geotechnical conditions - Secure coal storage, ash storage, and ash disposal
6	Pollution Control	- NOx, SOx, PM10

Source: JICA Survey Team

3.1.2 Identification of Candidate Sites

(1) Selection of Site for Mine Mouth in Thar

The Government of Sindh (GoS) has established and opened 12 blocks, however, only three blocks are currently being developed. The progress of Block II by Sindh Engro Coal Mining Company (SECMC)[1] is the earliest, and there are development plans for mining and for construction of a power plant. As shown in Figure 3.1-1, the development of Block II is the most realistic in the Thar coalfield.



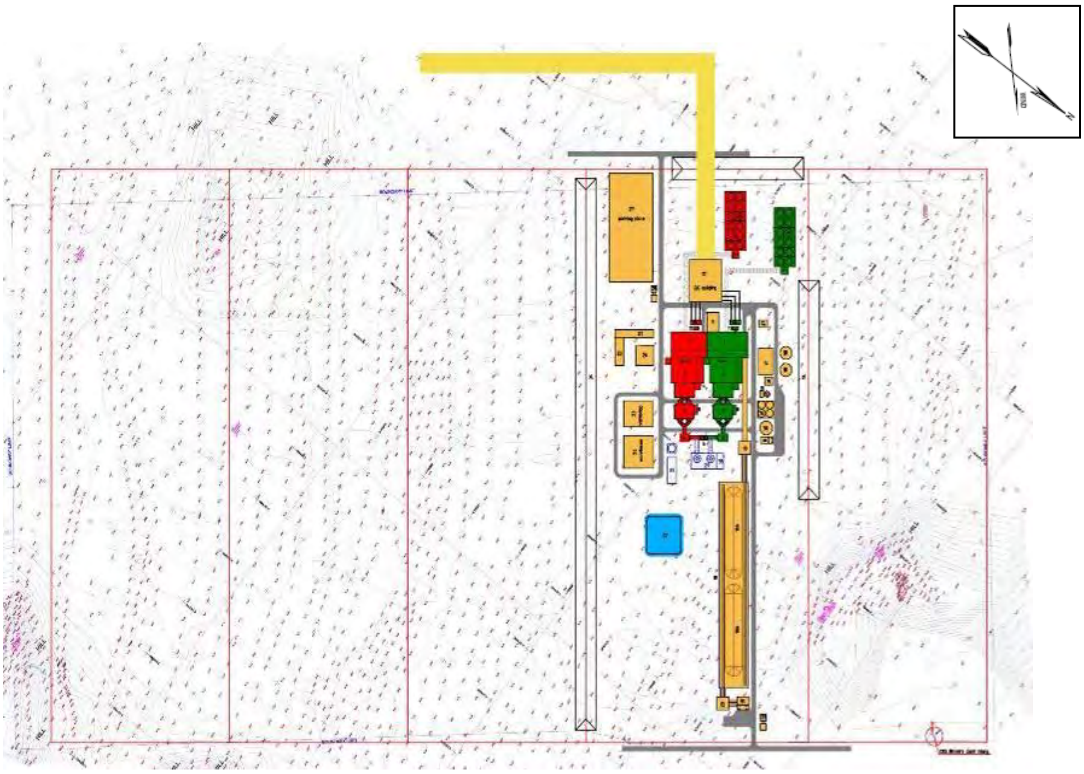
Source: SECMC

Figure 3.1-1 Development Plan for Block II

SECMC has a plan to develop an “energy park” (0.8 km x 1.5 km) as shown in Figure 3.1-2. A power plant of 300 MW x 2 units will be installed in the energy park during the initial stage in 2018. In addition, in case the energy park is selected as a candidate site, the ash pond and coal

[1] SECMC is a joint venture between the GoP and Engro Powergen. SECMC was established in 2009 with the objective of making effective use of the ample coal reserves in the Thar Desert to meet Pakistan’s power generation needs, spur economic development, and bring energy security to the country.

storage in Block II can be shared, and construction cost can be reduced.



Source: SECMC

Figure 3.1-2 Power Plant Plan in Block II as Energy Park

As mentioned above, since the infrastructure has been developed by GoS in order to work on an early realization of development of Block II, the energy park in Block II is selected as the candidate site in the mine mouth in Thar.

Source: JICA Survey Team

Photo 3.1-1 Selected Site in the Mine Mouth in Thar (Block II)

Source: JICA Survey Team

Photo 3.1-2 Selected Site in the Mine Mouth in Thar (Block II)

Table 3.1-2 Current Situation of Development of Infrastructure

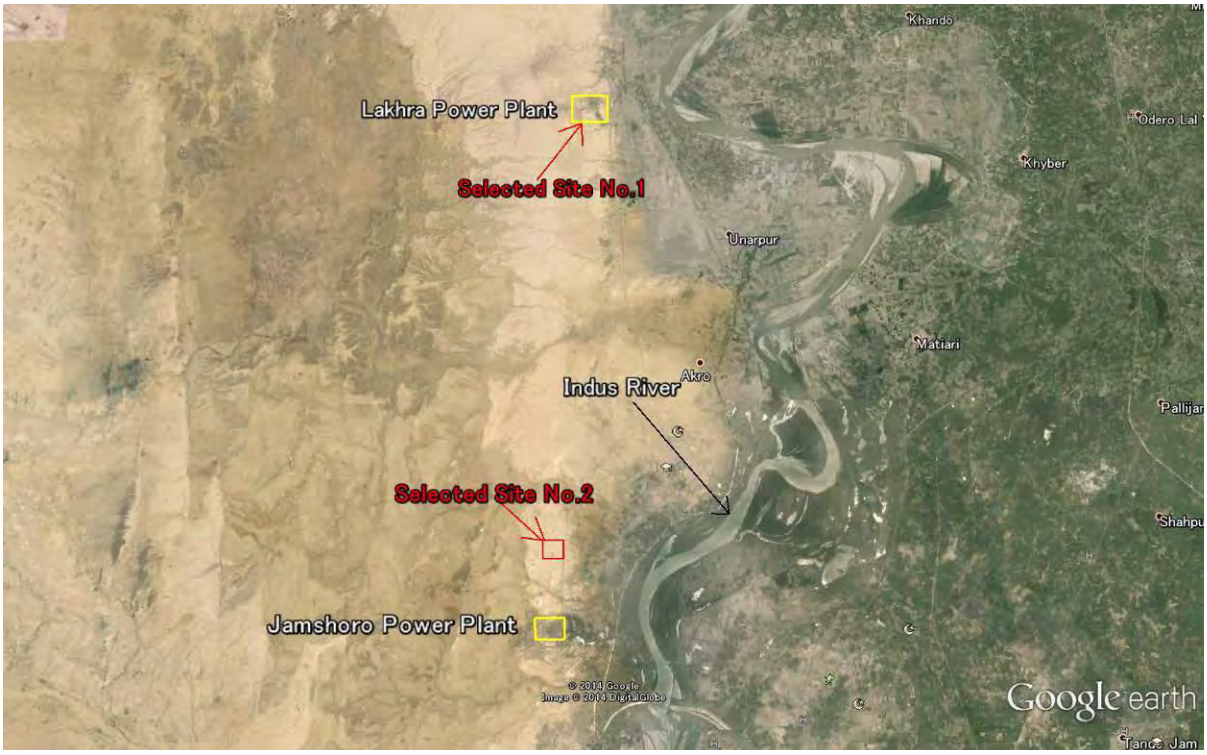
No.	Type of Infrastructure	Budget Allocation	Progress and Status

1.	Transmission Line	**No allocated budget**	Feasibility study (F/S) is completed already
2.	Water Supply	Budget is allocated by the Government of Sindh	Construction stage is ongoing and will be completed in August 2016
3.	Mine Water Disposal	Budget is allocated by the Government of Sindh	Construction stage is ongoing and will be completed in March 2015
4.	Road	Budget is allocated by the Government of Sindh	Construction stage is ongoing and will be completed in September 2015

Source : TCEB

(2) Selection of Site in the Indus River Area

Since there are a lot of residential areas in the downstream side of the Jamshoro Power Station and considering availability of large land area for the power station and environmental impacts, the area between the Jamshoro Power Station and the Lakhra Power Station, as shown in Figure 3.1-3, is appropriate as a candidate site.



Source: Prepared by the JICA Survey Team using Google Maps

Figure 3.1-3 Location Map of Indus River Area

As for the candidate site between the Jamshoro Power Station and Lakhra Power Station, in consideration of land acquisition, distance to water intake, and presence or absence of residential area, there are two suitable candidate sites identified, i.e., one is fallow land in the existing Lakhra Power Station, and the other is approximately 3 km upstream of the Jamshoro Power Station.

1) Selected Site No.1 (Lakhra Power Station)

The location map of selected site no. 1 is shown in Figure 3.1-4. The existing Lakhra Power

Station has spare land that is sufficient for construction of another power plant, while GENCO recommended their land to be a candidate site for the power plant. In addition, according to information provided by GENCO, the existing Lakhra Power Station will be abolished in five years since it has a lot of malfunctioning equipment and its availability ratio is low.

Source: JICA Survey Team

Figure 3.1-4 Location Map of Selected Site No.1 in the Indus River Area

Source: JICA Survey Team

Photo 3.1-3 Selected Site No. 1 in the Indus River Area

Source: JICA Survey Team

Photo 3.1-4 Selected Site No.1 in the Indus River Area

2) Selected Site No. 2 (Near the Jamshoro Power Station)

The location map of selected site no. 2 is shown in Figure 3.1-5. Candidate site no. 2 is located approximately 3 km upstream of the Jamshoro Power Station and approximately 4 km away from the Indus River. In addition, the candidate site is approximately 0.7 km away from an existing 500 kV transmission line.

Source: JICA Survey Team

Figure 3.1-5 Location Map of Selected Site No. 2 in the Indus River Area

Source: JICA Survey Team

Photo 3.1-5 Selected Site No. 2 in the Indus River Area

Source: JICA Survey Team

Photo 3.1-6 Selected Site No. 2 in the Indus River Area

(3) Selection of Site in the Karachi Port Area

For the Karachi Port area, a suitable candidate site was selected near Qasim Port in consideration of use of imported coal, availability of land for loading coal, and availability of land without residences. As a result of the survey and consideration of impacts to the marine environment and availability of land, an undeveloped industrial land approximately 2.5 km away from the sea was selected as the candidate site in the Karachi Port area. The location map of the candidate site is shown in Figure 3.1-6.

At the time of scoping consultations, the information of the other candidate sites located in Qasim Port area was not explained to stakeholders.

Source: JICA Survey Team

Figure 3.1-6 Location Map of the Selected Site in the Karachi Port Area

Source: JICA Survey Team

Photo 3.1-7 Selected Site in the Karachi Port Area

Source: JICA Survey Team

Photo 3.1-8 Mangroves (Coastal Area in Qasim Port Area)

3.1.3 Major Issues Affecting Site Selection

(1) Unconfirmed Start Period of Coal Production in Thar

The power plant under the Project is planned to use the Thar coal reserve which has 175 billion t of lignite coal[2] having low heating value, containing high moisture and having spontaneous combustion. Mine mouth generation is preferable since it is not suitable for long distance transportation.

The development schedule of coal mining has not been fixed because financing for it has not yet been settled.

(2) Issues of the Mine Mouth in Thar

1) Water Supply

Since it is necessary to supply sufficient volume of water to operate thermal power plants, securing necessary water is one of the major issues of plants that are located far from the coast or river. In Japan, all thermal power plants are located on the coast or nearby a river so that may be able to use huge amounts of cooling water.

Since the Thar coalfield has no water resource nearby except underground, the Engro Powergen Thar Limited (EPTL) plans to take water from the Left Bank Outfall Drain (LBOD) for the plants which will be installed in Block II, after being treated by reverse osmosis membrane method (RO). These water supply infrastructures are prepared by GoS as facilities for development. The intake facilities are being installed with intake water volume[3] of 1.0 m^3/s (35 cusec) initially, which will be completed by December 2014, and the intake volume of water is planned to be 2.8 m^3/s (99 cusec), which is still being conceptualized for the future (in case of total 3,600 MW installed capacity).

The water cost shall be set taking into consideration the selected construction site of the power plant.

2) Comparison of Water Supply Volume for Each Cooling System

It is difficult to compare the quantity of water in these different conditions, e.g., the difference of the cooling type and ambient temperature. However, most of the amount of supplied water is spent for water cooling. Typical usage of water for coal thermal reference plants are shown in Table 3.1-3.

---

[2] The value of coal storage at Thar cola field is announced by TCEB.
[3] Intake water volume includes cooling water and boiler use.

Table 3.1-3 Comparison of Water Usage for Coal Thermal Power Plants

	Plant Capacity	Water Usage for Cooling per 100 MW	Total Water Usage for Cooling	Calculation Base	Cooling Type
Engro Powergen (Plan)	1,200 MW	0.083 m^3/s (2.92 cusec)	1 m^3/s (35 cusec)	3,595 t/h	Wet cooling
China (model)	1,000 MW	0.063 m^3/s (2.24 cusec)	0.634 m^3/s (22.4 cusec)	20 Mt/year*1	Wet cooling
USA (average in the USA)	-	0.075 m^3/s (2.65 cusec)	-	2,700 l/MWh*2	Wet cooling
India (simulation)	1,000 MW	0.083 m^3/s (2.94 cusec)	0.833 m^3/s (29.4 cusec)	3,000 t/h*3	Wet cooling
India (simulation)	1,000 MW	0.0153 m^3/s （0.54 cusec）	0.153 m^3/s (5.4 cusec)	550 t/h*3	Dry air cooling
Japan (existing)	440 MW	5 m^3/s (177 cusec)	22 m^3/s (777 cusec)	22 m^3/s*4	Seawater cooling

Note:
*1 : Coal Initiative Reports White Paper Series“ Coal in China Resources, Uses, and Advanced Coal Technologies “ March 2010
*2 : Water Conservation Options for Power Generation Facilities (Power website on 1 September 2012)
*3 :“Report on Minimisation of Water Requirement in Coal Based Thermal Power Stations” issued by the Central Electricity Authority India in January 2012
*4 : Not including water for boiler use

Source : JICA Survey Team

According to a simulation done in India at ambient temperature of 38 °C, the adoption of a dry condenser type cooling system instead of a wet type cooling system raised the internal auxiliary power consumption twice, i.e., by more than 7%. Therefore, cautious comparison should be made between the lowered efficiency of the dry cooling system especially during the summer season and increased cost for the additional water supply needed. The difficulty of adopting the dry type cooling for the mine mouth in Thar is explained in the next section.

As shown in Table 3.1-3, the quantity of cooling water is less than 0.1 m^3/s (3.5 cusec) per 100 MW for the reference plants which adopted a wet cooling type system. Therefore, a water supply plan of 1.0 m^3/s (35 cusec) for 1,200 MW generation is appropriate. In addition, it is estimated that 20 to 25 million t per year, which is equivalent to 0.63 m^3/s (22.2 cusec) to 0.79 m^3/s (27.7 cusec) groundwater, shall be pumped up for mining according to the simulation of dewatering. The water also can be used for wet cooling supplementary after purification.

3) Influence of High Ambient Temperature to Generation Efficiency

The Thar coalfield is located in a desert area wherein ten months in a year the highest temperature at daytime exceeds 40 °C.

Since the generation efficiency decreases with high ambient temperature according to thermodynamics, it is very important to select the type of condenser cooling system.

(3) Issues of the Indus River Area

The availability of cooling water causes no problem in the operation of the coal fired thermal power plant as water can be taken from the Indus River. The ambient temperature of the area is not so high that generation efficiency would not be affected. Otherwise, it would be a key issue to locate a vast area of approximately 1 km^2 which includes a coal yard and ash pond due to broadening of the residential area in the Indus River area.

(4) Issues of the Karachi Port Area

There are no problems on the availability of cooling water and the ambient temperature. The area is located in an industrial area and owned by the Karachi Port Authority. Land acquisition of approximately 1 km^2 shall be considered for the Project.

3.2 Site Conditions

3.2.1 Mine Mouth in Thar

(1) Meteorological and Geological Conditions

1) Meteorological Conditions

The average monthly temperature and rainfall in the Thar coalfield in the past five years as measured by the Climate Data Processing Centre of the Pakistan Meteorological Department are shown in Table 3.2-1

Table 3.2-1 Climate Conditions in the Thar Coalfield

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temp (˚C)	17	19	27	31	34	34	32	31	30	29	24	19
Rainfall (mm)	0	6	1	23	0	19	63	111	126	5	4	12

Source: Pakistan Meteorological Department

The annual rainfall in this area is 370 mm and the rainy season is from July to September. This area is the largest of the three candidate sites as to the amount of rainfall.

On the other hand, the average monthly temperature is between 17 °C (January) and 34 °C (May). The climate is usually dry except during the short monsoon from July to September.

2) Geological Conditions

The Sindh Region is located in the western part of the Indian subcontinent and is part of the ancient continent Gondwana. The Himalayas mountain range had been formed from the collision of India and Eurasia. The Indus River had been developed between these continents. The river had transported sand from the upstream, and formed by an alluvial fan around the Sindh Region. The stratum of the Thar coalfield area mainly consists of river sand. The percolated coefficient is confirmed more than 1×10^{-4} stratum.

3) Outline Design of Foundation

The bearing layer exists at around 10 m underground. Therefore, spread foundation or pile foundation will be applied to the equipment foundation.

(2) Environmental and Social Aspects

The site, Block II in the Thar coalfield, is owned by SECMC and located in Tharparkar Village, Mithi District, Sindh Province (refer to Figure 3.2-1). The site is undulating land with shrubs and short trees (see Photo 3.2-1). According to an environmental and social impact assessment (ESIA) final report for Thar Coal Block II Mining Project (SECMC), agricultural fields are the dominant habitat (56%), sand dunes are the second dominant (35%), and the remaining is the plain area (9%) including area covered by settlements (2%). There are two small villages within a radius of 5 km from the site (refer to Figure 3.2-2).

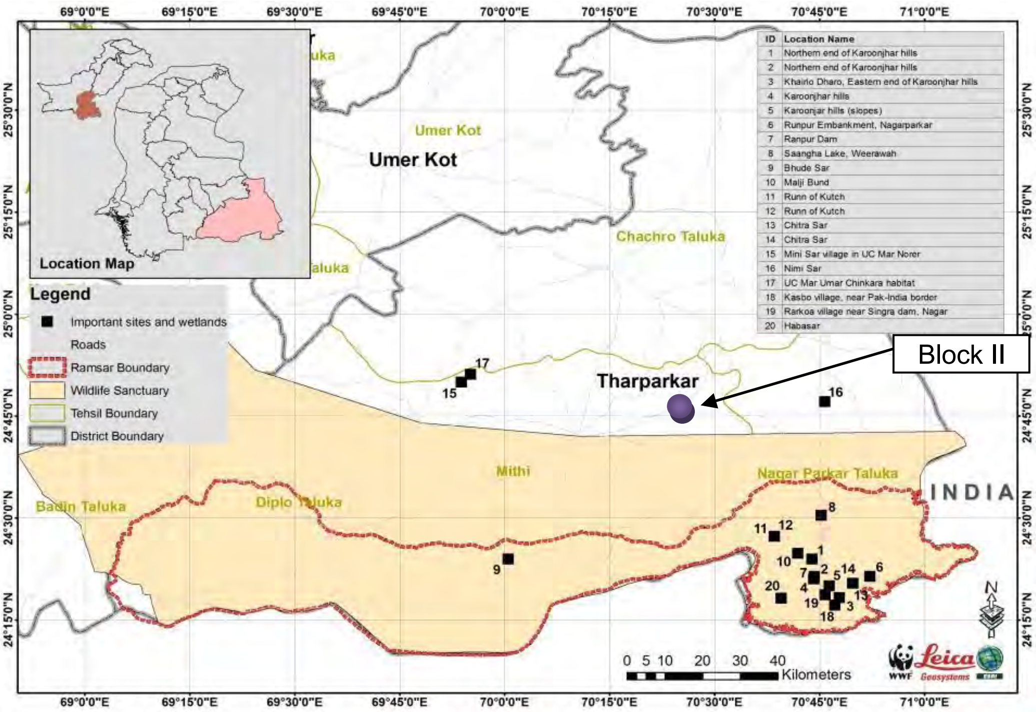
The site is not part of any protected area, such as a wildlife sanctuary. A Sindh wildlife sanctuary called Rann of Kutch is located approximately 10 km south of Block II (refer to Figure 3.2-1). However, the Block II is not a part of the Rann of Kutch Wildlife Sanctuary. According to the above ESIA report for Thar Coal Block II Mining Project, no flora and fauna listed under either the International Union for Conservation of Nature (IUCN) Red List 2010 or under Pakistan legislation was found in Block II. In the southern part, 50 km far from the site, i.e., Rann of Kutch, which is registered as an international wetland under the Ramsar Convention, is expanding beyond the border between Pakistan and India. There is also one of the salt lakes in the northern area of the Ramsar site (see Photo 3.2-2) wherein salt production is being conducted by the local people.

On the other hand, developments at other blocks have been made as well. As Block V[4] and Block III[5] are partially included within a radius of 5 km from the site, cumulative impact on air quality by SO_x, NOx, and suspended particulate matter (SPM) coming from the power stations in each block should be taken into consideration (refer to Figure 3.2-3). Further investigation on their development status shall be required.

GoS has already been developing water conveyance facilities from LBOD to the Thar coalfield. A water reservoir site has been decided in Vajihar, which is located in the northern area 14 km away from Block II wherein dune and shrubs are dominant and no residences are located.

4 Block V is planned to be financially supported by Oracle.

5 Block III is planned to be financially supported by Couger.



Source: TCEB

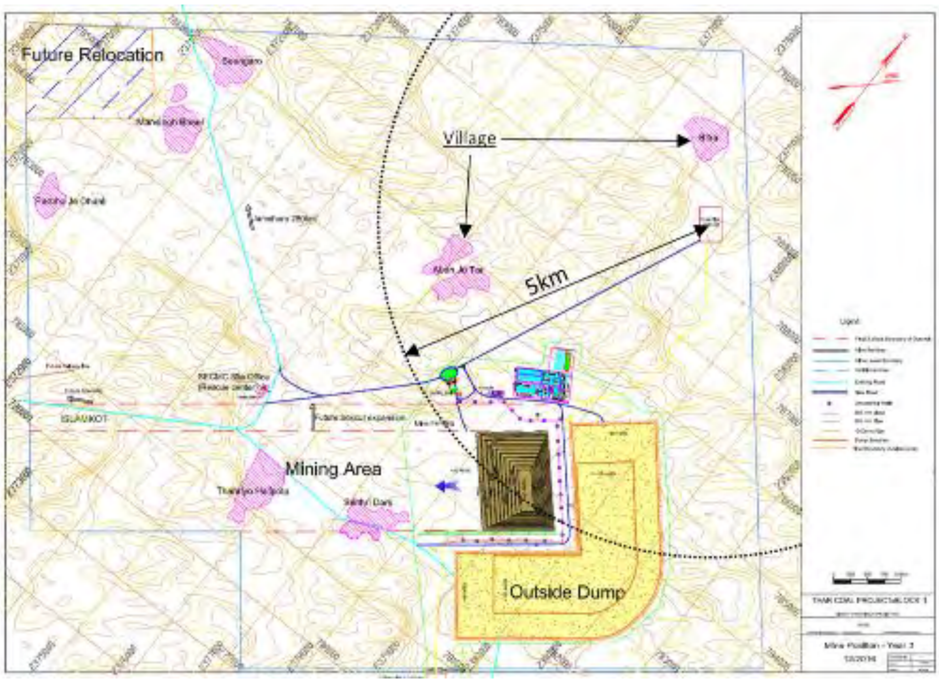
Figure 3.2-1 Rann of Kutch Wildlife Sanctuary

Source: JICA Survey Team

Photo 3.2-1 Thar Coalfield (Block II)

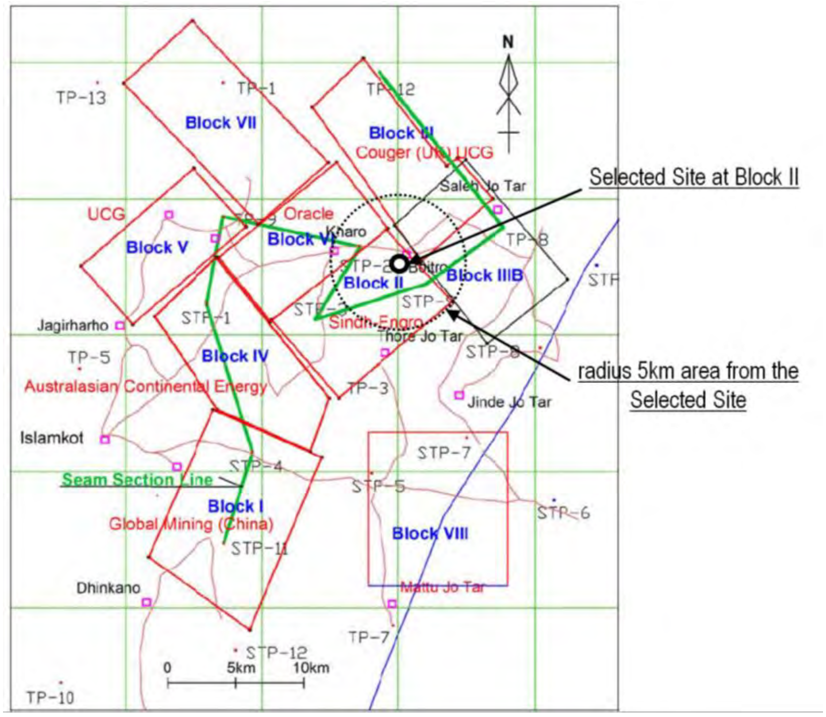
Source: JICA Survey Team

Photo 3.2-2 Salt Lake



Source: JICA Survey Team

Figure 3.2-2 Location Map of the Selected Site in the Mine Mouth in Thar



Source: JICA Survey Team

Figure 3.2-3 Location Map of All Blocks

The Coal and Energy Development Department (CEDD) of GoS developed a resettlement policy framework (RPF) for the Thar coalfield to guide the Project's land acquisition, compensation, and resettlement activities (hereinafter referred to as "the activities") in accordance with international guidelines and safeguard policies, and the legal framework of

Land Acquisition Act 1984. The RPF was disclosed to stakeholders after September 2013 and finalized with the inputs of stakeholders in 2013. The RPF has been under the approval process with GoS. The RPF is valid for the activities in the entire Thar coal development project executed with CEDD's supervision and coordination. The activities for subprojects (individual block development) are the responsibility of the project donor that could be a private company, local government organization, international financier or any combination of these.

For the associated infrastructure (i.e., water supply and discharge facilities, roads, railway, and airport) with the Thar coal development project, the activities are undertaken by relevant executing agencies, such as the Federal Government of Pakistan, GoS and other public-private companies.

According to the information provided by SECMC as a response to the questionnaire, SECMC plans to acquire land in two stages. The ESIA report estimated that the total number of affected people[6] may be nearly 3,200. In the initial stage, 22 km^2 of land is required for mining and the power plant project. In the initial stage, Senhri Dars Village, which is situated at the mine footprint of the mining site, will be relocated within nine years after the start of mining. In the second stage, the remaining land will be acquired for long-term mining operations and Thahriyo Halipota Village will be relocated after 20 years. To launch the plan, the physical land survey has been conducted by the Revenue Department in liaison with the SECMC team to update the land records for initial land acquisition. Also, the power plant candidate site is mainly used for farming and livestock keeping. There are some resting huts for workers but no existence of houses in the candidate site. Therefore, physical displacement is not expected while economic displacement is expected as a result of project implementation.

Source: ESIA Thar Coal Block II Mining Project, Final Report Volume 1 (2012)

Photo 3.2-3 Example of Houses in Block II

Source: Hagler Bailly Pakistan (Pvt.) Ltd.

Photo 3.2-4 Example of Workers' Resting Huts in Block II

6 Affected people are people who could undergo (1) physical displacement in the form of relocation or loss of shelter, and (2) economic displacement in the form of loss of assets or access to assets that leads to loss of income sources.

3.2.2 Indus River Area

(1) Selected Site No. 1 (Lakhra Power Station)

1) Meteorological and Geological Conditions

a. Meteorological Conditions

The average monthly temperature and rainfall in the Indus River area in the past five years as measured by the Climate Data Processing Centre of the Pakistan Meteorological Department are shown in Table 3.2-2.

Table 3.2-2 Climate Conditions in the Indus River Area

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temp (°C)	17	20	27	31	34	33	33	31	30	30	25	19
Rainfall (mm)	4	1	1	9	0	26	37	53	57	0	3	10

Source: Pakistan Meteorological Department

The annual rainfall in this area is 201 mm and the rainy season is from June to September. This area has the least amount of rainfall among the three candidate sites. However, maximum rainfall of 1,500 mm caused flooding of the Indus River in 2010.

On the other hand, the average monthly temperature is between 17 °C (January) and 34 °C (May). The climate is usually dry except during the short monsoon from July to September.

b. Geological Conditions

The Sindh Region is located in the western part of the Indian subcontinent and is part of the ancient continent Gondwana. The Himalayas mountain range had been formed from the collision of India and Eurasia. The Indus River had been developed between these continents. The river had transported sand from the upstream, and formed by an alluvial fan around the Sindh Region. The stratum of the Jamshoro area consists of ground formed by limestone from GL -2.0 m.

c. Outline Design of Foundation

Bearing capacity is very strong at the limestone layer. Therefore, spread foundation will be applied to the equipment foundation.

However, rock excavation will be required during construction.

2) Environmental and Social Aspects

The Lakhra Power Station is located 30 km north of the Jamshoro Power Station. The existing plant has an ash disposal site of large capacity. The limestone mine is adjacent to the power station located west of the power station. As shown in Figure 3.2-4, residential areas are found 5 km south of the existing power station and in the east side of the Indus Highway, where dominant land use is agriculture.

The candidate site is located within the Lakhra Power Station. The site is flat gravel plain with vegetation of shrubs and grasses. The Lakhra Power Station is the only coal fired thermal power plant in Pakistan with capacity of 150 MW (3 x 50 MW) and it started operation in 1995.

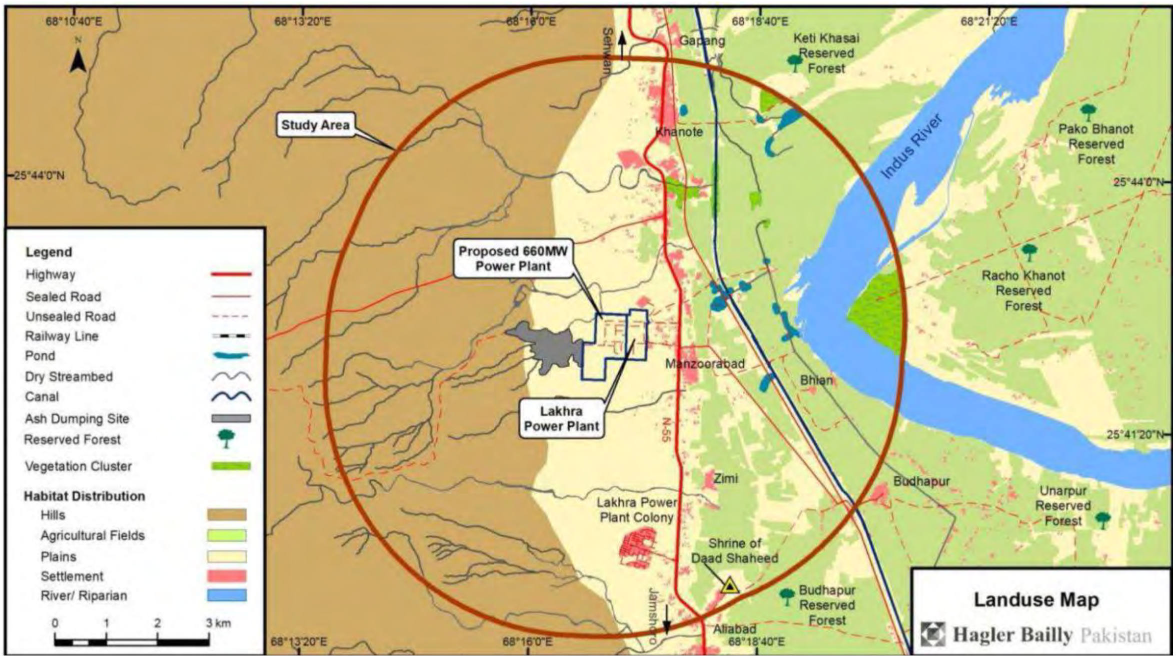
Although the plant has been using limestone for absorbing sulfur from coal, SO_2 concentration has most likely exceeded the limits defined by the National Environmental Quality Standards (NEQS) 2000. NOx concentration is also likely exceeding the limits of NEQS as no mitigation facilities are installed presently. Although some dust collectors are installed in the plant vast amount of dust being disposed from the boiler was occasionally observed during site investigation. Therefore, the amount of SPM might exceed the limits of NEQS. As a result of this observation, installation of additional mitigation facilities for the existing power plant is recommended to decrease baseline emissions of these air pollution substances before another new coal fired power station is developed.

The existing power station withdraws water from the Indus River, which is 4.2 km east of the site, and drains the thermal discharge back to the river. For the Project, water will be taken from the Indus River and thermal discharge will be drained back to the river; therefore, the impact on aquatic organisms shall be considered.

In case that a new railway branch line is installed for transporting imported coal from the nearest existing railway, the branch line will be constructed through agricultural land. Though the candidate site is not located in any protected area, Keti Khasai, Budhapur and Racho Khanot Reserved Forests are in about 6 to 8.5 km from the site as shown in Figure 3.2-4. Since there is no detailed information on those reserved forests, further information collection and site visit should be required.

In addition, a connecting transmission line which is approximately 1.7 km long will be constructed from the candidate site to the existing transmission line that lies west of the candidate site.

Land acquisition and involuntary resettlement are not required for the power plant construction. However, the land acquisition of farmland is required for the sidetrack of the existing railway line. In addition, land acquisition is required for the construction of transmission tower(s) and the right-of-way of the transmission line will be prepared. In the study area that includes the candidate site and the surrounding area with a 5 km radius from the boundary of the site, there are seven residential colonies/settlements especially along the Indus Highway. A residential colony for workers/staff of Lakhra Power Station is situated approximately 3.5 km away from the candidate site. There are no other sensitive social environment items such as heritage, landscape, ethnic minorities, and indigenous people. Nevertheless, further examination is required to assess the possible social impacts as a result of associated infrastructure developments (i.e., coal transport facilities such as road and railway, water supply and discharge facilities, and transmission line).



Source: Hagler Bailly Pakistan

Figure 3.2-4 Location Map of Selected Site No. 1 in the Indus River Area

(2) Selected Site No. 2 (Near the Jamshoro Power Station)

1) Meteorological and Geological Conditions

The climate and geological conditions in Jamshoro can be considered the same as in Lakhra due to the short distance between them, i.e., approximately 30 km.

2) Environmental and Social Aspects

This site is located approximately 3 km north of the Jamshoro Power Station and 1 km west of the Indus Highway. The site is dominated with rocks and gravels with vegetation and shrubs. There are no residences located within the site. Within a radius of 5 km from the site, some residential areas have been observed, as shown in Figure 3.2-5.

In case that a new sidetrack is extended from the existing railway line, which passes along the east side of the Indus Highway, the sidetrack will be laid through agricultural land. Though the land is not part of any protected area, Rialo Bada Reserved is located within 3.5 km to the east from the site and Rada Reserved Forest and Shar Bukhan Reserved Forest are located in about 6 km to the southeast and in about 7.5 km to the east-southeast from the site respectively. As there is no detailed information on those reserved forests, further investigation should be required.

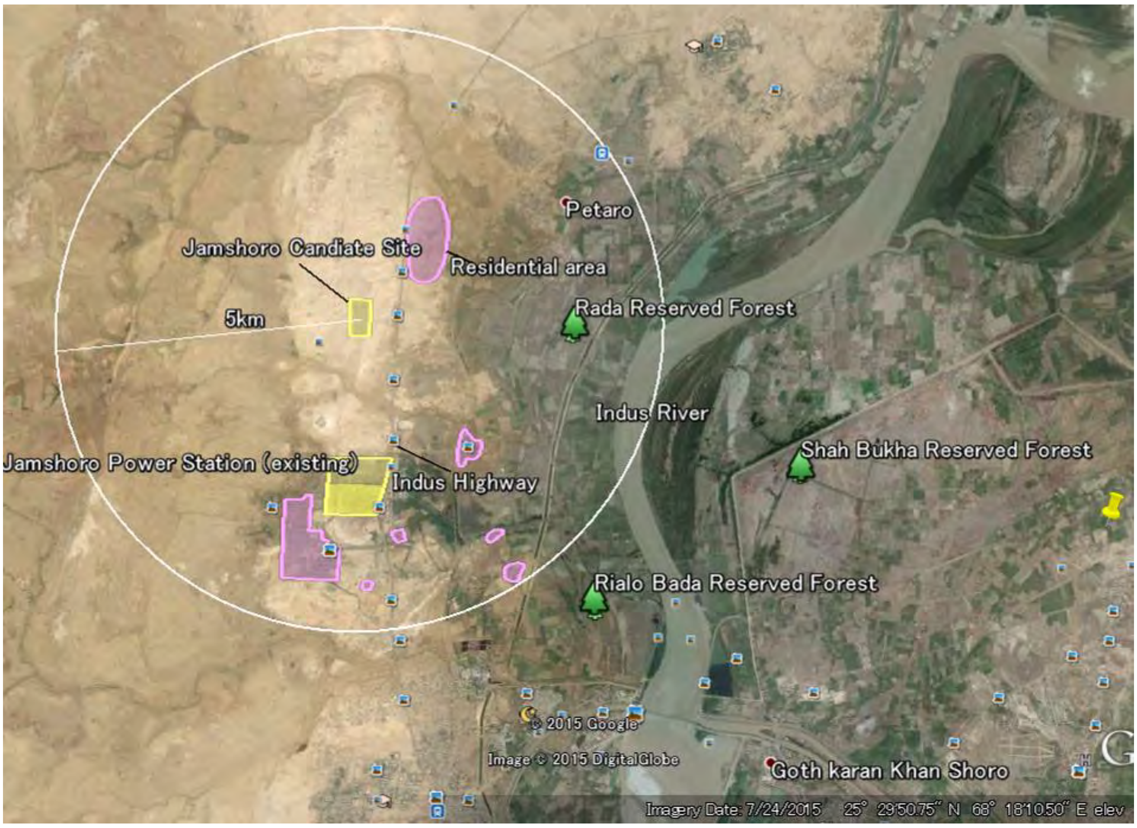
In addition, a connecting transmission line which is approximately 0.7 km long will be constructed from the candidate site to the existing transmission line that lies west of the candidate site.

As water will be taken from the Indus River, which is approximately 5 km away from the site, and thermal discharge will also be drained to the river, the impact on aquatic organisms shall be considered.

Besides, as the Jamshoro Power Station is included within a radius of 5 km from the site as shown in Figure 3.2-5, cumulative impacts by air pollution substances (SO_2, NOx, and SPM) coming from the Jamshoro Power Station should be considered, which depends on wind directions. According to the draft environmental impact assessment (EIA) for Jamshoro Power Generation Project (25 June 2013), SO_2 concentration exceeds the limits defined by NEQS.

Four physical structures were observed within the candidate site based on land use analysis which used a satellite image dated 25 May 2013. Therefore, the possibility of involuntary resettlement including both physical relocation and economic relocation might be expected for the power plant construction. In addition, land acquisition of farmland is required for the sidetrack of the existing railway line as well as for the transmission tower(s). The right-of-way of the transmission line is required to be prepared.

In a study area of 5 km radius from the boundary of the site, some residential colonies/settlements were observed especially along the Indus Highway and in the area between the said highway and the Indus River. A residential colony for workers/staff of the existing Jamshoro Power Station is located south of the said power plant. In addition, the possibility of adverse impacts on the surrounding social environment resulting from the development of associated facilities (such as coal transportation facilities (road and railway), water intake and discharge line, and transmission line) might be expected.



Source: Prepared by the JICA Survey Team using Google Maps

Figure 3.2-5 Location Map of Selected Site No. 2 in the Indus River Area

3.2.3 Karachi Port Area

(1) Meteorological and Geological Conditions

1) Meteorological Conditions

The average monthly temperature and rainfall in the Karachi coastal area in the past five years as measured by the Climate Data Processing Centre of the Pakistan Meteorological Department are shown in Table 3.2-3.

Table 3.2-3 Climate Conditions in the Karachi Port Area

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temp (°C)	19	21	27	30	32	32	29	30	30	29	26	21
Rainfall (mm)	5	1	1	0	0	50	85	52	111	0	0	15

Source: Pakistan Meteorological Department

The annual rainfall in this area is 320 mm and the rainy season is from June to September.

On the other hand, the average monthly temperature is between 19 °C (January) and 32 °C (May). The climate is usually dry except during the short monsoon from July to September.

2) Geological Conditions

Sindh Region is located in the western part of the Indian subcontinent and is part of the ancient continent Gondwana. The Himalayas mountain range had been formed from the collision of India and Eurasia. The Indus River had been developed between these continents. The river had transported the sand from the upstream, and formed by an alluvial fan around the Sindh Region. The stratum of Karachi area mainly consists of river sand. The percolated coefficient was confirmed to be more than 1 x 10-4 stratum.

3) Outline Design of Foundation

The bearing layer exists at around 20 m underground. Therefore, pile foundation will be applied to the equipment foundation. In addition, liquefaction will be considered for the structural foundation because the groundwater level is high as the site is located in a coastal area.

(2) Environmental and Social Aspects

This site is located within Port Qasim's industrial area, which is 2.5 km from the coastal line as shown in Figure 3.2-6. The site is covered mainly with shrubs and grasses. In the site, local people grazing their cows were observed during the site investigation. As vast mangrove swamps inhabit beyond approximately 2 km offshore, water intake and thermal discharge shall be considered to avoid or mitigate any impacts to the mangrove swamps. According to NEQS, industrial effluents shall be discharged at least 10 miles (approximately 16 km) away from the mangroves. Therefore, the outlet site and discharge method shall be considered.

A steel factory owned by Pakistan Steel Mill and some chemical factories are located within a radius of 5 km from the site as shown in Figure 3.2-6. The current air quality shall be measured and cumulative impacts by air pollution substances coming from those factories shall be analyzed.

There are no settlements within the site as it is situated in Port Qasim's industrial area and the land belongs to the Port Qasim Authority according to the Master Plan of Port Qasim 2010[4]. Therefore, there is no possibility that the Project would result in involuntary resettlement within the power plant construction site.

This candidate site does not involve additional construction of associated facilities such as train, railway, and port as there are existing ones nearby. Meanwhile, connecting transmission lines from the site to the existing substation (NTDC-KESC Interconnection), which is located 60 km away from the site, are required. Therefore, land acquisition is required for the construction of transmission tower(s) and the right-of-way of the transmission line will be prepared.

The fishing villages such as Goth Rehri and Goth Ibrahim Haideri are located approximately 15 and 30 km, respectively, northwest of the candidate site on the shore of the Arabian Sea. Prawn and shrimp fishing from inshore waters is the main source of income of the majority. Meanwhile, quite a substantial number of people are employed on deep-sea fishing boats. These fishing activities are observed in creeks and the Arabian Sea in the study area.

Though this candidate site is not located in any protected area, Matho Kotri Wildlife Sanctuary and Indus Delta Ramsar site vastly exist to the southern east area from the candidate site as shown in Figure 3.2-7. Those protected area consists of wet land where a huge variety of organisms are living and migrant birds come over every year.

---

[4] Port Qasim Authority, Master Plan (DWG. No. PQA/MP/IM/SS/06/10-01)

Source: Prepared by the JICA Survey Team using Google Earth

Figure 3.2-6 Location Map of Selected Site in the Karachi Port Area

Source: Prepared by the JICA Survey Team using Google Earth

Figure 3.2-7 Location Map of Protected Areas near the Karachi Port Area

3.3 Infrastructure

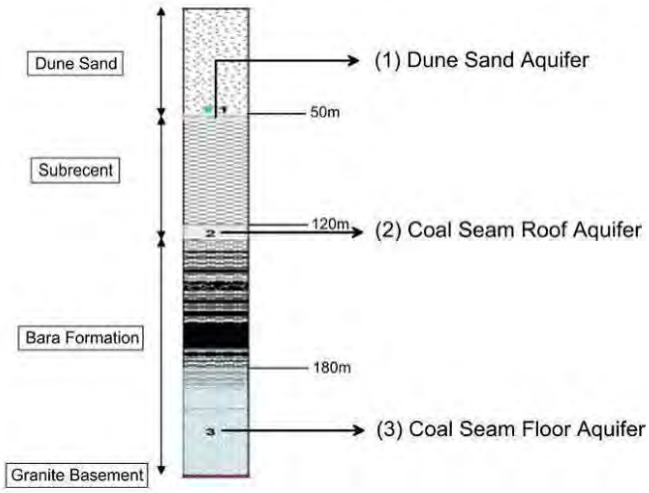
3.3.1 Mine Mouth in Thar

(1) Water Supply and Drainage Facilities

1) Basic Conditions Related to Water

The main water sources in Sindh Province are surface runoff irrigation channels and groundwater. However, surface water is not present in the Thar Desert, and the nearest river and channel located in the Indus River Valley to the Thar Desert run about 120 km west. Therefore, it is difficult to identify a surface water source and water body for wastewater discharge around the mine mouth in Thar.

The area has at least three aquifers, i.e., dune sand aquifer, coal seam roof aquifer (sub-recent aquifer), and coal seam floor aquifer (footwall aquifer) as shown in Figure 3.3-1 and Table 3.3-1. Coal seam floor aquifer is the main aquifer in this region. Most of the people in Thar Village use groundwater in the sand dune aquifer for their consumption, both for domestic purposes and water requirements for cattle. The groundwater in all aquifers is of brackish quality[5] with total dissolved solid (TDS) values in the order of around 3,000 to 8,000 mg/L (Sindh Engro Coal Mining Company, 2010).



Source: SECMC (2010)

Figure 3.3-1 Aquifers in the Thar Coalfield Area

Table 3.3-1 Characteristics of Aquifers

Name of Aquifer	Lithology	Depth / Thickness	Recharge	Permeability (m/s)

5 : Brackish quality means the water condition in which freshwater and seawater are mixed. In brackish water regions, salinity concentration changes according to the tide, seawater flows back at high tide and freshwater flows into the river mouth at low tide, which is affected by both freshwater and seawater.

		(m)		
(1) Sand Dune Aquifer	Bottom of sand dune, fine grained silty yellowish sand	50–60 / 0–5	Rainfall, 10 mm/year	7 x 10^{-6}
(2) Coal Seam Roof Aquifer (Sub-recent Aquifer)	Bottom of sub-recent, silty to coarse sand with partly substantial fractions of fine gravel	115–120 / 0–12	Poor (Indian side)	1 x 10^{-4}
(3) Coal Seam Floor Aquifer (Footwall Aquifer)	Bottom of the Bara Formation, medium to coarse sand, partly silty with more or less numbers of small clay (stone) beds	180–190 / 30–50	100 Mm^3/a From Northeast (Indian side)	1 x 10^{-4} (pure sand)

Source: Sindh Engro Coal Mining Company (2010)

Water availability for the additional thermal power plant considers the following:

- The required amount of water for the new thermal power (600 MW; NET) plant of the Project is approximately 0.5 m^3/s (18 cusec).
- Surface water will be available because surface water from LBOD, which is described later, can be allocated to the additional thermal power plant, as of October 2013.
- Groundwater is considered unavailable for the additional thermal power plant. The reason for this is that SECMC reported in their revised groundwater model in August 2013 that the estimated amount of groundwater which can be abstracted from Block II of the Thar coal area is not more than 22 million m^3/year (0.70 m^3/s)[7], which is the water requirement of the 600 MW (NET) coal thermal power plant. Therefore, the groundwater which will be abstracted from Block II will be available only for the thermal power plants (300 MW x 2) which will be developed ahead by TPC .
- Moreover, the Sindh Coal Authority (SCA) has been preparing a comprehensive master plan for the management of water supply and wastewater disposal in the whole project for coal mining and electrical power generation in Thar for a period of 1.5 years from the middle of October 2013. Therefore, water allocation for each block in the Thar coalfield is possible to be changed by the outcome of the comprehensive master plan.

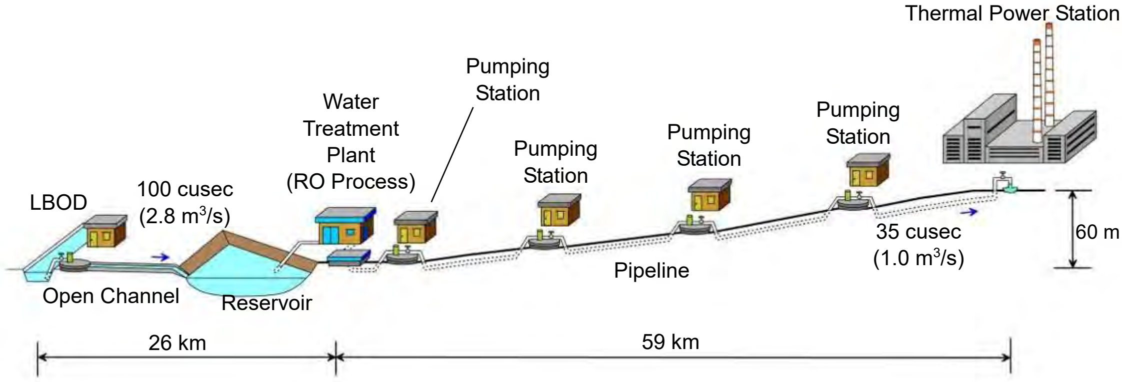
2) Outline of the Existing Plan on Water Supply and Drainage for Power Plant

a. Whole System of Water Supply and Drainage

In order to supply water to the Thar coal area, SCA has a plan to take water from LBOD. LBOD is located approximately 90 km west of the Thar coal area, and the water from LBOD will be conveyed through 26 km of open channel and 59 km of pipeline. Additionally, SCA has a plan to take water from underground around the Thar coalfield, which has at least three aquifers as described above.

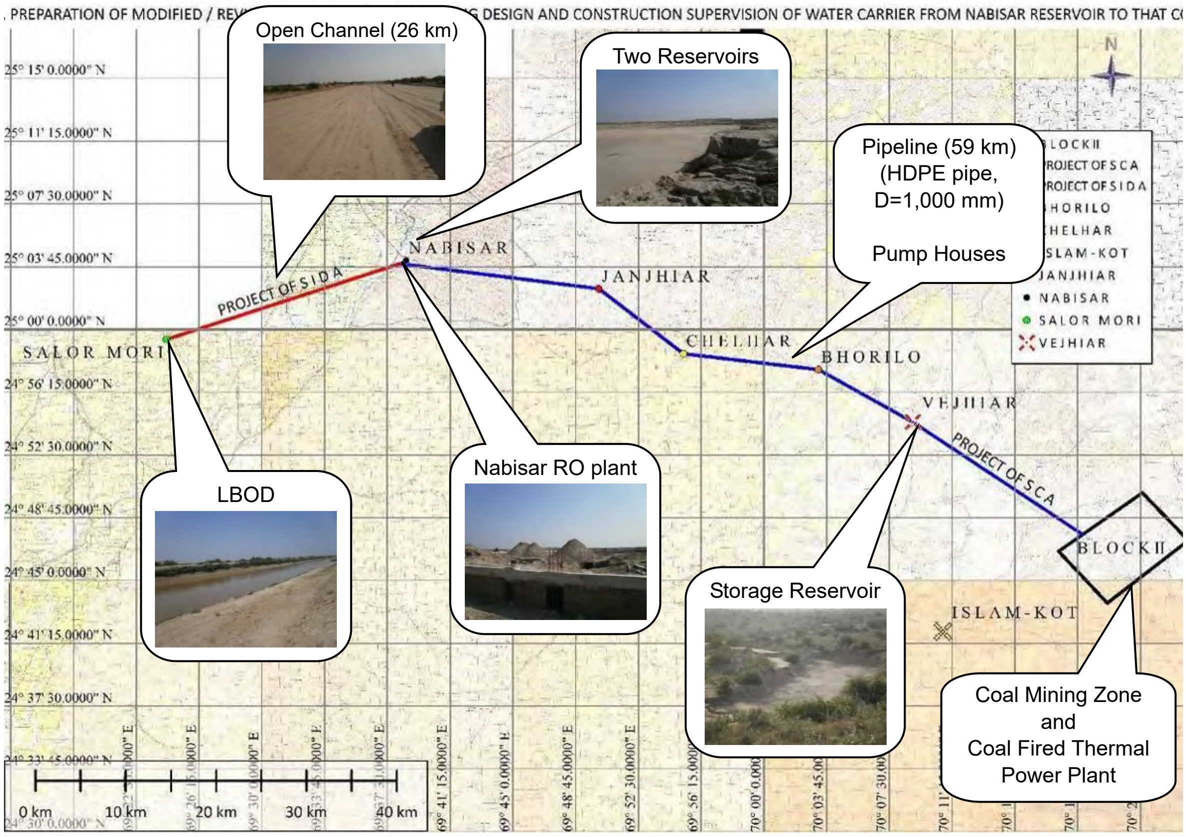
[7] (Daily abstracted water amount) = 22 mil <m^3/year> / (365 <days>)* 24 <hrs> * 60 <min> * 60 <s>)
≅ 0.7 <m^3/s>

The outline of the whole system of water supply and drainage is illustrated in Figure 3.3-2 and Figure 3.3-3.



Source: JICA Survey Team

Figure 3.3-2 Outline of the Water Supply System for the Thar Coalfield



Facility	Function	Water Volume	Startup Target
LBOD (Canal)	Intake of raw water	100 cusec (2.8 m^3/s)	December 2014
Open Chanel (26 km) (LBOD – Nabisar)	Delivery of raw water Disposal of effluent	100 cusec (2.8 m^3/s)	December 2014
Nabisar RO Plant	Water treatment	100 cusec (2.8 m^3/s)	December 2014
Nabisar Reservoirs	Storage of raw water	100 cusec (2.8 m^3/s)	December 2014

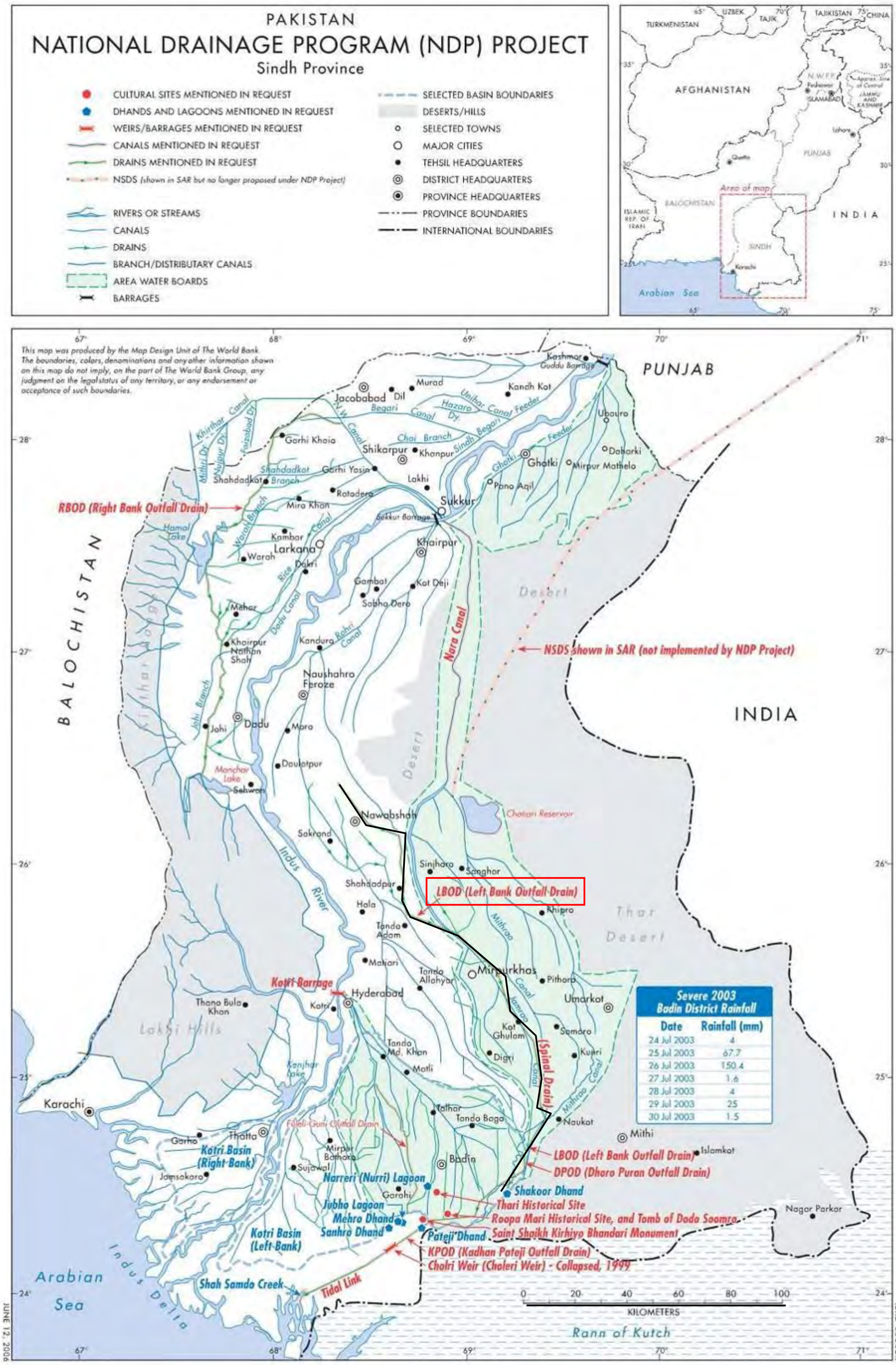
	Storage of treated water	35 cusec (1.0 m^3/s)	
Conveyance Pipe (59 km) (Nabisar – Vajhiar)	Delivery of treated water	35 cusec (1.0 m^3/s)	To be decided
Vajhiar Reservoir	Storage of treated water	35 cusec (1.0 m^3/s)	To be decided
Conveyance Pipe (30 km) (Vajhiar – Power station)	Delivery of treated water	35 cusec (1.0 m^3/s)	To be decided
Wastewater Treatment Plant	Treatment of wastewater from the power station	35 cusec (1.0 m^3/s)	To be decided
Drainage Pipe (35 km)	Delivery of treated wastewater	35 cusec (1.0 m^3/s)	To be decided
Evaporation Pond	Evaporation of treated wastewater (Final disposal)	35 cusec (1.0 m^3/s)	To be decided

Source: JICA Survey Team

Figure 3.3-3 Location and Components of the Water Supply and Disposal System for the Thar Coalfield

b. LBOD

LBOD is a canal which is located on the left bank of the Indus River as shown in Figure 3.3-4, and is used for drainage of unavailable irrigation water.



Source: POE Drainage Master Plan

Figure 3.3-4 National Drainage Program (NDP) Project Map

As mentioned above, SCA has a plan to take water from LBOD and convey it to Nabisar. The water intake point is proposed to be located at RD-362 on LBOD as illustrated in Figure 3.3-5.

Source: Irrigation Department of GoS, Google Earth

Figure 3.3-5 Location of Water Intake Point (RD-362)

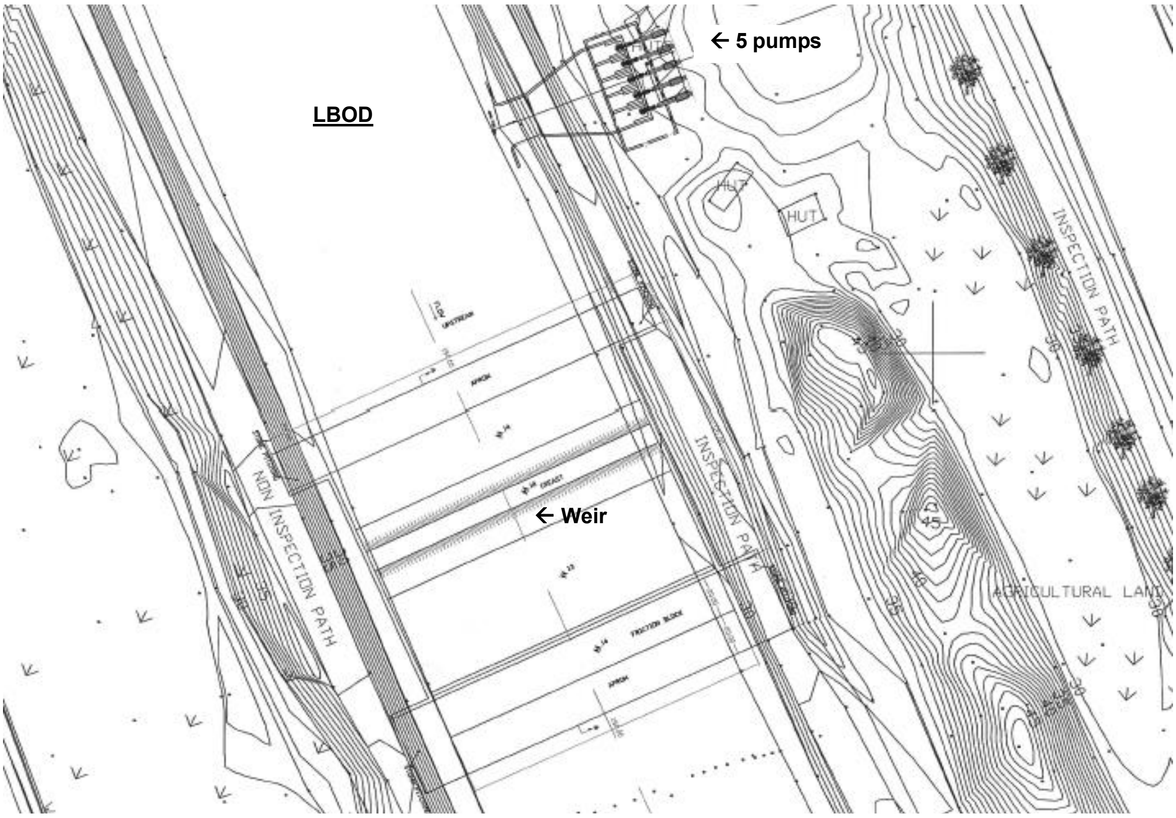
SCA has proposed to develop a diversion weir, a head gate and five pumps as water intake structures as shown in Figure 3.3-6, and the proposed capacity of the water intake is 2.8 m^3/s (100 cusec). As of the middle of October 2013, the construction work is at a stage prior to commencement. Accordingly, commencement of the construction work is at the end of October 2013.

Source: JICA Survey Team

Photo 3.3-1 Overview of LBOD

Source: JICA Survey Team

Photo 3.3-2 Planned Site of Pumping Station

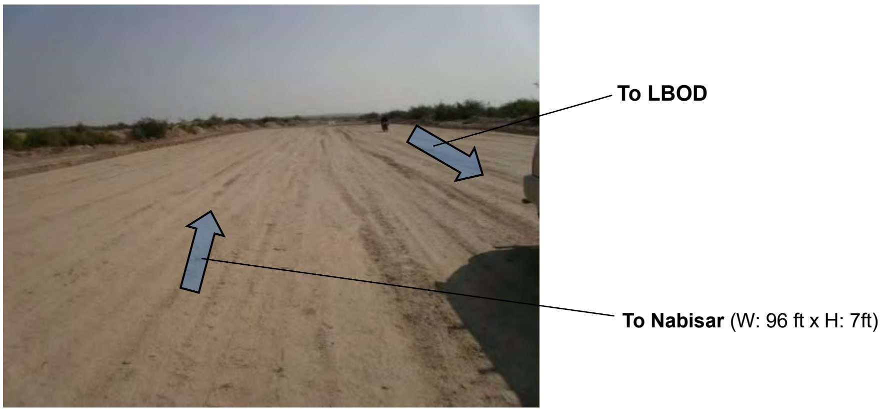


Source: SCA

Figure 3.3-6 Design Drawing of the Water Intake Point

c. Open Channel

SCA has a plan to develop two kinds of open channels of approximately 26 km between LBOD and Nabisar. One will be used for water conveyance to Nabisar from LBOD by gravity flow, and the other will be used for disposal of effluent from the RO water treatment plant in Nabisar. These two open channels, as shown in Photo 3.3-3, are under construction.

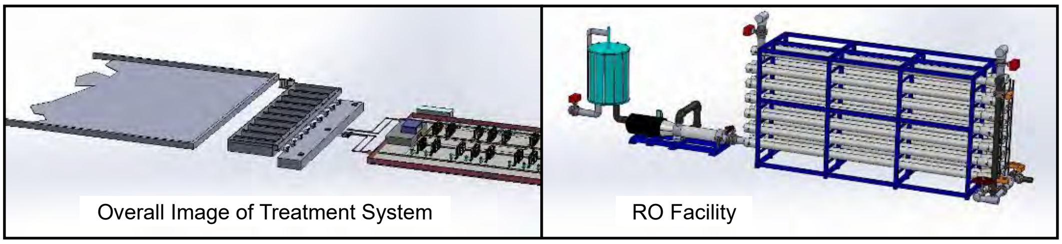


Source: JICA Survey Team

Photo 3.3-3 Overview of Open Channels

d. Nabisar Water Treatment Plant

SCA has a plan to develop a water treatment plant in Nabisar which is located between LBOD and the Thar coalfield. Raw water from LBOD has highly-concentrated saline content (TDS = 10,000 mg/L, Cl^- = approximately 4,200 mg/L), and the water quality of boiler water for the thermal power plant is required to be improved to the level of freshwater (Cl^- = 15–500 mg/L). Accordingly, SCA has proposed to install a water treatment plant with desalination facility, and the water treatment process will be RO, as illustrated in Figure 3.3-7. The RO plant has been designed to have a treatment capacity of 35 cusec (1.0 m^3/s, 24 MGD), and TDS of the treated water shall not be more than 500 mg/L.



Source: Irrigation Department of GoS

Figure 3.3-7 Conceptual Diagram of the RO Plant

The progress situation of the installation of the RO plant as of the middle of October 2013 is that 1) the procurement work for required equipment is at 90%, and 2) the construction work is at 40% and the foundation work of the RO plant site has been executed, which is shown in Photo 3.3-4.

Photo 3.3-4 Construction Site of the RO Plant

Photo 3.3-5 Procured Units of the RO Plant

e. Water Reservoirs in Nabisar

SCA has a plan to develop two kinds of reservoirs in Nabisar. One is a pre-treated saline/raw water reservoir which has an area of 0.61 km^2 (150 acres). The other is a treated water reservoir which has an area of 0.40 km^2 (100 acres). The status of construction work for both reservoirs as of the middle of October 2013 is that earth excavation is in progress, as shown in Photo 3.3-6.

Source: JICA Survey Team

Photo 3.3-6 Raw Water Reservoir

Source: JICA Survey Team

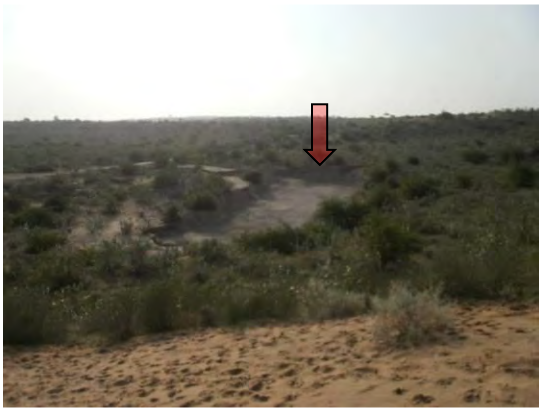
Photo 3.3-7 Treated Water Reservoir

f. Water Conveyance Pipeline and Pumping Stations

SCA has a plan to develop a water conveyance system from Nabisar to the Thar coal area. The distance between Nabisar and the Thar coalfield is approximately 59 km, and the proposed water conveyance system consists of two pressure pipelines of 1.2 m (4 ft) diameter and five pumping stations. The construction works for these water conveyance facilities have not commenced yet, as of the middle of October 2013, but SCA and the Sindh Irrigation and Drainage Authority (SIDA) have entered into a memorandum of understanding (MOU) stating that the construction works for these conveyance facilities will be delegated to SIDA by SCA. Therefore, it is expected that the construction works will be started in a short time.

g. Storage Reservoir in the Thar Coalfield (Vajhiar)

SCA has a plan to develop a reservoir in the Thar coalfield for the purpose of impounding water conveyed from Nabisar. The construction works for this water reservoir have not commenced yet, as of the middle of October 2013. The site of the reservoir is shown in Photo 3.3-8.



Source: JICA Survey Team

Photo 3.3-8 Distant View of the Reservoir Site

Source: JICA Survey Team

Photo 3.3-9 Close-up View of the Reservoir Site

h. Wastewater Disposal System

In the service period for the coal mining works and the operation of thermal power plant, some amount of wastewater will be discharged from several kinds of generation sources such as the thermal power plant, coal mining block, administration house, and residential area.

Table 3.3-2 Environmental Quality Standards for Municipal and Liquid Industrial Effluent (unit: mg/L)

Parameter	Into Inland Waters	Into Sewerage Treatment	Into the Sea
Temperature or Temperature Increase	40 °C +-3 °C	40 °C +-3 °C	40 °C +-3 °C
pH value	6-9	6-9	6-9
Biochemical Oxygen Demand $(BOD)_5$ at 20 °C	80	250	80
Chemical Oxygen Demand (COD)	150	400	400
Total Suspended Solids (TSS)	200	400	200
Total Dissolved Solids (TDS)	3500	3500	3500
Oil and Grease	10	10	10
Phenolic Compounds (as phenol)	0.1	0.3	0.1
Chloride (as Cl^-)	1000	1000	SC*
Fluoride (as F^-)	10	10	10
Cyanide (as CN^-) total	1.0	1.0	1.0
Anionic detergents (as MBAS)	20	20	20
Sulfate (SO_4^{2-})	600	1000	SC*
Sulfide (S^{2-})	1.0	1.0	1.0
Ammonia (NH_3)	40	40	40
Pesticides	0.15	0.15	0.15
Cadmium	0.1	0.1	0.1
Chromium (Trivalent and Hexavalent)	1.0	1.0	1.0
Cooper	1.0	1.0	1.0
Lead	0.5	0.5	0.5
Mercury	0.01	0.01	0.01
Selenium	0.5	0.5	0.5
Nickel	1.0	1.0	1.0
Silver	1.0	1.0	1.0
Total Toxic Metals	2.0	2.0	2.0
Zinc	5.0	5.0	5.0
Arsenic	1.0	1.0	1.0
Barium	1.5	1.5	1.5
Iron	8.0	8.0	8.0
Manganese	1.5	1.5	1.5
Boron	6.0	6.0	6.0
Chlorine	1.0	1.0	1.0

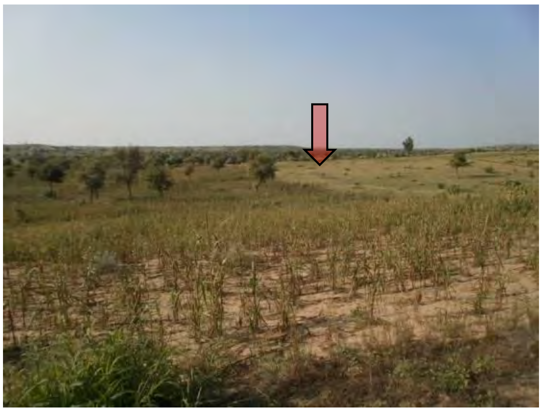
NOTE
*: Discharge concentration at or below sea concentration
Source: Ministry of Environment

Wastewater must be treated appropriately before discharging to public water bodies in order to meet the National Environmental Quality Standards for Municipal and Liquid Industrial Effluent which are summarized in Table 3.3-2 above. In order to dispose appropriately the wastewater generated by the activities related to coal mining and power generation, SCA has a plan to develop a wastewater disposal system for Block II as described below.

- As the candidate site of disposal point of wastewater, an evaporation pond will be constructed at the place which is located near Dakkar Shah Village, which is 7 km away from the Ramsar site, as shown in Figure 3.3-8 and Photo 3.3-10.
- An effluent pipeline for wastewater of around 20 km in length will be installed from the Thar coalfield to the proposed evaporation pond.
- The estimated amount of wastewater is approximately 1.4 m^3/s (50 cusec).
- As a countermeasure against percolation from the proposed evaporation pond, sheet lining work is considered in the current feasibility study.
- The wastewater treatment plant has not been designed in detail.
- As of the middle of October 2013, this development plan is in the stage of feasibility study, which was executed by a local consultant.
- The EIA of this development plan has not yet been approved by the Environmental Protection Agency (EPA) as of the middle of October 2013.

Source: SECMC, Google Earth

Figure 3.3-8 Location of the Candidate Site of the Disposal Point and the Proposed Route of the Effluent Pipeline



Source: JICA Survey Team

Photo 3.3-10 Candidate Site of the Disposal Point

3) Issues to be Considered for Development of the New Thermal Power Plant

From the abovementioned fact-finding, the following issues associated with water should be considered and clarified in order to develop the new thermal power plant in the mine mouth in Thar under the Project:

- SCA should take the EIA procedure after the feasibility study of the wastewater disposal system is completed.
- If the EIA report on the current wastewater disposal plan will not be approved by EPA, an alternative solution should be proposed.
- The wastewater treatment plant should be designed in detail, and the treatment process and the location of the plant should be studied.

(2) Transmission Line

1) Power System Analysis

Power system analysis was carried out in order to check if the NTDC's future power system with/without connection of the new coal-fired power plant (hereinafter referred to as "CFPP") would meet the transmission planning criteria, which are stipulated in the Grid Code. The analysis tool PSS/E ver. 33.4.0 was utilized.

a. Power Flow

The following criteria are referred to for evaluation of the power flow calculation results:

- Under normal operating conditions (N-0), all transmission lines and transformers shall be loaded below their normal continuous maximum ratings.

- Under contingency conditions (N-1), all transmission lines and transformers shall be loaded below their emergency ratings.

b. Voltage

For steady-state conditions, voltages of all buses shall be within the following ranges:

- From 5% to +8%[8] of nominal system voltage under normal operating conditions (N-0).

- From 10% to +10% of nominal system voltage under contingency conditions (N-1).

c. Study Conditions

The power flow analysis was carried out under the following conditions:

- Target year of the study is 2020, which is the expected year of commercial operation of the CFPP proposed in this study.
- The base case file for the study was provided by NTDC on 28 November 2013.
- Power generation plan up to February 2021 was considered to develop the case file.
- Only winter low water condition was considered for analysis since the power flow from the thermal power plants planned in the southern part of Pakistan is considered dominant in the period, thus being severer condition for the southern system.
- Only 500 kV HVAC and 600 kV HVDC systems were considered the targets of the power system analysis in this study. Therefore, reinforcement of the system with lower

[8] The voltage profile is allowed up to +8% of nominal voltage during steady-state condition in the Operation Code of the NTDC Grid Code.

voltage than 220 kV was not studied in detail except for the purpose of making the calculation converged.

- The power flow of the following 600 kV HVDC systems was set out to 3,300 MW (1,650 MW/cct) based on the data provided by NTDC:
  - Gadani converter station to Faisalabad West converter station;
  - Gadani converter station to Lahore South converter station;
  - Matiari converter station to Lahore South converter station; and
  - Thar CFPP to Lahore South converter station.
- An arbitrary amount of reactive power sources (switched shunt capacitors) were assumed to be connected to maintain bus voltage within the allowable level.
- The transmission capacity of each transmission section was based on the data on transfer limit (MVA) provided by NTDC.
- The same conductor type (AAAC Araucaria) was selected for the conductor of 600 kV HVDC bi-pole line from the Thar CFPP to Lahore South substation (S/S).

d. Study Cases

The study cases were set out depending on the location of the candidate CFPPs as well as on the difference in the methods of system reinforcement, as shown in Table 3. 3-3

Table 3.3-3 Study Cases

Base Condition (No CFPP Case)		Mine Mouth in Thar		Indus River		Karachi Port	
HVAC	HVDC	HVAC	HVDC	HVAC	HVDC	HVAC	HVDC
Case 0	Case 0d	Case 1	Case 1d	Case 2	Case 2d	Case 3	Case 3d

Source: JICA Survey Team

Two ways of system reinforcement are expected. One is by adding circuits by 500 kV HVAC transmission lines, and the other is by introducing another 600 kV HVDC bi-pole transmission system from the Thar coalfield, the location of the aggregate of power plants to Lahore South S/S, the load center of the country in order to directly evacuate bulk power to the load center. Therefore, both the 500 kV HVAC and 600 kV HVDC system configurations were considered for each candidate power plant location.

e. Base Condition

NTDC updated the power system plan in order to make it possible for the system to evacuate the bulk power from the planned large-scale power plants in the southern part of the country, such as the Gadani Power Park (600 MW x 10 units) and the K-2/K-3 nuclear power plant (1,100 MW x 2 units) in the coastal area, and the Thar coal power plant in the Thar Desert. The schematic diagram of the power system dated 25 October 2013, which envisioned the prospective power system as of 2021, was provided by NTDC (Appendix 3-1). In this power system plan, the following three routes of ±600 kV bi-pole HVDC transmission lines are considered:

- From Gadani converter station to Faisalabad West converter station;
- From Gadani converter station to Lahore South converter station; and
- From Matiari converter station to Lahore South converter station.

In this plan, only 1,200 MW (600 MW x 2) was taken into account for power generation in the Thar Desert from the Engro Thar coal power plants (Phase-1 and Phase-2).

On the other hand, based on the latest information on the addition of power generation in the Thar coalfield prepared by TCEB, which was provided by NTDC on 28 November 2013, the expected total generation addition is 3,600 MW, including the aforementioned Engro Thar coal power plants.

f. Case 0

Considering the maximum transmission capacity of the existing 500 kV HVAC power system as well as that of some planned transmission sections in the NTDC's original plan, the following sections will be overloaded under N-1 contingency condition:

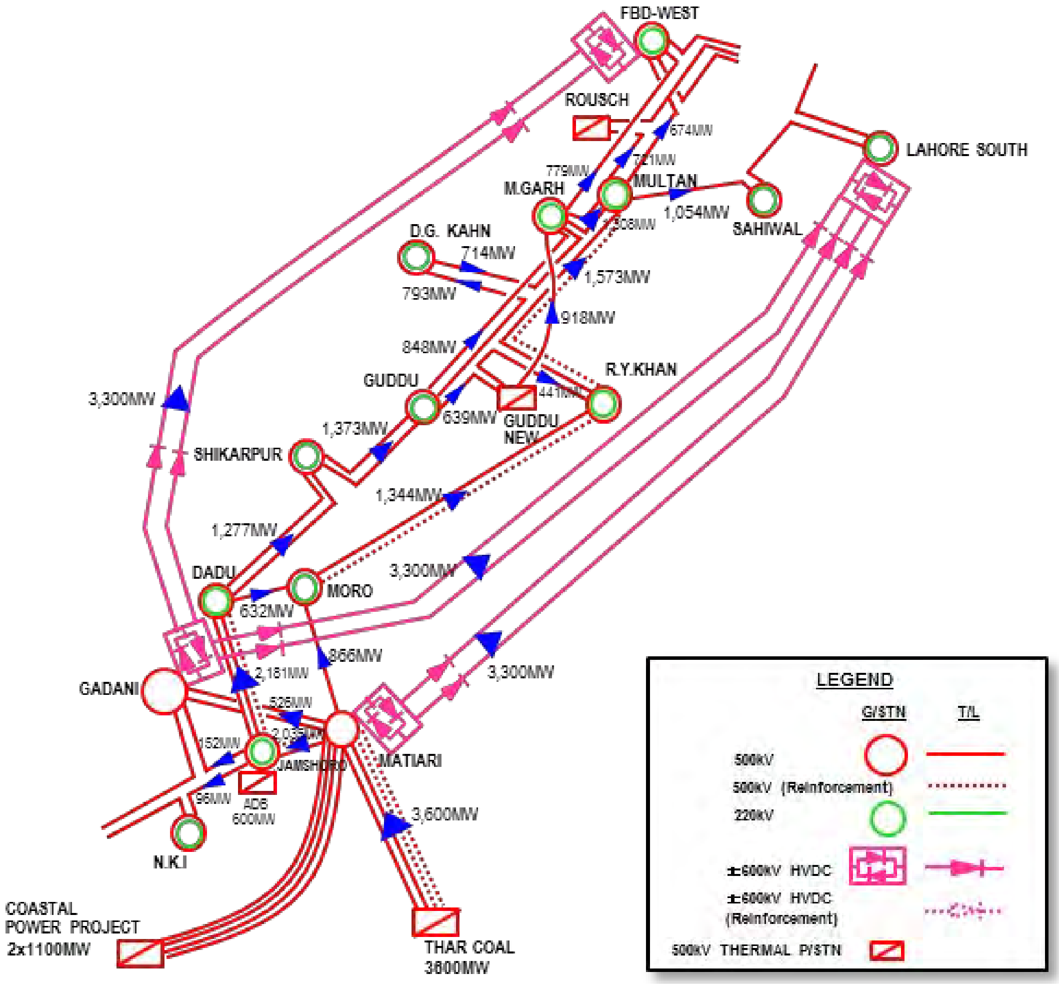
- Thar coal power plant (PP) to Matiari substation (S/S);
- Matiari S/S to Jamshoro S/S;
- Jamshoro S/S to Dadu S/S;
- Moro S/S to R.Y. Khan S/S; and
- R. Y. Khan S/S to Multan S/S.

In order to avoid overloading of the above listed sections, the following reinforcement is required by adding circuits:

- Thar Coal PP to Matiari S/S : 2 circuits
- Matiari S/S to Jamshoro S/S : 1 circuit
- Jamshoro S/S to Dadu S/S : 1 circuit

- ➢ Moro S/S to R.Y. Khan S/S : 1 circuit
- ➢ R. Y. Khan S/S to Multan S/S : 1 circuit

The system configuration after the reinforcement is shown in Figure 3.3-9. The red dotted lines depict the additional circuits, while the blue arrows depict the direction of the power flow.

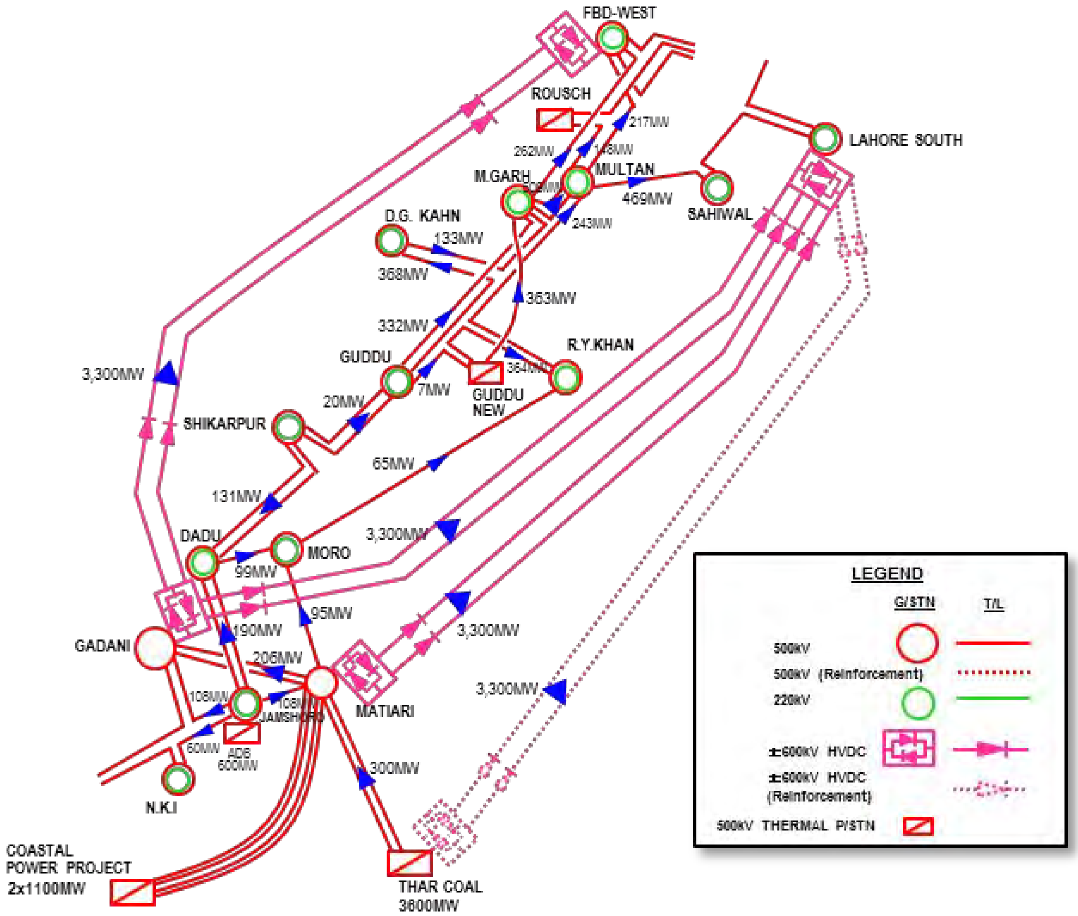


Source: JICA Survey Team

Figure 3.3-9 Power Flow Diagram (Case 0)

g. Case 0d

For the HVDC 600 kV option, reinforcement of the 500 kV transmission lines is not necessary considering the N-1 contingency condition. The power flow diagram is shown in Figure 3.3-10.



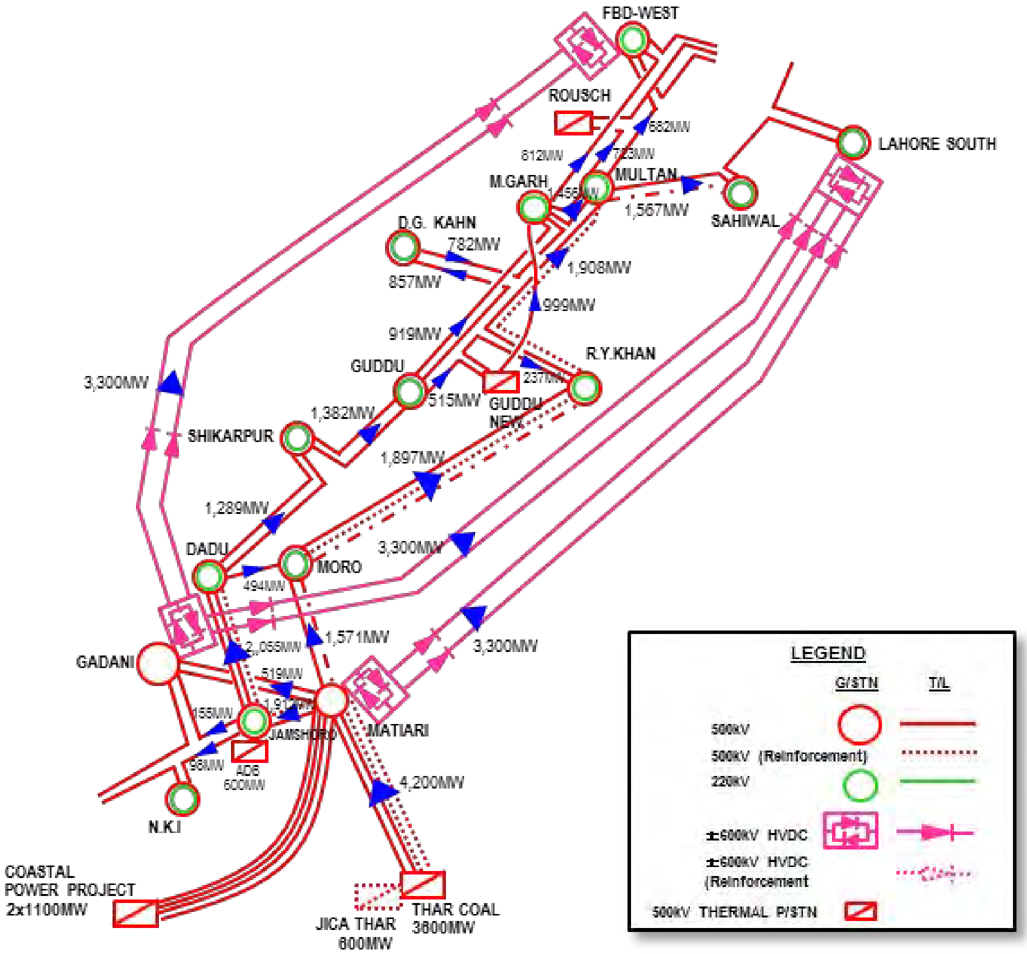
Source: JICA Survey Team

Figure 3.3-10 Power Flow Diagram (Case 0d)

Base condition of Case1 and Case1d for power system analysis is referred for the Thar Coal area, the Indus River area and the Karachi Port area, respectively.

It should be noted that the abovementioned reinforcements for Case 1 and Case 1d are not included in the Project. Neither the cost of reinforcement nor the cost estimation is included.

h. Case 1



Source: JICA Survey Team

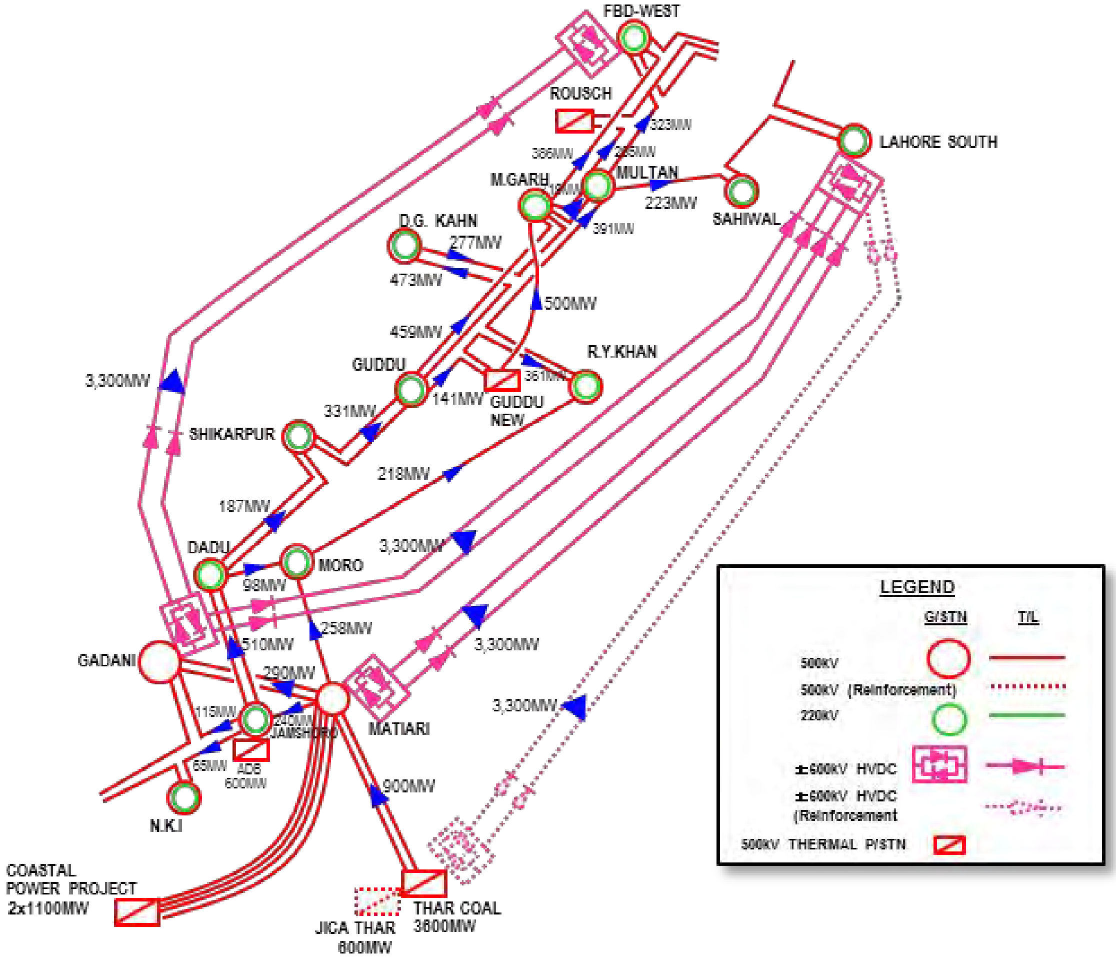
Figure 3.3-11 Power Flow Diagram (Case 1)

The following reinforcements of 500 kV HVAC transmission lines from the system configuration in the "No CFPP case" is necessary in order to avoid overloading under N-1 contingency condition. The power flow diagram is shown in Figure 3.3-11. The dashed/dotted lines depict the circuits added.

- Matiari S/S to Moro S/S : 1 circuit
- Moro S/S to R.Y. Khan S/S : 1 circuit
- Multan S/S to Sahiwal S/S : 1 circuit

i. Case 1d

For the HVDC 600 kV option, reinforcement of the 500 kV transmission lines is not necessary considering the N-1 contingency condition. The power flow diagram is shown in Figure 3.3-12.



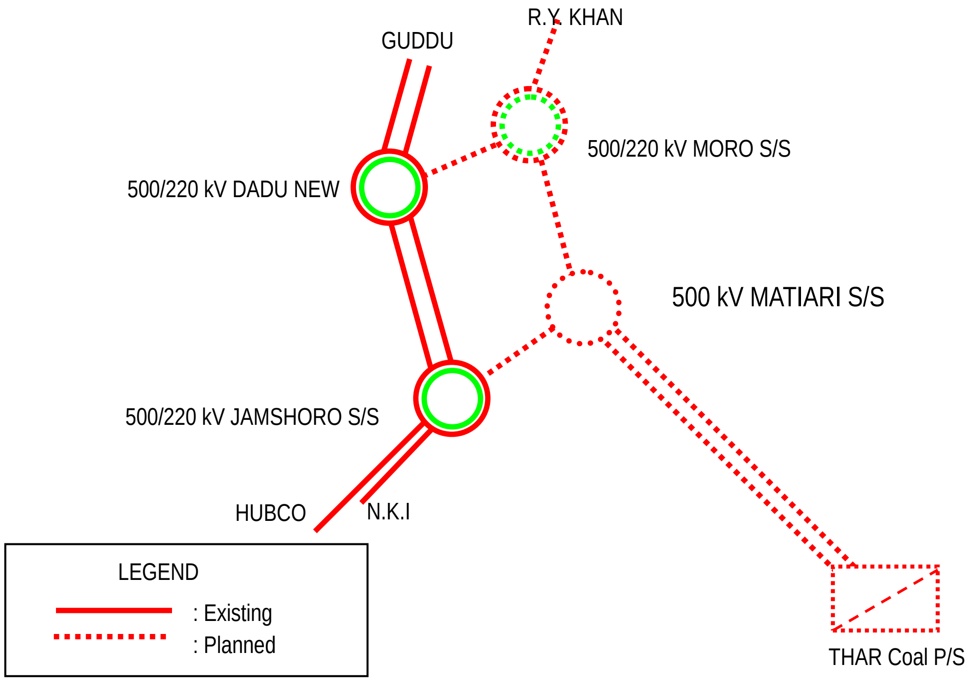
Source: JICA Survey Team

Figure 3.3-12 Power Flow Diagram (Case 1d)

Transient stability analysis was examined in Appendix 3-2 and its detailed results are shown in Appendix 3-3.

2) Transmission Line

The nearest 500 kV substation is located in Jamshoro, which is around 250 km away from the Thar coalfield. Consequently, NTDC has planned the extension of the 500 kV network systems to the Thar coalfield. The connection method for the existing power grid system is shown in Figure 3.3-13. PC-1 for the 500 kV transmission line has already been approved on 28 August 2012. The cost of the Project is estimated at around Rs 22 billion.



Source: NTDC

Figure 3.3-13 Connection Method for the Existing Power Grid System

In addition, in case the candidate site in the mine mouth in Thar is selected for the construction of the power plant, it will be connected to the above transmission line from the power plant under the Project.

(3) Transportation

1) Road

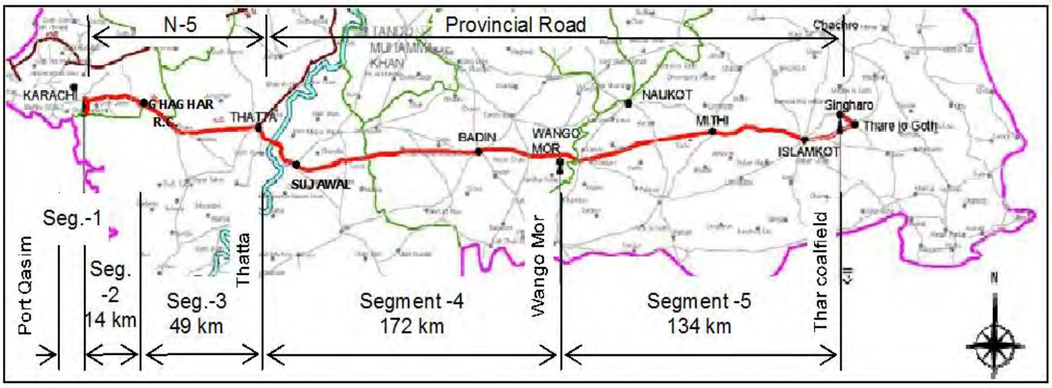
a. Outline

The planned access route to the Thar coalfield from Karachi Port (Port Qasim) is the existing public road subject to upgrading.

The route passes through major towns including Thatta, Badin, Wango Mor, Mithi, and Islamkot. The route map of the access road and the schematic diagram of the route are shown in Figures 3.3-14, 3.3-15, and 3.3-16.

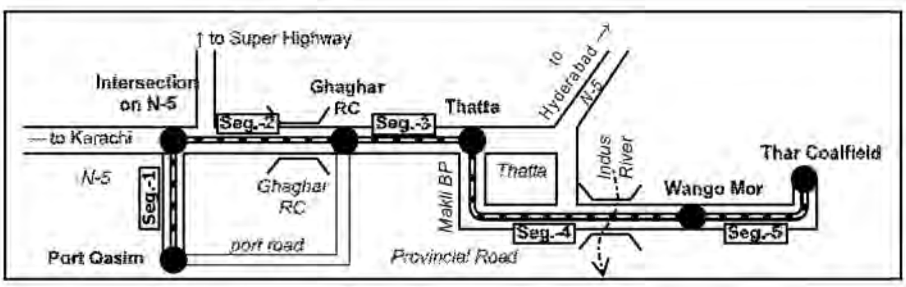
The route is divided into five segments, as given below, in consideration of the study in this report. The route and sectional length were confirmed by SCA.

Segment-1	Port Qasim to intersection on N-5 (11 km)
Segment-2	Intersection on N-5 to Ghaghar Railway Crossing (RC) (14 km)
Segment-3	Ghaghar RC to Thatta 8 (49 km)
Segment-4	Thatta to Wango Mor (172 km)
Segment-5	Wango Mor to the Thar coalfield (134 km)



Source: JICA Survey Team

Figure 3.3-14 Route Map of the Access Road to the Thar Coalfield



Source: JICA Survey Team

Figure 3.3-15 Schematic Route Map

Source: Prepared by the JICA Survey Team using Google Maps

Figure 3.3-16 Route Map of the Access Road to the Thar Coalfield

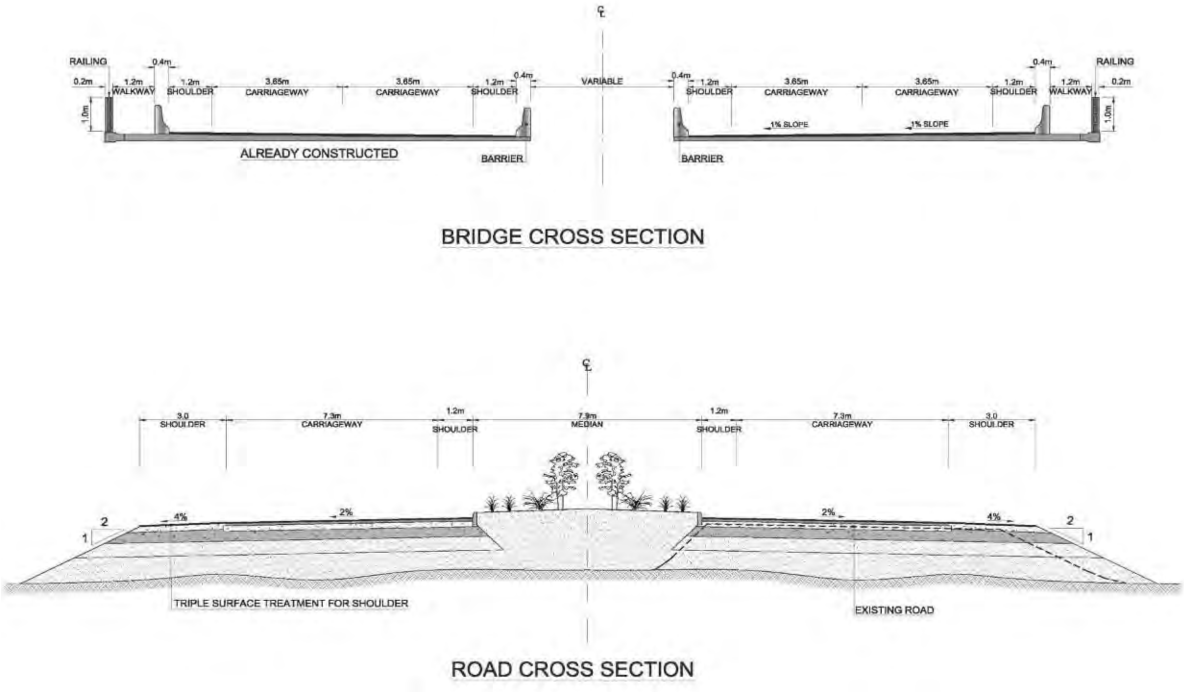
b. Road Improvement Plan

Road improvement including road widening, reconstruction, and rehabilitation of structures and pavement are planned for the following three segments in order to secure transportation of heavy vehicles that will be used for the Thar coalfield development:

- Segment-3: Ghaghar RC to Thatta : Improvement by public-private partnership (PPP) (Karachi-Thatta Dual Carriageway Project);
- Segment-4: Thatta to Wango Mor : Improvement by SCA using the budget of GoS; and
- Segment-5: Wango Mor to the Thar coalfield : Improvement by SCA using the budget of GoS.

Both Segment-1 and Segment-2 have no improvement plan since heavy vehicle traffic along the said segments are currently the same as that considered for the Thar coalfield development.

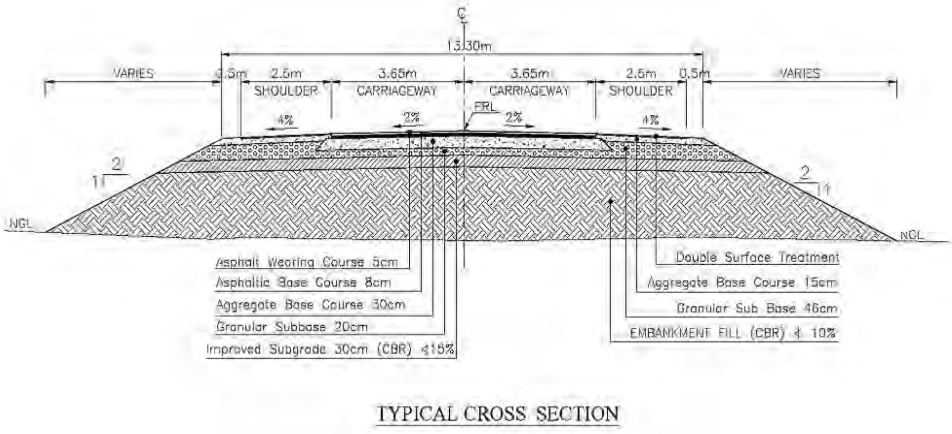
According to request for proposals (RFP) documents of the Works and Services Department and the Public Private Partnership Unit of the Finance Department of GoS, the typical cross sections of Segment-3 are shown in Figure 3.3-17.



Source: Sindh Engro Coal Mining Company

Figure 3.3-17 Typical Cross Sections of Segment-3

According to an interview with SCA, the typical cross section shown in Figure 3.3-18 was considered for Segment-4 and Segment-5. Also, the design traffic volume shown in Table 3.3-4, was provided by SCA.



Source: Sindh Engro Coal Mining Company

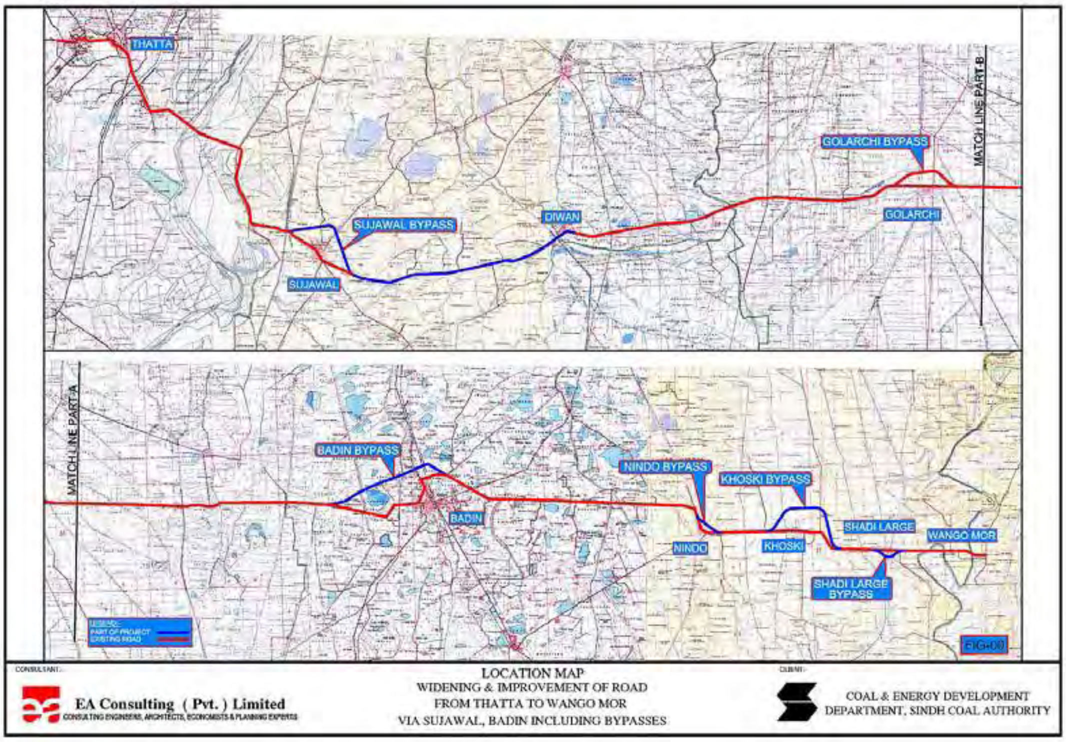
Figure 3.3-18 Typical Cross Section of Segment- 4 and Segment-5

Table 3.3-4 Expected Daily Traffic

Expected Daily Traffic		Minibuses, Coaches & Coasters	Buses	Trucks		Trailers				Tractor Trolley	Total
				1.2	1.22	1.2-2	1.2-22	1.2-222	1.22-222		
				2-Axle	3-Axle	3-Axle	4-Axle	5-Axle	6-Axle		
2012	(Normal Traffic)	66	58	271	173	116	138	90	29	236	1177
	(Construction Traffic)	7	6	28	18	12	14	9	3	24	121
	Total traffic in 2012	73	64	299	191	128	152	99	32	260	1298
2013	(Normal Traffic)	69	61	282	180	121	144	94	31	244	1226
	(Construction Traffic)	7	7	29	18	13	15	10	4	25	128
	Total traffic in 2013	76	68	311	198	134	159	104	35	269	1354
2014	(1st Year of Operation)	73	64	293	187	126	150	98	33	252	1276
2015		77	67	307	196	132	157	103	35	264	1338
2016		81	71	321	205	138	165	108	37	276	1402
2017		85	75	336	215	145	173	113	39	289	1470
2018		89	79	352	225	152	181	119	41	303	1541
2019		94	83	368	236	159	190	125	43	317	1615
2020		99	87	385	247	167	199	131	45	332	1692
2021		104	91	403	259	175	208	137	48	347	1772
2022		109	96	422	271	183	218	144	51	363	1857
2023	(10th Year of Operation)	114	101	441	284	192	228	151	54	380	1945

Source: Sindh Coal Authority

Road improvement of the study road basically involves widening of the existing road. Therefore, the alignment will be kept as it is except on new five bypasses serving as detour to congested towns. The location map of the new six bypasses designed for Segment-4 is shown in Figure 3.3-19.



Source: Prepared by the JICA Survey Team using the location map obtained from SCA

Figure 3.3-19 Location of New Bypasses

According to information from SCA, the road alignment is planned based on the following requirements for traffic of multi-axle trailers:

- Tentative length of a multi-axle trailer is 30 m. It will be carrying 280 metric t of load.
- Minimum horizontal radius is 280 m at 80 to 100 km/h speed and maximum vertical grade is 4.0%. Widening of curves will be as per design by providing proper superelevation. Generally, vertical grade is 3% or less but at three locations, it is up to 4% where high sand dunes cutting are involved.

c. Schedule of the Improvement Plan

Segment-3 is planned to be procured for the private sector. Design for the road improvement is also planned to be completed in 2013. Then, construction work is expected to commence in 2014, and be completed by the end of 2015.

There are 12 contract packages for road improvement of Segment-4 and Segment-5 between Thatta and the Thar coalfield. Table 3.3-5 shows the contents, status, and schedules of each package. The packages are expected to be completed by June 2015.

Table 3.3-5 Contents, Status, and Schedule of Segments (as of October 4, 2013)

Package	Route / Major Item	Current Status	Commencement	Expected Completion
Segment-3: Ghaghar RC – Thatta				
-	Ghaghar RC–Thatta	RFP is issued by PPP cell	Expected in January 2014	December 2015
Segment-4: Thatta to Wango Mor				
Pkg-1	Wango Mor to Khoski	Construction/ Rehabilitation	November 2012	December 2014
Pkg-2	Noori Village (Adjacent to Khoski) to Hassan Mangrio (near Badin)	Construction/ Rehabilitation	November 2012	December 2014
Pkg-3	Bhaneri (near Badin) to Goth Haji Allu (near Diwan sugar mill)	Rehabilitation	February 2013	November 2014
Pkg-4	Diwan sugar mill to Pinu Baran (near Sujawal)	Rehabilitation	January 2013	July 2014
Pkg-5	Sujawal Bypass	Re-tender		
Segment-5: Wango Mor to Thar Coalfield				
Pkg-1	Wango Mor to near village Modar	Rehabilitation (work from Km. 0.00 to 20.60 in progress)	January 2013	December 2014
Pkg-2	Dadwari Thakar Village to Pasarko Village	Rehabilitation (work from Km. 20.60 to 41.900 to be let-out)	Bids re-invited and kept on 07.11.2013	June 2015
Pkg-3	Rohiro Village to Marvi petroleum, Mithi	Rehabilitation (work from Km. 41.90 to 63.00 in progress)	January 2013	December, 2014
Pkg-4	Mithi to Landhar Village	Rehabilitation (work from Km. 63.00 to 84.20 in progress	January 2013	December 2014
Pkg-5	Under preparation	Rehabilitation (work from Km. 84.20 to 106.30 to be let-out)	Bids re-invited and kept on 07.11.2013	September 2015
Pkg-6	Under preparation	Rehabilitation (work from Km. 106.30 to 125.30 to be let-out)	Bids re-invited and kept on 07.11.2013	September 2015
Pkg-7	Under preparation	Rehabilitation (work from Km. 125.30 to 134.034 to be let-out)	Bids re-invited and kept on 07.11.2013	September 2015

Source: Sindh Coal Authority

d. Imported Coal Transportation

This alternative public road transport of Thar coal will not be necessary because the power station will be located just adjacent to the mining sites. It is suitable to transport them by belt conveyor or special large trucks exclusively in the area.

In case imported coal is adopted at the initial stage (before coal mining in the Thar coalfield), traffic volume including traffic of trailers of imported coal transportation, and traffic capacity of Segment-4 and Segment-5 are as shown in Table 3.3-6.

Table 3.3-6 Outline Calculation of Capacity of Imported Coal Transportation

Item	Unit	Value	Item	Unit	Value
Number of Trailer for imported coal transfer			Traffic Capacity of 2-lane road		
Imported Coal Volume	ton/year	2,000,000	Basic capacity	pcu/h	2,500
Type of Trailer	ton/Veh	60	Correction factor by road width	-	1.00
Carrying capacity	ton/Veh	35	Correction factor of shoulder width	-	1.00
Number of Trailer	Veh/day	380	Correction factor of intersection	-	1.00
Design Dairy Traffic in 2014		*1	Correction factor of roadside condition	-	0.90
Passage car	Veh/day	325	Correction factor of level of service	-	0.85
Heavy vehicle	Veh/day	951	Synthetic correction factor	-	0.765
Trailer for imported coal	Veh/day	380	Possible capacity	pcu/h	1,913
Total "T_D"	Veh/day	1,656			
Commercial vehicle ratio "P_γ"	%	82			
Peak flow ratio "K"	%	12			
Passenger car equivalent	-	2.10			
Correction factor "$\alpha\gamma$"	-	0.99 *2			
Design Dairy Traffic	pcu/h	201 *3	11%		

*1: Table 3.3-4 Expected dairy traffic *2: $100/(100-P_\gamma+B_T \times P_\gamma)$ *3: $T_D \times (K/100)/\alpha\gamma$

Source: JICA Survey Team

According to the results of outline calculation, transportation of imported coal with diesel trailers is possible. The coal trailer type has been selected from Table 3.3-7 below. A 6-axis trailer with gross weight of 58.5 t was used for calculation of traffic capacity. An example of 60 t class trailer is shown in Photo 3.3-11.

Source: JICA Survey Team

Photo 3.3-11 60 t Trailer

Table 3.3-7 Possible Gross Weight of Trucks

TRUCK TYPE	Permissible Gross Vehicles Weight (In Tons)
2 AX SINGLE (Bedford)	17.5
2 AX SINGLE (Hino/Nissan)	17.5
3 AX TENDEM	27.5
3 AX SINGLE	29.5
4 AX SINGLE-TENDEM	39.5
4 AX TENDEM-SINGLE	39.5
4 AX SINGLE	41.5
5 AX SINGLE-TRIDEM	48.5
5 AX TENDEM-TENDEM	49.5
5 AX SINGLE-SINGLE-TENDEM	51.5
5 AX TENDEM-SINGLE-SINGLE	51.5
6 AX TENDEM-TRIDEM	58.5
6 AX TENDEM-SINGLE-TENDEM	61.5

Source: Sindh Coal Authority

According to an interview with a truck driver, most trucks are owned by an individual. Therefore, the method of securing vehicles for coal transportation needs to be examined.

e. Existing Road Conditions

- The Port Qasim – Intersection on N-5 (Segment-1)

  This segment is part of the port road connecting Port Qasim and the intersection on National Highway No. 5 (N-5).The 2-lane road is asphalt paved having a total width of 12 m including shoulders. There are many ruts and cracks found on the surface, and many heavy vehicles (especially trailers), which stop on the soft shoulder cause disorder.

- Intersection on N-5 – Ghaghar RC (Segment-2)

  This segment is part of N-5 in Karachi District. Thatta District starts from the end of the Ghaghar RC to the east. On this segment, there is a branch to a bypass road leading to the superhighway located in the northern part of N-5. The 2-lane road is asphalt-paved with each direction separated by a median. The road was rehabilitated recently therefore its condition is relatively good. There are overhead traffic signboards, advertisement boards, pedestrian bridges, and low voltage electric cables crossing the road.

- Ghaghar RC – Thatta (Segment-3)

  This segment is part of N-5 running through Thatta District. There are some towns along the segment including Dhabeji, Gharo, and Guijo. The road has two lanes without a median. There are many traces of patching works on the surface. Poor maintenance has spoiled flatness. Humps are installed on the roads within towns in order to reduce vehicle speed.

- Thatta – Sujawal (Segment-4)

  Segment-4 is part of a provincial road under the management of GoS, and has a road length of 172 km. The section from Thatta to Rahu Kharia is 11 km long and consists of an asphalt-paved, 2-lane road without median. The road was rehabilitated recently therefore its condition is relatively good. Construction of Sujawal Bypass has not yet been started.

Source: JICA Survey Team

Photo 3.3-12 Road Improvement Near Sujawal

- Sujawal – Badin (Segment-4)

This section is located in Thatta District and Badin District. Road improvement is carried out at several sections. Photo 3.3-13 shows the improvement area near Sujawal Town. Construction of Golarchoi Bypass has not yet been started. In Badin Bypass, most of the roadbed construction is completed and the bridge construction has started.

Source: JICA Survey Team

Photo 3.3-13 Road near Sujawal

Source: JICA Survey Team

Photo 3.3-14 Badin Bypass

- Badin – Wango Moro (Segment-4)

Regarding new bypass construction on this section (Nindo Bypass, Khoski Bypass, and Sujawal Bypass), the roadbed construction is almost completed, and the bridge construction and pavement construction have started.

Source: JICA Survey Team

Photo 3.3-15 Khosiki Bypass

Source: JICA Survey Team

Photo 3.3-16 Nindo Bypass (Near Bridge Section)

- Wango Mor – Mithi (Segment-5)

Road improvement of this section has started. The earthwork construction is almost completed at around 60% of the sections.

Source: JICA Survey Team

Photo 3.3-17 Road Improvement from Mithi to Wango Moro (Basin-Mithi Road)

Source: JICA Survey Team

Photo 3.3-18 Road Improvement from Mithi to Wango Moro (Basin-Mithi Road)

- Mithi – Thar Coalfield (Segment-5)

Construction of Mithi Bypass and road improvement of Islamkot Road have started. For Mithi Bypass, earthwork construction is almost completed. Road improvement of Islamkot Road has already completed approximately 20 km for the Mithi side, however, for the Thar coalfield side, construction has not yet been started.

Source: JICA Survey Team

Photo 3.3-19 Islamkot Road Improvement

Source: JICA Survey Team

Photo 3.3-20 Mithi Bypass under Construction

Source: JICA Survey Team

Photo 3.3-21 Islamkot Road

2) Railway

a. Thar Coal Transport

In this alternative, railway transport of Thar coal will not be necessary because the power station will be located just adjacent to the mining sites. It is suitable to transport them by belt conveyor or special large trucks exclusively in the area.

b. Imported Coal Transport at Initial Stage

In case imported coal is adopted in the initial stage, it is necessary to construct a new railway line connecting the Thar coalfield with the existing Mirpur Khas-Khokhropar Line (approximately 150 km).

However, transport demand will be so small if only to construct new railway line for the above mentioned purpose. Even if the railway is opened for public transportation use when the Thar coal supply starts, the facilities connecting the power station and new line will be exclusively used for the Project, and the cost will be too high. Therefore, rail transport is impractical to be applied for this purpose.

3.3.2 Indus River Area

(1) Water Supply and Drainage Facilities

1) Basic Conditions Related to Water

In case the additional thermal power plant will be developed along the Indus River, it is necessary to consider that water for power generation will be taken from the Indus River and wastewater from the thermal power plant will be discharged into the Indus River after appropriate treatment. Therefore, the basic quantity and quality conditions of the Indus River water are described below.

The monthly water flow of the Indus River is summarized in Table 3.3-8. The water flow data were acquired from Kotri Barrage, which was built in 1955 and is used to divert water to irrigation canals and to provide protection against flood.

Table 3.3-8 Indus River Monthly Flow at Kotri Barrage

Month	Flow (m^3/s)*	
	Upstream	Downstream
Jan	369	161
Feb	305	91
Mar	465	105
Apr	648	427
Jun	1,005	565
Jul	1,535	741
Aug	4,056	3,227
Sep	3,905	3,276
Oct	1,035	586
Nov	387	110
Dec	213	68
Annual	1,787	1,349

*: The 18-year monthly averaged data recorded from 1986-87 season to 2003-04 season
Source: Sindh Irrigation and Drainage Authority, EIA report of Jamshoro Power Generation Project

The required amount of water for the new thermal power plant (600 MW: NET) under the Project is approximately 0.5 m^3/s (18 cusec). The water flow in December is the least in the year. In the upstream of Kotri Barrage the average water flow in December is 213 m^3/s, and the required amount of water intake for the additional thermal power plant corresponds to 0.23% of water flow on the Indus River. Meanwhile, at the downstream of Kotri Barrage the average water flow in December is 68 m^3/s, and the required amount of water intake for the additional thermal power plant corresponds to 0.74% of water flow on the Indus River.

According to an interview with the Irrigation Department of GoS, water in the Indus River can be used for the additional thermal power plant because the required amount of water is much smaller than the flow on the Indus River.

The results of water quality analysis of Indus River are summarized in Table 3.3-9. The samples were acquired at the upstream of the intake point of the Jamshoro Power Station in the Indus River and an irrigation canal which is diverted from Kotri Barrage.

Table 3.3-9 Results of Water Quality Analysis

Parameters	Unit	Indus River Upstream of the Intake Point of the Jamshoro Power Station	Kalri Baghar Canal
Al	μg/L	7	91
As	μg/L	3	3
B	μg/L	97	150
Ba	μg/L	60	100
Cd	μg/L	<1	<1
Cr	μg/L	<1	<1
Cu	μg/L	2	1
Hg	μg/L	<0.5	<0.5
Mn	μg/L	17	1
Ni	μg/L	<1	<1
Pb	μg/L	<1	<1
Sb	μg/L	<1	<1
Se	μg/L	<10	<10
Zn	μg/L	<5	15
BOD	mg/L	<4.0	4.0
COD	mg/L	<5.0	<5.0
NH_3	mg/L	<0.5	<0.5
Nitrate	mg/L	0.22	-
TDS	mg/L	462	444
TSS	mg/L	12.5	17
Phosphates	mg/L	<0.1	<0.1
pH		7.3	7.2

Source: EIA report of Jamshoro Power Generation Project

From the results of water quality analysis, TDS is smaller than the regulation for potable water (1,000 mg/L), thus water for the additional thermal power plant does not require to undergo desalination process.

2) Outline of the Existing Water Supply Facilities

a. Water Supply Facilities for the Jamshoro Power Station

Water used for the Jamshoro Power Station is taken from the main stream of the Indus River, which provides stable water supply throughout the year. Two intake towers are in operation and taken water is being conveyed by pumps and pipelines to the Jamshoro Power Station at a distance of about 4 km, as shown in Figure 3.3-20 and Photo 3.3-22.

Source: Prepared by the JICA Survey Team using Google Maps

Figure3.3-20 Location of the Existing Water Intake Tower for the Jamshoro Power Station

Source: JICA Survey Team

Photo 3.3-22 Distant View of Intake Tower-1

Source: JICA Survey Team

Photo 3.3-23 Pumps in Intake Tower-1

Source: JICA Survey Team

Photo 3.3-24 Close-up View of Intake Tower-1

Source: JICA Survey Team

Photo 3.3-25 Distant View of Intake Tower-2

b. Water Supply Facilities for the Lakhra Power Station

Water used for the Lakhra Power Station is taken from a small creek which diverts from the main stream of the Indus River. At first the water in the main stream of the Indus River is conveyed to the small creek by two pumps. After which, 300 m^3/h (0.083 m^3/s) of water is conveyed by three pumps and a pipeline to the Lakhra Power Station at a distance of about 2.5 km, as shown in Figure 3.3-21 and Photo 3.3-26. The JICA Survey Team expects that the water supply system for the Lakhra Power Station cannot maintain a stable water supply throughout the year because the water level of the small creek seems not able to intake enough water even in October and is expected to become lower in the dry season.

Source: Prepared by the JICA Survey Team using Google Maps

Figure3.3-21 Location of the Existing Water Intake Facility for the Lakhra Power Station

Source: JICA Survey Team

Photo 3.3-26 Distant View of Intake Pump House

Source: JICA Survey Team

Photo 3.3-27 Close-up View of Intake Pump House

Source: JICA Survey Team

Photo 3.3-28 Three Existing Pumps

Source: JICA Survey Team

Photo 3.3-29 Small Creek

Source: JICA Survey Team

Photo 3.3-30 Existing Water Conveyance Pipeline

Source: JICA Survey Team

Photo 3.3-31 Pumps at the Main Stream of the Indus River

c. Issues to be Considered for the Development of the New Thermal Power Plant

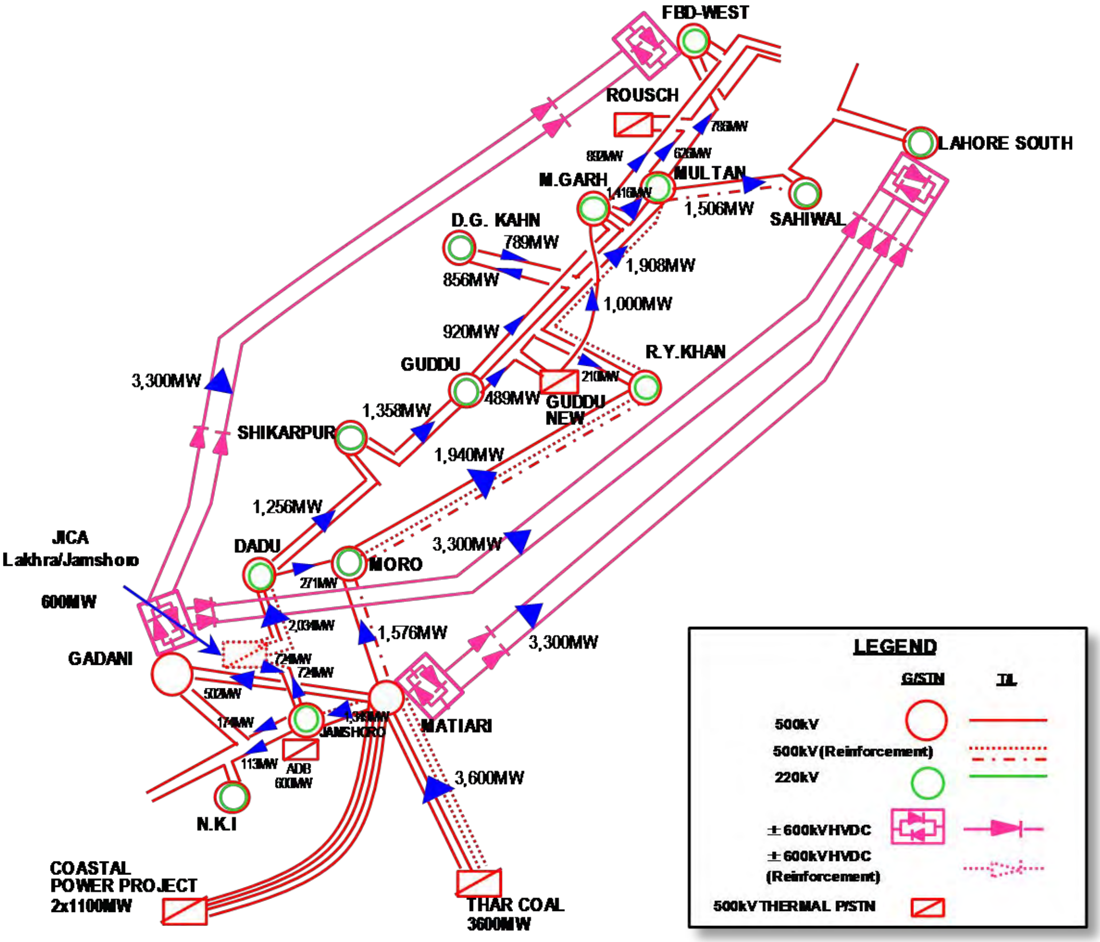
From the abovementioned fact-finding, the following issues associated with water should be considered and clarified in order to develop the additional thermal power plant along the Indus River under the Project:

- Water for the new thermal power plant as well as for the existing Jamshoro Power Station shall be taken from the main stream of the Indus River to maintain a stable water supply.
- Wastewater from the new thermal power plant shall be treated appropriately before discharging into the Indus River in order to meet the National Environmental Quality Standards for Municipal and Liquid Industrial Effluent. Therefore, the planning of facilities of the wastewater treatment plant is required.
- It is necessary to officially establish and apply water use rights for the Indus River.

(2) Transmission Line

1) Power System Analysis

a. Case 2



Source: JICA Survey Team

Figure 3.3-22 Power Flow Diagram (Case 2)

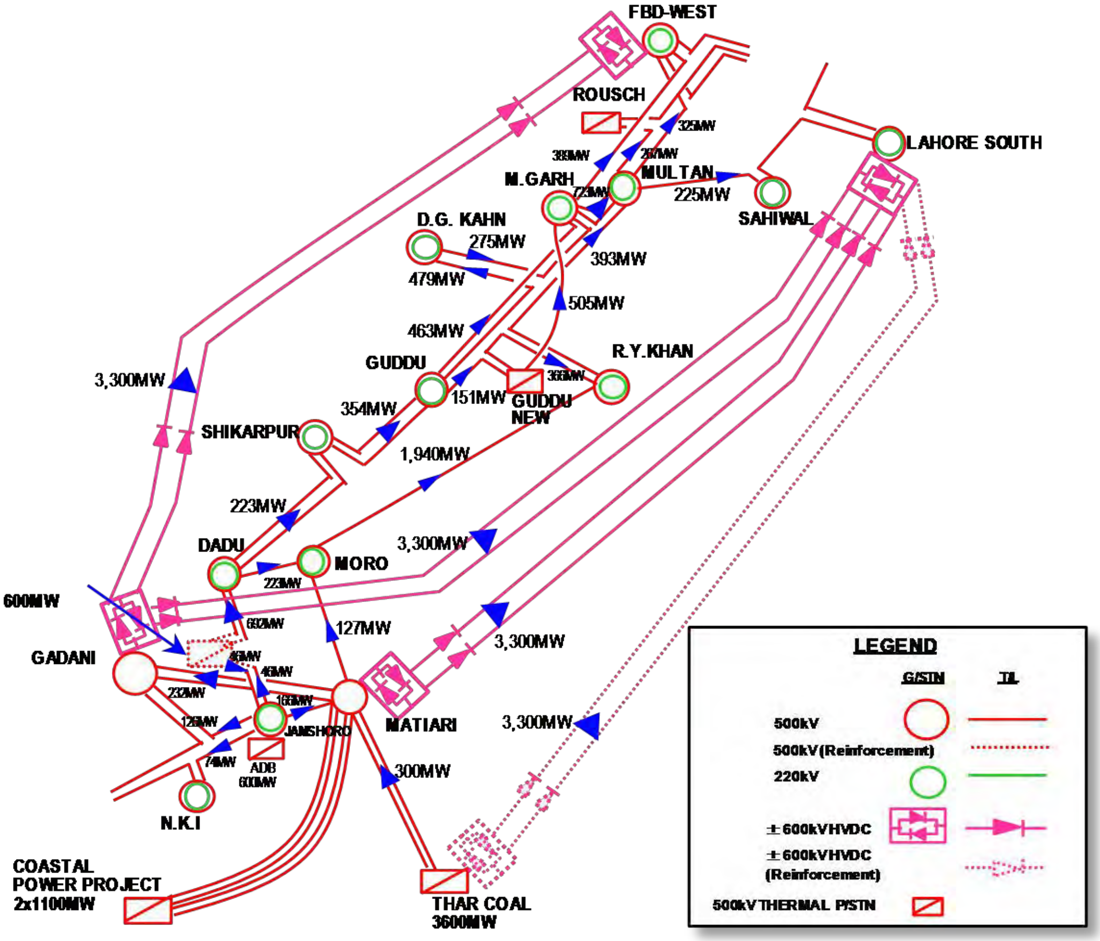
The following reinforcements of 500 kV HVAC transmission lines from the system configuration of “No CFPP case” is necessary in order to avoid overloading under N-1 contingency condition. The power flow diagram is shown in Figure 3.3-22. The dashed/dotted lines depict the circuits added.

- Matiari S/S to Moro S/S : 1 circuit
- Moro S/S to R.Y. Khan S/S : 1 circuit
- Multan S/S to Sahiwal S/S : 1 circuit

b. Case 2d

For the HVDC 600 kV option, reinforcement of the 500 kV transmission lines is not necessary considering the N-1 contingency condition. The power flow diagram is shown in Figure 3.3-23.

-



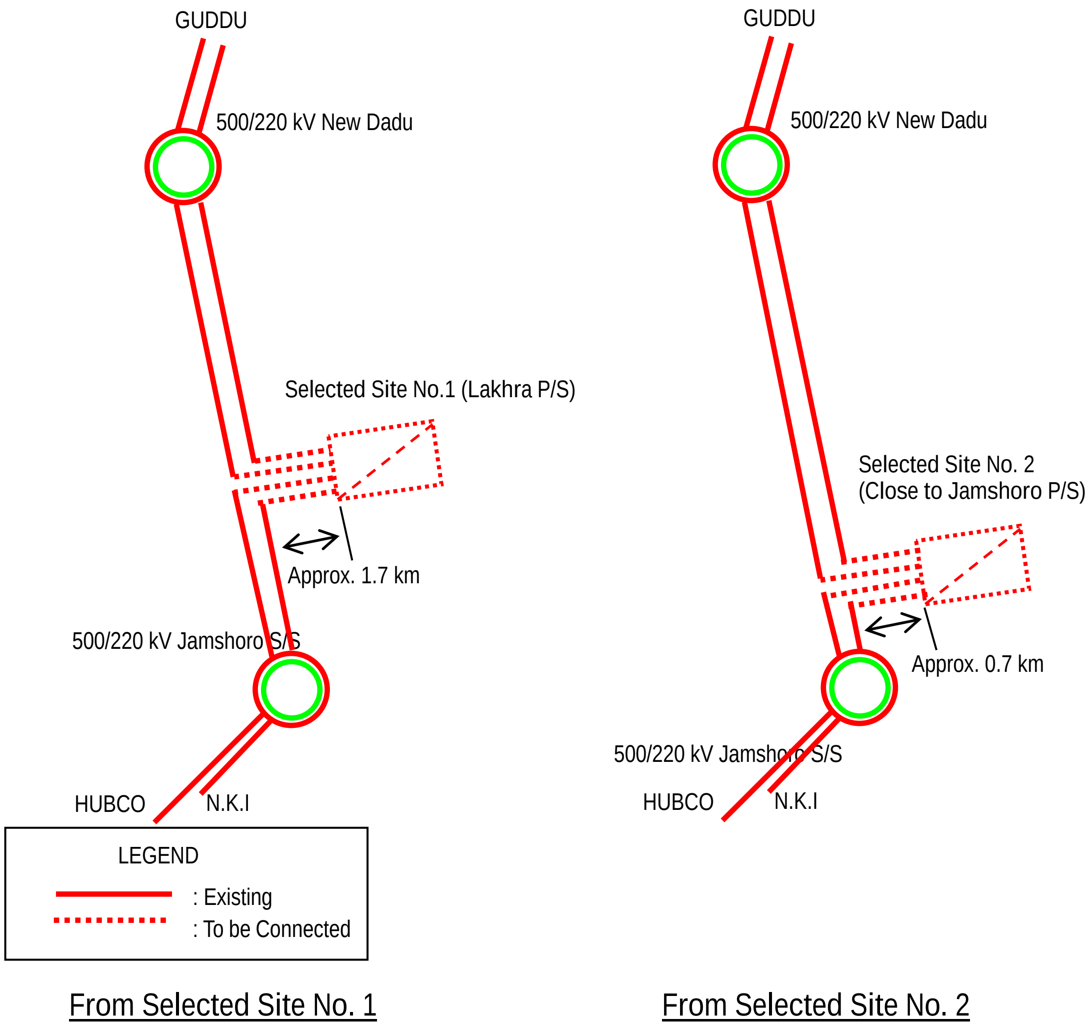
Source: JICA Survey Team

Figure 3.3-23 Power Flow Diagram (Case 2d)

Transient stability analysis was examined in Appendix 3-2 and its detailed results are shown in Appendix 3-3.

2) Transmission Line

As for the selected site in the Indus River area, there are existing 500 kV transmission lines of double circuit between the Jamshoro S/S and the new Dadu S/S. In case the candidate site in the Indus River area is selected for the construction of the power plant, the power plant will be connected to the above said transmission line, in either case.



Source: JICA Survey Team

Figure 3.3-24 Connection Method for the Existing Power Grid System

(3) Transportation

1) Road (From Qasim Port to the Indus River Area)

a. Outline

The planned access route to the Jamshoro and Lakhra areas from Karachi Port (Port Qasim) will be three existing highways, province roads, and a road to Qasim Port.

Source: Prepared by the JICA Survey Team using Google Maps

Figure 3.3-25 Route Map for Port Qasim to M-9

M-9, also called the "Super Highway", is a national high-grade trunk highway being managed by the National Highway Authority (NHA) and connects Karachi and Hyderabad. The road length of M-9 is 136 km. The existing 4-lane Super Highway begins from the end of Mohammad Ali Jinnah Road, located in the north side of Karachi. A trumpet interchange links the highway its start with the Karachi Northern Bypass. Outside Karachi, the highway continues on a northeast track before forming a junction with the National Highway N-5. Via a link road, the motorway merges with N-5 after Hyderabad in the suburban town of Kotri at a cloverleaf interchange. The current 4-lane Super Highway is in the process of being upgraded into a 6-lane access-controlled motorway. NHA has invited companies to signify their expression of interest (EOI) for the upgrading project in May 2011. NHA awarded the Rs 24.93 billion contract to a Malaysian construction company, Bina Puri Holdings Bhd, under build-operate-transfer (BOT) scheme in January 2012. The proposed 36 km long motorway was scheduled to be completed in three years. M-9 will have seven interchanges, two service areas at the midway points, and 16 toll plazas at entry/exit points.

The National Highway N-55, also called the "Indus Highway", is a national highway being managed by NHA and connects Kotri-Larkana-D.G. Khan-D.I. Khan-Peshawar. The road length of N-55 is 1,264 km.

The route from Port Qasim to the Super Highway (M-9) is via Qasim Port Road, National Highway N-5, and the Eastern Bypass.

b. Existing Road Conditions

- Port Qasim – Intersection on N-5

  This section is part of the port road connecting Port Qasim and the intersection on the National Highway No. 5 (N-5). The width and the radius of the ramp are enough to accommodate traffic flow of trailers.

Source: Prepared by the JICA Survey Team based on Google Earth

Figure 3.3-26 Satellite View of the Intersection on National Highway No. 5

Source: JICA Survey Team

Photo 3.3-32 Qasim Road on Adjacent Part of the Intersection

Source: JICA Survey Team

Photo 3.3-33 Qasim Road

- National Highway No. 5 (N-5)

  The 2-lane road is asphalt-paved having a total width of 12 m including shoulders. There are many ruts and cracks found on the surface, and many heavy vehicles (especially tankers) stop on the soft shoulder cause disorder.

Source: JICA Survey Team

Photo 3.3-34 National Highway No. 5

Source: JICA Survey Team

Photo 3.3-35 National Highway No. 5

- Eastern Bypass (M-9 and N-5 Link Road)

  This bypass is a 2-lane paved road without median that connects N-5 and M-9. The road continues up to the eastern area of Karachi City. The intersection of the Eastern Bypass and the Super Highway is a trumpet type interchange, and the intersection of the Eastern Bypass and N-5 is a T-shaped at-grade intersection. On the surface of the carriageway, there are some ruts and cracks found. Poor maintenance has ruined the flatness of the road surface. Repair works for the traffic lane and shoulders are required.

Source: JICA Survey Team

Photo 3.3-36 Eastern Bypass

Source: JICA Survey Team

Photo 3.3-37 Eastern Bypass

Source: Prepared by the JICA Survey Team based on Google Earth

Figure 3.3-27 Satellite View of the Intersection on Super Highway (M-9)

Source: Prepared by the JICA Survey Team based on Google Earth

Figure 3.3-28 Satellite View of the Intersection on National Highway (N-5)

- M-9 (Super Highway)

  The Super Highway (M-9) is a national highway in Pakistan that connects Karachi with Hyderabad in Sindh Province. The highway is currently under rehabilitation to become a 6-lane motorway. The pavement of the carriageway and shoulder are relatively good and few ruts and cracks were found on the surface. The pavement of the traffic lane and shoulder is relatively good, but there are some ruts and cracks. The pavement of the median side is regarded as temporary treatment, and there are some bumps, and road surface flatness is inferior. The travel speed of heavy vehicles was estimated at approximately 40 km/h, but the speed might fall to approximately 20 km/h along the long uphill slope.

Source: JICA Survey Team

Photo 3.3-38 Up-bound Traffic Lane of M-9 (Super Highway)

- N-55 (Indus Highway)

  This highway is a 2-lane paved road without median that connects M-9 and Jamshoro in the Kotri area. The pavement of the traffic lane and shoulder is relatively good.

Source: JICA Survey Team

Photo 3.3-39 N-55 around Lakhra

Source: JICA Survey Team

Photo 3.3-40 Entrance of the Lakhra Power Station

2) Road (From the Thar Coalfield to the Indus River Area)

Indigenous coal, if sourced from the Thar coalfield, will be transported to the Indus River area by road as a rail network is currently not available in the Thar coalfield (Block II).

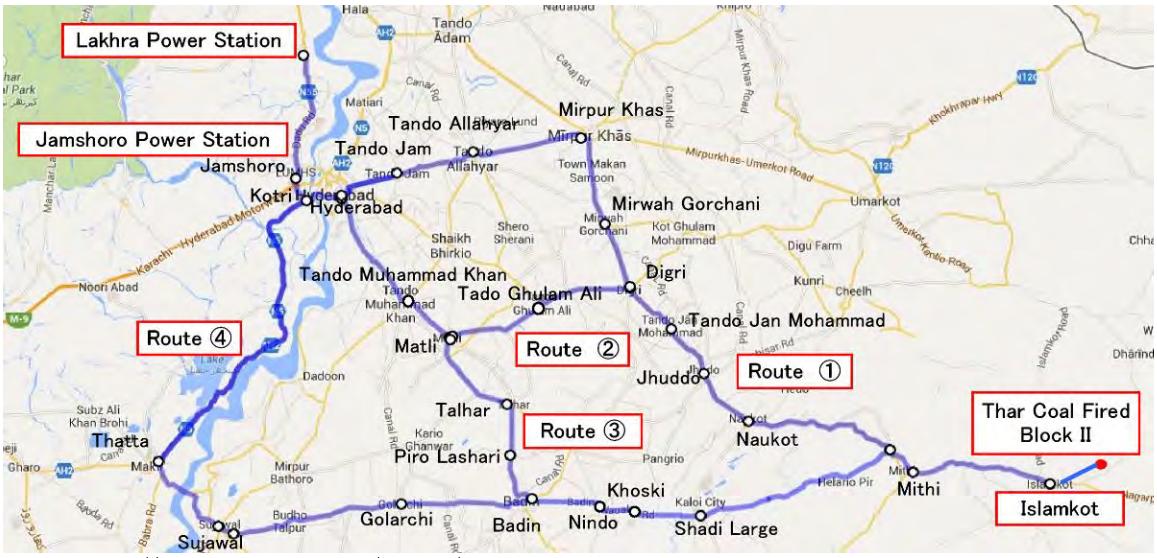
As shown in Figure 3.3-29, there are four possible routes for transportation of coal, as follows:

Route 1: Islamkot-Mithi-Digri-Mirpur Khas-Hyderabad-Indus River area;

Route 2: Islamkot-Mithi-Digri-Matli-Hyderabad-Indus River area;

Route 3: Islamkot-Mithi-Badin-Matli-Hyderabad-Indus River area; and

Route 4: Islamkot-Mithi-Badin-Thatta-Indus River area.



Source: Prepared by JICA Survey Team using Google Maps

Figure 3.3-29 Route Map between the Thar Coalfield and the Indus River Area

The length of the routes, number of intersections on the route, number of water bodies, settlement density, and average road width are summarized in Table 3.3-10 below.

The average lane width of each route is wider than the truck body width (2.5 m or less).

The lengths of Route 1 and Route 2 are shorter than the other routes. Furthermore, the average lane width of Route 1 is relatively wide.

Therefore, Route 1 is the recommended route, but this route may result to environmental degradation along the road due to air pollution and scattering of coal.

Table 3.3-10 Coal Transportation Options from Thar to Jamshoro

Option	Route	Major Towns	Length	No of Road Intersections	No of Water bodies	Settlement Density*	Average Width**
1	Islamkot-Mithi-Digri-Mirpur Khas-Hyderabad-Jamshoro	Islamkot, Mithi, Naukot, Jhuddo, Tando Jan Mohammad, Digri, Mirwah Gorchani, Mirpur Khas, Tando Allahyar, Tando Jam, Hyderabad, Jamshoro	268 km	99	38	13.80%	3.32 m
2	Islamkot-Mithi-Digri-Matli-Hyderabad-Jamshoro	Islamkot, Mithi, Naukot, Jhudo, Tando Jan Mohammad, Digri, Tado Ghulam Ali, Matli, Tando Muhammad Khan, Hyderabad, Jamshoro	262 km	98	54	14.50%	2.84 m
3	Islamkot-Mithi-Badin-Matli-Hyderabad-Jamshoro	Islamkot, Mithi, Shadi Large, Khoski, Nindo, Badin, Piro Lashari, Talhar, Matli, Tando Muhammad Khan, Hyderabad, Jamshoro	278 km	89	84	11.50%	2.82 m
4	Islamkot-Mithi-Badin-Thatta-Jamshoro	Islamkot, Mithi, Shadi Large, Khoski, Nindo, Badin, Golarchi, Sujawal, Thatta, Kotri, Jamshoro	359 km	94	82	7.90%	3.59 m

<NOTE> * Estimated percentage of area covered by settlements and structures within 200m of the route.

** Weighted average width of different segments of the route.

Source: Environmental Impact Assessment Draft Report of Jamshoro Power Generation Project, June 2013

The number of trailers needed for Thar coal transportation considering the following two alternatives is summarized in Table 3.3-11:

Alternative 1: Use only Thar coal.

Alternative 2: Imported coal 80% and Thar coal 20%.

Table 3.3-11 Number of Trailers for Thar Coal Transportation

Alternative	Coal Volume (t/year)		Type of Vehicle	Number of Trailers	
	Import	Thar		vehicle/year	vehicle/day
1	0	3,225,000	60 t Trailer	92,150	320
2	2,000,000	500,000	60 t Trailer	14,300	50

Source: JICA Survey Team

The traffic volume in Alternative 1 is seven times of Alternative 2. In consideration of environmental degradation, it is hard to adopt Alternative 1.

3) Railway

The main scope of the coal transportation project at Lakhra (Railway Project) includes the construction of a dedicated spur line (approximately 7 km) between Budhapur Station and the power plant, and procurement of dedicated locomotives and coal wagons. Though the Railway Project is separated from the power plant project, those projects are identified as indivisible projects in accordance with JICA Guidelines for Environmental and Social Considerations (April 2010).

a. Thar Coal Transport

For coal transport to the power station in the Project, bulk transport by railway is suitable. However, in order to realize rail transport, the construction of a new railway line connecting the Thar coalfield with the existing Mirpur Khas-Khokhropar Line is necessary (approximately 150 km). Besides, it is inevitable that the rail is founded as a public rail and opened ready in time because the demand of only this power station cannot afford to construct and sustain the new rail of 150 km. In addition, some facilities for connecting the power station and the nearest railway station need to be provided as part of the facilities of the power station.

b. Imported Coal Transport

For transportation of imported coal to the power station of the Project, the existing railway lines from Qasim Port and Karachi Port are available both for immediate use and permanent use if some facilities connecting the power station and the nearest railway station be provided. However, in consideration with the huge amount of investment to newly constructed railway facilities, it would hardly be appropriate if the railway line is used only for new developed power plant for the Project.

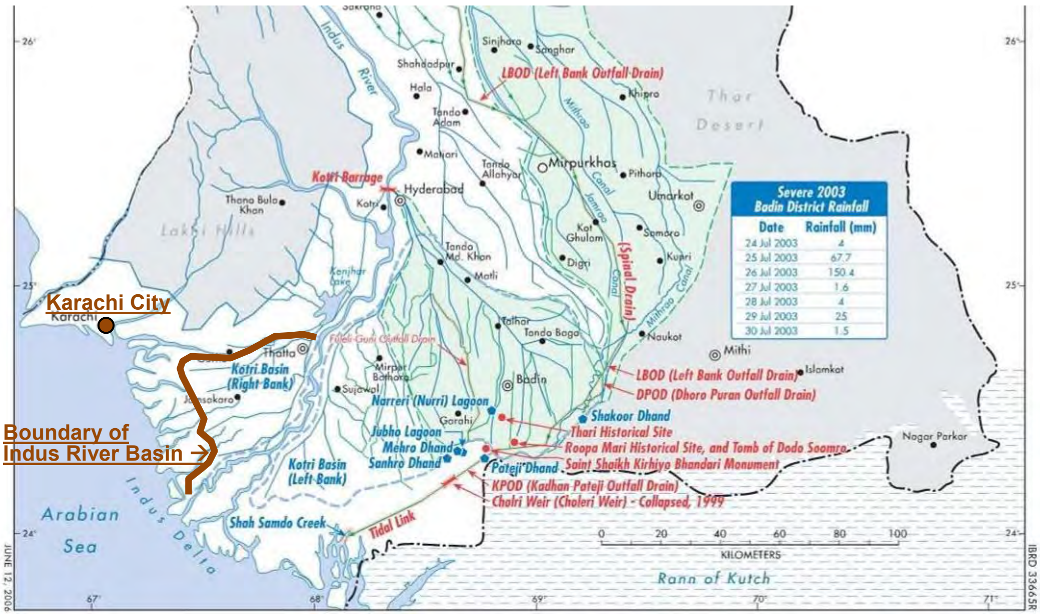
3.3.3 Karachi Port Area

(1) Water Supply and Drainage Facilities

1) Basic Conditions Related to Water

The basic conditions related to the quantity and quality of water around the Karachi Port area are described below.

According to an interview with the Irrigation Department of GoS, irrigation water cannot be allocated to additional industrial activities around the Karachi Port area because there is no surplus irrigation water around Karachi. Figure 3.3-30 shows the National Drainage Program project map around Karachi City. The map shows that the boundary of the Indus River basin is located at least 40 km far from Karachi City and there is no irrigation canal from the Indus River around Karachi City. This means that Karachi City does not have surplus freshwater resources for additional power generation activities. Therefore, seawater is the only water source around Karachi which can be used for the additional power plant. In case seawater will be used for the new thermal power plant (600 MW: NET) under the Project, the required amount of water is estimated to be approximately 30 m^3/s.



Source: POE Drainage Master Plan

Figure 3.3-30 National Drainage Program (NDP) Project Map around Karachi City

In general seawater is a fluid composed of sodium chloride and other minerals, and its chloride ion concentration is around 19,000 mg/L. Also, TDS concentration of seawater near the Middle East area is around 45,000 mg/L. The water quality of boiler water for the thermal power plant is required to be improved to the level of freshwater (Cl^- = 15–500 mg/L). Accordingly, in case the additional thermal power plant will be constructed in the Karachi Port area, it is necessary to install a water treatment plant with desalination facility.

2) Outline of the Existing Water Supply Facilities

According to the field survey around Qasim Port, the following items related to water supply facilities for the additional thermal power plant have been observed:

- There is a wide-scale mangrove forest along Qasim Port, as shown in Photo 3.3-41, thus it is necessary to select the location of water intake facilities with consideration of the environment.
- Existing roads in the Qasim Port area, as shown in Photo 3.3-42, are typically wide because the Qasim Port area is used by some industrial zones.

Source: JICA Survey Team

Photo 3.3-41 Mangrove Forest

Source: JICA Survey Team

Photo 3.3-42 Existing Road in Qasim Port Area

3) Issues to be Considered for Development of the New Thermal Power Plant

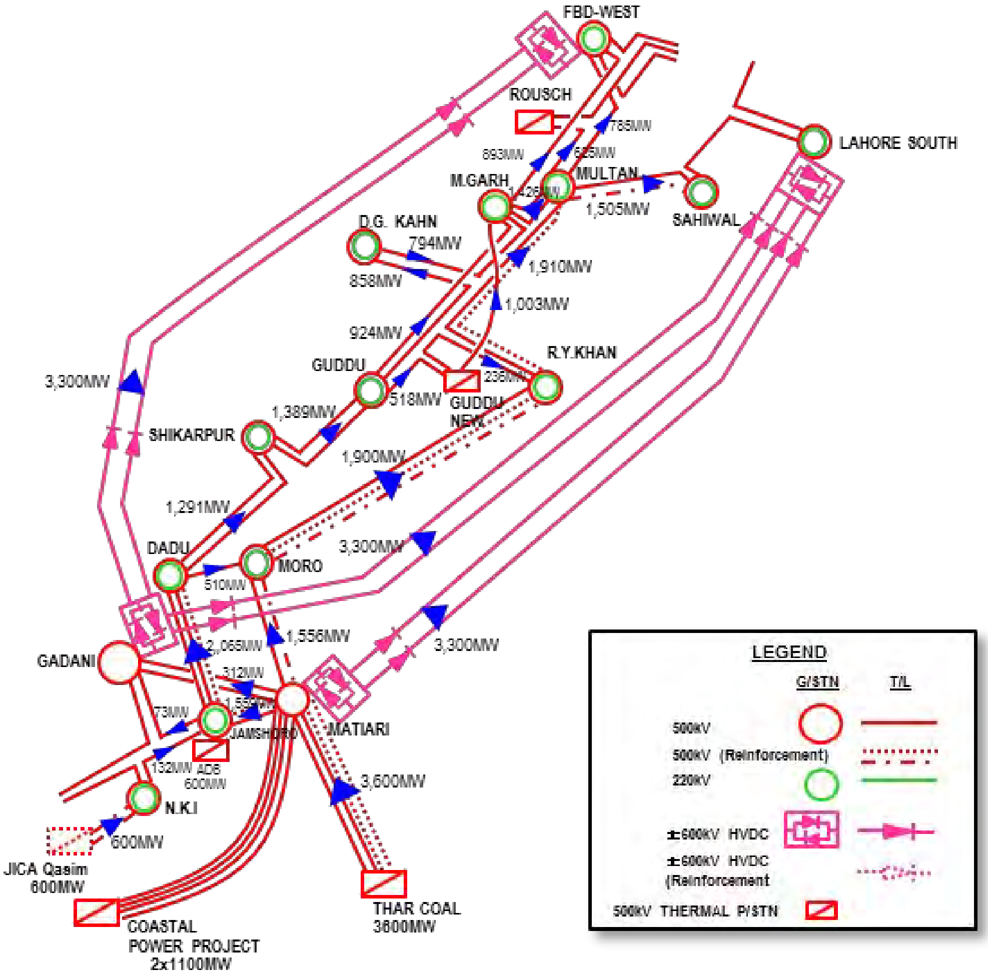
From the abovementioned fact-finding, the following issues associated with water should be considered and clarified in order to develop the new thermal power plant in the Karachi Port area under the Project:

- The approval of usage of seawater shall be obtained from the Karachi Water Board.
- The approval of occupation of space required for the water intake facilities shall be acquired from the port management authority or other related organizations.
- The most appropriate location of the water intake facilities shall be selected with consideration of environmental impacts.
- The water conveyance pipeline will be installed under the public road, thus it is necessary to study the detailed route of the pipeline.
- Wastewater from the new thermal power plant shall be treated appropriately before discharging to Karachi Bay in order to meet the National Environmental Quality Standards for Municipal and Liquid Industrial Effluent. Therefore, the planning of facilities of the wastewater treatment plant is required.

(2) Transmission Line

1) Power System Analysis

a. Case 3



Source: JICA Survey Team

Figure 3.3-31 Power Flow Diagram (Case 3)

The following reinforcements of 500 kV HVAC transmission lines from the system configuration of "No CFPP case" as well as development of a new transmission line between the candidate CFPP location and N.K.I S/S is necessary in order to transmit power from the CFPP to the existing power system and to avoid overloading under N-1 contingency condition. The power flow diagram is shown in Figure 3.3-31. The dashed/dotted lines depict the circuits added.

New Transmission Line:

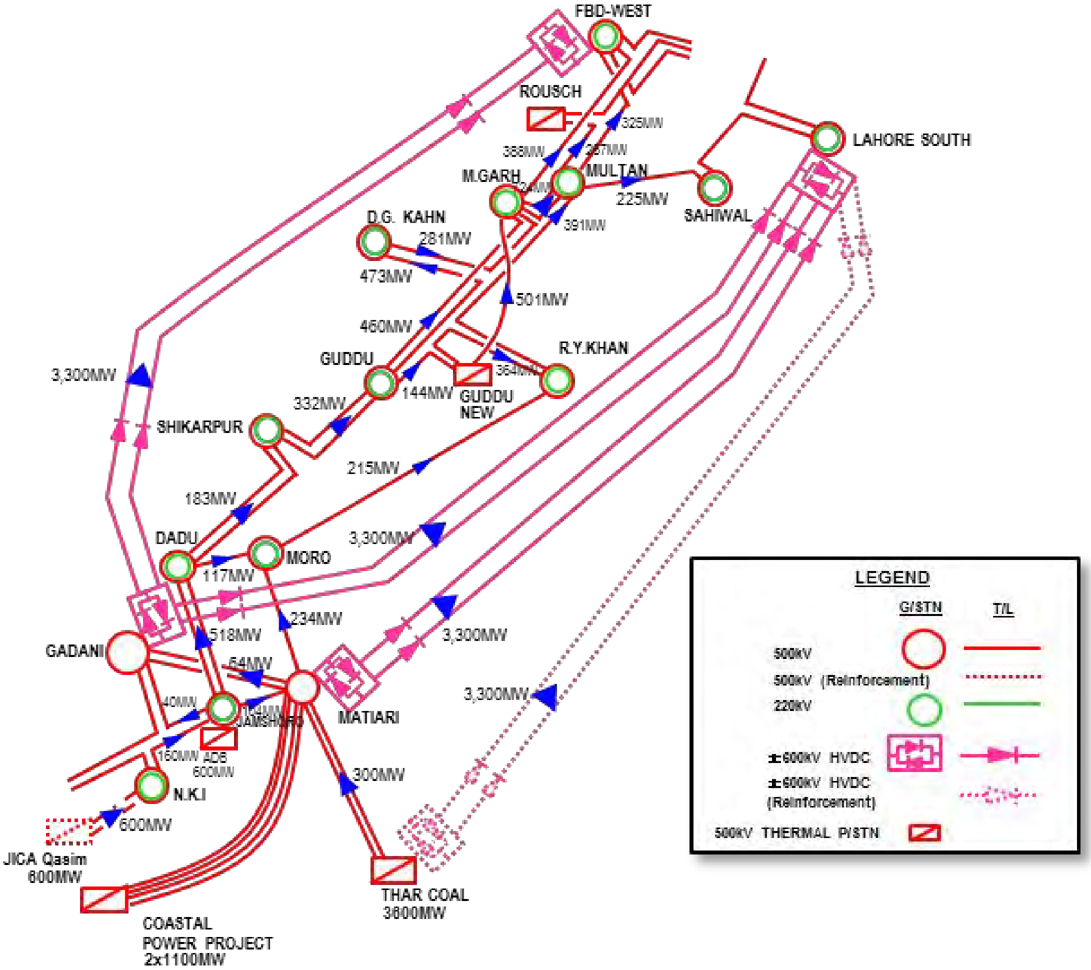
- Candidate Location of CFPP to N.K.I S/S : 2 circuits

Reinforcement of Existing Transmission Lines:

- Matiari S/S to Moro S/S : 1 circuit
- Moro S/S to R.Y. Khan S/S : 1 circuit
- Multan S/S to Sahiwal S/S : 1 circuit

b. Case 3d

For the HVDC 600 kV option, reinforcement of the 500 kV transmission lines is not necessary considering the N-1 contingency condition. The power flow diagram is shown in Figure 3.3-32.



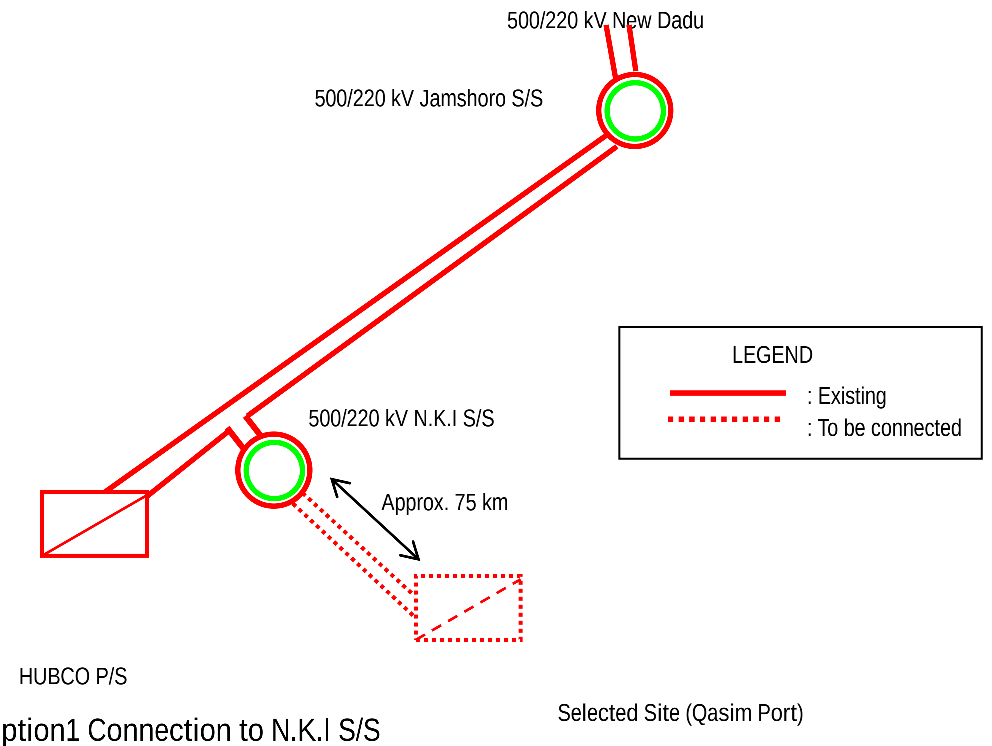
Source: JICA Survey Team

Figure 3.3-32 Power Flow Diagram (Case 3d)

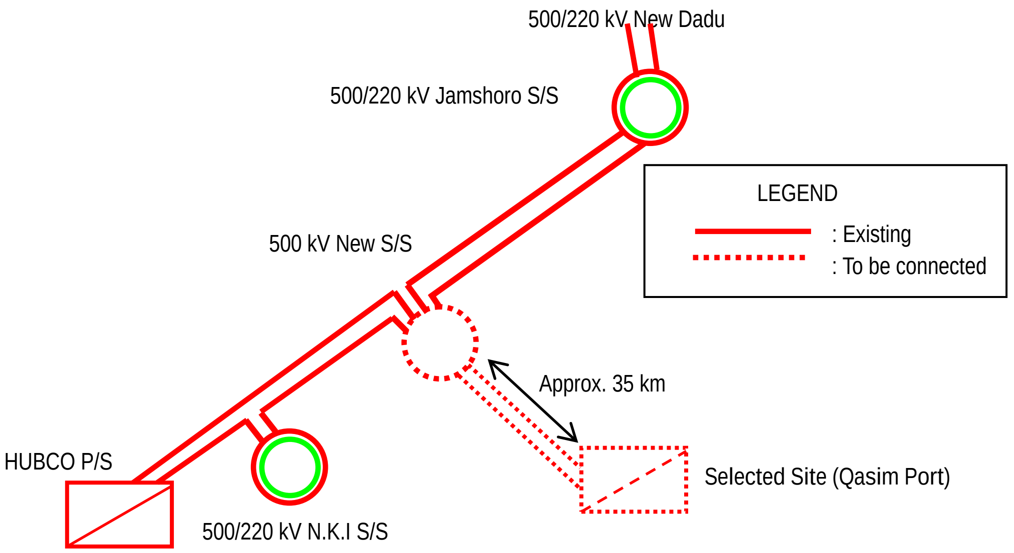
Transient stability analysis was examined in Appendix 3-2 and its detailed results are shown in Appendix 3-3.

2) Transmission Line

As for the selected site in the Karachi Port area, since there is no existing 500 kV transmission line around the selected area, it is necessary to connect to existing N.K.I S/S (Option1) or existing 500kV transmission line between N.K.I S/S and Jamshoro S/S (Option 2) as shown in Figure3.3-33.



Option1 Connection to N.K.I S/S



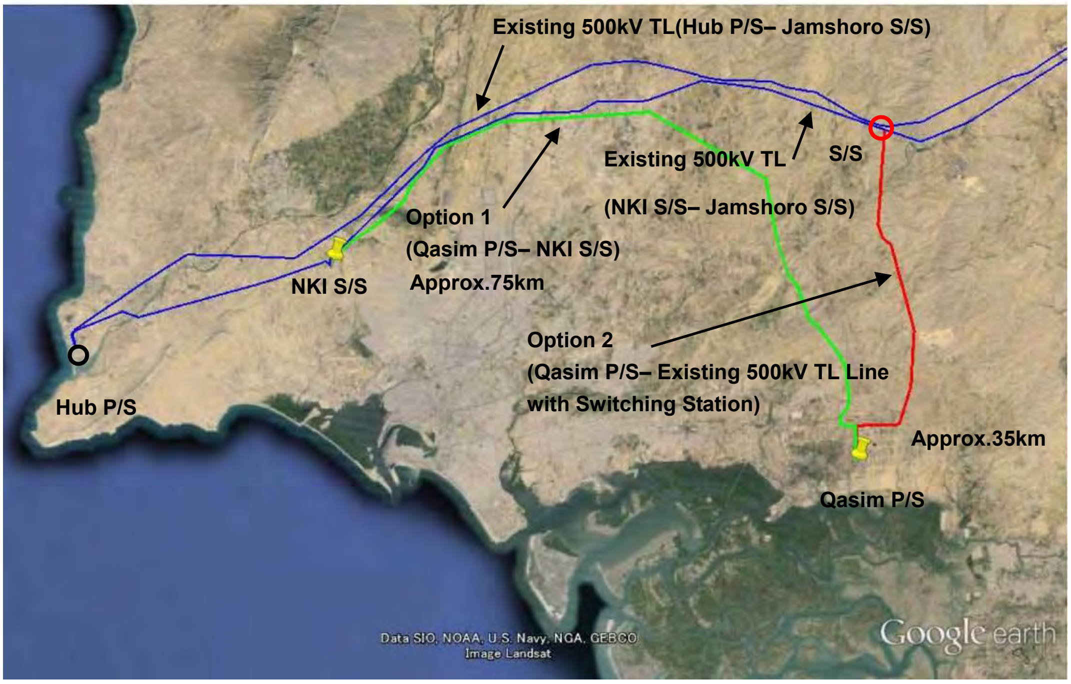
Option2 Connection to Existing 500kV Transmission Line (to be installed New S/S)

Source: JICA Survey Team

Figure 3.3-33 Connection Method for the Existing Power Grid System

Route map is as shown in Figure 3.3-34. N.K.I S/S is approximately 75 km away from the selected site. In order to urban area is avoid, distance between selected area and N.K.I S/S will be long.

On the other hand, in case of connect to existing 500kV transmission, switching station is constructed between N.K.I S/S and Jamshro S/S, and transmission line from selected area will be connected. New S/S is approximately 35 km away from the selected site. Therefore, construction cost is economical compared with connection to K.K.I S/S, in addition, stability will improve if the switching station is installed at the midpoint of transmission line. Accordingly, connection method is adopted Option 2.



Source: JICA Survey Team

Figure 3.3-34 Connection Method for the Existing Power Grid System

Power System Analysis for Option 2 was examined in Appendix 3.4 and 3.5.

(3) Transportation

1) Road

In case of transportation to Thar from Port Qasim, there are passes through the same route as mentioned in Section 3.3.1.

2) Railway Line

a. Thar Coal Transport

For coal transport to the power station in the Project, bulk transport by railway is suitable. However, in order to realize rail transport, the construction of a new railway line connecting the Thar coalfield with the existing Mirpur Khas-Khokhropar Line is necessary (approximately 130 km). Besides, it is inevitable that the rail is founded as a public rail and opened ready in time because the demand of this power station only cannot construct and sustain the new rail of 130 km. At present, the schedule of the new line is uncertain.

In addition, some facilities for connecting the power station and the nearest railway station need to be provided as a part of the facilities of the power station. The suitable length of 10 km.

b. Transport of Imported Coal for Immediate Use

In this alternative, railway transport of imported coal will not be necessary because the power station will be located within the Qasim Port area. It is suitable to transport them by belt conveyor or trucks.

3) Port

As mentioned in Section 5.3, in case imported bituminous coal will be used in the new thermal power plant under the Project in the initial stage, since the estimated coal volume is approximately 2.0 million t for the power plant, it is judged that both Karachi Port and Qasim Port will be able to handle the required coal volume.

3.4 Selection of Major Technology

3.4.1 Usage of Coal

There are two alternative candidates for coal usage. One is Thar lignite (100%), and another is a blend of Thar lignite and imported coal. While the generation cost of blended coal is more expensive than that of 100% of Thar lignite coal, the advantages of using blended coal are higher plant efficiency and lower capital cost due to the size of boiler. On the other hands, there is the risk of delay for coalfield development at Thar and then it would not be able to commence the commercial operation after installation. The detail of risk of delay is described the detail in section 3.5.1. Considering the mentioned advantages and disadvantages, the use of blended coal for the Project was examined.

(1) Blending Ratio of Imported Coal and Thar Coal

1) Comparison of Different Types of Coal

Table 3.4-1 Characteristics of Coal

	Bituminous Coal	Subbituminous Coal	Thar Coal
HHV (kcal/kg)	6,250	5,000	3,146
Moisture (%ar)	10.0	22.4	47.6
Ash (%ar)	11.31	8.06	7.8
Fixed Carbon (%ar)	38.17	33.77	19.6
Volatile Matter (%ar)	40.52	35.77	25.0
Sulfur (%ad)	0.75	0.49	1.1

Source: Source: JICA Survey Team based on Indonesian Coal Book 2012/2013 and SECMC Expert Statement on the Equivalence of Thar Lignite and Indonesian Brown Coal

The characteristics of both types of coals are entirely different as shown in Table 3.4-1. The differences in pulverizing system, firing process and furnace profile between Thar coal and imported coal are shown in Table 3.4-2.

Table 3.4-2 Differences in Processes and Equipment between Thar Coal and Imported Coal

Type of Coal		Thar Coal	Imported Coal (Bituminous / Subbituminous)
Difference of Pulverizing System	Fineness Requirement	Low	High
	Classifier	Not required	Required
	Type of Pulverizer	Horizontal type (Beater wheel type)	Vertical roller type
	Drying of Raw Coal	Required. High temperature gas from the boiler furnace shall be	Not required

		recirculated into the pulverizer to reduce moisture content of coal down to around 20%.	
	Prevention of Firing in Process	Required. Can be achieved by the recirculation of furnace gas.	Not required
Difference of Firing Process	Firing out	Worse, requires longer time	Better, requires shorter time
	Firing Pattern	Fire-ball firing	Individual firing
	Gas Temperature at Furnace Outlet	1,000 to 1,050	1,150 to 1,200
Difference of Furnace Profile (Ratio)	Height	1.3 to 1.5	1.0
	Cross Section Area	1.5 to 1.6	1.0
	Overall Size	2.0	1.0

Source: JICA Survey Team

As Thar coal has a large amount of moisture, a high temperature furnace gas will be introduced into the pulverizing process for drying up of raw coal and for conveying to burners. The types of pulverizer for both coal are quite different. Both types of coal have quite different firing characteristics, and require different types of burner and firing process. Thar coal requires a larger furnace size, which is approximately twice the furnace size for a bituminous or subbituminous coal firing boiler. A comparison of general boiler sizes is provided in Appendix 3-6.

2) Imported Coal–Thar Coal Blend at 50:50 Weight Ratio

The characteristics of 50:50 ideally blends of Thar coal and bituminous coal, and of Thar coal and subbituminous coal are shown in Table 3.4-3.

Table 3.4-3 Characteristics of Blended Coal (50 : 50)

	Bituminous Coal	Subbituminous Coal	Thar Coal	Mixed Coal (50% Bituminous and 50% Thar)	Mixed Coal (50% Subbituminous and 50% Thar)
HHV (kcal/kg)	6,250	5,000	3,146	4,698	4,073
Moisture (%ar)	10.0	22.4	47.6	28.8	35.0
Ash (%ar)	11.31	8.06	7.8	9.56	7.93
Fixed Carbon (%ar)	38.17	33.77	19.6	28.89	26.69
Volatile Matter (%ar)	40.52	35.77	25.0	32.76	30.39
Sulfur (%ad)	0.75	0.49	1.1	0.93	0.80

Source: Source: JICA Survey Team based on Indonesian Coal Book 2012/2013 and SECMC Expert Statement on the Equivalence of Thar Lignite and Indonesian Brown Coal

From the average figures, it seems possible to fire blended coal in the boiler. However, it is almost impossible to get an ideal uniform mixture at a coal yard. Likewise, there are many difficulties in uniform pulverizing and burning out of blended coal. It is considered almost impossible to apply blended coal firing of Thar coal and bituminous or subbituminous coal at 50:50, respectively, for the boiler design.

3) Imported Coal–Thar Lignite Blend at 80:20 Weigh Ratio

a. Blended Coal Characteristics

The characteristics of blended coal at 80% bituminous or subbituminous coal and 20% Thar coal are shown in Table 3.4-4. It should be noted that the heating value of mixed coal is lower than that of the original bituminous coal. Therefore, the consumption of blended coal should be more than that of bituminous for the same order of boiler output.

Table 3.4-4 Characteristics of Blended Coal (80:20)

	Bituminous Coal	Subbituminous Coal	Thar Coal	Mixed Coal (80% Bituminous and 20% Thar)	Mixed Coal (80% Subbituminous and 20% Thar)
HHV (kcal/kg)	6,250	5,000	3,146	5,629	4,629
Moisture (%ar)	10.0	22.4	47.6	17.5	27.4
Ash (%ar)	11.31	8.06	7.8	10.61	8.01
Fixed Carbon (%ar)	38.17	33.77	19.6	34.46	30.94
Volatile Matter (%ar)	40.52	35.77	25.0	37.42	33.62
Sulfur (%ad)	0.75	0.49	1.1	0.82	0.61

Source: JICA Survey Team based on Indonesian Coal Book 2012/2013 and SECMC Expert Statement on the Equivalence of Thar Lignite and Indonesian Brown Coal

b. Application of 20% Thar Coal to 80% Bituminous Coal Firing Boiler

As shown in Table 3.4-4, the characteristics of both bituminous and Thar coal are entirely different. It is recommended to select equipment such as pulverizing system and burner for blended coal firing through model testing. In order to achieve stable operation (steam temperature, boiler output, etc.) with blended coal, the design margin for pulverizer, burner and other equipment which handle coal shall be increased considering increased coal consumption.

Bigger design of the boiler can be acceptable for additional fuel consumption and allow the boiler to operate with full output using 20% blending of Thar coal. However, unburned carbon in ash may be increased resulting from incomplete burn out of mixed coal, which causes difficulty of controlling steam temperature. Consequently, 20% in weight (in calorific value, up to 10%) of Thar coal in maximum can be acceptable. If there is some variety of coal usage in blending coal in the future, additional model testing is recommended.

(2) Type of Coal Blended with Thar Coal

Two types of coal,i.e., bituminous coal and subbituminous coal, are acceptable as mixed fire coal with Pakistani coal (lignite). Bituminous coal is by far the largest group and is characterized as having lower fixed carbon and higher volatile matter than anthracite. The key distinguishing characteristics of bituminous coal are its relative volatile matter and sulfur content as well as its slugging and agglomerating characteristics. Subbituminous coal has higher moisture, and volatile matter and lower sulfur content than bituminous coal and may be used as an alternative fuel for some boilers originally designed to burn bituminous coal. Generally, bituminous coal has heating values from 5,833 to 7,778 kcal/kg on a wet, mineral-matter-free basis. The heating values of subbituminous coal range from 4,611 to 6,389 kcal/kg on a wet, mineral-matter-free basis.

1) Pakistani Coal (Lignite)

GoS established and opened 12 blocks in the Thar coalfield for coal development by investors in Pakistan and overseas. However, actual activities are only carried out in four out of the 12 blocks. Table 3.4-5 shows the current situation of each block in the Thar coalfield.

The Government of Pakistan (GoP) then decided to convert the Jamshoro oil-fired power plant to a coal-fired power plant. Either SECMC will supply Block II coal for the Jamshoro coal-fired thermal power project under the coal offtake agreement, before the Block II mine mouth generation operation. Then, Block II coal is set as design coal. Table 3.4-6 shows the specifications of Pakistani coal (Thar Block II) for comparison in cost estimation among candidate sites.

Table 3.4-5 Current Situation of Each Block in the Thar Coalfield

Block	Developer	Exploration License Granted	Bankable F/S Completed	Mining Lease Issues	ESIA for Mining Accepted	Mining Started Planned	Coal Coming	Note
I	Global Mining Company of China (10.0 Mt/a)	October 2011	March 2012	May 2012	EIA public hearing was done on 27 September 2012	In 2013	Three years from the start of mining	Financing of the project is being arranged
II	Sind Engro Coal Mining Company (6.5 Mt/a)	August 2009	August 2010	Februar y 2012	EIA public hearing was held in November 2012	In 2013	Three years from the start of mining	Financing of the project is being arranged
V	UCG Pilot Project by GoP					Test burn conducted in December 2011, and syngas produced		Presently the 8-10 MW Power Plant is being established at the cost of Rs 1.8 billion
VI	Oracle Coalfields PLC (2.4 Mt/a)	November 2007	October 2011	April 2012	In the near future	In 2013	Two years from the start of mining	Joint Venture Agreement (JDA) was conducted with KESC

Source: Data Collection Survey in the Thar coalfield in Pakistan

Table 3.4-6 Design Coal Specifications

	Lignite
Total Moisture (%ar)	47.6
Proximate Analysis (Air-dried basis)	
Moisture (%ad)	
Ash (%ad)	14.9
Volatile Matter (%ad)	47.9
Fixed Carbon (%ad)	37.4
Caloric Value	
Gross as received (kcal/kg)	3,146
Net as received (kcal/kg)	2,773
Ultimate Analysis	
Carbon (%daf)	74.0
Hydrogen (%daf)	6.1
Nitrogen (%daf)	1.0
Sulfur (%daf)	2.5
Oxygen (%daf)	18.0
Ash Fusion Temperature	
Initial Deformation	1,166
Spherical	1,190
Hemispherical	-
Flow	1,200
Ash Analysis	
SiO_2 (%db)	25.24
Al_2O_3 (%db)	15.26
Fe_2O_3 (%db)	11.79
CaO (%db)	14.25
MgO (%db)	6.43
TiO_2 (%db)	1.86
Na_2O (%db)	2.67
K_2O (%db)	0.43
P_2O_5 (%db)	-
SO_3 (%db)	13.18

Source: Received data from SECMC

2) Imported Coal (Bituminous or Subbutuminous)

Table 3.4-7 shows the top coal exporting countries in 2012. Due to relatively shorter shipping distances and coal availability, Indonesian, South African, and Australian coal have lower freight shipping costs than farther countries such as Russia, USA, Colombia, and Canada.

Table 3.4-7 Top Coal Exporters (2012)

Country	Total [Mt]	Steam [Mt]	Coking [Mt]
Indonesia	383	380	3
Australia	301	159	142
Russia	134	116	18
USA	114	51	63
Colombia	82	82	0
South Africa	74	74	0
Canada	35	4	31

Source: World Coal Association

Indonesian coal has better coal quality due to its low sulfur and ash contents. Many new coal-fired thermal plants in India have been built and will be designed to utilize Indonesian coal. Indonesian coal will be adopted in this survey.

Table 3.4-8 shows the design coal specifications for comparison to be used in cost estimation among candidate sites.

Table 3.4-8 Design Coal Specifications

	Bituminous	Subbituminous
Total Moisture (%ar)	10.0	22.4
Proximate Analysis (Air-dried basis)		
Moisture (%ad)	4.5	14.3
Ash (%ad)	12.0	8.9
Volatile Matter (%ad)	43.0	39.5
Caloric Value		
Gross as received (kcal/kg)	6,250	5,000
Ultimate Analysis		
Carbon (%daf)	79.5	76.6
Hydrogen (%daf)	6.80	5.52
Nitrogen (%daf)	1.43	1.15
Sulfur (%daf)	0.96	0.70
Oxygen (%daf)	11.3	16.0
Ash Fusion Temperature		
Initial Deformation	1,460	1,200
Spherical	1.520	1,220
Hemispherical	1,580	1,250
Flow	1,590	1,280
Ash Analysis		
SiO_2 (%db)	48.1	45.1
Al_2O_3 (%db)	35.8	23.1
Fe_2O_3 (%db)	9.1	12.6
CaO (%db)	1.2	8.34
MgO (%db)	0.5	3.58
TiO_2 (%db)	2.80	1.31
Na_2O (%db)	0.20	0.26
K_2O (%db)	0.30	0.61
SO_3 (%db)	1.80	5.06
Sizing		
Above 50 mm*	0.0	0.0
Under 2 mm	15.0	20.0

NOTE: Bituminous :as of typical value of Arutmin 6250
Subbituminous :as of typical value of Arutmin 6250
Source: Indonesian Coal Book 2012/2013

3) Type of Coal for Blending

Table 3.4-9 shows one example of provisional operation cost for 30 years of bituminous coal blending and subbituminous coal blending with Thar coal lignite in Lakhra. Bituminous coal has a higher generation cost than subbituminous coal because the fuel cost per unit caloric value of bituminous coal is higher than of subbituminous coal. However, bituminous coal has a lower transportation than subbituminous coal because the weight per unit caloric value of bituminous coal is lower than of subbituminous coal. Therefore, bituminous coal is more advantageous than subbituminous coal in terms of the total operation cost. Hence, bituminous coal is adopted for the Project's cost estimation for comparison among candidate sites. From an operational point of view, the probability for reduction of operation cost is expected through bids compared with cost estimation in this report. Further provisional cost calculation is done for each candidate site in Section 3.5.2. It should be noted that procurement of coal in use has not been secured at the time of writing this report, thus the coal type shall be decided at the end of this survey.

Table 3.4-9 Operation Cost of Blended Coal in Lakhra

Operation cost for 30 years	20%Thar coal to 80% bituminous coal (Rs million)	20% Thar coal to 80% subbituminous (Rs million)
Coal transportation cost	163,636	193,066
Generation cost	353,699	332,852
Total	517,335	525,918
Remarks	Hereinafter, this blended is used for cost estimation.	

Source: JICA Survey Team

Note: Assumption for the calculation in the above table
i) Plant efficiency a) blended coal of bituminous coal: 36.9 %
b) blended coal of subbituminous coal: 36.4 %
ii) Transportation of coal a) Imported coal: railway <660 Rs/(ton*km)>
b) Thar coal : Ttuck <4.2 Rs/(ton*km)>

3.4.2 Plant Size and Steam Condition

(1) Plant Size

The power plant unit size is determined from the following criteria:

First is an economical matter. In terms of construction cost per plant capacity (MW), a larger unit is more economical than a smaller unit.

Second is the stability of the power network system. A power plant has the risk to be shut down due to a trouble in the power plant itself or for other reasons. The effect to the power system stability is according to the power loss magnitude. If the magnitude of power loss by plant outage is large, the whole power system can be shut down owing to the power grid voltage fluctuation, the decrease of system frequency and destabilized power system. The stability strongly depends on the backup power which can be promptly supplied to the power system, however, it is difficult to clearly prescribe in advance. It is said in general that abrupt loss of 10% or less in the whole network is regarded safe. In Pakistan, the total power generation capacity is about 20,000 MW, and so 600 MW is regarded small and safe considering the above criteria..

Third is actual performance in foreign countries. There are very many actual operations of 600 MW class plants in foreign countries. Under the consideration of the above criteria, 600 MW is regarded as a suitable capacity in Pakistan.

(2) Steam Conditions

1) General

In order to achieve high net plant efficiency of fossil fuel-fired power plants, materials and metallurgy technology have been developed, and the thermal cycle main steam pressure and temperature have been raised over the years.

As shown in Table 3.4-10, recent large-scale fossil power plants are divided into three categories, namely, subcritical, supercritical, and ultra-supercritical.

Table 3.4-10 Categories of Thermal Power Plants

Categories	Boiler type	Main steam pressure	Main steam temperature or Reheat steam temperature
Subcritical	Drum type boiler	15–17 MPa	538–566 °C

Supercritical	Once-through boiler	24–25 MPa	538–566 °C
Ultra-supercritical	Once-through boiler	24–31 MPa	593 °C and higher

Source: JICA Survey Team

The definition of SC and USC is sometimes different between associations.

In this report the definition by US Electric Power Research Institute (EPRI) is used,Where steam condition of 593°C / 593°C is regarded as USC.

Reference; Updated Cost and Performance Estimates for Clean Coal Technologies Including CO2 Capture—2005 chapter 4, EPRI

The three categories of power plants are compared in Table 3.4-11.

Table 3.4-11 Comparison of Three Categories of Thermal Power Plants

Items	Subcritical	Supercritical	Ultra-supercritical
Boiler type	Drum type boiler	Once-through boiler	Once-through boiler
Plant efficiency	Base	Better	Best
Technology expansively	Base	Better	High technology
Construction cost	Base	Higher	Much higher
Fixed Operation & maintenance cost	Base	A little higher	A little higher
Variable Operation & maintenance cost	Base	Better	Much better
Plant operation	Base (manual operation available)	Vulnerable (automation required)	Vulnerable (automation required)
Water quality management	Base	Be cautious	Be cautious
Fuel Consumption and Carbon Dioxide Emission	Highest	Relatively low	Lowest
Technical summary	Stable operation but low efficiency	Step up to higher efficiency	Jump up to highest efficiency
Recommendation			Appropriate

Source: JICA Survey Team

As a comparison of drum type boiler and once-through boiler is described in detail in Table 7.3-15 of chapter 7, a once-through boiler does not have reserve tank like drum, so the boiler has a small time constant for its plant dynamic characteristics, which require quick response on disturbance. Wide range of the highly automatic boiler and turbine control is required.

In addition to that, feed water quality should be strictly managed with use of a condensate polishing plant (Demineralizer) which is not installed in the drum type of boiler. Otherwise, the boiler tubes would easily corrode and the steam turbine blades would also suffer from scale damage.

As for operation and maintenance (O&M) cost comparisons are, in general, as follows,

- Drum type is a little better for fixed O&M cost owing to a little smaller maintenance labor cost

- a once-through boiler is better for variable O&M cost owing to a little smaller supply of water and chemicals during the operation.

In Pakistan labor cost is not regarded so a big factor, a once-through boiler seems having O&M advantage.

In regard with environmental aspect, USC takes advantage to sub-critical and super critical boilers as mentioned in chapter 11.

In spite of above mentioned difficulties, a once-through boiler is recommended to achieve high efficiency and technical development.

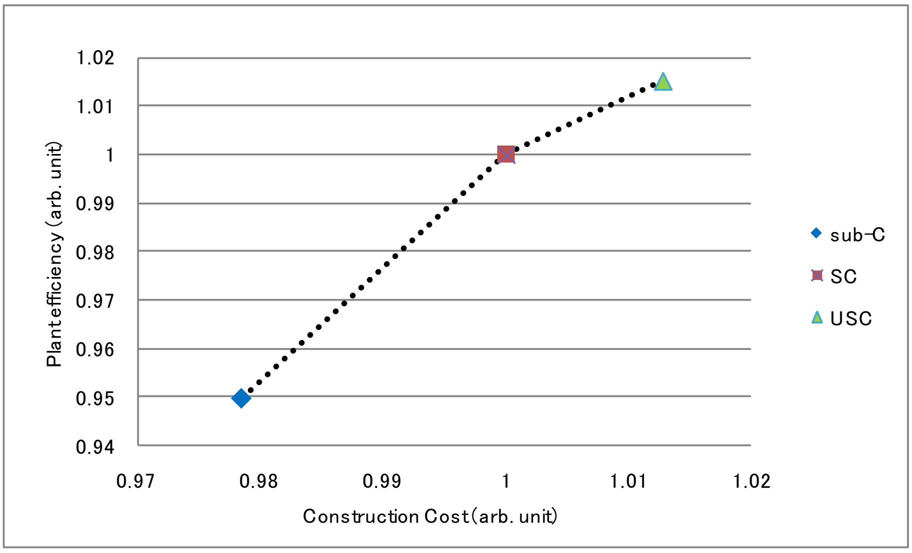
Recently, supercritical units have become the standard selection for large fossil power plants of 600~660 MW units in Asia. They are supercritical with pressure of 24-25 MPa and temperature of 566 °C / 566 °C. The steam condition of 24.1MPa/ 593°C / 593°C, regarded as USC here, is actually the boundary between SC and USC, and this type also has been established and reliable.

2) Specified Steam Conditions and Cost Benefit

The specified steam conditions for the main steam pressure and combination of main steam temperature / reheat steam temperature for each plant type are as follows:

Subcritical	:	16.7 MPa	538 °C / 538 °C
Supercritical (SC)	:	24.1 MPa	566 °C / 566 °C
Ultra-supercritical (USC)	:	24.1 MPa	593 °C / 593 °C

Samples of plant efficiency and cost estimation ratio for the abovementioned types of plants are as shown in Figure 3.4-1.



Source: JICA Survey Team

Figure 3.4-1 Cost Benefit of Each Steam Condition

	Subcritical	:	SC	:	USC
Plant Efficiency (ratio)	0.950	:	1	:	1.015
Cost (ratio)	0.978	:	1	:	1.012

Construction (erection) costs and plant efficiencies are normalized with those of SC condition. In the comparison among subcritical, SC, and USC, fixed operation and maintenance cost result in much smaller difference than the others, so that efficiencies and costs are considered. Compared with SC and USC, increase ratio in plant efficiency (1.015) is slightly larger than that in cost (1.012). In addition, the Project's plant is expected to be operated of base load operation in which higher plant efficiency is the most costly effective, which result that USC is the most beneficial.

USC is the highest in performance ratio, however, it should be managed with cautious operation and maintenance. The repair cost due to operational errors might be high owing to the use of highly advanced materials and the welding process for the plant's boiler and turbine, which have high temperature and high pressure tolerance.

In terms of power system instability, load fluctuation or load shedding might occur more in Pakistan than in Japan, hence, thermal stress might be induced into the boiler and turbine materials due to drastic change in temperature thus resulting in the shortened life of materials.

Although there are some qualitatively disputed matters, the high efficient steam condition of 24.1MPa / 593°C /593°C is recommended for the Project. In addition, it is better to introduce prevented maintenance technology for the equipment in order to lower the maintenance cost over the long life.

3.4.3 Condenser Cooling and Vacuum

(1) Relation Between Condenser Cooling, Vacuum and Plant Efficiency

Steam turbines extract power from steam as the steam passes from high pressure and high temperature conditions at the turbine inlet to lower pressure and lower temperature conditions at the turbine outlet. Steam exiting the turbine goes to the condenser, where it is condensed to water.

The condensation process is intended to create low pressure conditions at the turbine outlet. Lower exhaust pressure result in greater generation of energy that is available to drive the turbine, which in turn increases the overall efficiency of the system.

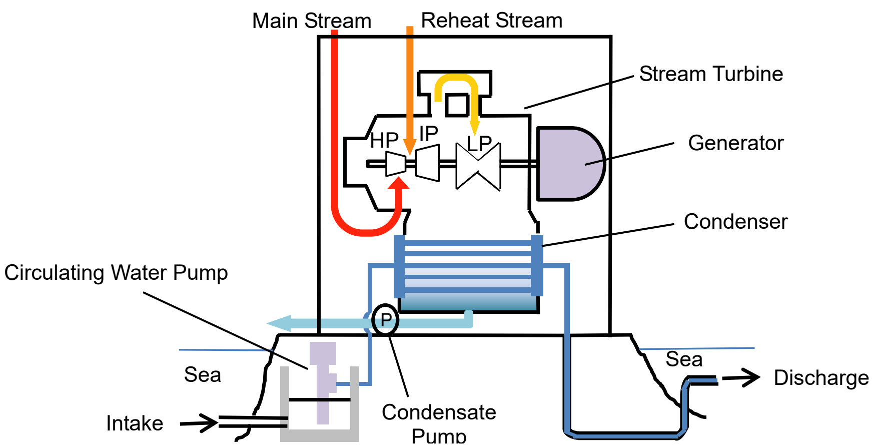
The exhaust pressure of steam turbine (or vacuum) is a function of the temperature maintained at the condensing surface, which is dependent on the design and operating conditions within the condensing system (e.g., surface area, materials, and cooling fluid flow rate), and especially the temperature of the cooling water used to absorb heat and reject it from the condenser.

(2) Condenser Cooling

The use of a different cooling system can affect the temperature maintained at the steam condensing surface. This difference can result in a change in the efficiency of the power plant. The cooling water systems between the inland site and the coastal site are different.

a. Coastal Area Site Case

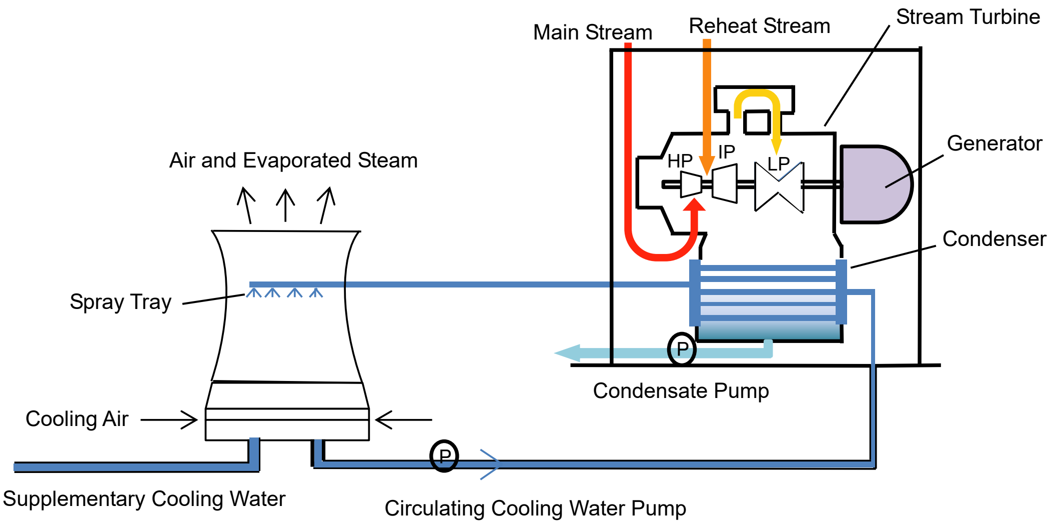
In case of coastal site, seawater is directly used as the cooling water, and a huge amount of seawater can be available. The amount of water for a plant of 600 MW (NET) class is around 100,000 m^3/h.



NOTE: HP : High Pressure Turbine
IP : Intermediate Pressure Turbine
LP : Low Pressure Turbine
Source: JICA Survey Team

Figure 3.4-2 Cooling Water System (Coastal Area)

b. Inland Site Case



Source: JICA Survey Team

Figure 3.4-3 Cooling Water System (Inland Area)

On the other hand, in case of inland site, which refer to both the mine mouth in Thar and the Indus River area, the condenser cooling water is cooled at the cooling tower with use of evaporation heat loss. The temperature of the cooling water is affected by the wet bulb temperature of the ambient atmosphere. The cooling water is recirculated between the condenser and the cooling tower, and the amount of evaporated water, which is a part of circulating water, should be supplied as compensation. The total amount of water supplied for the cooling tower is around 1,700 m^3/h.

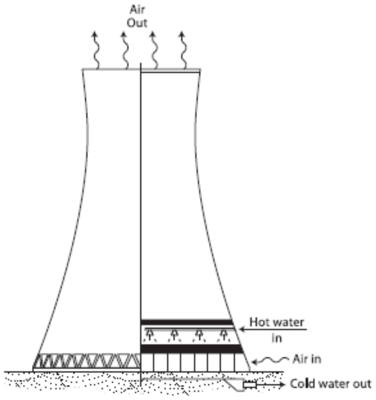
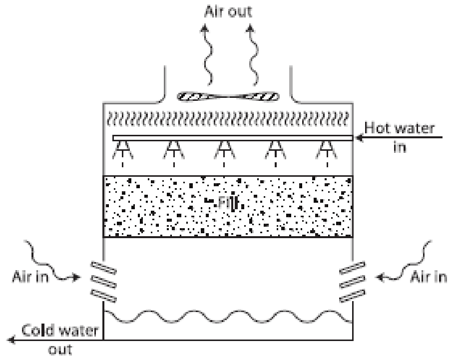
There are two types of wet cooling tower systems for large thermal power stations, namely, natural draft type, and mechanical draft type.

The mechanical draft type is further classified as induced type, and forced type; however, the forced type is not applicable to large flow.

The characteristics of the natural draft type and the mechanical induced draft type are shown in Table 3.4-12. Owing to less operating costs and trouble-less maintenance merit, the natural draft type is recommended for a large-scale power plant at an inland site.

In case water supply is not sufficient, dry cooling system may be applied. But if the dry bulb temperature is high, the turbine output will be restricted and plant efficiency will be decreased so much. In addition, there are few installation and operation records of high exhaust pressure turbine of large capacity. The dry cooling system is not recommended for the Project.

Table 3.4-12 Comparison of Two Types of Cooling Tower

Item	Natural draft type	Mechanical draft type
Typical sketch	Natural draft hyperbolic tower 	Induced draft tower 
Principle	Stack effect increase with height	Induced draft by fan
Application	High heat loads and large water flow Common for large power plants	Common for industrial use
Operation cost	Low	High (Fan motor load)
Maintenance cost	Low	High (Fan and motor maintenance)
Capital cost	High (Large tower size)	Low
Operation limit	----	Fan more susceptible to vibration and corrosion
Temperature control	Cooling water temperature control is difficult	Temperature control is better
Seismic condition	Be quakeproof	Better
Noise	Noiseless	Noise protection

Source: JICA Survey Team

c. Condenser

The aim of the condenser is to reduce exhaust pressure of the steam turbine, increase heat drop inside of the turbine and condense steam. In general, surface type condensers are used for large thermal power plants. The condenser shell contains numerous cooling tubes in which cooling water flows. The exhaust steam is condensed in the shell owing to the heat exchange with the cooling water. The condensate temperature is determined from the following relation: the amount of heat loss from the steam to condensate is equivalent to the heat increase of the cooling water during the condenser process.

d. Summary

Based on the investigation of the condenser cooling and vacuum, a comparison of the design conditions of the three sites is shown in Table 3.4-13.

Table 3.4-13 Condenser Cooling and Vacuum at Design Conditions

No	Item	Unit	I	II	III
1	Power Unit Site	-	Mine mouth in Thar	Indus River	Karachi Port
2	Cooling Water system	-	Cooling Tower (Wet cooling)	Cooling Tower (Wet cooling)	Seawater
3	Wet Bulb Temperature	ºC	29 Ref. Fig. 3.1- (Chhor data)	28.6 Ref. Fig. 3.2- (Hyderabad data)	-
4	Cooling Water Temp to Condenser	ºC	36	35.6	26.9 Ref. Fig. 3.3- (Karachi data)
5	Cooling Water Temp. from Condenser	ºC	46.0	45.6	34.9
6	Condenser Saturated Temp	ºC	48.0	47.8	38.9
7	Condenser Vacuum	kPa	11.3	11.1	7.0
		mmHg	84.3	83	52.5

Source: JICA Survey Team

(3) Plant Specifications

Meteorological data, as attached in Appendix 3-7, are basic half a year data for the plant conditions especially for condenser cooling performance and a little modification has been done with the hearing of additional yearly trend.

The plant specifications for each site in the case of supercritical type are shown in the attached Appendix 3-8. Provisional plant efficiencies for each site were calculated with several coal types including blended coal.

A table on the amount of water supply is provided in the attached Appendix 3-9.

3.5 Selection of Candidate Site

3.5.1 Evaluation of Technical Aspects

The results of consideration of each candidate site in terms of technical aspects are shown in Table 3.5-1.

In addition, the evaluation of each candidate site in terms of technical aspects is summarized as follows:

(1) Mine Mouth in Thar

The mine mouth in Thar has advantages as a mine-mouth power plant. Also, the site has no issues on land acquisition and the environment.

However, the following are its disadvantages and risks:

- High cost of initial investment for using lignite coal;
- Delaying for coalfield development;
- Opacity of availability of transmission capacity in the future; and
- Availability of cooling water.

1) High Cost of Initial Investment for Using Lignite Coal

After the speech of US President Barack Obama in June 2013, the situation of support on the construction of a coal-fired thermal plant has been changed greatly as compared with the situation before the survey. As a result, since organization of co-financing is limited, it is difficult to secure such. Since the Project cost is very large, reducing the initial cost is one of the key issues for the realization of the Project.

A lignite coal boiler is twice the size of a bituminous or subbituminous coal boiler, hence, the cost will rise for the main boiler unit and ancillary facilities. Consequently, the total project cost for adoption of a lignite coal boiler will be Rs 20 billion higher than the adoption of a bituminous or subbituminous coal boiler. Furthermore, consideration of additional infrastructure such as transmission line, the cost will be expensive at around Rs 40 billion.

Table 3.5-1 Comparison of the Candidate Sites

<table>
<tr><th colspan="3" rowspan="2">Items for Comparison</th><th colspan="3" rowspan="2">Mine Mouth in Thar</th><th colspan="4">Indus River</th><th colspan="3" rowspan="2">Karachi Port</th></tr>
<tr><th colspan="2">Candidate 1 <Lakhra></th><th colspan="2">Candidate 2 <Jamshoro></th></tr>
<tr><td colspan="3">Overview of the candidate sites</td><td colspan="3">The vacant plot of energy park in Block II (approximately 0.9 km × 1.5 km; owned by SECMC)</td><td colspan="2">The vacant plot inside of the Lakhra Power Station (0.777 km^2)</td><td colspan="2">Area north side of the Jamshoro Power Station (approximately 1.0 km × 1.0 km)</td><td colspan="3">Vast land in the industrial area possessed by the Port Qasim Authority (approximately 1.0 km ×1.0 km)</td></tr>
<tr><td colspan="3">Water intake and drainage</td><td colspan="3">Water intake point shall be LBOD. Water pipeline shall be constructed by GoS from LBOD to the Thar coalfield passing through an RO water treatment facility in Nabisar (approximately 85 km).
Effluent water will be treated by a water treatment facility in Bock II.</td><td colspan="2">Water shall be taken from the Indus River. Water pipeline shall be constructed from the intake point to the site (approximately 4.2 km).
Cooling tower discharge will be drained off through the water pipeline into the Indus River. Other effluents will be treated in the site.</td><td colspan="2">Water shall be taken from Indus river. Water pipeline shall be constructed from the intake point to the site (approximately 4.0 km).
Cooling tower discharge will be drained off through a water pipeline to the Indus River. Other effluents will be treated in the site.</td><td colspan="3">Seawater shall be taken from the gulf of Karachi. Water pipeline to the site and an RO water treatment facility for seawater shall be installed (approximately 3 km).
Thermal discharge will be drained to Qasim Port taking into consideration the mangroves. Based on NEQS, the outlet should be set at least 10 miles far from the mangrove.</td></tr>
<tr><td colspan="3">Connection to transmission line</td><td colspan="3">Transmission line between Matiari S/S and Thar coalfield by NTDC shall be constructed.
(approximately 250km)</td><td colspan="2">Transmission line from the site to existing transmission line shall be constructed by NTDC.
(towards the west from the site, approximately 1.7 km)</td><td colspan="2">Transmission line from the site to existing transmission line shall be constructed by NTDC.
(toward the west from the site, approximately 0.7km)</td><td colspan="3">Option1: Transmission line from the site to NKI (NTDC-KESC INTERCONNECTION) S.S. (approximately 75 km)
Option2: Transmission line from the site to existing 500kV transmission line <New S/S will be required to install> (approximately 35 km)</td></tr>
<tr><td colspan="3">Power system analysis (reinforcement of 500 kV HVAC considered with power flow)</td><td colspan="3">Recommended reinforcements of 500 kV HVAC transmission line are the following:
(I) Matiari S/S to Moro : 1 circuit
(II) Moro S/S to R.Y. Khan S/S : 1 circuit
(III) Multan S/S to Sahiwal S/S : 1 circuit</td><td colspan="4">Recommended reinforcements of 500 kV HVAC transmission line are the following:
(I) Matiari S/S to Moro : 1 circuit
(II) Moro S/S to R.Y. Khan S/S : 1 circuit
(III) Multan S/S to Sahiwal S/S : 1 circuit</td><td colspan="3">Recommended reinforcements of 500 kV HVAC transmission line are the following:
(I) Matiari S/S to Moro : 1 circuit
(II) Moro S/S to R.Y. Khan S/S : 1 circuit
(III) Multan S/S to Sahiwal S/S : 1 circuit</td></tr>
<tr><td colspan="3">Geometrical conditions</td><td colspan="3">Mainly very dense sand strata are distributed. Spread foundation or pile foundation will be applied to equipment foundation, due to bearing layer (N Value > 30) existing at around 10 m deep underground.</td><td colspan="4">Limestone is widely distributed. Bearing capacity is very strong, but rock excavation will be required while under construction.</td><td colspan="3">Underground water level is estimated to be high as the site is located in a coastal area. Therefore liquefaction shall be considered for the structural foundation.
Detailed geological data shall be required to be collected in the second site survey.</td></tr>
<tr><td colspan="3" rowspan="2">Plant efficiency
(USC 600 MW< NET>, HHV)</td><td>Thar Coal 100%</td><td>Subbituminous 80% +Thar Coal 20%</td><td>Bituminous coal 80% + Thar Coal 20%</td><td>Thar Coal 100%</td><td colspan="2">Subbituminous 80% +Thar Coal 20%</td><td>Bituminous coal 80% + Thar Coal 20%</td><td>Thar Coal 100%</td><td>Subbituminous 80% +Thar Coal 20%</td><td>Bituminous coal 80% + Thar Coal 20%</td></tr>
<tr><td>35.0%</td><td>36.4%</td><td>36.8%</td><td>35.0%</td><td colspan="2">36.4%</td><td>36.9%</td><td>35.7%</td><td>37.1%</td><td>37.6%</td></tr>
<tr><td rowspan="4">Project cost
(Rs in millions)</td><td colspan="2">Type of coal</td><td colspan="2">Thar Coal 100%</td><td>80% Bituminous : 20% Thar Coal</td><td>Thar Coal 100%</td><td>80% Bituminous : 20% Thar Coal</td><td>Thar Coal 100%</td><td>80% Bituminous : 20% Thar Coal</td><td colspan="2">Thar Coal 100%</td><td>80% Bituminous : 20% Thar Coal</td></tr>
<tr><td colspan="2">Construction cost</td><td colspan="2">154,631</td><td>159,897</td><td>162,426</td><td>118,536</td><td>163,329</td><td>119,439</td><td colspan="2">167,815</td><td>123,521</td></tr>
<tr><td colspan="2">Operation cost for 30 years in Scenario 4</td><td colspan="2">501,569</td><td>562,145</td><td>460,059</td><td>526,923</td><td>453,641</td><td>526,342</td><td colspan="2">415,519</td><td>488,718</td></tr>
<tr><td colspan="2">Total cost</td><td colspan="2">656,201</td><td>722,042</td><td>622,485</td><td>645,460</td><td>616,970</td><td>645,781</td><td colspan="2">583,333</td><td>612,239</td></tr>
<tr><td rowspan="5">Transportation of coal</td><td rowspan="3">Use of Thar coal</td><td>Road</td><td colspan="3">—</td><td colspan="4">Road Condition -The rehabilitation of existing road and construction work of bypass have already been started between Badin and the Thar coalfield. Another bypass between Sujawal and Badin is required due to existence of some towns along the existing road. Between Sujawal and Ghaghar RC, the road condition is relatively good while rehabilitation work planned by PPP between Ghaghar RC and Thatta is required to be duly completed on schedule. Road condition between Ghaghar RC and Jamshoro and Lakhra is relatively good except in some parts. Repair works on the Easter Bypass (between M-9 and N-5) is required. And, long uphill slope on M-9 causes slow speed of heavy vehicles.
Alternatives of Routes - There are four alternative routes for coal transportation from Thar to the Indus River area. The route of Islamkot – Mithi- Digri- Mirpur Khas – Hyderabad – the Indus River area is relatively wider and shorter distance than the others.</td><td colspan="3">The rehabilitation of existing road and construction work of bypass have already been started between Badin and the Thar coalfield. Another bypass between Sujawal and Badin is required due to existence of some towns along the existing road. Between Qasim Port and Sujawal, the road condition is relatively good while there is conjunction near Qasim Port and rehabilitation work planned by PPP between Ghaghar RC and Thatta is required to be duly completed on schedule.</td></tr>
<tr><td rowspan="2">Railway</td><td colspan="3" rowspan="2">—</td><td colspan="4">New railway line connecting Thar with the existing Mirpur Khas-Khokhropar Line shall be constructed (approximately 150 km).</td><td colspan="3" rowspan="2">New railway line connecting Thar with the existing Mirpur Khas-Khokhropar Line shall be constructed (approximately 150 km).
Railway connection shall be provided from the Karach-Hyderabad Line (approximately 4-5 km).</td></tr>
<tr><td colspan="2">Spur line shall be provided from the existing line to the new plant (distance of straight line is approximately 2.2 km).</td><td colspan="2">Spur line shall be provided from the existing line to the new plant (approximately 1.8 km).</td></tr>
<tr><td rowspan="2">Use of imported coal</td><td>Road</td><td colspan="3">The widening and rehabilitation of existing road and construction work of bypass have already been started between Tatta and the Thar coalfield.</td><td colspan="4">Road condition between Qasim Port and Jamshoro and Lakhra is relatively good except in some parts.
Repair works on the Eastern Bypass (between M-9 and N-5) is required. And, long uphill slope on M-9 causes slow speed of heavy vehicles.</td><td colspan="3">The road condition is relatively good except in the conjunction.</td></tr>
<tr><td>Railway</td><td colspan="3">New railway line connecting Thar with the existing Mirpur Khas-Khokhropar Line shall be constructed (approximately 150 km). Railway connection shall be provided from the Thar Station of the new line.</td><td colspan="4">The existing railway line from Qasim Port or Karachi Port is available to use if some facilities are installed and nearest railway station has been provided.</td><td colspan="3">—</td></tr>
</table>

Land acquisition		As part of the Thar Coal Block II Mining Project, Sindh Engro Coal Mining Company (SECMC) has conducted a land survey and has been preparing for land acquisition, compensation, and resettlement activities for the priority section (22 km^2) within Block II. The priority section includes the mine pit, dumping area, and the proposed power plant candidate site. Therefore, land acquisition may not be needed for this Project depending on SECMC's progress.	Land acquisition is unlikely expected for the power plant construction site as it is located within the existing Lakhra Power Station. However, land acquisition is required for the railway connection to some extent. Moreover, land preparation for the right-of-way of the transmission line (1.7km) is required.	Land acquisition is required for both the power plant and railway connection. Land preparation for right-of-way of the transmission line (0.7 km) is required.	According to the Port Qasim Authority's Master Plan 2010, the site is available for industrial purposes. An update on the situation of the site, whether it is still available or already designated to another user, has been examined. If this candidate site is selected, the extent of land acquisition will be further confirmed.
Environmental and social consideration	Natural environment	The candidate site is covered with shrub, meadow, and agricultural crops, where no threatened plants are found. The area is not located in any reserves. Therefore, no significant impact on the natural environment due to Project implementation is anticipated. Further investigation is needed for ground subsidence caused by pumping ground water.	As the candidate site is located in dune area and the vegetation is very poor, no significant impact on the natural environment due to Project implementation is anticipated. Water intake from the Indus River may result to some impacts on the aquatic ecosystem. As the land for railway lines for coal transportation are mainly farm land, no significant impact on the natural environment is anticipated.	As the candidate site is located in a dune and rocky area and the vegetation is very poor, no significant impact on the natural environment is anticipated. Water intake from the Indus River may result to some impacts on the aquatic ecosystem. As the land for railway lines for coal transportation are dune and farmland, no significant impact on the natural environment is anticipated.	As the vegetation at the candidate site is very poor, where shrubs and meadow are found, no significant impact on the natural environment is anticipated. On the other hand, as mangroves inhabit in the sea approximately 2 km far from the land, thermal discharge would have some impacts on them. According to Pakistan's environmental regulations, outlet of the thermal discharge into the sea must be away at more than 10 miles from the mangroves. Regarding the impact on marine organisms, further investigation is needed.
	Social environment	The candidate site is mainly used for farming and livestock keeping. There are some resting huts for workers but no existence of houses in the candidate site. Therefore, physical displacement would not be expected, while economic displacement of farmlands would be expected as a result of Project implementation. If this site is selected, an extent of economic displacement and the potential of adverse impacts on the social environmental items will be further examined.	Involuntary resettlement including both physical and economic displacement would be unlikely caused by Project implementation. No sensitive social environmental items such as heritage, landscape, ethnic minorities, and indigenous people were observed in the site.	Some physical structures were observed within the candidate site and nearby area, mainly along the Indus Highway. Therefore, the possibility of involuntary resettlement including both physical relocation and economic relocation might be expected. If this site is selected, the extent of involuntary resettlement and the potential of adverse impacts on social environmental items will be further examined.	There are no settlements within the site as it is situated in the Qasim Port industrial area and the land belongs to the Karachi Port Authority. Therefore, there is no possibility that the Project would result in involuntary resettlement. Socially sensitive situations and resources were not observed in the site during the site investigation. However, further study is required to evaluate any risks and impacts to the existing fishing activities in the Qasim Port area (i.e., near the Korangi and adjoining creeks.)
Evaluation and selection		Advantage; The candidate site has advantages in terms of environmental aspects. Disadvantage; The candidate site has disadvantages on (i) high cost of initial investment for usage of Thar lignite, (ii) probability of delay for coalfield development, (iii) opacity of availability of transmission line in the future, and (iv) securing of cooling water for the plant. Evaluation; Therefore, this candidate site is NOT feasible for the Project.	Advantage; The candidate site has advantages in terms of erection cost, environmental aspects, securing cooling water and connecting to transmission line. In addition, it also has an advantage in the social aspect due to land use of vacant plot inside the existing Lakhra Power Station. Evaluation; Therefore, this candidate site is concluded as the most feasible site among the alternatives.	Advantage; This candidate site has advantages in terms of erection cost, environmental aspects, securing cooling water and connecting to transmission line. Disadvantage; However, from a social point of view, involuntary resettlement will be involved and acquisition will be required. Evaluation; Therefore, this candidate site is inferior to the Lakhra candidate site.	Advantage; This site has advantages in terms of plant efficiency due to the direct use of seawater and transportation of imported coal. Disadvantage; However, this site will have environmental problems related to the mangrove forests within seaside and future development plan of the coal-fired thermal power plant in the area, thus this site will have difficulty in complying with JICA's environmental guidelines in the future. In addition, land acquisition shall be required. Evaluation; Therefore, this candidate site is NOT feasible for the Project.

2) Concerned Delay for Coalfield Development

GoS has been allocated budget of around Rs 30 billion and necessary infrastructure such as road, airport, and water supply are under construction at the moment. In addition, the bid for the construction of the power station (300 MW x 2) in Block II by Chinese companies has been ongoing as of December 2013.

However, the main coal seam thickness ranges from 12 m to 21 m at an average depth of 170 m with the upper 50 m being loose sand (sand dune). Hence, removal of the thick sand dune will spend huge amount of money. Moreover, abundant underground water exists above ad under the coal seam zone in Thar coalfield, which affects mining safety. In consideration of the risk of delay for the coalfield development, imported coal would be needed instead of Thar coal. This will result to additional generation cost due to the long distance of inland transportation of coal from ports.

3) Concerned Development Schedule of Transmission Line

Although a new transmission line between Thar and Matiari will be constructed in accordance with the existing plan of NTDC, construction of transmission line by NTDC is required with development plan of power stations. The cost impact of delay in coalfield development is discussed in 3.5.2(2). Further, in case of increase of generation capacity in Thar area as well as Gaddani or coastal area, further expansion of transmission capacity. (i.e. 600 kV direct current transmission line to northern Pakistan) may be required to evacuate maximum power from Thar area.

4) Availability of Cooling Water

The construction of a water supply system from LBOD to Thar is partially ongoing as mentioned in 3.3.3.

However, water from LBOD would be shortage in case all planned power stations are constructed in Thar with more than 3,600 MW capacities. It would be necessary to expand water supply facilities.

(2) Indus River

As mentioned in Table 3.5-1, as for both candidate sites of the Lakhra Power Station and north of the Jamshoro Power Station site, cooling water would be secured easily from the Indus River. Moreover, access to the existing transmission line is nearer than the other candidate sites.

As for the Lakhra Power Station, fallow land inside the existing power station will be used, hence, land acquisition and involuntary resettlement for construction of the new power station will not be required except for the spur track for imported coal transportation, which of a straight line is approximately 2.0 km from the Kotri – Habib Kot Line.

In terms of the existing Lakhra Power Station, the availability ratio is extremely low, therefore, GENCO is currently groping privatization of the Power Station. Including the privatization plan, three future options are assumed in future as follows;

- i) The existing Power Station will be privatized.
- ii) The commercial operation will last by GENCO IV.
- iii) The existing Power Station will be demolished before/after commencement of operation of new Power Station under the Project.

The existing colony for the Power Station will be available with option ii) and III) mentioned above. Whereas, colony shall be planned and constructed for the Project with option i).

On the other hand, involuntary resettlement will be involved to some extent and land acquisition is needed to a large extent in the north of the Jamshoro site. Moreover, cumulative impacts on the environment such as emission of gas that will be brought about by the existing Jamshoro oil-fired power station (850 MW) and the installation of the new coal-fired thermal power station (660 MW x 2) financed by ADB shall be considered.

(3) Karachi Port Area

One of the major issues for the Karachi Port area is securing sufficient land for the construction of the power station. However, the selected candidate site in Qasim Port has sufficient land. In addition, the site has an advantage on imported coal transportation since the selected site is near an available port for coal handling in case imported coal is used. Furthermore, generation efficiency is highest due to direct use of seawater for condenser cooling.

However, there is one major issue with regard to environmental impacts. A part of a mangrove forest located along the seaside shall be removed to install water pipelines of approximately 27 km in length. The removal would affect the ecosystem in the sea; therefore it would be difficult to comply with the JICA guidelines on the environment. In addition, the Indus River Delta, which is registered under the Ramsar Convention, exists 20–25 km from the candidate site.

Furthermore, it is assumed that additional power stations are planned and be constructed in this area in the future. In this regard, there is a possibility for environmental deterioration due to pollution, which therefore causes difficulty for the Project to comply with the JICA guidelines.

3.5.2 Evaluation of Economical Aspects

(1) Alternatives for the Location and Usage of Coal

Considering reduction of the initial investment cost, in addition to 100% use of Thar coal, as for the candidate sites in the Indus River and the Karachi Port area, blended coal of 80% imported bituminous coal and 20% Thar coal is considered, which is a possible mixture ratio as mentioned in Section 3.4 above.

Consequently, there are eight alternatives as shown in Table 3.5-2.

Table 3.5-2 Alternatives for the Location and Usage of Coal

Alternative	Location	Usage of Coal
Alternative 1	Mine Mouth in Thar	Thar Coal (Lignite) :100%
Alternative 2	Indus River (Lakhra Power Station)	Thar Coal (Lignite) :100%
Alternative 3	Indus River (North of the Jamshoro Power Station)	Thar Coal (Lignite) :100%
Alternative 4	Karachi Port (Qasim Port)	Thar Coal (Lignite) :100%
Alternative 5	Mine Mouth in Thar	Imported Coal (Bituminous) : 80% Thar Coal (Lignite) : 20%
Alternative 6	Indus River (Lakhra Power Station)	Imported Coal (Bituminous) : 80% Thar Coal (Lignite) : 20%
Alternative 7	Indus River (North of the Jamshoro Power Station)	Imported Coal (Bituminous) : 80% Thar Coal (Lignite) : 20%
Alternative 8	Karachi Port (Qasim Port)	Imported Coal (Bituminous) : 80% Thar Coal (Lignite) : 20%

Source: JICA Survey Team

(2) Construction Cost (Initial Investment Cost)

Construction cost for the power station including related infrastructure is shown in Table 3.5-3. Construction cost for the power plant was estimated depending on the specifications of each alternative and based on DOE. In case 100% Thar coal is used, the size of boiler facilities will be large due to lignite coal. Mixture combustion with imported coal will be more economical as compared with use of 100% Thar coal.

The cost of 500 kV transmission line connecting the existing substation and transmission line from the power station was estimated, and the cost of railway is estimated depending on the coal transportation conditions in Table 3.5-5.

Table 3.5-3 Construction Cost (Initial Cost)

Unit: Rs in million

	Alternative 1 Thar Thar Coal 100%	Alternative 2 Lakhra Thar Coal 100%	Alternative 3 Jamshoro Thar Coal 100%	Alternative 4 Karachi Thar Coal 100%	Alternative 5 Thar Mix (80% Bitu)	Alternative 6 Lakhra Mix (80% Bitu)	Alternative 7 Jamshoro Mix (80% Bitu)	Alternative 8 Karachi Mix (80% Bitu)
Power Station	133,631	135,951	136,584	133,315	113,897	117,061	117,694	114,741
Intake and Pipeline	2,720 *1	940 *2	1,020 *3	4,170 *4	2,720 *1	940 *2	1,020 *3	4,170 *4
Drainage and Effluent Disposal Facilities	980 *5	270 *6	330 *7	210 *8	980 *5	270 *6	330 *7	210 *8
500 kV Transmission Line	17,300 *9	85 *10	35 *11	4,400 *12	17,300 *9	85 *10	35 *11	4,400 *12
Railway	0	25,180 *13	25,360 *14	25,720 *15	25,000 *16	198 *17	162 *18	0
Total	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521

Note: Above cost is based on below condition, these cost is construction cost only, not included consulting services, physical contingency, price escalation, interest during construction.

*1: Pump House:15 m^3/min x 2 x 1 step, Raw water conveyance pipeline D=800 mm x 30 km

*2: Water intake facilities (30 m^3/min, Raw water conveyance pipeline D=800 mm x 4 km, Raw water treatment plant

*3: Water intake facilities (30 m^3/min, Raw water conveyance pipeline D=800 mm x 5 km, Raw water treatment plant

*4: Water intake and conveyance facilities (Pump 450 m^3/min x 4), Raw water conveyance pipeline D=1,500 mm x 3 km

*5: Pump House: 15 m^3/min x 2 x 1 step, Wastewater drainage pipeline D=600 mm x 10 km

*6: Wastewater treatment plant(30 m^3/min, waste and sludge pond), Wastewater drainage pipeline D=600 mm x 4 km

*7: Wastewater treatment plant(30 m^3/min, waste and sludge pond), Wastewater drainage pipeline D=600 mm x 5 km

*8: Wastewater treatment plant(30 m^3/min, waste an sludge pond), Wastewater drainage pipeline D=600 mm x 3 km

*9: Thar – Matiari 250 km x D/C

*10: Power Station – Existing transmission Line: 1.7 km x D/C

*11: Power Station – Existing transmission Line: 0.7 km x D/C

*12: Power Station – N.K.I S/S : 60 km x D/C, Expansion of transmission Line Bay x 2 at N.K.I S/S

*13:Thar – Existing Railway :150 km, Spur line to power station: 2 km

*14:Thar – Existing Railway :150 km, Spur line to power station:2 km

*15:Thar – Existing Railway :150 km, Spur line to power station: 5 km

*16: Thar – Existing Railway :150 km, No Branch line

*17:Spur line to power station: 2 km

*18:Spur line to power station: 2 km

Source: Prepared by the JICA Survey Team

(3) Operation Cost

1) Consideration of Scenario

In case the Thar coalfield development is delayed, the operation cost for Alternatives 1, 2, 3, and 4 are calculated on the assumption that imported lignite coal is used due to the unavailability of Thar coal. However, in case of mixture combustion with bituminous such as for Alternatives 5, 6, and 7, the operation cost is calculated on the assumption that 100% of bituminous coal is used by the time when Thar coal is supplied.

In consideration of delaying for mining, there are four scenarios as follows:

Scenario 1 : Mining operation has started on schedule

Scenario 2 : Mining operation is delayed for five years

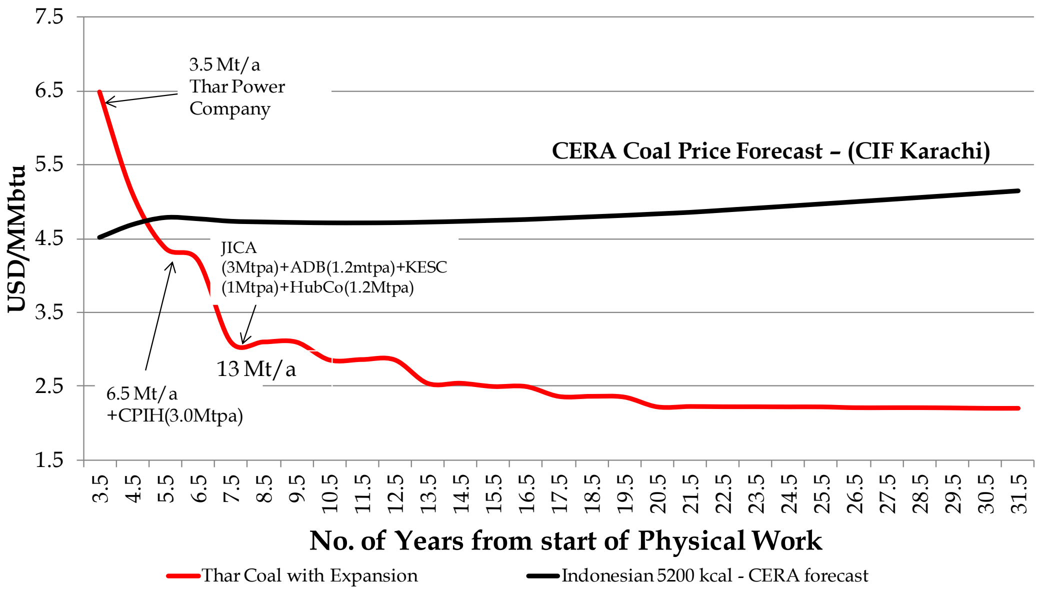
Scenario 3 : Mining operation is delayed for ten years

Scenario 4 : Mining operation is delayed for fifteen years

2) Coal Price

a. Thar Coal

Transition of coal prices of Thar coal from Block II as prepared by SECMC is shown in Figure 3.5-1.



Source: SECMC

Figure 3.5-1 Coal Price Reduction as Mine Scales Up

With the forecast on the increase of coal-fired thermal station which use Thar coal, it is assumed that coal prices will reduce with the increase of coal production. Therefore, Thar coal has a lower price than imported lignite coal. In this time, the following coal prices according to Figure 3.5-1 were adopted:

- 1st five years : USD 35.0/t (USD 2.8/MMBtu)
- 2nd five years : USD 32.5/t (USD 2.6/MMBtu)
- 3rd five years : USD 23.7/t (USD 1.9/MMBtu)
- 4th five years, or more : USD 22.5/t (USD 1.8 /MMBtu)

b. Imported Coal

Coal prices for bituminous coal are shown in Table 3.5-4. Since necessary parameters can be obtained for calculation of generation efficiency, the price of Arutmin A6250 coal, as given in Table 3.5-4, is adopted for calculation of generation cost.

Table 3.5-4 Prices of Bituminous Coal

Brand Name of Coal (Indonesia)	Heating Value (kcal/kg)	Unit Price (USD/t)	Remarks
Medco Bara 6500	6,500	69.66	
Pinang 6000 NAR	6,300	76.23	
Arutmin A6250	**6,250**	**73.96**	Adopted coal
Medco Bara 6200	6,200	62.17	
SKB Coal	6,130	67.34	
Arutmin A6100	6,100	71.57	
Bangun Coal	6,072	66.66	
Pinang 6000	6,000	71.43	
Indominco IMM_MCVHS	5,970	67.27	
Multi Coal Middle	5,900	66.98	

Source: HARGA PATOKANBATUBARA as of September 2013.

3) Coal Transport Conditions

Transport conditions for coal are shown in Table 3.5-5. Transportation method depends on coal volume and term.

Table 3.5-5 Coal Transport Conditions

Alternative	Condition	Usage Coal	Transportation Method
Alternative 1 (Thar)	Before Mining	Imported Coal (Lignite)	Truck from Port Qasim: 380 km (Rs 4.2/km*t) *1
	After Mining	Thar Coal	Truck from coalfield(not only Bolck II but also other block) :20km(Rs 4.2/km*t)
Alternative 2 (Lakhra)	Before Mining	Imported Coal (Lignite)	Truck from Port Qasim: 180 km (Rs 4.2/km*t) *1
	After Mining	Thar Coal	Railway from Thar: 312 km (281-410 km: Rs 820/t) *2
Alternative 3 (Jamshoro)	Before Mining	Imported Coal (Lignite)	Truck from Port Qasim: 150 km (Rs 4.2/km*t) *1
	After Mining	Thar Coal	Railway from Thar: 282 km (281-410 km: Rs 820/t) *2
Alternative 4 (Qasim)	Before Mining	Imported Coal (Lignite)	Truck from Port Qasim: 10 km (Rs 4.2/km*t)
	After Mining	Thar Coal	Railway from Thar: 401 km (281-410 km: Rs 820/t) *2
Alternative 5 (Thar)	Before Mining	Imported Coal (Bituminous) 100%	Railway from Thar: 401 km (281-410 km: Rs 820/t) *2
	After Mining	Imported Coal (Bituminous) 80%	Railway from Thar: 401 km (281-410 km: Rs 820/t)
		Thar Coal 20%	Truck from coalfield (not only Block II but also other blocks) : 20 km (Rs 4.2/km*t)
Alternative 6 (Lakhra)	Before Mining	Imported Coal (Bituminous) 100%	Railway from Port Qasim: 196 km (1-280 km: Rs 660/t) *2
	After Mining	Imported Coal (Bituminous) 80%	Railway from Port Qasim: 196 km (1-280 km: Rs 660/t) *2
		Thar Coal 20%	Truck from Thar: 310 km (Rs 4.2/km*t) *3
Alternative 7 (Jamshoro)	Before Mining	Imported Coal (Bituminous) 100%	Railway from Port Qasim: 167 km (1-280 km: Rs 660/t) *2
	After Mining	Imported Coal (Bituminous) 80%	Railway from Port Qasim: 167 km (1-280 km: Rs 660/t) *2
		Thar Coal 20%	Truck from Thar: 280 km (Rs 4.2/km*t) *3
Alternative 8 (Qasim)	Before Mining	Imported Coal (Bituminous) 100%	Truck from Port Qasim: 10 km (Rs 4.2/km*t)
	After Mining	Imported Coal (Bituminous) 80%	Truck from Port Qasim: 10 km (Rs 4.2/km*t)
		Thar Coal 20%	Truck from Port Qasim: 380 km (Rs 4.2/km*t) *3

Note: *1: Truck transport is adopted due to use temporary of imported coal
*2: Railway transport is adopted due to large amount and permanently use
*3: Truck transport is adopted due to small amount of use
Source: Prepared by the JICA Survey Team

4) Operation Cost

The operation cost consists of coal transportation cost and generation cost. The results of calculation for the operation cost are summarized in Table 3.5-6.

Table 3.5-6 Operation Cost (30 years)

Unit: Rs million

	Alternative 1 Thar Thar Coal 100%	Alternative 2 Lakhra Thar Coal 100%	Alternative 3 Jamshoro Thar Coal 100%	Alternative 4 Karachi Thar Coal 100%	Alternative 5 Thar Mix (80% Bitu)	Alternative 6 Lakhra Mix (80% Bitu)	Alternative 7 Jamshoro Mix (80% Bitu)	Alternative 8 Karachi Mix (80% Bitu)
Scenario 1 (0)*1								
- Transportation	8,216	80,230	80,230	78,683	160,068	163,636	162,473	135,824
- Generation	308,76	275,632	275,606	270,292	357,803	353,699	3453,699	346,337
Subtotal	**316,962**	**355,862**	**355,836**	**348,975**	**517,870**	**517,335**	**516,172**	**482,161**
Scenario 2 (5) *2								
- Transportation	74,112	119,293	117,154	105,103	162,887	164,441	163,472	135,668
- Generation	304,386	271,284	271,284	267,543	388,809	356,090	356,090	348,678
Subtotal	**378,498**	**390,577**	**388,438**	**372,646**	**551,696**	**520,531**	**519,562**	**484,347**
Scenario 3 (10) *3								
- Transportation	140,007	158,357	154,078	131,524	165,707	165,245	164,470	133,512
- Generation	300,027	266,961	266,961	262,558	391,213	358,482	358,482	351,020
Subtotal	**440,034**	**425,318**	**421,039**	**394,083**	**556,920**	**523,727**	**522,952**	**486,532**
Scenario 4 (15) *4								
- Transportation	205,903	197,421	191,003	157,945	168,527	166,050	165,468	135,356
- Generation	295,667	262,638	262,638	2957,573	393,618	360,873	360,874	353,362
Subtotal	**501,569**	**460,059**	**453,641**	**415,519**	**562,145**	**526,923**	**526,342**	**488,718**

Source: JICA Survey Team

<NOTE> *1 Mining operation will commence on schedule.

*2 Mining operation will be delayed for 5 years.

*3 Mining operation will be delayed for 10 years.

*4 Mining operation will be delayed for 15 years.

(4) Economic Evaluation

A comparison of total costs is provided in Table 3.5-7. Alternative 6 is the most economical in terms of initial cost.

On the other hand, as for the total cost including operation cost, in case coalfield development progresses on schedule and is not delayed, Alternative 1 is the most economical. However, if coalfield development is delayed for 15 years or more, Alternative 1 will be the most expensive in the contrary.

Table 3.5-7 Comparison of Total Cost

Unit: Rs million

	Alternative 1 Thar Thar Coal 100%	Alternative 2 Lakhra Thar Coal 100%	Alternative 3 Jamshoro Thar Coal 100%	Alternative 4 Karachi Thar Coal 100%	Alternative 5 Thar Mix (80% Bitu)	Alternative 6 Lakhra Mix (80% Bitu)	Alternative 7 Jamshoro Mix (80% Bitu)	Alternative 8 Karachi Mix (80% Bitu)
Scenario 1 (0)*1								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	316,962	355,862	355,836	348,975	517,870	517,335	516,172	482,161
Total	**471,593**	**518,288**	**519,166**	**516,790**	**677,768**	**635,889**	**635,413**	**605,682**
Scenario 2 (5)*2								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	378,498	390,577	388,438	372,646	551,696	520,531	519,562	484,347
Total	**533,129**	**553,004**	**551,767**	**540,461**	**711,593**	**639,085**	**638,803**	**607,868**
Scenario 3 (10)*3								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	440,034	425,318	421,039	394,083	556,920	523,727	522,952	486,532
Total	**594,665**	**587,744**	**584,368**	**561,897**	**716,818**	**642,281**	**642,193**	**610,053**
Scenario 4 (15)*4								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	501,569	460,059	453,641	415,519	562,145	526,923	526,342	488,718
Total	**656,201**	**622,485**	**616,970**	**583,333**	**722,042**	**645,477**	**645,583**	**612,239**

Source: JICA Survey Team

<NOTE> *1 Mining operation will commence on schedule.

*2 Mining operation will be delayed for 5 years.

*3 Mining operation will be delayed for 10 years.

*4 Mining operation will be delayed for 15 years.

In addition, if power stations are not constructed as planned, coal prices may rise since production of coal does not increase.

In case coal prices are not reduced, the generation cost of Alternative 1 will be higher than other alternatives, as shown in Table 3.5-8 below.

For example, even if mining operation is started on schedule, in case the price of Thar coal is more than USD 3.7/MMBtu, Alternative 5 (Lakhra) will be more economical than Alternative 1 (mine mouth in Thar).

As for the four alternatives which use 100% Thar coal, if coal prices are not reduced as planned, the operation cost will saliently rise as shown in Table3.5-8. The operation costs of other alternatives are greatly dependent on coalfield development and the increase of power stations. It should be noted that the adopted economical coal price for this evaluation is unclear at the moment and is not committed as the implementation price of the Project.

Table 3.5-8 Comparison of Total Cost by Fluctuation of Coal Prices (Scenario 1)

Unit: Rs in millions

Coal Price	Alternative 1 Thar Thar Coal 100%	Alternative 2 Lakhra Thar Coal 100%	Alternative 3 Jamshoro Thar Coal 100%	Alternative 4 Karachi Thar Coal 100%	Alternative 5 Thar Mix (80% Bitu)	Alternative 6 Lakhra Mix (80% Bitu)	Alternative 7 Jamshoro Mix (80% Bitu)	Alternative 8 Karachi Mix (80% Bitu)
Original USD 2.8–1.8/MM Btu								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	316,962	355,862	355,836	348,975	517,870	517,335	516,172	482,161
Total	**471,593**	**518,288**	**519,166**	**516,790**	**677,768**	**635,889**	**635,413**	**605,682**
USD 3.0/MMBtu								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	431,727	469,659	469,634	460,578	528,652	528,059	526,896	492,660
Total	**586,358**	**632,086**	**632,964**	**628,393**	**688,549**	**646,613**	**646,137**	**616,181**
USD 3.7/MMBtu								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	522,673	559,839	559,814	549,019	537,195	536,557	535,394	500,980
Total	**677,304**	**722,265**	**723,143**	**716,833**	**697,093**	**655,111**	**654,635**	**624,501**
USD 4.0/MMBtu								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	561,650	598,487	598,462	586,922	540,857	540,199	539,036	504,546
Total	**716,281**	**760,914**	**761,792**	**754,737**	**700,754**	**658,753**	**658,277**	**628,067**
USD 5.0/MMBtu								
- Initial	154,631	162,426	163,329	167,815	159,897	118,554	119,241	123,521
- Operation	691,573	727,315	727,290	713,266	553,062	552,339	551,176	516,432
Total	**846,204**	**889,741**	**890,620**	**881,080**	**712,960**	**670,893**	**670,417**	**639,953**

Source: JICA Survey Team

3.5.3 Conclusion

(1) Mine Mouth in Thar

If coalfield development progresses well and on schedule, the total cost in case of the mine mouth in Thar would be the most economical due to coal price and transportation cost.

However, the expansion of transmission lines and securing of water supply when the number of power stations increases in Thar will be necessary.

Furthermore, the initial investment cost especially the construction cost is the highest.

The delay risk of development of Thar coalfield is high, and then, mine mouth in Thar would be mostly affected in total cost as discussed in 3.5.1 (1)

Consequently, the mine mouth in Thar site is judged to be eliminated as compared with the case of 80 % use of imported coal in the other candidate sites.

(2) Karachi Port Area

In consideration of using imported coal, the Karachi Port site has advantages of being able to reduce the initial investment cost and total cost including operation cost. In addition, generation efficiency is the highest since seawater is directly used for cooling water.

However, mangroves along the seaside and the possibility of expansion of power stations in this area make it difficult to comply with required standards.

Consequently, in terms of environmental impacts, the Karachi Port site is judged to be eliminated considering the construction site.

(3) Indus River

The Indus River sites by 80 % use of imported coal are the most economical in terms of initial investment cost. On the other hand, due to the use of imported coal as mixed with Thar coal, the operation cost is the highest. However, disadvantages and risks are extremely lower than the case of the mine mouth in Thar.

In addition, even if Thar coalfield development is delayed, the effect on operation of the power station is extremely low.

Comparing the two sites, the north of the Jamshoro Power Station site involves involuntary resettlement to some extent and requires land acquisition to a large extent. Furthermore, cumulative impact of emission gas from other plants should be considered.

On the other hand, as for the existing Lakhra Power Station site, involuntary resettlement and acquisition will not be needed. GENCO is currently considering privatization of the existing Lakhra Power Station due to low availability factor of it. There are still three options assumed as i) privatization from GENCO IV, ii) continuing operation by GENCO IV and iii) demolishment before / after commencement of operation of new Lakhra Power station. There would be several advantages with option ii) and iii).

Consequently, as a result of evaluation, <u>the Lakhra Power Station's site is judged as the most suitable construction site.</u>

3.6 Proposed Conceptual Plan

The most suitable site selected for the construction of the power station under the Project is Lakhra.

The proposed outline for the plant plan and plant efficiency is presented below. The power station under the Project has a plant size of 600 MW and involves ultra supercritical steam condition.

At present, there are two methods for the plant system depending on the usage of imported coal. The boiler type and plant efficiency depend on the characteristics of blended coal. Bituminous coal is more advantageous in terms of construction cost and operation cost as mentioned in Section 3.4.

On the other hand, in terms of availability of coal, there is information that subbituminous coal is more advantageous because demand for bituminous coal is higher in developed countries. In accordance with worldwide demand, the type and availability of coal are considered in Chapter 5.

The conceptual design is carried out as shown in Table 3.6-1.

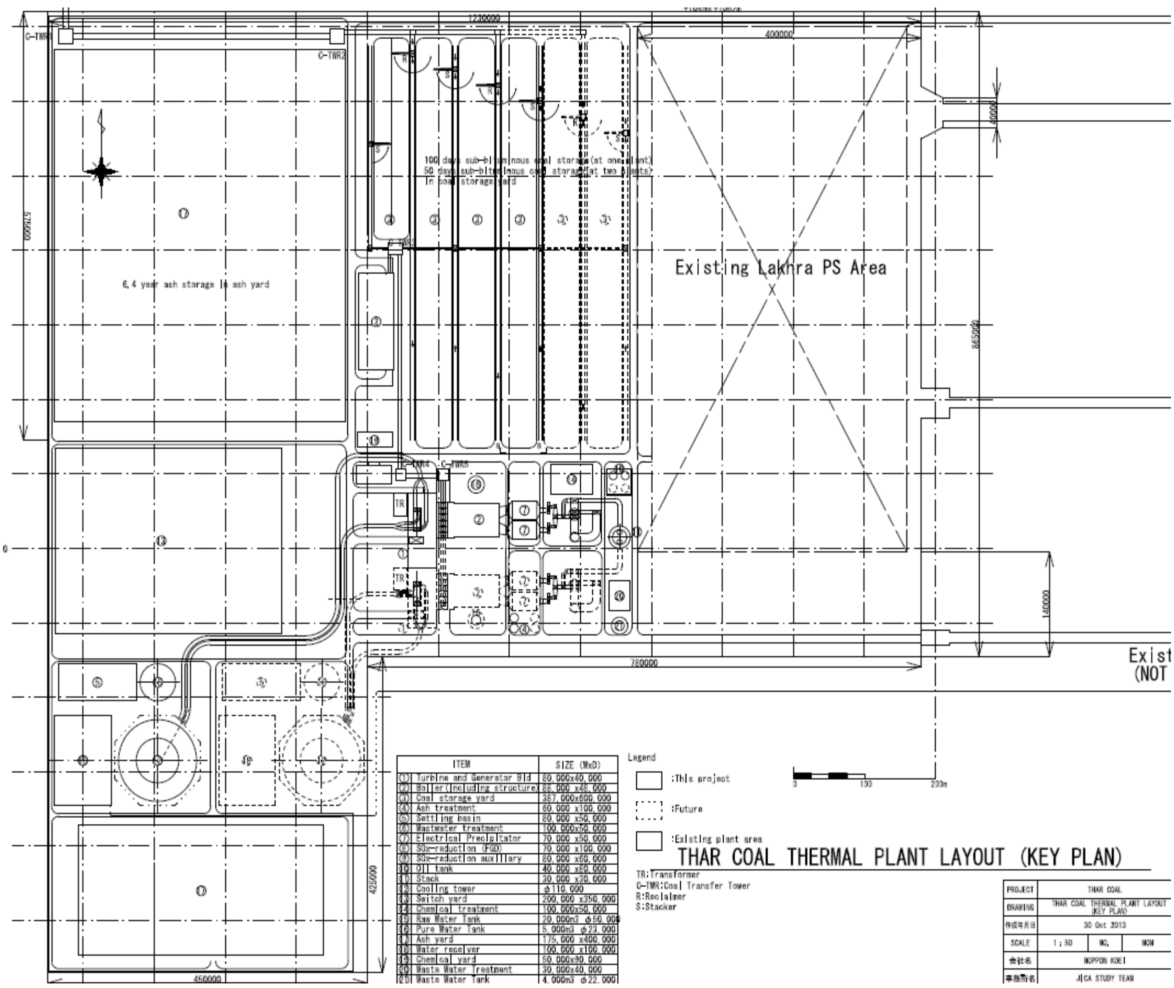
Table 3.6-1 Proposed Outline of the Plant Plan

Main Coal	Subbituminous 80% +Thar lignite 20%	Bituminous coal 80% + Thar lignite 20%
Plant System	Supercritical steam cycle	Same as on the left
Boiler	Subbituminous coal-fired balanced draft boiler	Bituminous coal-fired balanced draft boiler
Turbine	Single reheat condensing, tandem-compound turbine	Same as on the left
Generator	Totally enclosed, three phase, 50 Hz, synchronous machine	Same as on the left
Boiler Feed Pump	Turbine driven BFPs (50% x 2)	Same as on the left
Cooling Tower	Natural draft type cooling tower	Same as on the left
Plant Output (Net)	600 MW	600 MW
Plant Efficiency (Net) (HHV)	36.4%	36.9%
Plant Efficiency (Gross) (HHV)	38.9%	39.4%
Plant Efficiency (Gross) (LHV)	42.3%	42.3%
Main Steam Pressure	24.1 MPa	24.1 MPa
Main Steam Temperature	593 °C	593 °C
Hot Reheat Temperature	593 °C	593 °C
Condenser Vacuum	11.1kPa	11.1kPa

Note: Plant efficiency depends on characteristics of coals selected. Hence, the efficiencies mentioned above would be changed due to consideration of coal procurement in and after the next survey.

Source: JICA Survey Team

The proposed layout plan for the power station in the existing Lakhra Power Station site is shown in Figure 3.6-1.



Source: JICA Survey Team

Figure 3.6-1 Layout Plan of the Lakhra Power Station

CHAPTER 4
STATUS OF EXISTING LAKHRA POWER STATION

Chapter 4 Status of Existing Lakhra Power Station

4.1 History of Lakhra Power Station

4.1.1 Establishment of Lakhra Power Station

Several feasibility studies were conducted from 1967 to 1988 for the construction of the coal-fired power station in Lakhra, where about 1,300 million t of coal reserves were estimated.

In 1985, the Water and Power Development Authority (WAPDA) took in hand the preparation of PC-1 for the construction of 3x50 MW coal power plants. Dongfang Electric Corporation (DEC) of China provided supplier's credit to the project and consequently, the contracts for supply and erection of the mechanical/electrical equipment as well as the main civil works were signed in August 1989 and February 1990, respectively.

The 3x50 MW fluidized bed combustion (FBC) power station in Lakhra is an experimental power station. The FBC technology has been introduced for the first time. Even the contractor did not have sufficient expertise on this size of unit (50 MW). The Foster Wheeler and Company of USA, who designed the boilers after testing the coal samples from different locations of Lakhra coalfield, was contacted for the initial design of the FBC boilers. FBC is a relatively new technology for combusting low-grade and high-sulfur coal for power generation. In this system, coal and limestone are suspended (fluidized) throughout the furnace by means of air entering the furnace bottom.

The contractor faced a number of problems and carried out several modifications during the guarantee period. A lot of problems remained on boilers due to high sulfur and ash content in the coal. Consequently, erosion of different parts of the boiler is on the increasing trend. The continuous operation of boilers for longer periods, i.e., beyond 50 days, has not been achieved so far due to heavy clinker formation after burning coal. Therefore, the boilers are slopped and should be cleaned after operation of about 40 days.

The major data of the plant are as follows:

- Address: Indus Highway, Jamshoro District, Sindh Province
- Installed Capacity: 3X50 MW
- Area: 462.32 acres (Colony: 114 acres, Plant: 277.5 acres, Intake area: 12.32 acres, others 58.5 acres)
- Fuel: Lignite coal

- Coal Supply Source: Lakhra Coal Development Company (LCDC)
- Water Source: Indus River (9 m^3/sec) by underground pipe of 20" P/L
- Power Dispatch: Through three 132 kV transmission lines to Jamshoro

Table 4.1-1 Main Characteristics of the Plants

Unit	Type	Commissioning Date	Installed Capacity	Steam Condition	Boiler/Turbine Manufacturer	Fuel
1	Fluidized Bed Combustion	6 Jun.1995	50 MW	514 °C at 9.8 MPa	Dongfang Electric Corporation	Lignite Coal
2		14 Oct.1995				
3		3 Jan.1996				

Source: Lakhra Power Station

4.1.2 Taking Over of LPGCL

Lakhra Power Generation Company Limited (LPGCL) was established as a public limited company, which was incorporated under the Companies Ordinance instituted in February 2002, and started functioning on 1 July 2002. WAPDA granted the power station to LPGCL through Generation License #GL/06/2005 by NEPRA on 18 February 2005. Tariff was determined by NEPRA on 21 February 2005.

4.1.3 Lease Contract of the Plant

In 2003, the new management made a rehabilitation program amounting to Rs 441 million, which was scrutinized by a technical committee in June 2003 upon the directive of the Board of Directors. However, based on nondestructive testing by experts of WAPDA Central Workshop in Faisalabad and historical data of shutdowns, the areas of replacement were reduced amounting at Rs 254 million.

Before the replacement was materialized, WAPDA decided to lease out the power plants and related facility on rehabilitation, operation, maintenance, and management (ROMM) basis. On the results of an open bid, a lease agreement for 20 years was signed on 11 September 2006 between LPGCL and the Associated Power Generation Company. However, the labor union of the plant and Habibullah Energy Ltd., one of the bidders, filed a petition to the High Court of Sindh against its lease.

The High Court of Sindh decides in favor of leasing on both petitions. The litigators appealed to the Supreme Court of Pakistan against the decision of the High Court of Sindh. In August 2013, the Supreme Court finally judged to set aside the lease agreement as the process of leasing the power plant lacked transparency and the entire process of bidding violated the rules of the Public Procurement Regulatory Authority.

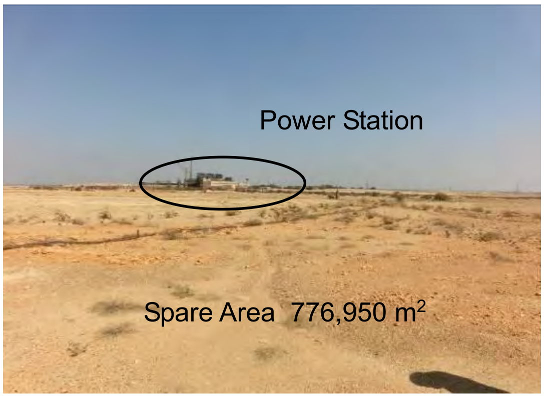
During the court case, LPGCL strived hard, rehabilitated Boiler No.1, and finally commissioned it in March 2007. Since then, the same unit has been successful under continuous operation on 35 MW. Major rehabilitation is needed for Boiler No. 2 and Boiler No. 3, which have not been in operation for a long period of time. Therefore, expenditure is far exceeding against revenue, and the annual deficit continue to rise since it closed for many years.

Source: JICA Survey Team

Photo 4.1-1 Bird's Eye View of the Lakhra Power Station

Source: JICA Survey Team

Photo 4.1-2 Overall View of the Lakhra Power Station



Source: JICA Survey Team

Photo 4.1-3 Spare Area

Source: JICA Survey Team

Photo 4.1-4 Coal Stockyard

Source: JICA Survey Team

Photo 4.1-5 Control Room

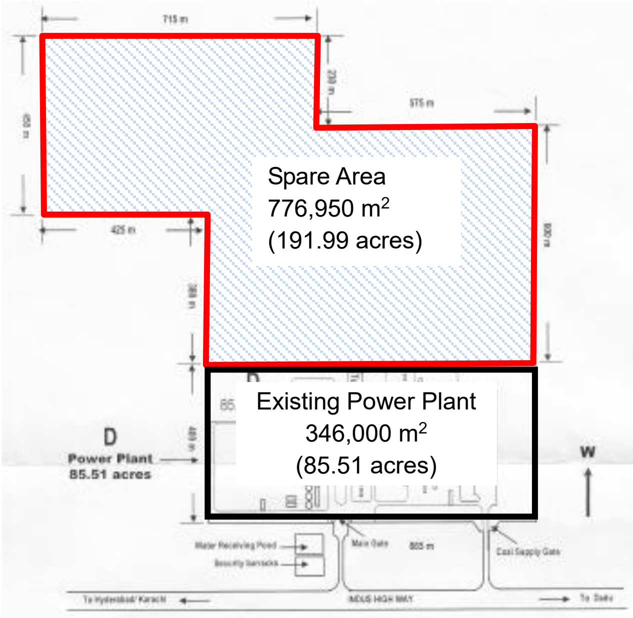
Source: JICA Survey Team

Photo 4.1-6 Turbine and Generator Unit No. 1

4.1.4 Privatization of the Plants

In February 2014, the Council of Common Interests (CCI) approved the privatization of the Lakhra power plants, because presently, the federal government has very limited resources to bear the losses of the power station.

According to the Ministry of Water and Power (MoWP), the extent of privatization is for the existing plant area only, which would not affect the Survey undertaken by the JICA Survey Team.



Source: JICA Survey Team on the Details of the Acquired Land by the Lakhra Power Station

Figure 4.1-1 Existing Plant Area and Spare Area

4.2 Operating Conditions

4.2.1 Operating Conditions

The major technical problems are listed as follows:

- Frequent tube leaks caused by ash erosion;
- Acceleration depreciation of equipment especially due to coal handling system erosion and corrosion caused by high sulfur content rate in coal;
- Acute shortage of cooling water, as the course of the Indus River changes and moves, which the intake point follows each time.

The station formulated the comprehensive refurbishment plan with an estimated cost of about Rs 1.5 billion several years before, and requested for the allocation of the budget from MoWP.

However, the budget has not been allocated yet.

Therefore, only Unit No.1 is able to operate at present, with its spare parts taken from the other units, namely, Unit No. 2 and Unit No. 3.

The recent five-year operation data is shown in Table 4.2-1 below.

Table 4.2-1 Operation Data

		2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Gross Generation	GWh	113	116	88	96	61
Send Output	GWh	84	86	66	66	40
Auxiliary Consumption	%	26	26	26	31	21
Maximum Load	MW	37	38	36	32	40
Load Factor	%	35	35	28	34	17
Operating Time	hrs	3,506	3,906	2,823	3,359	2,138
Total No. of Shutdown	time	18	17	9	26	15
Availability Factor	%	18	15	11	13	8
Thermal Efficiency (gross)	%	24	23	23	23	24

Source: Prepared by JICA Survey Team based on the data shared from GHCL

It seems hard to continue the operation due to the: 1) low availability factor of the plant and 2) severely deteriorated structures, unless major rehabilitation will be done. According to GHCL, the plant will be decommissioned within a few years.

4.2.2 Coal and Limestone

Initially, LCDC supplied 3,000 t of coal per day and the necessary limestone for the generation of 150 MW had been supplied by 20-ton trucks. However, in recent years, supply is only for 800 t per day as the output was derated to 35 MW.

The cost of coal and limestone including taxes and transportation are Rs 3,962 and Rs 1,500 per ton, respectively, as of February 2014.

4.3 Water Supply and Drainage System

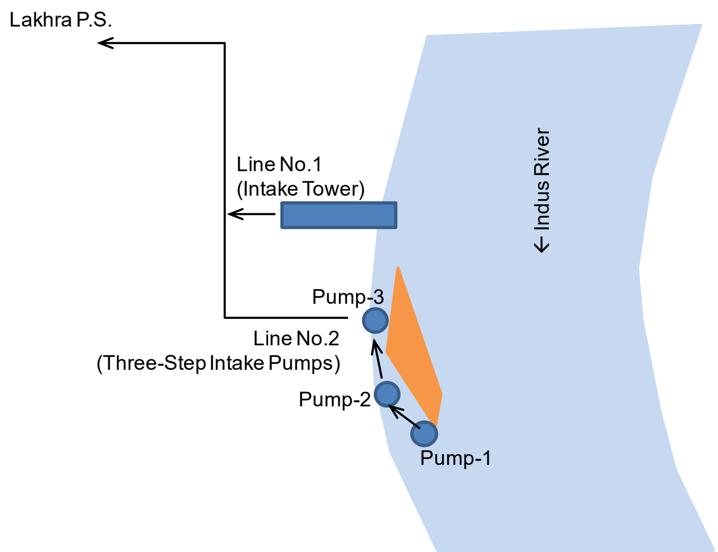
4.3.1 Water Supply System

The water used for the existing Lakhra Power Station is taken from the Indus River. As of 2014, there are two lines for the water intake facilities as described in Table 4.3-1 and Figures 4.3-1 and 4.3-2.

Table 4.3-1 Existing Water Intake Facilities of the Lakhra Power Station

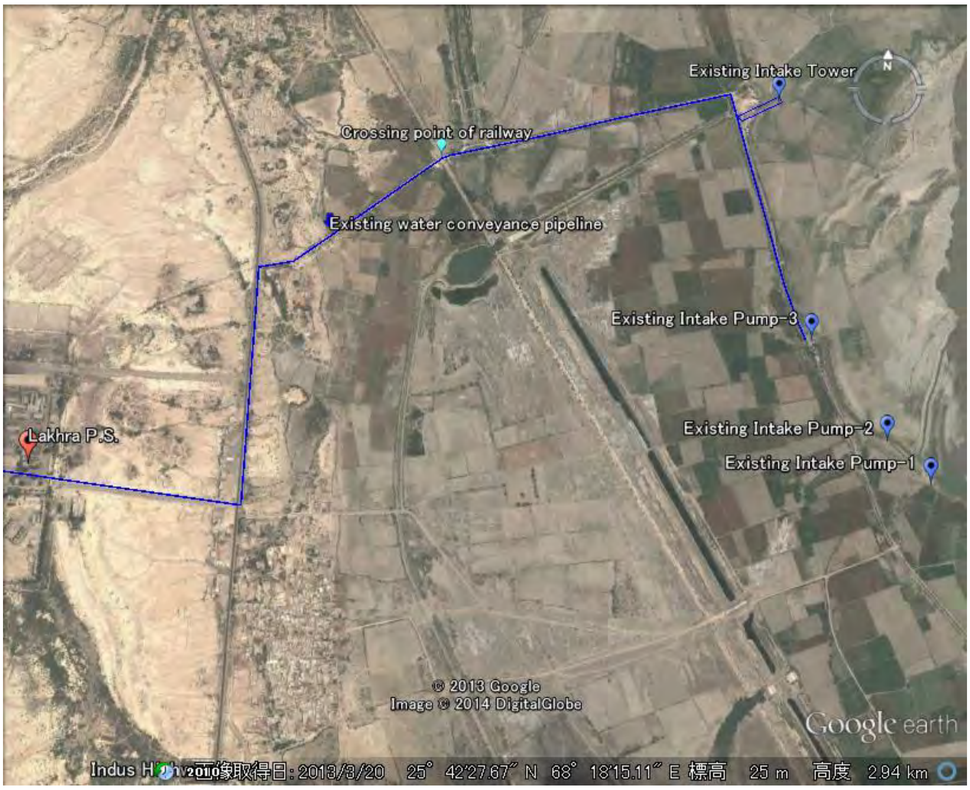
Line No.	Type of Water Intake Facility	Current Status
1	Intake tower	Operated during rainy season only
2	Intake pump station (3 locations)	Operated during dry season only

Source: JICA Survey Team



Source: JICA Survey Team

Figure 4.3-1 Outline of the Existing Water Intake Facilities of the Lakhra Power Station



Source: JICA Survey Team

Figure 4.3-2 Locations of the Existing Water Supply Facilities

Line No.1 is the main water intake facility, which is composed of a water intake tower. The intake pump has been installed near the river embankment and the river water around the intake tower is dries up during dry season. Consequently, this intake tower cannot be operated during dry season as shown in Photos 4.3-1 and 4.3.2.

Source: JICA Survey Team

Photo 4.3-1 Intake Tower

Source: JICA Survey Team

Photo 4.3-2 Intake Tower (distant view)

Line No. 2 is the alternative water intake facility for the existing Lakhra Power Station, which is composed of three intake pump stations. The water is taken from a small creek which is diverted from the mainstream of the Indus River. Firstly, the water of the mainstream of the Indus River is diverted to the small creek through Pump-1 or Pump-2. After that, 300 m^3/hr (0.083 m^3/sec) of water is conveyed to the Lakhra Power Station through Pump-3 with approximately 5 km of pipeline as shown from Photos 4.3-3 to 4.3-6. Line No. 2 is operated during the dry season only as an alternative to Line No.1.

Source: JICA Survey Team

Photo 4.3-3 Pump-1 (distant view)

Source: JICA Survey Team

Photo 4.3-4 Pump-1 (close-up view)

Source: JICA Survey Team

Photo 4.3-5 Pump-2

Source: JICA Survey Team

Photo 4.3-6 Pump-3 (distant view)

Source: JICA Survey Team

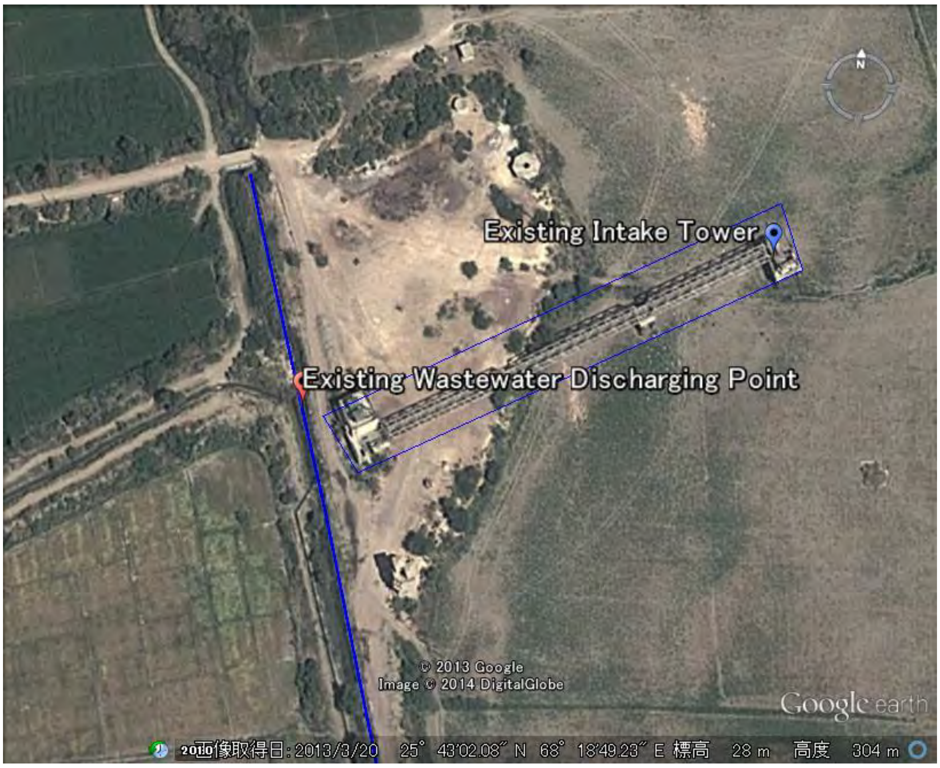
Photo 4.3-7 Pump-3 (Close-up view)

Source: JICA Survey Team

Photo 4.3-8 Water Conveyance Pipeline

4.3.2 Wastewater Drainage System

Currently, wastewater generated from the existing Lakhra Power Station is discharged to a small channel located near the existing water intake tower through a wastewater drainage pipeline. The location and current situation of the existing wastewater discharging point are shown in Figure 4.3-3 and Photos 4.3-9 and 4.3-10.



Source: JICA Survey Team

Figure 4.3-3 Location of the Existing Wastewater Discharging Point

Source: JICA Survey Team

Photo 4.3-9 Existing Wastewater Discharging Point

Source: JICA Survey Team

Photo 4.3-10 Existing Wastewater Discharging Point

4.4 Colony

The colony for the employees of the Lakhra Power Station is located about 3.5 km south of the power station with an area of approximately 46 ha (114 acres) and accommodates 685 houses, a mosque, a hospital, a primary school, a clubhouse, and guest houses. The area is fenced by rigid wall and secured by guards at the entrance gate for 24 hours. The buses for transporting employees to the power stations are running periodically.

Major facilities are shown in Photos 4.4-1 to 4.4-4.

Source: JICA Survey Team

Photo 4.4-1 Residential Street

Source: JICA Survey Team

Photo 4.4-2 Mosque

Source: JICA Survey Team

Photo 4.4-3 Commuter Bus for the Staff

Source: JICA Survey Team

Photo 4.4-4 Primary School

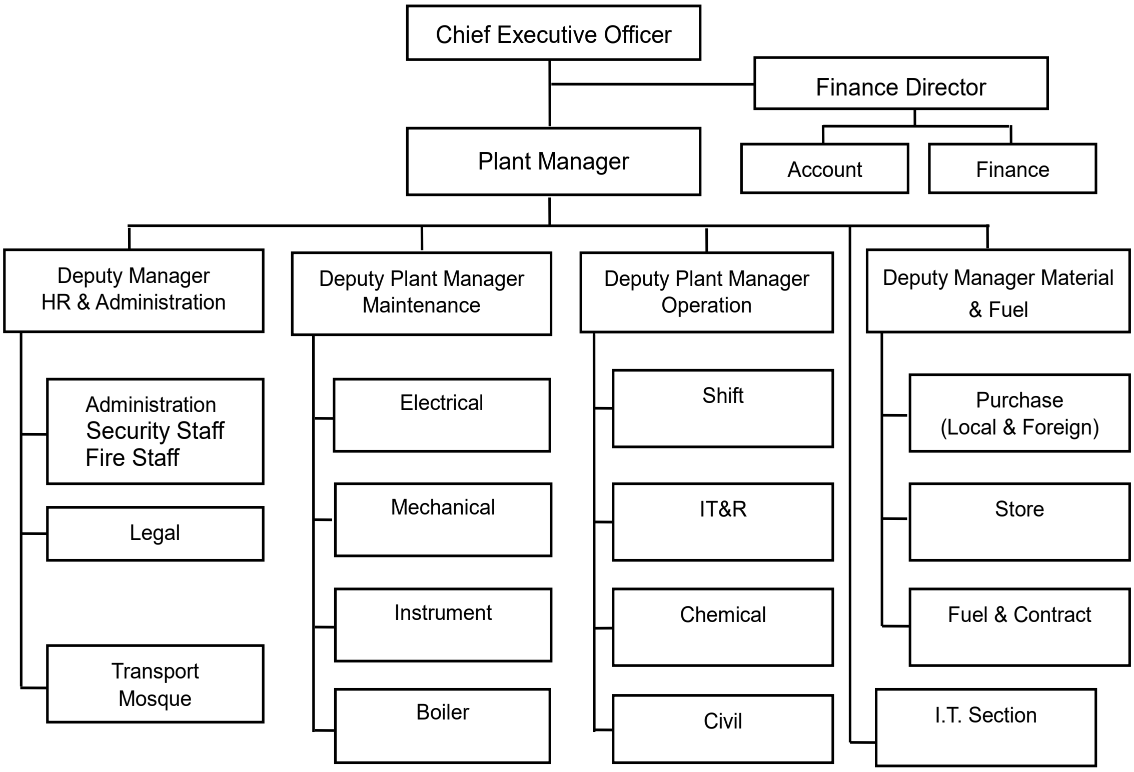
According to a staff of the Lakhra Power Station, about 70% of employees and their families live in the colony. About 287 houses out of 685 houses in total are vacant as of February 2014. Those vacant houses can be utilized for the staffs and their families of new Lakhra plant unless the existing Lakhra power plant will be privatized.

4.5 Organization

The organizational chart and number of staff of the Lakhra Power Station is shown in Figure 4.5-1 and Table 4.5-1.

The matter which economically affects the power station seems that its staff are not effectively distributed due to the manual operating facilities and job allocations. Most of the current facilities in the power station adapt manual operating system so allocation of a lot of personnel is needed as compared with other power stations, which perform at an equivalent output power. The manual operating system results in approximately 150 staff per shift, which causes a huge amount of operational cost. As for job allocation, operational items and tasks are subdivided into a lot of personnel, which resulted in a total of about 546 staff at present.

On the other hand, NEPRA recommends that around 381 employees are sufficient to operate the existing single operating unit according to the determination of tariff for LPGCL. NEPRA also advised that the staffs of the Lakhra Power Station are trained and well-experienced, hence, they should be utilized sufficiently.



Source: JICA Survey Team

Figure 4.5-1 Organizational Chart of the Lakhra Power Station

The organizational structure of the new Lakhra Power Station shall be considered based on the above situations. Details are proposed in Chapter 8.

Table 4.5-1 Number of Staff of the Lakhra Power Station

	Manager	Engineer*	Assistant/ Worker	Others	Total
Top Management	5				
Maintenance	11	24	81	39	155
Operation	17	93	95	71	276
(Per shift)	*(12)*	*(73)*	*(65)*	*(20)*	*(170)*
Material Management	3	3	7	8	21
IT	1	1			2
HR & Administration	3	11	10	204	228
(Security)	*1*			*(94)*	*(95)*
(Driver)				*(55)*	*(55)*
Finance	3	1	7	5	23
Total	43	133	200	437	705

*The number of engineers includes the engineers that hold a polytechnic diploma

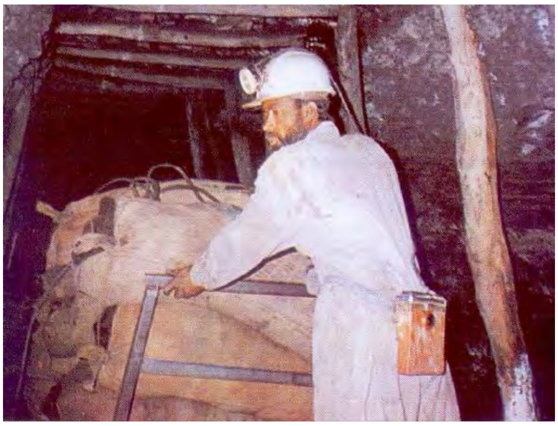
Source: JICA Survey Team based on the collected data from the Lakhra Power Station

4.6 Lakhra Coal Development Company Limited (LCDC)

LCDC, which was established through the joint venture of Pakistan Mineral Development Company (PMDC), Government of Sindh, and WAPDA, was set up to supply coal to the Lakhra Power Station which started generation in 1995. The mine of LCDC is located about 20 km west of the power station.

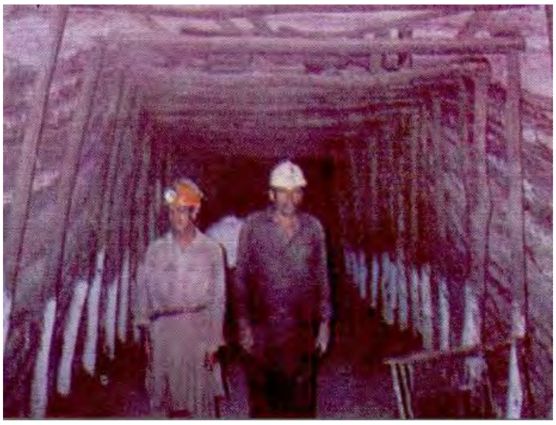
The production size of the mine is only for supplying coal for consumption of the power station. Specifically, from the period 1995-1996 to 1998-1998, it varied from 317,000 to 394,000 mtpa, respectively, for the generation 150 MW. However, since the output of the plant was derated, coal consumption has been reduced to 63,000 to 125,000 mtpa only from the period 2008-2009 to 2012-2013. Due to the decrease in coal consumption of the power station, LCDC has been selling the remaining coal to the open market.

Photos of the mining activities of LCDC are shown in Photos 4.6-1 to 4.6-4 below.



Source: LCDC Profile

Photo 4.6-1 Manual Coal Transportation in Coal Pit



Source: LCDC Profile

Photo 4.6-2 Coal Pit

Source: LCDC Profile

Photo 4.6-3 Coal Transportation

Source: LCDC Profile

Photo 4.6-4 Coal Loading on Truck

CHAPTER 5
FUEL SUPPLY PLAN

Chapter 5 Fuel Supply Plan

5.1 Procurement Policies

5.1.1 General

As mentioned in Section 3.4.1, 80% imported coal and 20% Thar coal will be blended and mixed for combustion at the 660 MW Lakhra Power Station.

However, in case the Thar coalfield development is delayed, 100% of imported coal will be used until the beginning of mining, as shown in Table 5.1-1.

Table 5.1-1 Usage of Coal

Condition	Usage of Coal	Transportation Method
Before Mining	Imported Coal: 100%	Railway from Port Qasim
After Mining	Imported Coal: 80%	Railway from Port Qasim
	Thar Coal: 20%	Truck from Thar

Source: JICA Survey Team

In consideration of current coal production, coal resources, coal consumption, and coal trade of each country, the possible procurement countries are assumed at the moment.

However, procured coal depends on the market trend and price at that time. Especially, since procurement of coal will be after five years at the earliest, it cannot be judged at the moment which country is most appropriate.

5.1.2 Procurement System

Approximately 4 mtpa coals are imported from abroad for supply cement, brick and textile industry, which are mainly from Indonesia and South Africa. There used to be 2 major importers namely Awan Trade and Seatrad Group shared to handle all above volume of coals supplying up to the consumers factories. In these years, Lucky Commodities, subsidiary company of Lucky Cement who had been purchased coal from above 2 trade companies, entered this business for their own coal supply. Now three companies do business in the field.

According to hearing from those traders, the cost of marine freight from South Africa is $18-22/ton, while that for Indonesia is $16 that includes insurance (<$1) to be paid by buyers. The cost of truck transportation to Islamabad area (approx. 1,200 km) is $40/ton, while Karachi area less than 70 km is $4/ton. One truck can transport 50-55 ton of coal.

For stable procuring the coal, they have contract to coal major such as Glencore and BHP or foreign trading company such as Itochu.

5.2 Coal Supply Option

New power plant in Lakhra will use approx. 2 mtpa in total which is based on mixture with imported coal and Thar coal.

5.2.1 Imported Coal

Since coal is one of the important energy sources for mankind, coal production and consumption are increased every year all over the world.

(1) Coal Resources

Proved reserves of coal at year-end of 2013 are shown in Table 5.2-1. Reserves of coal are about 891.5 billion tonnes in the world. The top five countries (up to India) with the most coal reserves account for 3/4 of the world's total.

Table 5.2-1 Proved Reserves at Year-end of 2013

Unit: million tonnes

No.	Name of Country	Anthracite and Bituminous	Subbituminous and Lignite	Total	Share of Total
1	United States	108,501	128,794	237,295	26.6%
2	Russian Federation	49,088	107,922	157,010	17.6%
3	PR of China	62,200	52,300	114,500	12.8%
4	Australia	37,100	39.300	76,400	8.6%
5	India	56,100	4,500	60,600	6.8%
6	Germany	48	40,500	40,548	4.5%
7	Ukraine	15,351	18,522	33,873	3.8%
8	Kazakhstan	21,500	12,100	33,600	3.8%
9	South Africa	30,156	-	30,156	3.4%
10	Indonesia	-	28,017	28,017	3.1%
11	Turkey	322	8,380	8,702	1.0%
12	Colombia	6,746	-	6,746	0.8%
13	Brazil	-	6,630	6,630	0.7%
14	Canada	3,474	3,108	6,582	0.7%
15	Poland	4,178	1,287	5,465	0.6%
16	Greece	-	3,020	3,020	0.3%
17	Bulgaria	2	2,364	2,366	0.3%
18	Pakistan	-	2,070	2,070	0.2%
19	Hungary	13	1,647	1,660	0.2%
20	Thailand	-	1,239	1,239	0.1%
21	Mexico	860	351	1,211	0.1%
22	Czech Republic	181	871	1,052	0.1%
	Other	7,379	25,410	32,789	3.7%
	Total World	403,199	488,332	891,531	100%

Source: BP Statistical Review of World Energy, June 2014

(2) Coal Production

The total world coal production reached 7,830.8 million t in 2012, increasing by 2.9% from 2011 as shown in Table 5.2-2 below.

Table 5.2-2 Total World Coal Production

Unit: million tonnes

	2010	2011	2012
Steam Coal	5,437.3	5,726.6	5,942.4
Coking Coal	911.6	970.0	983.8
Lignite	861.0	911.0	904.6
Peat	17.5	16.5	*
Total Coal	7,209.9	7,607.6	7,830.8

Note: * : Total coal excludes peat
Source: Coal Information 2013

A coal-fired thermal power plant mainly utilizes steam coal (i.e., bituminous and subbituminous) in the above classification.

Steam coal production is shown in Table 5.2-3 and Figure 5.2-1. Steam coal production in the world increased in recent years. The top four steam coal producing countries (up to Indonesia) accounted for 3/4 of the world's total production. Indonesia, the Russian Federation, and Australia increased noticeably.

Table 5.2-3 Major Steam Coal Producers

Unit: million tonnes

	2010	2011	2012
PR of China	2,680.7	2,909.3	3,038.6
United States	856.5	850.7	782.0
India	491.3	495.6	504.3
Indonesia	322.8	357.5	440.0
South Africa	252.7	251.1	258.5
Russian Federation	178.7	179.9	201.5
Australia	189.4	184.5	200.3
Kazakhstan	91.7	95.7	107.6
Colombia	70.5	81.8	85.5
Poland	65.1	65.0	68.1
Ukraine	40.0	49.9	53.9
Vietnam	44.8	44.5	42.1
DPR of Korea	32.0	39.1	39.2
Canada	29.5	27.9	26.0
United Kingdom	18.1	18.2	16.5
Mexico	11.2	13.7	13.0
Other	62.3	62.2	65.3
World	5,437.3	5,726.6	5,942.4

Source: Coal Information 2013

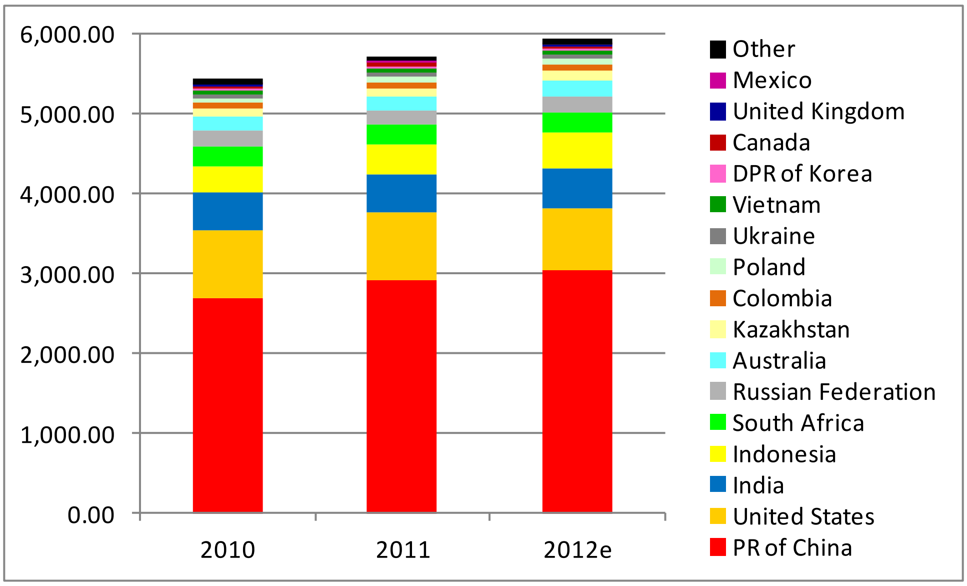


Figure 5.2-1 Major Steam Coal Producers

Source: Prepared by the JICA Survey Team based on Coal Information 2013

(3) Coal Consumption

Major steam coal consumers are shown in Table 5.2-4 and Figure 5.2-2. World steam coal consumption increased by 2.4% in 2012 with a total of 5,813.6 million t. Coal consumption in China and India have been increased.

Table 5.2-4 Major Steam Coal Consumers

Unit: million tonnes

	2010	2011	2012
PR of China	2,698.6	2,960.1	3,086.5
United States	862.3	826.1	730.7
India	565.0	588.4	625.9
South Africa	186.3	182.8	185.0
Japan	127.7	120.3	131.6
Russian Federation	97.8	93.6	116.9
Korea	92.8	98.3	95.7
Kazakhstan	61.1	65.6	76.3
Poland	72.5	71.6	64.1
Indonesia	57.8	59.7	60.2
Australia	61.9	58.2	59.7
United Kingdom	45.1	45.2	58.5
Chinese Taipei	57.8	60.6	56.1
Ukraine	39.7	45.4	51.9
Germany	43.5	41.5	40.9
DPR of Korea	27.4	27.9	28.3
Other	314.0	331.0	345.3
World	5,411.3	5,676.7	5,813.6

Note: Steam coal comprises anthracite, other bituminous coal, and subbituminous for all countries

Source: Coal Information 2013

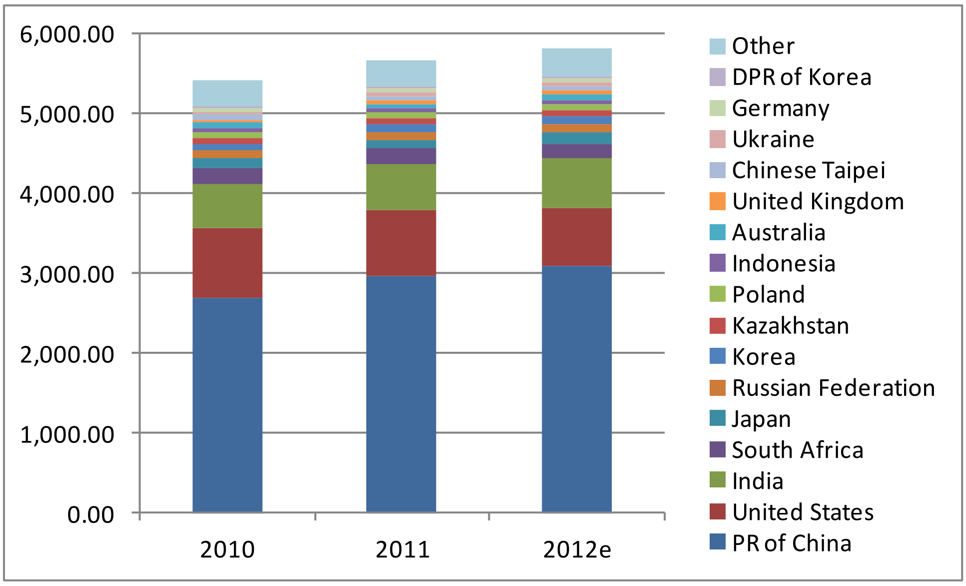


Figure 5.2-2 Major Steam Coal Consumers

Source: Prepared by the JICA Survey Team based on Coal Information 2013

(4) Coal Trade

Exporters of major steam coal are shown in Table 5.2-5 and Figure 5.2-3. Indonesia further increased their export and their world steam coal market share is approximately 40%. Following Indonesia are Australia, the Russian Federation, Colombia, and South Africa with respective shares of approximately 17%, 12%, 9%, and 8%.

Table 5.2-5 Major Steam Coal Exporters

Unit: million tonnes

	2010	2011	2012
Indonesia	265.0	297.8	379.8
Australia	135.4	144.1	159.2
Russian Federation	114.2	109.6	115.9
Colombia	66.9	77.9	81.7
South Africa	66.4	68.4	73.6
United States	23.0	34.1	50.6
Kazakhstan	29.1	29.8	31.3
Vietnam	19.7	17.7	19.1
DPR of Korea	4.6	11.2	12.0
PR of China	20.2	18.1	8.8
Poland	8.2	5.3	5.4
Ukraine	5.9	6.7	5.3
Other	30.6	36.8	20.0
World	789.2	857.5	926.7

Source: Coal Information 2013

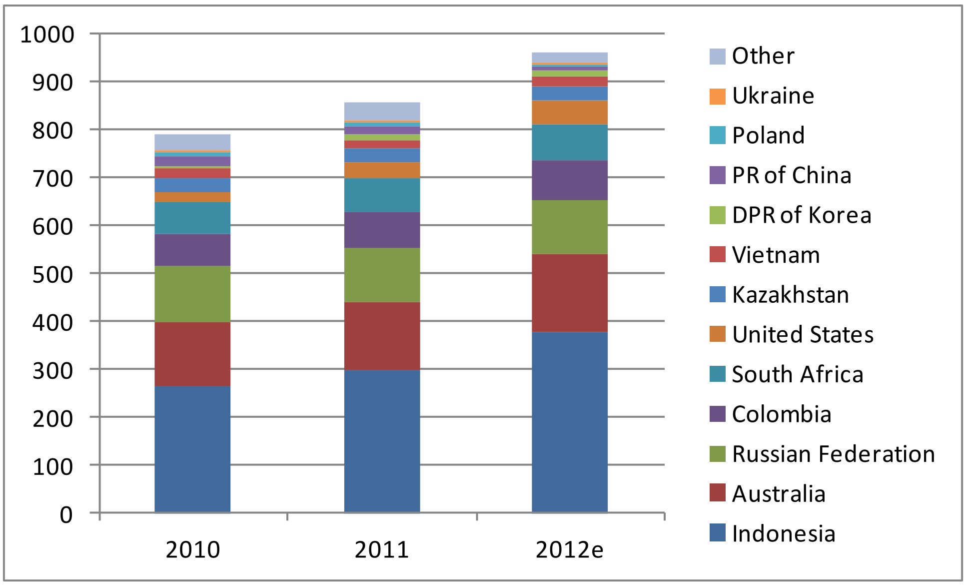


Figure 5.2-3 Major Steam Coal Exporters

Source: Prepared by the JICA Survey Team based on Coal Information 2013

On the other hand, importers of major steam coal are shown in Table 5.2-6 and Figure 5.2-4. The People's Republic of China further increased and their world steam coal market share is approximately 22%. Following the People's Republic of China are Japan, India, and Korea with respective shares of approximately 13%, 12%, and 10%.

Table 5.2-6 Major Steam Coal Importers

Unit: million tonnes

	2010	2011	2012
PR of China	116.0	137.3	218.1
Japan	127.7	120.3	131.6
India	81.3	98.2	123.0
Korea	90.4	96.9	94.3
Chinese Taipei	57.6	60.6	56.1
United Kingdom	19.9	26.6	40.0
Germany	37.9	39.1	35.9
Russian Federation	24.0	23.1	31.4
Malaysia	20.7	21.9	22.0
Turkey	16.2	16.9	21.1
Spain	10.0	13.7	20.2
Italy	17.0	17.9	19.8
Thailand	16.8	19.5	16.8
Israel	12.3	12.5	14.7
Hong Kong (China)	10.3	12.5	12.6
Other	147.8	150.5	131.7
World	806.1	867.3	989.3

Source: Coal Information 2013

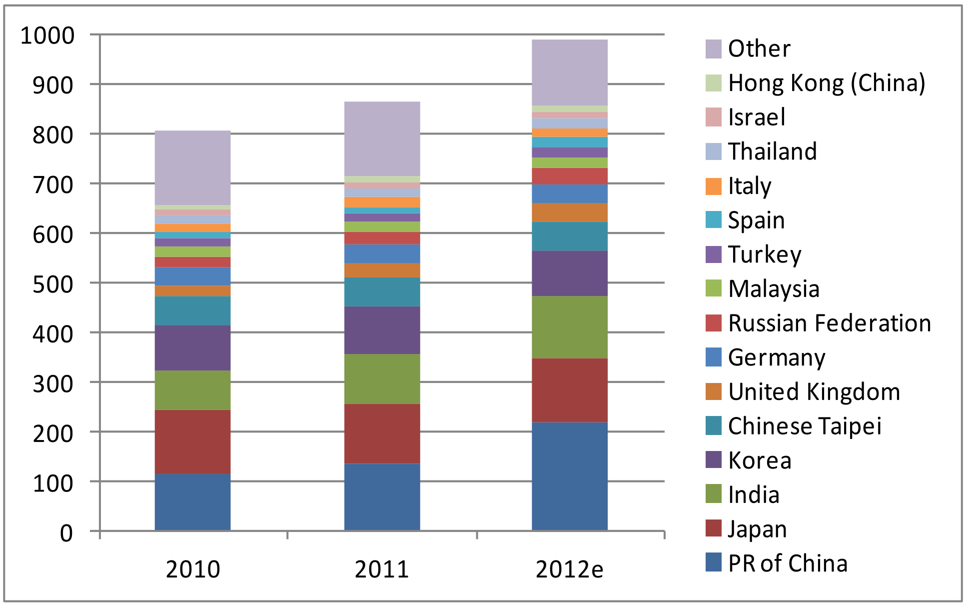


Figure 5.2-4 Major Steam Coal Importers

Source: Prepared by the JICA Survey Team based on Coal Information 2013

In consideration of the production and export situation as mentioned above and geographical conditions, Indonesia, Australia, and South Africa are the candidates for importing coal at present. The situation of the three countries is as follows.

(5) Indonesia

1) Production and Exports of Steam Coal

As described in Figure 5.2-3, Indonesia has the largest value of imported coal among major steam coal exporters. The situation of steam coal production and exports of Indonesia is shown in Table 5.2-7. Among the total coal produced, 86% is exported.

Table 5.2-7 Production and Exports of Steam Coal

Unit: million tonnes

	2010	2011	2012
Steam Coal Production	322.8	357.5	440.0
Coal Exports	265.0	297.8	379.8

Source: Coal Information 2013

In addition, the long-term outlook of Indonesian coal is shown in Figure 5.2-5. Coal exports will be approximately 6,550 million tonnes in 2025.

However, on the other hand, the Indonesian government has considered for the number of coal-fired power stations be increased as a government policy; hence, there is a possibility that domestic consumption will increase.

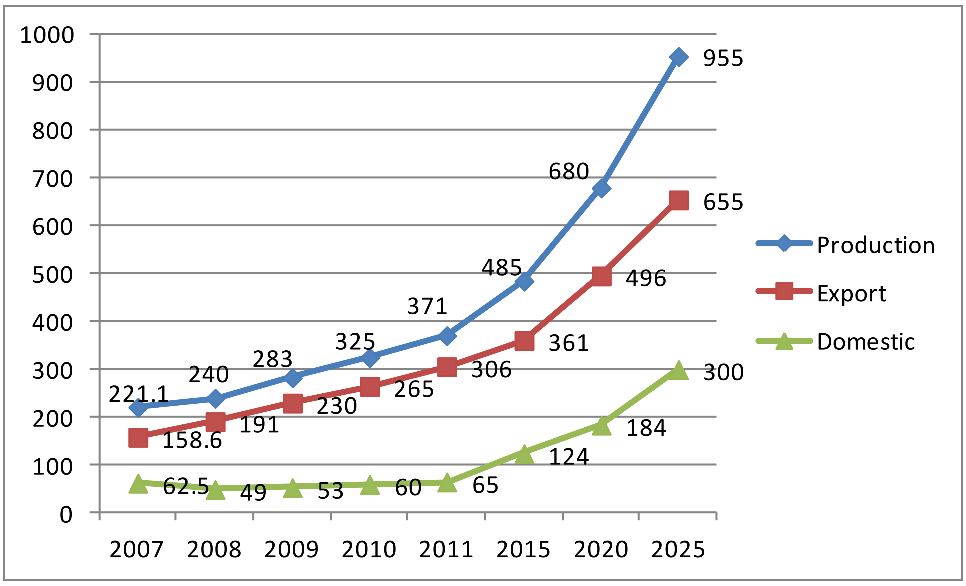


Figure 5.2-5 Long-Term Outlook of Indonesian Coal

Source: Indonesian Coal Mining Association

Steam coal exports from Indonesia are shown in Table 5.2-8. The People's Republic of China further increased and their world steam coal market share is approximately 22%. Following the People's Republic of China are Japan, India, and Korea with respective shares of approximately 13%, 12%, and 10%.

Table 5.2-8 Steam Coal Exports from Indonesia

Unit: 1,000 t

Name of Country	1990	2000	2005	2010	2011	2012
PR of China	105	142	1,008	57,430	69,984	115,557
India	110	3,373	11,657	44,990	71,099	96,200
Korea	33	4,825	12,885	43,102	38,482	41,478
Japan	663	13,101	19,511	35,746	32,924	33,685
Chinese Taipei	546	11,786	19,132	21,280	24,634	27,193
Hong Kong, China	660	2,816	9,826	8,725	11,685	11,790
Spain	-	2,793	3,146	2,616	3,433	5,970
Italy	-	1,637	2,422	6,835	5,768	3,836
United States	-	627	1884	1583	805	416
Russian Federation	-	-	-	-	75	81
Turkey	-	-	-	46	228	53
United Kingdom	-	-	1,772	165	-	56
Netherlands	133	2,700	1,076	2,804	504	-
Mexico	-	-	-	-	69	-
Germany	38	105	109	-	33	-
Greece	-	133	80	36	-	-
France	-	-	306	-	-	-
Brazil	-	468	146	-	-	-
Portugal	-	70	119	-	-	-
Belgium	6	-	6	-	-	-
Poland	-	7	-	-	-	-
Other	2,350	10,803	34,215	40,387	46,653	46,296
Total World	4,574	54,480	118,396	265,000	297,836	382,421

Source: Coal Information 2013

Table 5.2-9 shows coal production and sales of Indonesian coal. In Indonesia, Adaro Indonesia, Arutmin Indonesia, Berau Coal, Indominco Mandiri, Kaltim Prima Coal, Kideco Jaya Agung, and Tambang Batubara Bukit Asam are stable coal producers with over 10 mtpa in 2011.

Table 5.2-9 Coal Production and Sales of Indonesian Coal

No	Company	Production		Domestic Sales		Export	
PKP2B[*1] and Stated-owned							
1	Adaro Indonesia, PT[*2]	42.20	47.67	10.36	10.66	32.08	36.56
2	Antang Gunung Meratus, PT	0.75	1.40	0.75	1.18	0.00	0.11
3	Arutmin Indonesia, PT	20.43	22.83	3.30	4.13	17.14	18.64
4	Asmin Koalindo Tuhup, PT	1.74	2.86	0.00	0.01	1.44	1.52
5	Bahari Cakrawala Sebuku, PT	1.10	1.51	0.01	0.00	1.08	1.68
6	Bangun Bauna Persada Kalimantan, PT	0.61	0.94	0.75	0.85	0.00	0.00
7	Baramarta, PD[*3]	2.53	4.43	2.53	4.43	0.00	0.00
8	Batu Alam Selaras, PT	0.05	0.04	0.04	0.04	0.00	0.00
9	Baturona Adimulya, PT	0.28	0.53	4.42	0.36	0.05	0.24
10	Berau Coal, PT	17.38	19.44	4.42	2.47	12.65	17.35
11	Borneo Indobara, PT	1.12	2.75	0.07	0.29	0.76	2.22
12	Firman Ketaun Perkasa, PT	0.49	1.27	0.00	0.00	0.47	1.27
13	GunungBayan Pramacoal, PT	4.05	3.46	3.00	2.01	1.04	1.30

14	Indominco Mandiri, PT	14.25	14.76	0.87	1.55	13.63	13.31
15	Insani Baraperkasa, PT	2.25	4.22	0.13	0.35	2.11	3.79
16	InterexSacra Raya, PT	0.09	0.00	0.08	0.00	0.00	0.00
17	Jorong BatutamaGreston, PT	0.90	1.43	0.27	0.44	0.76	0.98
18	Kadya Caraka Mulia, PT	0.04	0.23	0.05	0.20	0.00	0.00
19	Kalimantan Energi Lestari, PT	0.00	0.00	0.00	0.00	0.00	0.00
20	Kaltim Prima Coal, PT	39.95	40.45	3.95	5.48	36.06	34.98
21	Kartika Selabumi Mining, PT	0.26	0.29	0.08	0.04	0.16	0.23
22	Kideco Jaya Agung, PT	29.05	31.39	6.60	7.43	22.42	24.36
23	Lanna Harita Indonesia, PT	1.98	2.24	0.01	0.04	2.10	2.14
24	Mahakam Sumber Jaya, PT	5.30	7.98	0.61	0.42	4.58	7.54
25	Mandiri Intiperkasa, PT	2.98	3.07	0.01	0.06	2.98	3.00
26	Marunda Grahamineral, PT	1.34	0.96	0.00	0.01	1.44	0.85
27	Multi Harapan Utama, PT	1.83	1.31	0.00	0.00	1.91	1.12
28	Multi Tanpangiaya Utama, PT	0.64	0.45	0.08	0.06	0.56	0.43
29	Nusantara Termal Coal, PT	1.45	1.12	0.14	0.82	0.00	0.00
30	Pendoro Energi Batubara	0.00	0.01	0.00	0.01	0.00	0.00
31	Persaka Inakakerta, PT	2.69	3.13	0.00	0.00	2.63	3.06
32	Pesona Khatulistiwa Nusantara, PT	0.71	1.30	0.28	0.71	0.38	0.62
33	Riau Bara Harum, PT	2.22	1.55	0.00	0.18	2.41	1.47
34	Santan Batubara, PT	1.99	1.72	0.14	0.00	1.92	1.66
35	Senamas Energindo Mulia, PT	0.05	0.00	0.05	0.00	0.00	0.00
36	Singlurus Pratama, PT	1.10	1.75	0.00	0.00	1.22	1.71
37	Sumber Kurnia Buana, PT	0.72	0.91	0.79	0.75	0.00	0.02
38	Tambang Batubara Bukit Asam, PT	11.92	12.39	8.31	8.80	4.66	4.71
39	Tanito Harum, PT	3.51	2.47	1.15	0.76	2.34	1.63
40	Tanjung Alam Jaya, PT	0.96	0.81	0.99	0.78	0.24	0.00
41	Teguh Sinar Abadi, PT	1.09	1.29	0.00	0.00	1.37	0.97
42	Trubaindo Coal Mining, PT	5.55	7.02	2.55	2.66	2.98	4.16
43	Wahata Baratama Mining, PT	2.57	4.23	0.00	0.00	2.42	4.18
	Subtotal	230.11	257.63	56.78	58.01	177.99	197.79
KP*4 and Cooperatives							
1	East Kalimantan	22.52	46.33	5.83	9.40	9.88	33.09
2	South Kalimantan	17.02	29.14	5.47	8.63	0.00	28.72
3	Central Kalimantan	0.79	2.86	0.31	0.00	0.08	0.71
4	Riau	0.78	0.02	0.23	0.00	0.08	0.01
5	West Sumatra	0.79	2.78	0.16	0.68	0.11	0.00
6	Bengkulu	0.45	5.96	0.05	1.19	0.08	2.39
7	Jambi	1.05	0.00	0.39	0.00	0.09	4.17
8	South Sumatra	1.65	8.56	0.91	1.65	0.07	5.77
	Subtotal	45.05	95.64	13.35	21.55	10.38	74.88
	Total	275.16	353.27	70.13	79.56	188.37	272.67

Source: Indonesian Coal Book 2012/2013

<NOTE> *1 PKP2B (Perjanjiau Kontrak Penambangan Batubara) : Coal Mining Concession Agreement
*2 PT (Perseroan Terbatas) : Company Limited
*3 PD (Persahaan Dagang) : Trading Company
*4 KP (Kuasa Pertambangan) : Mining Authority

2) Transportation

Coal is mainly produced in the Sumatra and Kalimantan islands. Railway transportation is carried out in limited parts of South Sumatra, and as for the rest, coal is mainly transported to the river by trucks, and transported offshore by barge carriers. Subsequently, coal is transhipped and finally transported to destination countries. Transhipment points are shown in Table 5.2-10 below.

Table 5.2-10 Transshipment Points

Port Name	Location	User	Handling Capacity (t/day)
Teluk Adang	East Kalimantan	Kideco	8,000 – 12,000
PTeluk Apar	East Kalimantan	Various	8,000 – 10,000
Mura Berau / Muara Jawa	East Kalimantan	Various	8,000 – 10,000
Muara Pantai	East Kalimantan	Berau Coal	12,000 – 20,000
Tarakan	East Kalimantan	MIP, Adani	8,000 – 10,000
Jorong	East Kalimantan	Jorong Barutama	8,000 – 12,000
Sebuku	South Kalimantan	Bahari Cakrawala	8,000 – 12,000
Muara Satui	South Kalimantan	Arutmin, Various	8,000 – 10,000
Taboneo	South Kalimantan	Adaro, Various	8,000 – 20,000
Tanjung Petang	South Kalimantan	Arutmin, Various	8,000 – 12,000
Tanjung Pemancingan	South Kalimantan	Arutmin, Various	5,000 – 7,000

Source: Indonesian Coal Book 2012/2013

The marine transport route map is shown in Figure 5.2-6. The distance from Kalimantan, Indonesia to Pakistan is approximately 3,950 NM, and the required travel time is more than 13 days.

Figure 5.2-6 Marine Transport Route Map between Indonesia and Pakistan

Source: Prepared by the JICA Survey Team based on UN Map

(6) Australia

1) Production and Exports of Steam Coal

Coalfields in Australia are concentrated in Queensland and New South Wales. The situation of steam coal production and exports is shown in Table 5.2-11. Among the total coal produced, 79% is exported.

Table 5.2-11 Production and Exports of Steam Coal

Unit: million tonnes

	2010	2011	2012
Steam Coal Production	189.4	184.5	200.3
Coal Exports	135.4	144.1	159.2

Source: Coal Information 2013

In addition, the long-term outlook of Australian coal is shown in Figure 5.2-7. As a government policy, the amount of coal exports has a tendency to increase.

On the other hand, domestic coal consumption has decreased, and its amount is scheduled to be supplemented with oil and gas.

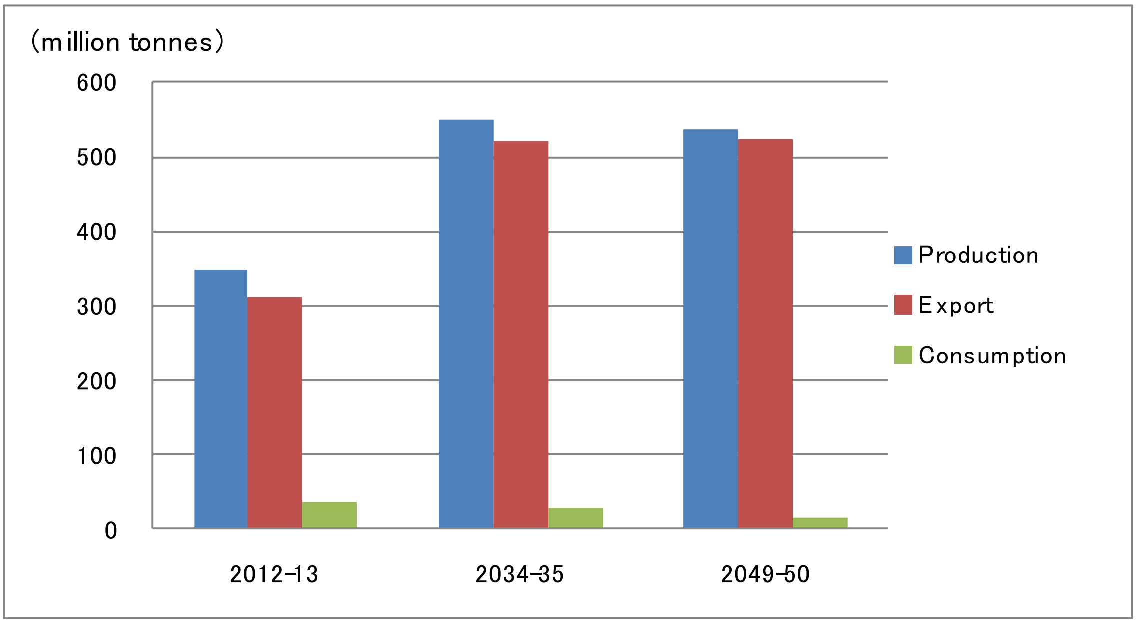


Figure 5.2-7 Long-Term Outlook of Australian Coal as of 2011

Source: Prepared by JICA Survey Team based on Australian Energy Projections to 2049-50, December 2012, BREE

Steam coal exports from Australia are shown in Table 5.2-12. At present, Japan is Australia's top export market for coal with a share of approximately 44%. Following Japan are the People's Republic of China, Korea, and Chinese Taipei with respective shares of approximately 19%, 18%, and 11%.

Table 5.2-12 Steam Coal Exports from Australia

Unit: thousand tonnes

Name of Country	1990	2000	2005	2010	2011	2012e
Japan	26,569	47,449	57,574	66,413	66,961	69,817
PR of China	2,443	1,429	2,121	15,192	17,867	29,968
Korea	3,633	11,452	17,970	24,840	28,273	28,925
Chinese Taipei	3,046	10,034	14,329	19,553	20,124	17,516
Mexico	-	-	4,238	3,109	1,703	3,595
India	47	2,469	1,461	610	495	1,165
Israel	528	2,623	1,165	516	501	494
Chile	120	1,301	412	309	691	388
Sweden	155	83	164	73	145	39
New Zealand	-	16	56	59	58	22
United States	31	127	102	167	318	-
Brazil	158	-	33	20	41	-
Netherlands	4,236	2,550	760	127	-	-
France	934	434	469	66	-	-
United Kingdom	328	1,499	993	13	-	-
Spain	205	1,445	671	-	-	-
Ireland	133	284	568	-	-	-
Italy	-	428	141	-	-	-
Germany	125	72	115	-	-	-
Turkey	-	55	45	-	-	-
Belgium	129	428	17	-	-	-
Denmark	1,149	142	-	-	-	-
Greece	-	110	-	-	-	-
Romania	33	-	-	-	-	-
Switzerland	29	-	-	-	-	-
Other	1,615	3,371	4,011	4,289	6,904	7,223
Total World	45,646	87,801	107,415	135,356	144,081	159,152

Source: Coal Information 2013

2) Transportation

Major coal loading ports are located in Queensland and New South Wales as shown in Table 5.2-13 and Figure 5.2-8. Total handling capacity of their ports is more than 330 million tonnes per year.

Table 5.2-13 Coal Export Ports

Port	State
Port of Abbot Point	Queensland
Port of Hay Point	Queensland
Port of Gladstone	Queensland
Port of Brisbane	Queensland
Port of Newcastle	New South Wales
Port Kembla	New South Wales

Source: JICA Survey Team

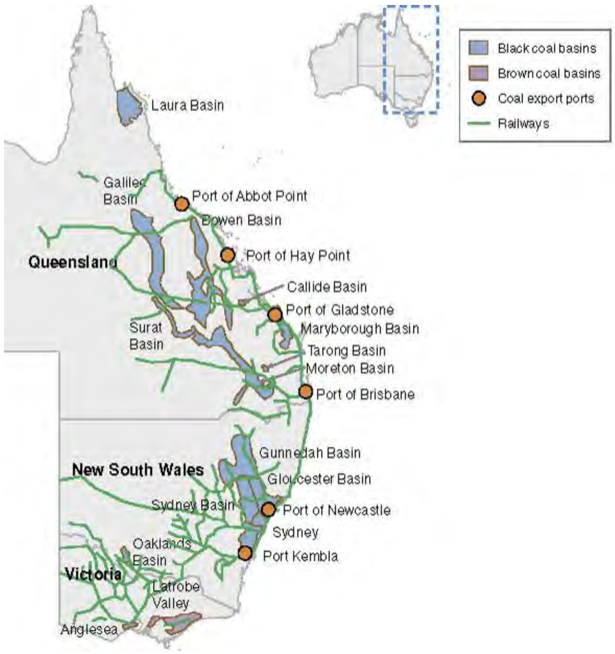


Figure 5.2-8 Location Map of the Coalfield and Export Ports

Source: Newcastle Coal Infrastructure Group

The marine transport route map between Australia and Pakistan is shown in Figure 5.2-9. The distance from Newcastle, Australia to Pakistan is approximately 6,540 NM, and the required travel time is more than 21 days.

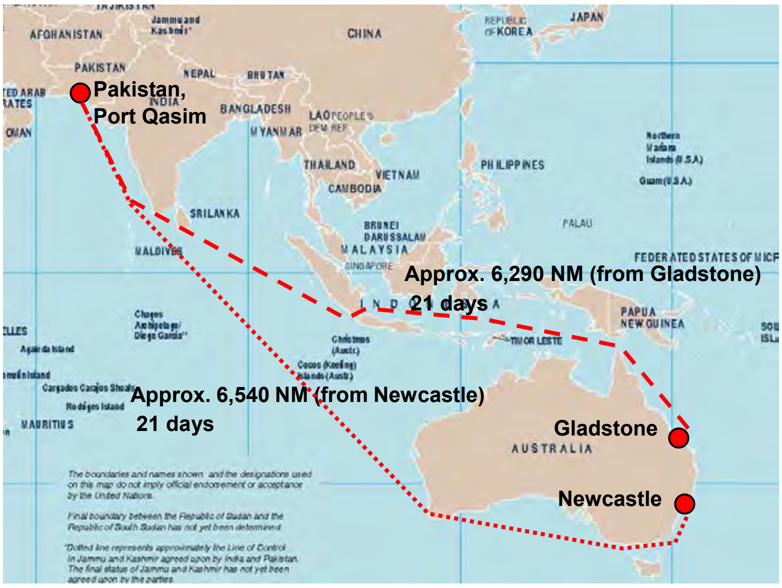


Figure 5.2-9 Marine Transport Route Map between Australia and Pakistan

Source: Prepared by the JICA Survey Team based on Coal Information 2013

(7) South Africa

1) Production and Exports of Steam Coal

The situation of steam coal production and exports is shown in Table 5.2-14. Among the total coal produced, 28% is exported. Since South Africa is the most dependent on coal for thermal power generation in the world, there is a lot of domestic consumption of mined coal.

Table 5.2-14 Production and Exports of Steam Coal

Unit: million tonnes

	2010	2011	2012
Steam Coal Production	252.7	251.1	258.5
Coal Exports	66.4	68.4	73.6

Source: Coal Information 2013

A map of coalfields in South Africa is shown in Figure 5.2-10. Proved reserves of coal in South Africa are mainly anthracite coal and bituminous coal.

Figure 5.2-10 Map of Coalfields in South Africa

Source: Prepared by the JICA Survey Team based on the UN Map

Steam coal exports from South Africa are shown in Table 5.2-15. At present, India is South Africa's top export market for coal, with a market share of approximately 29%. Following India are the People's Republic of China, and Chinese Taipei with respective shares of approximately 18%, and 6%.

Table 5.2-15 Steam Coal Exports from South Africa

Unit: thousand tonnes

Name of Country	1990	2000	2005	2010	2011	2012e
India	-	3,636	3,587	23,440	16,198	20,985
PR of China	-	522	-	4,226	11,870	13,171
Chinese Taipei	5,685	2,488	522	2,566	3,862	4,767
Israel	2,583	5,523	5,329	2,826	3,319	4,753
Italy	4,884	4,173	4,939	3,236	3,773	3,432
Turkey	1,252	2,547	1,324	2,080	3,615	2,873
Spain	4,667	8,403	8,642	2,724	2,740	2,410
Korea	5,733	2,385	139	1,956	3,405	1,939
France	863	5,872	5,340	1,323	1,658	1,456
Netherlands	1,304	7,564	6,527	2,723	1,778	1,447
Brazil	-	1,919	673	1,122	997	1,114
Germany	4,512	3,979	8,812	1,149	1,283	936
United Kingdom	356	4,503	12,144	744	663	767
Denmark	-	1,721	2,070	906	1,348	630
Japan	1,427	1,661	155	420	846	468
Morocco	-	1,978	2,993	810	65	405
Romania	-	-	-	189	231	316
Mexico	-	41	-	1,368	388	200
Greece	1,017	269	75	70	-	75
Belgium	4,365	2,504	1,757	527	598	59
United States	-	50	135	-	44	50
Norway	-	-	-	5	-	4
Portugal	2,112	2,112	1,926	321	-	-
Hong Kong, China	3,217	486	-	162	-	-
Ukraine	-	-	61	-	-	-
Poland	-	265	-	-	-	-
Bulgaria	-	107	-	-	-	-
Canada	-	46		-	-	-
Other	5,373	7,855	9,096	13,495	12,006	16,099
Total World	45,867	67,001	70,917	65,562	67,368	73,603

Source: Coal Information 2013

2) Transportation

The coal export ports in South Africa are the ports of Richards Bay and Durban. Mostly, mined coal is exported from Richards Bay. In addition, coal is transported by railway from the mine mouth to Richards Bay as shown in Figure 5.2-11.

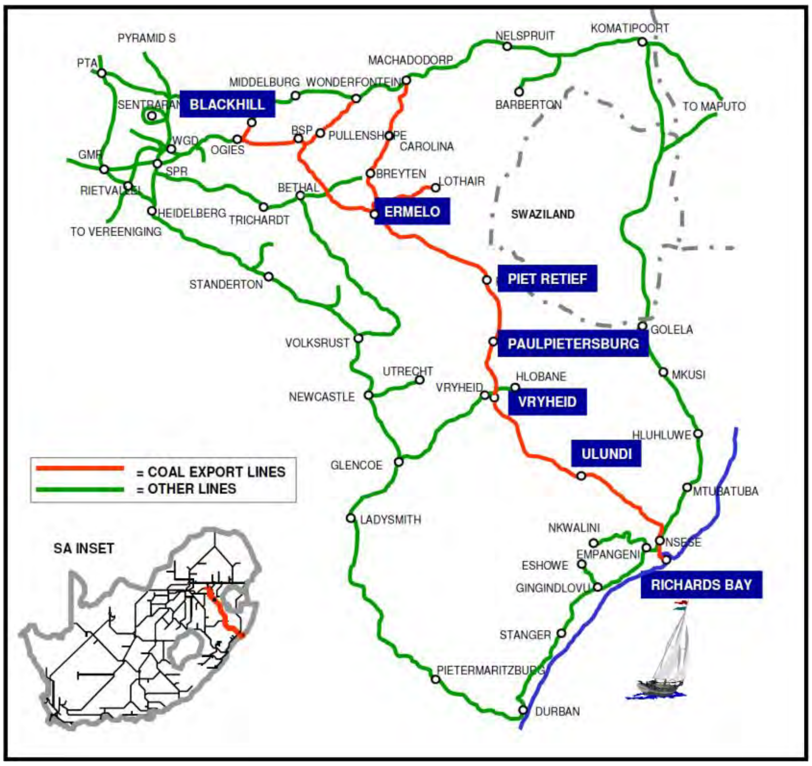


Figure 5.2-11 South African Rail Infrastructure

Source: TFR, 2009

The marine transport route map between South Africa and Pakistan is shown in Figure 5.2-12. The distance from South Africa to Pakistan is approximately 3,820 NM, and the required travel time is more than 13 days. However, in case route 2 is selected in order to avoid piracy zone, the distance will be approximately 4,350 NM, and the required travel time is more than 14 days.

Figure 5.2-12 Marine Transport Route Map between South Africa and Pakistan

Source: Prepared by the JICA Survey Team based on the UN Map

(8) Selected Coal

1) Usage of Coal

The characteristics of bituminous and subbituminous coal suitable for coal blending are given in Table 5.2-16.

Table 5.2-16 Classification of Coal

	Subbituminous	Bituminous
Coal Rank	Low ←	→ High
Calorific Value (kcal/kg)	4,000 – 6,000	4,500 – 7,000
Moisture (%)	30 – 15	Less than 15

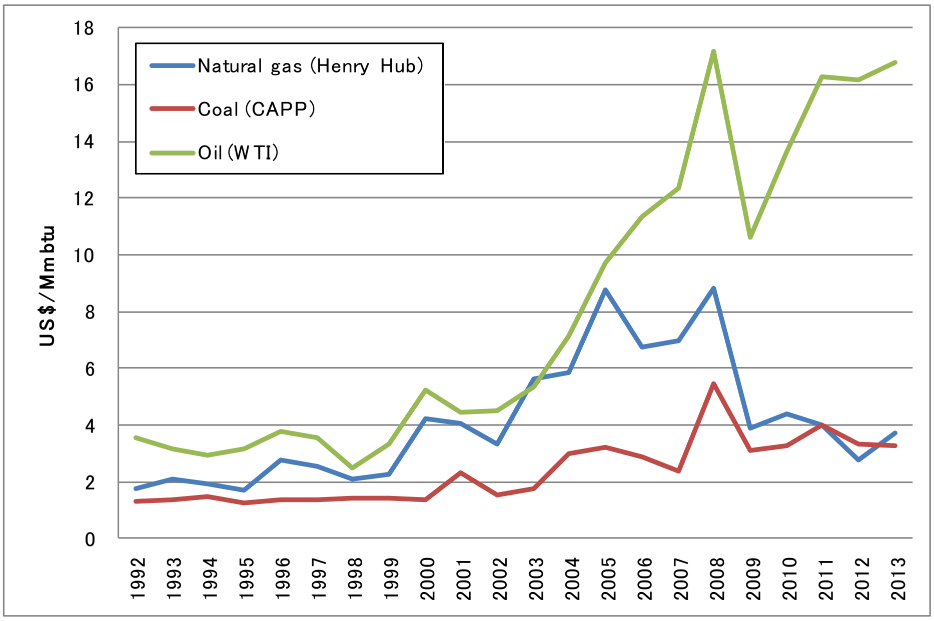
Source: Prepared by the JICA Survey Team

Consideration items for the usage of coal are shown as follows.

a. Running cost

Although unit price of bituminous coal is high than subbituminous coal, bituminous coal has high calorific value and efficient compared with subbituminous coal. In consequence, viewpoint of running cost, bituminous coal is more preferable than subbituminous coal as mentioned in Chapter 3.4.1.

b. Coal Demand



Note) CAPP : US Central Appalachian coal spot price index

WTI : West Texas Intermediate

Source: Prepared by JICA Survey Team based on “BP Statistical review of World Energy June 2014”

Figure 5.2-13 Price History of Natural gas, Coal and Oil in $/Mmbtu

Figure 5.2-13 shows price history of Natural gas, Coal and Oil in $/Mmbtu from 1992 to 2013. Oil price is rapidly increased, and the price of 2013 was more than 4.5 times of 1992. The price of Natural gas fluctuates most intensely through the period. On the other hands, Coal price is gradually increased with less fluctuation. Since coal price is steadier than other sources, there are a lot of plans for the coal-fired power station at mainly Asian region in the future. Consequently, demand for the bituminous coal is expected to expand due to running cost is economical.

c. Boiler size and blending coal

Boiler size is slightly different between bituminous coal and subbituminous coal, and the boiler for subbituminous coal is slightly larger. In addition, as usage of coal at Lakhra power station, Thar coal is used and blended with imported coal. In that case, since Thar coal contains high moisture, it is easier to blend high moisture of subbituminous coal than low moisture of bituminous coal. Furthermore, the boiler for the specification of subbituminous coal can use bituminous coal. However, it is possibility to restrict the boiler output in case that subbituminous coal is used for the smaller boiler specified for bituminous coal.

d. Importable coal

At the moment, coal is imported from Indonesia and South Africa, and Awan Trading and Seatrade are major coal importers in Pakistan. However, both companies do not import directly, namely, import via such as trading firms in Japan. In addition, coal importers are increased and coal procurement could not be exclusive to both companies. Additionally, at the moment, tender of coal procurement for the Jamshoro Project is being carried out, for which Japanese trading company is one of the tenderer. Therefore, the coal procurement from Indonesia carries a low risk as import coal.

e. Conclusion

As for running cost, bituminous coal is more economical than subbituminous coal, however, as a result of consideration of the future situation, coal demand will rise for development of coal fired thermal power stations over the world, mainly at Asian region, and then bituminous coal has several risks on securing coal resource for the Project as mentioned above.

Accordingly, in consideration of safe side for the operation, subbituminous coal is to be applied under the Project.

2) Assumed Import Destination

As mentioned in previous sections, in consideration of procurable coal and transportation distance and dates, Australian coal takes more days and longer transportation distance to be provided to Pakistan, hence, the cost relating to marine transportation would take more expensive. Therefore, Indonesia and South Africa are the potential import countries.

In comparison between Indonesian and South African coals, anthracite coal and bituminous coal are mainly produced in South Africa while subbituminous coal is produced and proved as reserves lots. Moreover, there are lots of coal fired thermal power stations running in South Africa and then the domestic use of coal is high proportion in the nation, which results only in 28.5 % (73.6 tonnes) of exporting against total production (258.5 tonne) in 2012. On the other hands, Indonesia has exported high ratio of 86.3 % (379.8 tonnes) against total production (440.0 tonnes) in 2012. Indonesian takes advantage on procurement of coal for the Project at present.

For the reference, as one of the indicators, a comparison of steam coal export costs among different countries is shown in Figure 5.2-14. Although coal prices differ according to coal specifications and comparison of coal prices in each country is difficult due to no existence of coal with quite same specification, Indonesia coal is the most economical in this figure at the moment among three countries.

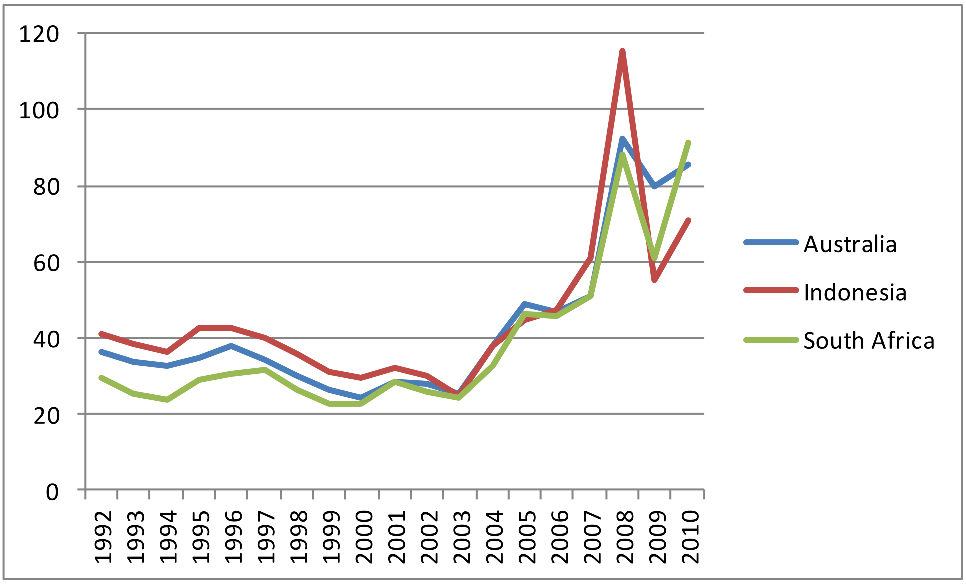


Figure 5.2-14 Steam Coal Export Costs (Average Unit Value, USD/t)

Source: Coal Information 2013

Accordingly, Indonesia is assumed as a candidate country for coal importation to Pakistan at this time. However, procured coal will depend on the market trend and prices at that time. Especially, since procurement of coal is after five years at earliest, it cannot be judged at the moment which country is most appropriate.

3) Performance Coal

At present, the brands of subbituminous coal that can be procured from the Indonesian market are shown in Table 5.2-17.

Table 5.2-17 Subbituminous Coal in the Indonesian Market

No.	Brand Name	CV (kcal/kg)	TM (%)	TS (%)	Ash (%)
1	Pinang 6000	6,000	16	0.6	5
2	Pinang 5900	5,900	19	0.9	4.5
3	Arutmin A5900	5,900	12	0.9	13
4	Indominco IM_East	5,700	17.5	1.63	4.8
5	TSA Coal	5,700	18	2	8
6	Tanito Coal	5,700	17.5	1	8.5
7	Mahakam Coal	5,700	17.5	1	8.5
8	Pinang 5700	5,700	19	0.5	5
9	Arutmin A5700	5,700	11	0.8	14
10	IBP 5500	5,500	20	1	7
11	LannaHarita Coal	5,500	22	1	6
12	Pinang 5500	5,500	21	0.4	5.5
13	Mahoni	5,500	20	0.8	4.7
14	Melawan Coal	5,400	22.5	0.4	5
15	Mahoni B	5,300	22.5	0.8	4.6
16	Kideco Coal	5,125	24.5	0.1	2
17	Agathis	5,100	25	0.82	4.5
18	LannaHarita Coal	5,000	27	1.2	6
19	IBP 5000	5,000	25	1	7
20	Sungkai	5,000	26	0.9	4.5
21	Arutmin A5000	5,000	22.4	0.54	8.9
22	Envirocoal	5,000	26	0.1	1.2
23	IBP 4600	4,600	28	0.5	7
24	Jorong J-1	4,400	32	0.25	4.15
25	Bas Gumay Coal	4,400	35	0.5	4.96
26	IBP 4400	4,400	30	0.5	7
27	AGM Warute Coal	4,350	33	0.4	4
28	Ecocoal	4,200	35	0.18	3.9
29	IBP 4200	4,200	32	0.5	6
30	PIC Coal	4,200	33	1.75	6

Source: HARGA BATUBARA ACUAN (HBA) & HARGA PATOKAN BATUBARA (HBP) BULAN SEPTEMBER 2013 and Indonesian Coal Book 2012/2013

4) Design Coal

Because each developed country will secure more high-quality coal, it is assumed that high-quality coal of more than 5,000 kcal will be difficult to procure in the future, although there is a large range of subbituminous coal (4,000-6,000 kcal). Furthermore, even if high-grade coal is used in Japan, so far, it is assumed that there will be a shortage in the coal of high calorific value in the future. In order to achieve a stable supply of coal, procurement of subbituminous coal of 5,000 kcal is considered in the near future.

Accordingly, in consideration of safe side calculation, more than 4,700 kcal/kg of coal is applicable in order to steadily procure and design coal under the Project, as follows:

Table 5.2-18 Design Coal Specifications

	Performance Coal (used for calculation)	Design Coal (Subbituminous)
Total Moisture (%ar)	22.4	＜ 30
Proximate Analysis (Air-dried basis)		
Moisture (%ad)	14.3	＜ 19
Ash (%ad)	8.9	＜ 10
Volatile Matter (%ad)	39.5	＞ 35
Caloric Value		
Gross as received (kcal/kg)	5,000	＞ 4,700
Ultimate Analysis		
Carbon (%daf)	76.6	70 – 80
Hydrogen (%daf)	5.52	4 – 6
Nitrogen (%daf)	1.15	＜ 2
Sulfur (%daf)	0.70	＜ 1
Oxygen (%daf)	16.0	14 – 23
Ash Fusion Temperature		
Initial Deformation	1,200	＞ 1,100
Spherical	1,220	＞ 1,150
Hemispherical	1,250	＞ 1,200
Flow	1,280	＞ 1,200
Ash Analysis		
SiO_2 (%db)	45.1	30 – 50
Al_2O_3 (%db)	23.1	10 – 30
Fe_2O_3 (%db	12.6	10 – 18
CaO (%db)	8.34	1 – 18
MgO (%db)	3.58	2 – 12
TiO_2 (%db)	1.31	＜ 2
Na_2O (%db)	0.26	＜ 3
K_2O (%db)	0.61	＜ 3
SO_3 (%db)	5.06	1 - 10
Sizing		
Above 50 mm*	0.0	0.0
Under 2 mm	20.0	20.0

NOTE: Bituminous : typical value of Arutmin 6250
Subbituminous : typical value of Arutmin 5000
Source: Indonesian Coal Book 2012/2013

5.2.2 Thar Coal

As mentioned in Chapter 3, mined coal from the Thar coalfield is to be used and blended with imported coal. Since development of Block II is the earliest, and the plan is the most realistic for the Thar coalfield, coal from Block II is adopted as design coal and performance coal. Design coal specifications are shown in Table 5.2-19.

Table 5.2-19 Design Coal Specifications

	Performance Coal / Design Coal
Total Moisture (%ar)	47.6
Proximate Analysis (Air-dried basis)	
Moisture (%ad)	
Ash (%ad)	14.9
Volatile Matter (%ad)	47.9
Foxed Carbon (%ad)	37.4
Caloric Value	
Gross as received (kcal/kg)	3,146
Net as received (kcal/kg)	2,773
Ultimate Analysis	
Carbon (%daf)	74.0
Hydrogen (%daf)	6.1
Nitrogen (%daf)	1.0
Sulfur (%daf)	2.5
Oxygen (%daf)	18.0
Ash Fusion Temperature	
Initial Deformation	1,166
Spherical	1,190
Hemispherical	-
Flow	1,200
Ash Analysis	
SiO_2 (%db)	25.24
Al_2O_3 (%db)	15.26
Fe_2O_3 (%db)	11.79
CaO (%db)	14.25
MgO (%db)	6.43
TiO_2 (%db)	1.86
Na_2O (%db)	2.67
K_2O (%db)	0.43
P_2O_5 (%db)	-
SO_3 (%db)	13.18

NOTE: Bituminous : typical value of Arutmin 6250
Subbituminous : typical value of Arutmin 6250
Source: Indonesian Coal Book 2012/2013

5.3 Ports in Pakistan

5.3.1 Ports in Pakistan

1) General

Pakistan has two gateway ports, namely, Karachi Port and Port Qasim. At Port Qasim, new bulk terminal, Pakistan International Bulk Terminal (PIBT), is under construction and will start operation in end of 2016. In this Section, these three are discussed below. Their locations are shown in the following map.

Source: Prepared by the JICA Survey Team based on Google Map

Figure 5.3-1 Location Map of Karachi Port, Port Qasim and PIBT

In fact, Pakistan imported 4.56 mil tons of coal in 2010, and its 80% was through Karachi Port. Table 5.3-1 shows the typical dimensions of coal carriers.

Table 5.3-1 Typical Dimensions of Coal Carriers

Ship Size (DWT)	LOA (m)	Beam (m)	Draft (m)
Handysize (25,000~35,000DWT)	130~150	21~27	8~10
Handymax (35,000~55,000DWT)	150~200	27~30	11~12
Panamax (60,000~80,000DWT)	200~230	30~32	13~15
Post Panamax (80,000~150,000DWT)	230~270	32~43	14~16
Capesize (150,000~200,000DWT)	270~300	43~50	17~18

Source: collected and summarized by JICA Survey Team

5.3.2 Karachi Port

Karachi Port is the biggest port in Pakistan, and handles 26 mil tons of cargo annually including 650,000TEUs of container cargo and liquid cargo with receiving about 1,600 ship calls. Karachi Port has 30 dry cargo berths, 13 berths on West Wharves and 17 berth on East Wharves, and 3 liquid cargo berths.

Coal is handled at bulk berths with depths of -13m and -10.5m. A grab unloader can be used, but ship crane is usually used for coal unloading. No belt conveyor system for coal handling is installed in this moment. According to the interview with Karachi Port Trust, the storage capacity is 0.8 mil tons and the coal handling capacity is 8 mil tons per year. The coal handling volumes in the recent 3 years in Karachi Port are shown below. These coals were mainly transported to cement companies.

Having interviewed to major coal trading firms in Pakistan, coal handling capacity is around 4 mil tons per year, which is half of the aforesaid handling capacity, because the coal transporting capacity by truck between the berth and coal storage yard, distance about 1km, is almost limit at 4 mil ton per year.

Table 5.3-2 Coal Handling Volumes in Recent 3 Years in Karachi Port

Year	Coal Handling Volume (ton)
2010-2011	3,895,492
2011-2012	3,054,462
2012-2013	3,626,995

Source: Karachi Port

The access channel with a length of 11.5km is being dredged from -12.2m to -13.0m. The existing maintenance dredging volume is 4~5 million m^3 per year. New container terminal is planned outside the breakwater. At that time, channel depth will be dredged to -16.0m.

Railway track has been installed to the port which had not utilized due to the lack of useful locomotive of Pakistan Railway (PR). However, in 2014 government allocated budget to purchase locomotives and wagons to transport coal to up-country, PR is increasing the capacity of coal handling. In 2014 coal handling is restarted.

There is no coal handling facilities at the both at bulk terminal and coal stock yard.

- Port berth operation (Photo 5.3-1 to 5.3-4) — Grab un-loader (4~5 ton), equipped on the vessel normally 4 un-loader is equipped on 55,000ton class, lift the coals from the vessel un-load on the berth ground

- Transporting to coal stock yard: Mobile loader lift the coal to the dump truck(10~12ton), which transport to the coal stock yard nearby.
- Coal stock yard operation (Photo 5.3-5 to 5.3-6): Dump truck unloads the coal on the coal stock yard and bulldozer fill up the coal around 10m height.
  Coal (imported from Indonesia) is screened to diameter 0 to 10, 10 to 25 and 25 to 50 for cement plant, textile mill and steel industry respectively.
  The selected coal is distributed by truck (50ton) to the consumers.

Source: JICA Survey Team

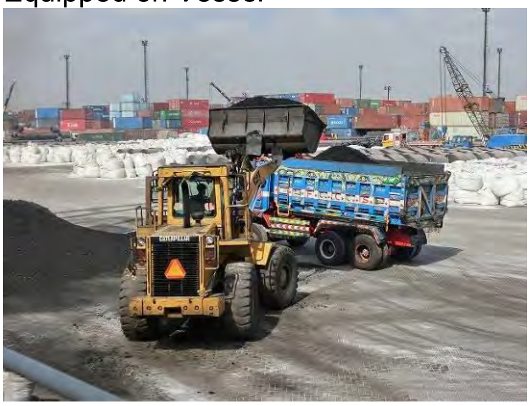
Photo 5.3-1 Coal Transporting Vessel 55,000 ton

Source: JICA Survey Team

Photo 5.3-2 Grab Unloader (4 ton) Equipped on Vessel

Source: JICA Survey Team

Photo 5.3-3 Coal Unloading from Vessel 3 days Unloading 55,000 ton of Coal



Source: JICA Survey Team

Photo 5.3-4 Loading Coal on Track (10~15ton) Transporting to Coal Stock Yard nearby

Source: JICA Survey Team

Photo 5.3-5 Coal Screening at Coal Stock Yard (0.6 mtpa) in Port Karachi

Source: JICA Survey Team

Photo 5.3-6 Loading on track (50ton) to Coal Consumer

5.3.3 Port Qasim

Port Qasim is the second biggest port in Pakistan. It handled 25 million tons including 722,000TEUs of container cargo and liquid cargo in the year 2012, with receiving about 1,060 ship calls. The approach channel to Port Qasim is 45 km long with a depth of 13.0m. The existing maintenance dredging volume is 5 mil m^3 per year.

At present, Port Qasim has three berths to handle coal, that is, marginal wharves, a jetty designated for Pakistan Steel Mills and Pakistan International Bulk Terminal (PIBT).

Source: JICA Survey Team

Figure 5.3-2 Location Map of 3 Berths in Port Qasim Area

1) Marginal Wharves

Port Qasim has marginal wharves with a total length of 800m, which is available for coal handling for the Lakhra Coal Fired Thermal Power Plant. A berth of 200m can receive a ship with a draft of -13.0m (berth depth is estimated at -14.5m), namely Panamax coal carrier, and others can do ships with a draft of -10.5m (berth depth is estimated at -12.0m). More than 30 ha land is available for stock yard. No equipment for coal handling is installed, so that coal handling equipment should be needed when coal is handled. Railway is available in the marginal wharves, but locomotives should be provided.

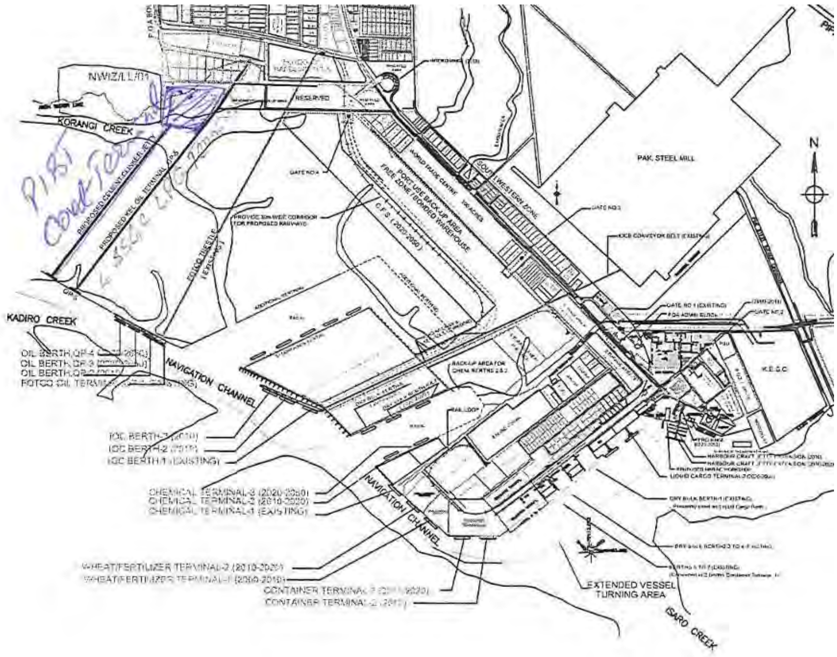
According to the interview with Port Qasim Authority, the capacity of coal handling volume at marginal wharves was not mentioned clearly. Therefore, it has been estimated at 8 mil tons per year, considering the port facility, by the Survey Team, excluding Pakistan Steel Mills. The coal handling volumes at marginal wharves in the recent 2 years in Port Qasim were almost zero.

According to a coal trader in Pakistan, who had been utilizing both bulk terminals of Port Krachi and Port Qasim because both draft was 10.5m in which the vessels transporting coal 40,000 ton can be docked. After Port Qasim up-graded the draft 13m in which vessels 60,000 ton can be docked, all coal unload have been done at Port Karachi. The transport cost by 40,000 ton vessel is US$2 per ton higher than that of 60,000 ton.

2) Designated Jetty for Pakistan Steel Mills

Pakistan Steel Mills has a designated jetty to import raw materials. Its capacity is 3 million tons per year. The existing handling volume of this jetty is less than 0.5 million tons per year. However, it is better not to expect to use this jetty for the Lakhra Coal Fired Thermal Power Plant because of the designated jetty.

The following figure shows the existing layout of Port Qasim. PIBT is located in the left side.



Source: Port Qasim Authority

Figure: 5.3-3 Layout of Port Qasim including PIBT

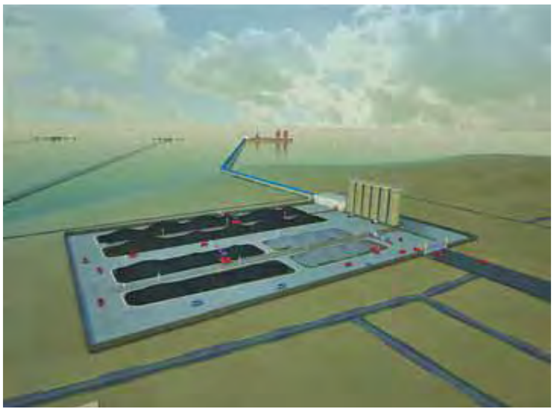
5.3.4 Pakistan International Bulk Terminal Limited (PIBT)

(1) General

PIBT will be the first bulk terminal in Pakistan, which is designated for dirty bulk cargo, such as coal, clinker and cement. This terminal is built with a 30-year BOT concession contract from Port Qasim Authority. It is located in the western side of existing Port Qasim as shown in Figures 5.3-3 and 5.3-4. PIBT is under construction.

Source: PIBT

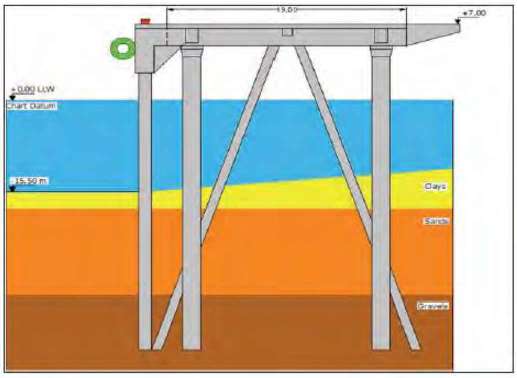
Figure 5.3-4: Artist Image of PIBT Jetty



Source: PIBT

Figure 5.3-5: Artist Image of PIBT Terminal Storage Area

This terminal will have a jetty with a length of 460m and a depth of -12.5m (Phase-1, target year of 2016) and -15.5m (Phase-2, 2020). It will be able to receive two Panamax coal carriers simultaneously. Typical cross section of jetty is shown in Figure 5.3-6. The jetty will be open deck type, which is supported by 1,500-mm vertical RC piles and 900-mm battered steel piles. Two grab-type un-loaders with a capacity of 1,500 ton/h will be installed on the jetty.



Source: Environmental & Social Impact Assessment (July 2011)

Figure: 5.3-6 Typical Cross Section of Jetty

25-ha stock yard is planned to have coal storage capacities of 0.6 mil tons (Phase-1) and 1.6 mil tons (Phase-2), and to connect to jetty with 2.5 km trestle. The terminal will handle 12 million tons of coal per year, and 4 mil tons of clinker and cement per year at the initial stage in 2016. Coal handling volume can be reached to 20 mtpa by 2020.

PIBT is doing civil work at the PQA site for the construction of project. For the works progress as of May 2014, land reclamation terminal storage area (250ha) had been finished and the construction 2.5km trestle is just started as shown in Photo 5.3-7 and 5.3-8 respectively.

Source JICA Survey Team

Photo 5.3-7: Land Reclamation (25ha)

Source JICA Survey Team

Photo 5.3-8: 2.5 km Trestle under Construction

(2) Unloading Machine

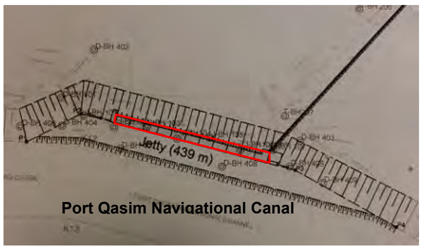
Planned unloading machines in 2020 are as follows.

- 2 coal unloading cranes 1.850 t/h
- 1 cement loading crane: 1.200 t/h
- 1 belt conveyor for cal on trestle 3,600 t/h
- 1 best conveyor for clinker/cement loading of 1,200t/h

Thus, the coal unloading capacity will be 28.5 mil ton per year (3,600t/h x 22 hours x 360 days) theoretically, assuming 22hours per day and 360 days per year operation.

(3) Other information

The cannels of 13m draft is maintained (dredged) by Port Qasim Authority, PIBT shall maintain about 80m between their jetty to Port Qasim Navigational Canal from their jetty as shown in Figure 5.3-7.



Source PIBT

Figure 5.3-7 Jetty and Canal

Port Qasim Authority is planning to deepen the canal to 14m from 13m at present, the dredging will starts 2015.

Railway is planned to be connected to main trunk line of PR (Pakistan Railway) running 4 to 5 km north so that imported coal can transport to up county by train. PIBT expect that the spur line up to their premise is constructed by PR.

(4) Financial Status of PIBT

1) Profit and Loss Statement

As the Project is still in construction stage, there is no revenue generated from the Project yet, resulting in financial loss.

Table 5.3-3: Profit and Loss Statement (Unit: 1,000 Rs.)

	2013	2012
Administrative expense	(39,005)	(20,397)
Other charges –workers welfare fund	(156)	(205)
Other income	8,142	10,237
Loss before taxation	**(31,018)**	**(10,367)**
Taxation	10,272	3,684
Loss after taxation	**(20,747)**	**(6,681)**

Source: PIBT Annual Report 2013

Note: Other income is from interest on saving account and unrealized gain on revaluation of short term investment.

2) Balance sheet

"Property, plant and equipment" in non current assets has increased from Rs. 873 million in 2012 to Rs. 2,665 million in 2013 as the construction work has progressed. All of the non current liabilities is advance against future issue of share capital. This represents advance received from the major shareholders.

Table 5.3-4: Balance Sheet (Unit: 1,000 Rs.)

	2013	2012
Non current assets	3,163,273	1,202,450
Current assets	87,728	44,550
Total assets	**3,251,001**	**1,247,049**
Share capital and reserves	516,321	537,068
Non current liabilities	2,105,000	700,000
Current liabilities	629,680	9,982
Total equity & liabilities	**3,251,001**	**1,247,049**

Source: PIBT Annual Report 2013

3) Cash flow statement

Cash flow from operating activities has increased to Rs. 574.1 million in 2013 due to a significant increase of "trade and other payables (Rs. 8.4 million in 2012 to Rs. 619.7 million in 2013). There is a huge cash outflow in investing activities in accordance with the ongoing construction work and the increase of property, plant, and equipment. Such cash outflows in investing activities are financed by the cash inflow of financing activities, mainly the increase of advance received from major stakeholders.

Table 5.3-5: Cash Flow Statement (Unit: 1,000 Rs.)

	2013	2012
Cash flows from operating activities	574,131	(463)
Cash flows from investing activities	(1,887,881)	(788,781)
Cash flows from financing activities	1,229,065	820,766
Net (decrease) / increase in cash and cash equivalents	(17,269)	27,943
Cash and cash equivalents at the beginning of the year	44,440	16,497
Cash and cash equivalents at the end of the year	**27,170**	**44,440**

Source: PIBT Annual Report 2013

PIBT has the loan agreements from various financial institutions such as IFC, OPEC Fund for International Development, and commercial banks, totalling to approximately Rs. 9,094.4 million. PIBT has not made any draw down from these loan schemes.

Table 5.3-6: Loan Agreement with Financial Institutions

Financial institution	Loan amount
1. International Finance Corporation	$26.5 Mil.
2. OPEF Fund for International Development	$20.0 Mil.
3. Four commercial banks (Faysal Bank Limited, NIB Bank Limited, Bank of Punjab & JS Bank)	Rs. 3,250 Mil.
4. Three financial institutions (Meezan Bank Limited, Al Baraka Bank & Bank Islami Pakistan Limited)	Rs. 1,120 Mil.
Total	**Approx. Rs. 9,094.4 Mil.**

Source: PIBT Annual Report 2013

Note: $1 = Rs. 101.6

(5) Concession of bulk transportation

PIL (Pakistan Intermodal Limited) same group of PIBT possesses two concessions of railway bulk transportation on two corridors: one is approx. 1,300km between Karachi and Lala Musa, the other is approx. 1,350km between Karachi and Daud Khel. Those concessions are exclusive for 20 years once they obtained. For the concession operation, procurement of facilities such as 60 locomotives and 700 wagons is tendering stage, and they target utilizing in September 2015. Capacity of bulk transportation by one train of them is planed carrying 2,400 tons of bulk, namely one train is composed of one locomotive and 40 wagons (60tons/wagon).

(6) Possibility of utilizing the PIBT for the Project

Survey Team of railway found out that the difficulty of connecting PIBT to PR trunk railway due to the land elevation difference between them, namely railway shall keep their gradient within 0.5%, however actual gradient is estimated at 1.0% or more. For realizing coal transportation by railway, further study or reroute of the connecting line should be changed from his original connection route.

5.3.5 Fauji Group Coal Import Terminal

For expanding future coal import in Pakistan, adding to PIBT, PQA is calling tender of BOT base coal terminal. Fauji Group, one of the large conglomerates in Pakistan, who is operating grain and chemical terminal in Port Qasim submitted EIO to PQA.

Layout plan is shown in Table 5.3-8. They plan to develop in three phases, 1st phase 4 mtpa with investment cost at USD 90 million, 2nd phase by end of 2017, 2nd 8 mtpa by end of 2018 and 3rd phase 12 mtpa by end of 2019 total investment at USD 225 million. Coal stockyard is planned in land 100 acres (about 0.4 km2) being able to storage 1.75 million tons of coals.

Expression of Interest (EoI) had been submitted to PQA in 2014, then they planned to prepare the full technical and financial proposal. However they have no prospect to submit the full proposal as of June 2015, because any Minutes of Understanding could not be concluded with the potential users. Therefore, this planned terminal cannot be candidate of Lakhra project.

Source: Presentation materials by FOTOCO

Figure 5.3-8 Fauji Group Coal Terminal Plan

5.3.6 Coal Import Capacity in Pakistan Ports

Based on the above discussions, the coal handling capacity and expected coal demand are summarized in Table 5.3-7. The estimated coal volume is 2 mil tons for the Lakhra Coal Fired Thermal Power Plant. It is judged only Port Qasim will be able to handle the required coal volume.

Table 5.3-7 Comparative Table of Coal Handling Capacity and Coal Demand

Port/Terminal	Coal Handling Capacity (mtpa)	Consumer	Coal Demand (mtpa)
Karachi Port	4.0 *1	Cement Companies	4.0
Port Qasim (Marginal Wharves)	8.0*2		*As draft is 10.5m, only 40,000DWT can dock*
Port Qasim (Pakistan Steel Mills)	3.0	Pakistan Steel Mills (dedicated)	3.0
Port Qasim (PIBT)	12.0 (future 20.0)	K-Electric 220MW x 2	1.4
		Jamshoro 660MW x 2	4.0
		Sahiwar 660MW x 2	4.0
		Cement Factory	2.0
		Lakhra 660MW x 1	**2.0**
			(13.4)
TOTAL	27.0 (future 35.0)	TOTAL	19.5

Note: Bin Qasim (IPP 1320MW) will construct their own jetty at Qasim canal.

*1 It is said that Karachi Port has coal handling capacity of 8 mtpa, however actual handling capacity is limit at 4 mtpa.

*2 Port Qasim (Marginal Wharves) has only berth, not has) unloading facilities. As draft is 10.5 m at present, only 40,000DWT vessel can berth, that economically inefficient.

Source: JICA Survey Team summarized based on the collected data by interview

5.4 Transportation of Thar Coal by Truck

In consideration of project cost estimation, the distance of 130km is too far to connect new branch line to existing line for Thar coal transportation for the Project site as mentioned in chapter 3, hence, road transportation was examined as the followings.

5.4.1 Outline

The indigenous coal, if sourced from Thar coalfield, will be transported to Lakhra area by road as presently rail network is not available in Thar coalfield (Block II).

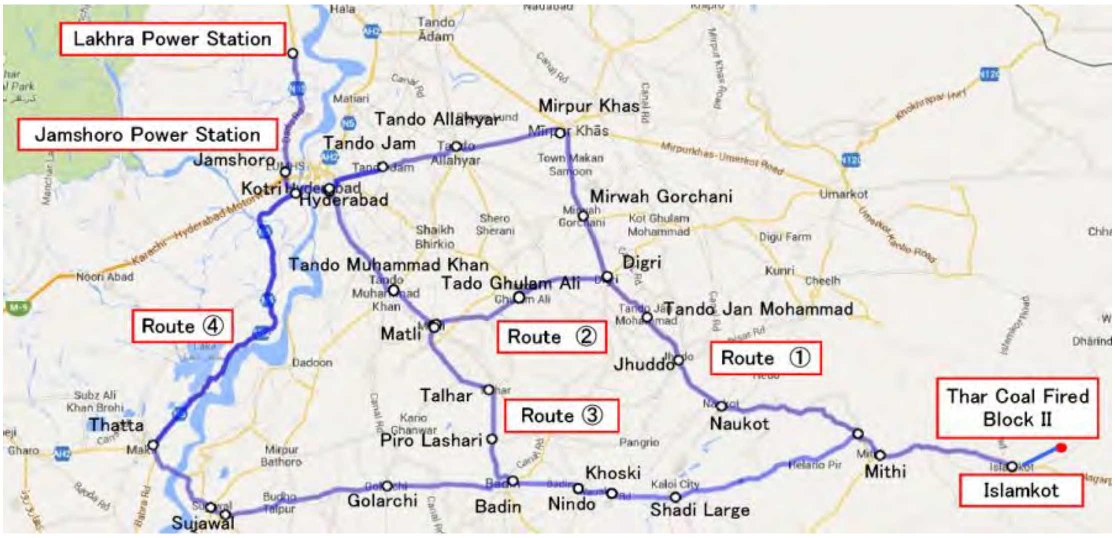
There are four possible routes as shown in Figure 5.4-1. These are:

Route 1: Islamkot-Mithi-Digri-Mirpur Khas-Hyderabad-Indus River area

Route 2: Islamkot-Mithi-Digri-Matli-Hyderabad-Indus River area

Route 3: Islamkot-Mithi-Badin-Matli-Hyderabad-Indus River area

Route 4: Islamkot-Mithi-Badin-Thatta-Indus River area



Source: prepared by JICA Survey Team based on Google Map

Figure 5.4-1 Route Map for the Thar Coalfield to Indus River Area

5.4.2 Existing Road Condition

1) Route 1

Road between Mithi and Naukot

The width of this section is narrow for two way traffic for dumps. In addition, there is no road shoulder as shown in Photo5.5-1, therefore, road improvement of the section is required.

Bypass plan for Naukot, Jhudo, Tando Jan Mohammad and Digri

Trailer transport through these townships is not in suitable due to narrow width and city crowds. However any bypass is not planned for these townships. Therefore new bypass construction are required at these towns.

Road between Naukot and Digri

The width of this section is approx. 6-8m, and the traffic condition is suitable for trailer traffics.

Road between Mirpur Khas and Hyderabad

National highway No. 120 connects these cities as 4-lane road with median. Big trailers and heavy traffic is acceptable for this section.

Bypass for Tando-Allahyar

This is for two (2) lane bypass of approx 6-7m width without median.

<u>Road between Kotri and Lakhra</u>

National highway No. 55 connects Kotri and Lakhra as 2-lane without median. The pavement of traffic lane and shoulder is in good condition.

Source JICA Survey Team

Photo 5.5-1 Road between Mithi and Naukot

Source JICA Survey Team

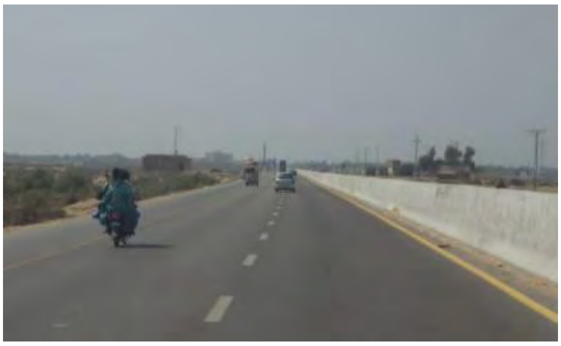
Photo 5.5-2 Naukot Town Center

Source JICA Survey Team

Photo 5.5-3 Jhudo Town Center

Source JICA Survey Team

Photo 5.5-4 Road between Naukot and Digri



Source JICA Survey Team

Photo 5.5-5 Road between Mirpur-Khas and Hyderabad. (National Highway No.120)

Source JICA Survey Team

Photo 5.5-6 Tando-Allahyar Bypass. (National Highway No.120)

Source JICA Survey Team

Photo 5.5-7 M-9 Bridge across Indus River

Source JICA Survey Team

Photo 5.5-8 National Highway No.55

2) Route 2

Road between Digri and Matli

Two (2) lane road paved with asphalt connects these cities as width of approx 6-10m including shoulders.

There are some ruts and cracks found on surface. Particularly, the road from Digri to Tado Ghulam Ali, winds and the surface condition is in bad condition. Therefore, this section needs road improvement for trailer transport.

Tando Ghulam Ali Bypass

Two (2) lane road paved with asphalt is in relatively good condition. The width of the road is approx 7m including shoulders.

Bypass for Matli

There is only one bypass connecting Digri side and Hyderabad side. Bypasses for Badin side to Digri side and Badin side to Hyderabad side don't exist. Two (2) lane road paved with asphalt is in relatively good condition. The width of the road is approx 8m including shoulders.

Road between Matli and Hyderabad

Two (2) lane road paved with asphalt is approx 8 to 10 m wide including shoulders. The section needs improvement partially, however the condition of the pavement is generally good.

Source JICA Survey Team

Photo 5.5-9 Road between Digri and Matli

Source JICA Survey Team

Photo 5.5-10 Tando Ghulam Ali Bypass

Source JICA Survey Team

Photo 5.5-11 Matli Bypass

Source JICA Survey Team

Photo 5.5-12 Road between Matli and Hyderabad

3) Route 3

Mithi Bypass

This bypass is built by the north side of Mithi city. Earthwork for the bypass has been completed. The road width is 13m including shoulders.

The road between Mithi and Wango Mor

This new road connects Naukot road and Kaloi–Mithi Bypass with length of approx. 50km. The road width is 13m including shoulders. According to SCA, the maximum vertical grade is 4% where high sand dunes are cut.

Badin Bypass

This bypass is built by the north side of Badin city of which length is approx 9.6 km and width is 13 m including shoulders. Earthwork of this bypass has been completed. Three bridge construction and paving work are on-going and will be completed in May, 2014.

The road between Matli and Badin

Two (2) lane road paved with asphalt connects these cities as width of approx 8-12m including shoulders. Some sections need improvement, however the condition of the pavement is generally in good condition. There are some towns on the route including Thalhal, Dokia Waah, Shah Waah, and Thand Ghulam Hyder. A bypass is necessary for the Thalhal town, however, in other towns, the road width is enough to pass through and less crowded so that new bypass is unnecessary.

Bypass for Matli city centre

New bypass that connects Badin side and Hyderabad side is required for trailer transports due to township crowds.

Source JICA Survey Team

Photo 5.5-13 Mithi Bypass

Source JICA Survey Team

Photo 5.5-14 Road between Mithi and Wango Mor

Source JICA Survey Team

Photo 5.5-15 Badin Bypass

Source JICA Survey Team

Photo 5.5-16 Thalhal Town

Source JICA Survey Team

Photo 5.5-17 Road between Matli and Badin

Source JICA Survey Team

Photo 5.5-18 Matli City Centre

4) Route 4

Road between Sujawal and Thatta

Road rehabilitation works by Sindh province is in progress. Planned roads are in width of 13 m including shoulders. The Sujawal bypass via the south area of Thatta and Makli is desirable for passing through. The passage of the Thatta city area is difficult due to township crowds so that the bypass is required.

Road between Thatta and Kotri

After Thatta city passed, the route runs the National highway No. 5 that running in the west bank of the Indus. Two (2) lane road paved with asphalt connected these cities with width of 10 to 12 m including shoulders. The condition of the pavement is relatively good.

Intersection of N5 and N55 around

This intersection locates west from Kotri town. There are railway crossing at the grade that is 60m away from the intersection. Therefore, it might become the bottleneck of the traffic. In addition, Jamshoro station is located beside N55, therefore the congestion is predicted. The congestion would result in low speed travelling of trailers.

Road between Jamshoro and Lakhra

Two (2)-lane road without median paved with asphalt connects these cities as width of approx 10 to 13 m including shoulders. The condition of the pavement is relatively good.

Source JICA Survey Team

Photo 5.5-19 Sujawal Bypass

Source JICA Survey Team

Photo 5.5-20 Thatta Town

Source JICA Survey Team

Photo 5.5-21 Road between Thatta and Kotri
(National Highway No.5)

Source JICA Survey Team

Photo 5.5-22 Bihar Colony near Kotri
(National Highway No.5)

Source JICA Survey Team

Photo 5.5-23 Intersection of N5 and N55
(National Highway No.5)

Source JICA Survey Team

Photo 5.5-24 Railway Crossing near Kotri
(National Highway No.55)

Source JICA Survey Team

Photo 5.5-25 Near Jamshoro station
(National Highway No.55)

Source JICA Survey Team

Photo 5.5-26 Road between Jamshoro and Lakhra
(National Highway No.55)

Table 5.5-1 Comparison Table of Coal Transport Route from Thar Coalfield to Indus River Area

Route	Route	Major Towns	Route Length	Bypass on Route							Improvement on Existing Road			Construction Cost (Milion PKR)			Average travel speed	
				Planned		Expected												
				BP Name	Length	Town	Length	Bridge		Land Acquisition	Section	Description of work	Length	Bypass Expected	Widening and improvement	Total	Average Speed	Running time (1 Direction)
			km		km		km	Number	Length (m)	km 2			km				km/h	Hr
1	Islamkot-Mithi-Digri-Mirpur Khas-Hyderabad-Jamshoro-Lakhra	Islamkot, Mithi, Naukot, Jhuddo, Tando Jan Mohammad, Digri, Mirwah Gorchani, Mirpur Khas, Tando Allahyar, Tando Jam, Hyderabad, Jamshoro	325	Mithi	7.0	Naukot	4.6	2	300	0.083	Mithi-Naukot	Widening and improvement	40	1,815	1,044	2,859	39.9	8.1
						Jhudo	6.0	0	0	0.108								
						Tando Jan Mohammad	5.4	0	0	0.097								
						Digri	4.6	1	30	0.083								
				Total	7.0	Total	20.6	3	330	0.371	Total		40					
2	Islamkot-Mithi-Digri-Matli-Hyderabad-Jamshoro-Lakhra	Islamkot, Mithi, Naukot, Jhudo, Tando Jan Mohammad, Digri, Tado Ghulam Ali, Matli, Tando Muhammad Khan, Hyderabad, Jamshoro	327	Mithi	7.0	Naukot	4.6	2	300	0.083	Mithi-Naukot	Widening and improvement	40	1,749	1,644	3,394	39.1	8.4
						Jhudo	6.0	0	0	0.108								
						Tando Jan Mohammad	5.4	0	0	0.097	Digri-Tado Ghulam Ali	Widening and improvement	23					
						Digri	4.2	0	0	0.076								
				Total	7.0	Total	20.2	2	300	0.364	Total		63					
3	Islamkot-Mithi-Badin-Matli-Hyderabad-Jamshoro-Lakhra	Islamkot, Mithi, Shadi Large, Khoski, Nindo, Badin, Piro Lashari, Talhar, Matli, Tando Muhammad Khan, Hyderabad, Jamshoro	339	Mithi	9.6	Talhar	3.0	1	90	0.054				1,080	0	1,080	39.1	8.7
				Badin-Mithi	54.0	Matli	4.7	1	350	0.085								
				Shadi Large	1.9													
				Khoski	8.9													
				Nindo	2.1													
				Badin	5.0													
				Total	81.5	Total	7.7	2	440	0.139	Total		0					
4	Islamkot-Mithi-Badin-Thatta-Jamshoro	Islamkot, Mithi, Shadi Large, Khoski, Nindo, Badin, Golarchi, Sujawal, Makli, Thatta, Kotri, Jamshoro	410	Mithi	9.6									0	0	0	39.7	10.3
				Badin-Mithi	54.0													
				Shadi Large	1.9													
				Khoski	8.9													
				Nindo	2.1													
				Badin	9.6													
				Golarchi	5.5													
				Sujawal	7.9													
				Total	99.5	Total	0.0	0	0	0.000	Total		0					

Source: JICA Survey Team

(3) Route selection

1) Route Selection

Route comparison among 4 alternatives is shown in table 5.5-1.

Based on the site investigation and comparative studies, evaluations of each route are described as below.

- Route 1: The route length and running time are shortest. The road improvement to be required is longer, and the estimation for construction hold second place.
- Route 2: The route length and running time hold second place. The road improvement to be required is longest and estimated as the most expensive.
- Route 3: The route length and running time hold third place. The road improvement of the existing route is unnecessary so that estimated cost is relatively low.
- Route 4: The route length and running time are longest. The road improvement of the existing route is unnecessary.

Therefore, route 3 is recommended route. The choice of the last plan should be carried out considering examination to environment.

2) Examination of selected route

The route of coal transportation and verification points of traffic capacity are shown in Figure 5.5-1.

Source: JICA Survey Team

Figure 5.5-1 Location of Traffic Capacity Verification Point

Table 5.5-2 shows the outline calculation of Transportation of Thar Coal on the route 3.

Table 5.5-2 Outline Calculation of Capacity of Thar Coal Transportation

Item		Unit	Number of Verification Point		
			No.1	No.2	No.3
Verification Point					
	Road Name （Verification Point）	-	National Highway No.55 (Near Jamshoro)	Hyderabad-Mirpurkhas dual carriage highway (Near Tand Jam)	Road between Mirpurkhas and Naukot (Near Digri)
	Traffic Survey Sauce	-	N55_Traffic Count- Data fm HBP	R4T03PST Traffic Situation Report Lakhra Coal fired Thermal Power Plant tracks	
	Lane Number	Nos.	2	4	2
Number of Trailer for coal transfer					
	Coal Volume	ton/year	9,300,000		
	Type of Trailer	tones	60		
	Payload	tones	35		
	Operation Rate	-	0.8		
	Number of Trailer	Veh/day	1,820		
Design Hourly Traffic Volume					
	Light Traffic	Veh/day	7,594	11,403	3,503
	Heavy Traffic	Veh/day	1,725	2,434	710
	Trailer for transfer Thar coal	Veh/day	1,820	1,820	1,820
	Total Trffic Number	Veh/day	11,139	15,657	6,033
	Commercial vehicle ratio	%	32	27	42
	Peak flow ratio	%	12		
	Passenger car equivalent	-	2.1	1.8	2.1
	Correction factor	-	0.74	0.82	0.68
	Design Hourly Traffic Volume	pcu/h	1,810	2,290	1,060
Traffic Capacity					
	Basic capacity	pcu/h	2,500	8,800	2,500
	Correction factor by road width	-	1.00	1.00	1.00
	Correction factor of shoulder width	-	1.00	1.00	1.00
	Correction factor of intersection	-	1.00	1.00	1.00
	Correction factor of roadside condition	-	0.90	1.00	0.90
	Correction factor of level of service	-	0.85	0.75	0.85
	Synthetic correction factor	-	0.765	0.750	0.765
	Traffic Capacity	pcu/h	1,910	6,600	1,910
	Traffic Capacity Ratio	%	95	35	55

Source: JICA Survey Team

NOTE: The number of trailer is assumed as below;
(Number of Trailer) = (annual consumption) / (365 days × operation rate) / (payload per trailer) × (go round: 2 directions)
1,820 veh / day = (9.3 mtpa) / (365 days × 0.8) / (35 t / veh) × 2

Approx. 9.3 mtpa of Thar coal is assumed to consume at Lakhra and Jamshoro power stations, hence, the sum of both consumption shall be considered when the road capacity for coal transportation is examined.

Thar coal is transported by trailers and a route is Thar - Naukot - Digri - Mirpurkhas - Hyderabad - Jamshoro - Lakhra.

The supposed coal trailer type is six-axis trailer with gross weight of 58.5 t for calculation of traffic capacity. An example of 60 t class trailer is shown in Photo 3.3-11.

As for fuel supply plan by railway from Port Qasim to Lakhra Power Plant, the detail was studied in Appendix 5-2 “Pre-feasibility study on coal transportation between Qasim and Lakhra by railway”.

CHAPTER 6
POWER SYSTEM ANALYSIS

Chapter 6 Power System Analysis

6.1 General of the Power System Analysis

Power system analysis on the southern system in Pakistan was carried out to examine the necessity of the system reinforcement of the existing power system upon development of the proposed coal-fired thermal power plant (hereinafter referred to as CFPP) in Lakhra, which is expected to start commercial operation in 2020. PSS/E ver. 33.4.0, the same power system analysis tool, was utilized for the analysis.

6.2 Impact of new Lakhra Power Plant to the Existing Power System

6.2.1 Scope of the Study

The power system analysis for the study consists of the following items:

1) Power flow analysis for the 500kV power system in southern area of Pakistan as of January 2021

2) Transient stability analysis of the 500kV power system in southern area of Pakistan as of January 2021

6.2.2 Analysis Model

The analysis models for both power flow and transient stability analyses were developed based on the relevant data provided by NTDC:

1) PSS/E case files for the power flow analysis obtained on November 28th, 2013.
2) PSS/E dynamic data obtained in October, 2013.

3) Annual Summary of Generation Addition as of November 2013.

The following assumptions were made in order to develop the analysis modes:

1) For the generator model of the new CFPP in Lakhra, the generator constants of similar scale were applied.

2) The same type of the conductor as that of the existing line in the same section between substations was applied if reinforcement of the section(s) was/were necessary.

3) Arbitrary amount of reactive power sources (static condensers) were connected to the buses to maintain bus voltage within the allowable level if the bus voltage exceeds the lower/upper limit.

4) For the power flow analysis, transmission capacity of each transmission section was based on the data on the transfer limit (MVA) provided by NTDC.

5) Only the low water case (January 2021) was considered since it was considered the severer condition rather than high water case taking into account the direction of the power flow that is toward the load center in the central part of the country in both low water and high water cases. Almost all Hydel Power Plants are located in North due to geological situation in Pakistan, while Thermal Power Plants are located in South in consideration with fuel supply, so that Power flow from South to North is more dominant in low water season. The bias of power flow would lead instability and severer condition on the power system.

6) As the connection scheme from the existing 500kV transmission line to the proposed Lakhra power plant, two-circuit connection between Jamshoro - Dadu line were assumed.

7) 2 units of generators (600MW x 2) were assumed for Jamshoro power plant[1].

8) The power output of Thar CFPP was set out as 1,200MW, which was same value as that of NTDC's plan.[2]

Assumed power plants for the simulation are listed in Table 6.2-1.

Table 6.2-1 List of Power Plants Assumed in PSS/E Analysis Model in Section 6.2

Name of Power Plant	Total Output	Unit Capacity and Number of Units
Lakhra	600MW	600MW x 1 unit
Gadani	6,000MW	600MW x 10 units
K-2/K-3	2,200MW	1,100MW x 2 units
Bin Qasim	1,200MW	600MW x 2 units
Thar	1,200MW	600MW x 2 units
Jamshoro	1,200MW	600MW x 2 units

Source: JICA Survey Team

6.2.3 Power Flow Analysis

(1) Evaluation Criteria

The evaluation of the power flow analysis results were based on the transmission planning criteria (in terms of both the power flow and bus voltages), which were described in Chapter 3. The evaluation only covered the 500kV transmission system.

[1] 1 unit of generator (600MW x 1) was assumed for Jamshoro power plant in the analysis model for comparison among the three candidate power plant locations based on the information that ADB changed the policy of financing, namely, financing for 1 unit.
[2] The power output of Thar CFPP was set out as 3,600MW based on the information provided by TECB in November 2013 for comparison among the three candidate power plant locations in the previous chapter, which was much severer power flow condition than that of NTDC's original system plan.

(2) Study Cases

Two study cases were set out depending on whether the Lakhra CFPP exists or not as shown in Table 6.2-2.

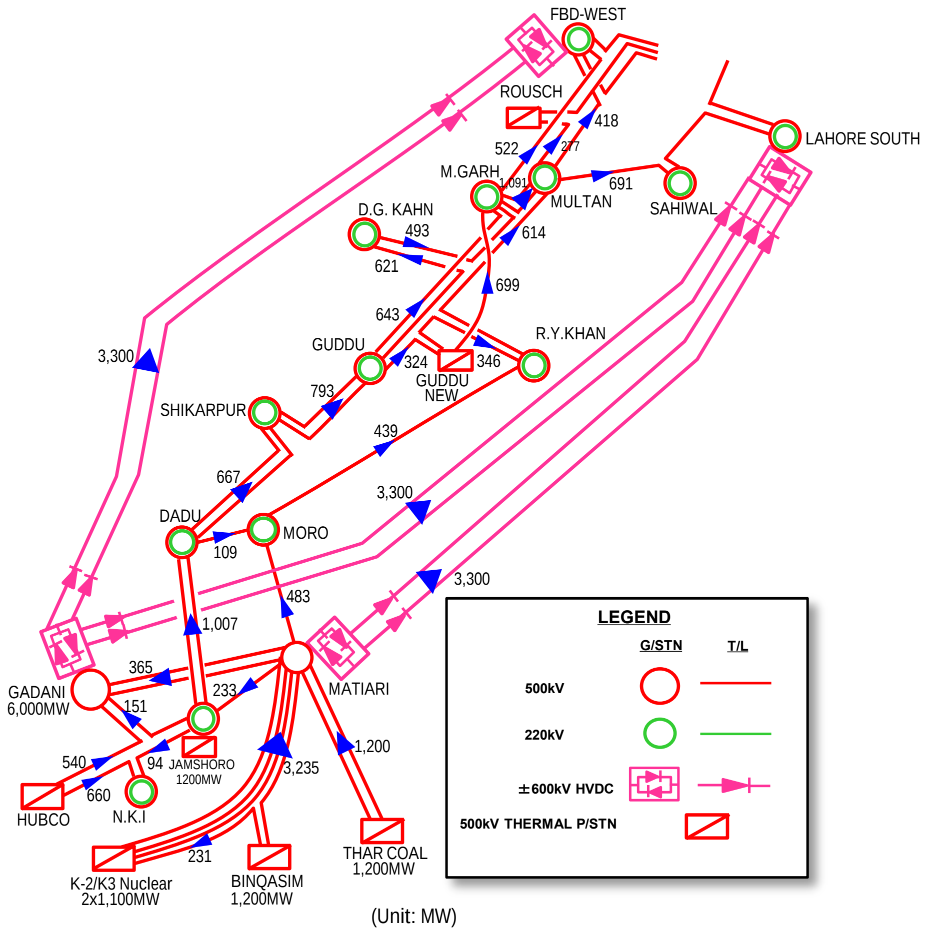
Table 6.2-2 Power Flow Analysis Study Cases

With/Without Lakhra CFPP	Case Name
Without	PF-WLK
With	PF-LK (PF 1-1)

Source: JICA Survey Team

(3) Analysis Results

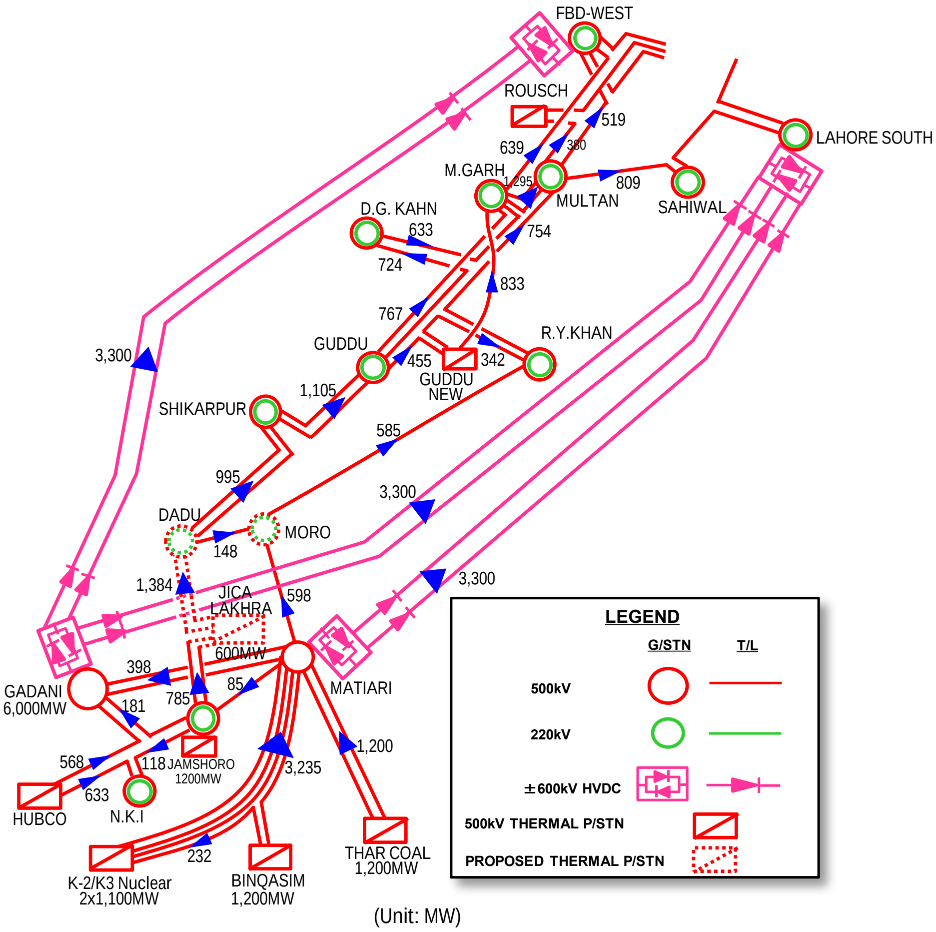
Under the normal operating condition, no overloading or voltage violation occurred to the 500kV power system in the South for both PF-LK (PF 1-1) and PF-WLK cases. The power flow diagrams for the normal operation condition are shown in Figure 6.2-1 and 6.2-2, respectively. The PSS/E power flow diagrams are shown in Appendix 6.3.



Source: JICA Survey Team

Figure: 6.2-1 Power Flow under Normal Operating Condition (Without Lakhra CFPP (PF-WLK))

Under N-1 contingency condition, no overloading occurred to any section for both PF-WLK case and PF-LK (PF 1-1) case. There was no voltage violation for both PF-WLK and PF-LK (PF 1-1) cases.



Source: JICA Survey Team

Figure: 6.2-2 Power Flow under Normal Operating Condition (With Lakhra CFPP (PF-LK: PF 1-1))

6.2.4 Transient Stability Analysis

(1) Evaluation Criteria

The power system was considered “stable” if the amplitude of oscillation waveforms of the rotor phase angle difference between arbitrary two generators of the south system is likely to be damped and converged under N-1 contingency condition.

(2) Study Cases

Two study cases were set out depending on whether the Lakhra CFPP exists or not as shown in Table 6.2-3.

Table 6.2-3 Transient Stability Analysis Study Cases

With/Without Lakhra CFPP	Case Name
Without	ST-WLK (ST1-1)
With	ST-LK

Source: JICA Survey Team

As the severe single contingency condition, a single circuit 3-phase short circuit fault at the sending end of the 500kV transmission sections between Jamshoro substation and Multan substations as well as those which were connected to Jamshoro and Matiari substations were selected.

The study cases and the fault sections are summarized in Table 6.2-4 The cells with "Y" indicate that the sections are relevant to the analysis, while the gray cells are not applicable for the study case in question.

The fault sequence for the analysis is shown in Table 6.2-5.

Table 6.2-4 Study Cases and the Fault Sections

Fault Section \ Case	ST-LK (ST 1-1)	ST-WLK
Jamshoro S/S – JICA Lakhra PP	Y	
JICA Lakhra PP – Dadu New S/S	Y	
Jamshoro S/S – Gadani S/S	Y	Y
Jamshoro S/S – NKI S/S	Y	Y
Jamshoro S/S – Dadu New S/S		Y
Dadu New S/S – Moro S/S	Y	Y
Matiari S/S – Gadani S/S	Y	Y
Matiari S/S – Jamshoro S/S	Y	Y
Matiari S/S – Moro S/S	Y	Y
Moro S/S – R. Y. Khan S/S	Y	Y
R. Y. Khan S/S – Multan S/S	Y	Y
Dadu New S/S – Shikarpur S/S	Y	Y
Shikarpur S/S – Guddu S/S	Y	Y
Guddu S/S – Muzaffargarh S/S	Y	Y
Guddu S/S – D. G. Khan S/S	Y	Y
Guddu New PP – Muzaffargarh S/S	Y	Y
Muzaffargarh S/S – Multan S/S	Y	Y

Source: JICA Survey Team

Table 6.2-5 Fault Sequence

Time	Sequence
0 ms	3-phase short circuit fault occurred to a circuit of 500kV transmission line
100 ms	Clear fault and open the faulted circuit
10 s	End of calculation

Source: JICA Survey Team

(3) Study Results

The oscillation waveforms of the generator rotor phase angle difference between a generator of HUBCO power plant and that of other principal power plants in the south system for all cases were shown in Appendix 6-1 (Without Lakhra Power Plant Case) and 6-2 (With Lakhra Power Plant Case), respectively. The analysis results are summarized in Table 6.2-6.

Table 6.2-6 Transient Stability Analysis Results

Case / Fault Section	With Lakhra P/S ST 1-1	Without Lakhra P/S
Jamshoro S/S – JICA Lakhra PP	Unstable	
JICA Lakhra PP – Dadu New S/S	Unstable	
Jamshoro S/S – Gadani S/S	Unstable	Stable
Jamshoro S/S – NKI S/S	Unstable	Stable
Jamshoro S/S – Dadu New S/S		Stable
Dadu New S/S – Moro S/S	Stable	Stable
Matiari S/S – Gadani S/S	Unstable	Stable
Matiari S/S – Jamshoro S/S	Unstable	Stable
Matiari S/S – Moro S/S	Unstable	Stable
Moro S/S – R. Y. Khan S/S	Stable	Stable
R. Y. Khan S/S – Multan S/S	Stable	Stable
Dadu New S/S – Shikarpur S/S	Stable	Stable
Shikarpur S/S – Guddu S/S	Stable	Stable
Guddu S/S – Muzaffargarh S/S	Stable	Stable
Guddu S/S – D. G. Khan S/S	Stable	Stable
Guddu New PP – Muzaffargarh S/S	Stable	Stable
Muzaffargarh S/S – Multan S/S	Stable	Stable

Source: JICA Survey Team

For “Without Lakhra” power plant case, the south system was proved to be stable in the case of any single circuit fault of the 500kV transmission lines. On the other hand, for “With Lakhra” power plant case, the system became unstable when a single circuit fault occurred to any sections from/to Jamshoro substation, Matiari switching station, and Lakhra power plant.

6.2.5 Influence of new Lakhra Power Plant

As the results of power flow and transient stability analyses, it is concluded that the proposed connection scheme for the proposed Lakhra power plant leads to instability in south system in the case of single circuit fault of some transmission sections. Hence further study on alternative connection schemes is necessary to resolve the issue.

Generally, addition of the number of circuits in the sections which cause instability in the system is considered effective way to improve the stability; however, there is a restriction that it was not accepted by NTDC to add another or more than two circuits to the existing 500kV transmission lines from Jamshoro substation to up-country due to difficulty in land acquisition for the right-of-way and construction. Therefore, as one of the alternative ways to satisfy the need of stability improvement, it is worth examining the additional connection to Matiari switching station, making a certain portion of the power flow divert to another transmission route to up-country through Moro and R. Y. Khan substations to Multan substation. Alternative connection methods are examined in Chapter 6.3.

A series of power system analysis in this chapter was carried out based on the condition that Lakhra power plant had only one unit of generator. It is expected that ensuring the system stability becomes more difficult if future expansion of Lakhra power plant, in other words, addition of another unit of generator is materialized. Furthermore, this situation becomes much severer if power development in Thar Desert area proceeds in much larger-scale as the information by TCEB shows. The power flow analysis results described in the previous chapter showed the necessity of reinforcement of existing and planned HVAC 500kV transmission lines in many sections. Increase in the number of circuits may make it possible to increase the transmission capacity of the line; on the flip side however, the short-circuit fault current level increase as well.

Another option to consider the improvement of power system expansion is direct connection of HVDC 600kV from Thar Coal Field to Lahore area, the load center of the country in order to evacuate the bulk power, to restrain the reinforcement of HVAC 500kV transmission lines in a number of sections, and to improve the system stability. Although the stability of power system is enhanced with the direct connection, the additional DC connection is not affordable of the cost.

6.3 Comparison of Alternative Connection Schemes

Power system analysis for alternative connection schemes was carried out in order to confirm if the alternative system configurations resolve the system instability problem inherent in the prospective connection scheme described in the previous section.

6.3.1 Analysis Model

The PSS/E base file for both power flow and transient stability analyses is the same one which was used for a series of analysis done in the previous section. As for the output of large-scale power plants in the southern area, two scenarios were assumed as shown in Table 6.3-1. The scenario 2 considered the situation that commencement of commercial operation of Gadani, K-2/K-3, and Bin Qasim power plants was expected to be delayed.

The different analysis model for the fault current analysis, which was provided by NTDC, was used for the 3-phase short circuit fault current calculation.

Table 6.3-1 Output of Large-scale Power Plants

Scenario 1	All the large-scale power plants in southern area are in operation: - Gadani CFPP: 6,000MW - K-2/K-3 Nuclear PP: 2,200MW - Bin Qasim PP: 1,200MW - Thar CFPP: 1,200 MW - Jamshoro PP: 1,200MW - Lakhra CFPP: 600MW
Scenario 2	- Gadani CFPP, K-2/K-3 Nuclear PP, Bin Qasim PP: Out-of-service - Thar CFPP: 1200MW - Jamshoro PP: 1,200MW - Lakhra CFPP: 600MW

Source: JICA Survey Team

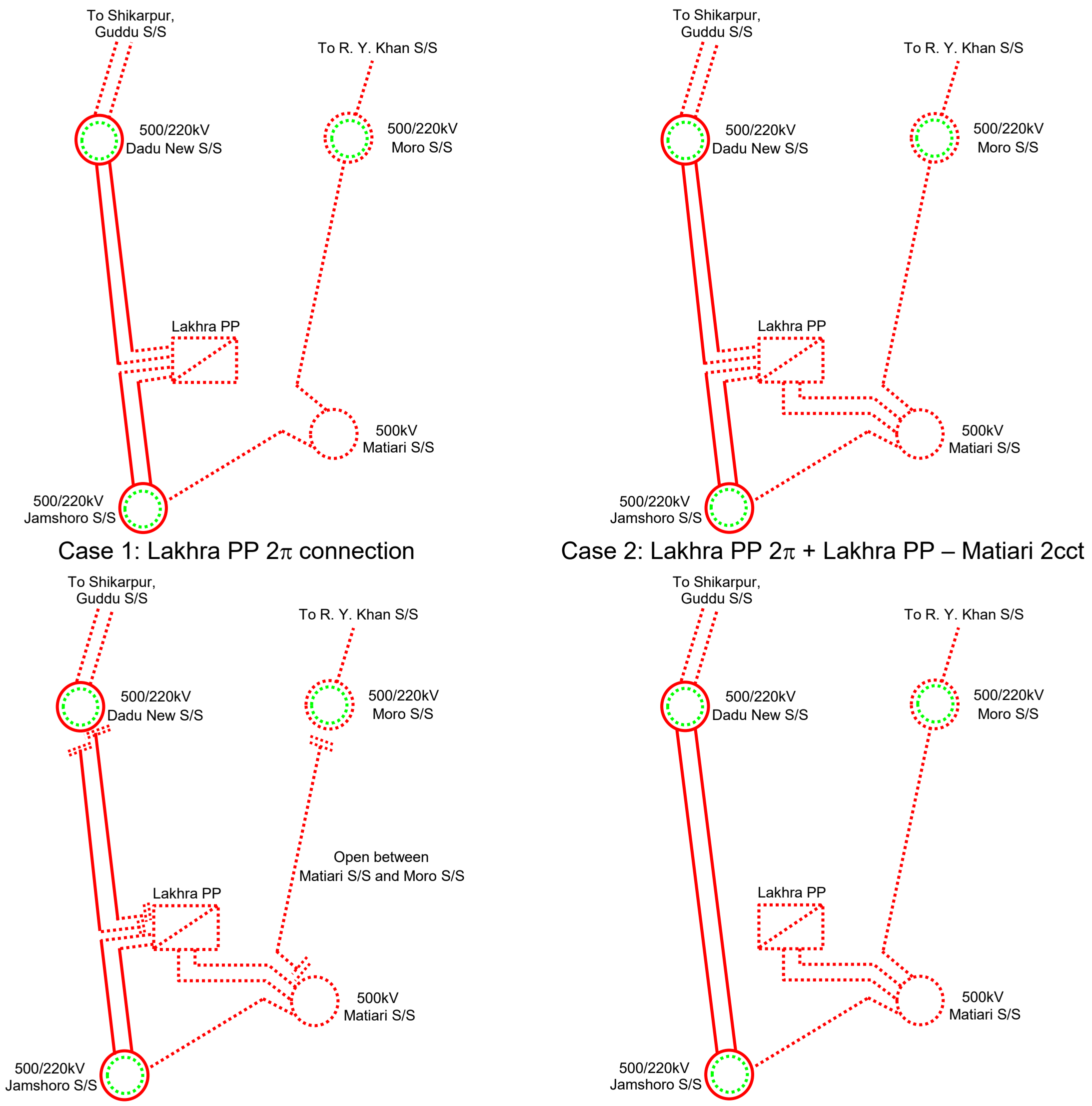
6.3.2 Power Flow Analysis

(1) Evaluation Criteria

The evaluation of the power flow analysis results were based on the transmission planning criteria (in terms of both the power flow and bus voltages), which were described in Chapter 3. The evaluation only covered the 500kV transmission system.

(2) Study Cases

Four study cases were set out based on the difference in the connection schemes as shown in Figure 6.3-1. Table 6.3-2 shows all the study cases considered. The analysis of Case 1-1 was excluded since the analysis model and its condition are the same as those used in section 6.3 and 6.4. The Case 4 was the connection scheme that was additionally proposed by NTDC. Only Case 4-1 was considered for the analysis to check the power flow situation under the severest power generation condition.



Case 1: Lakhra PP 2π connection

Case 2: Lakhra PP 2π + Lakhra PP – Matiari 2cct

Case 3: Lakhra PP 2π + Lakhra PP – Matiari 2cct, Matiari – Moro and Lakhra PP – Dadu New: Open

Case 4: Lakhra PP – Matiari 2cct

Source: JICA Survey Team

Figure 6.3-1 Connection Patterns for the Analysis

Table 6.3-2 Study Cases

Connection Pattern		Lakhra PP 2π	Lakhra PP 2π + Lakhra PP - Matiari 2cct	Lakhra PP 2π + Lakhra PP - Matiari 2cct, Matiari-Moro and Lakhra PP – Dadu New: Open	Lakhra PP - Matiari 2cct (NTDC's Proposal)
Case (X)		1	2	3	4
Generation	All planned large-scale Power Plant in South Area in Operation (PF X-1)	PF 1-1*	PF 2-1	PF 3-1	PF 4-1
	All of the Large-scale Power Plant in Southern Area but Thar Power Plant are out-of-service (PF X-2)	PF 1-2	PF 2-2	PF 3-2	

Source: JICA Survey Team

<NOTE> * Study on PF 1-1 was excluded in this section since the analysis model and its condition are the same as those used in Section 6.3 and 6.4.

(3) Analysis Results

Both under normal operation and N-1 contingency conditions, no overloading or voltage violation occurred to the 500kV system for all of the study cases in Table 6.3-1.

6.3.3 Transient Stability Analysis

(1) Evaluation Criteria

The same evaluation criteria are applied as described in the section 6.3.1.

(2) Study Cases

Four study cases were set out depending on the difference in the connection schemes for the new Lakhra CFPP as shown in Table 6.3-3.

Table 6.3-3 Study Cases

Connection Pattern		Lakhra PP 2π	Lakhra PP 2π + Lakhra PP - Matiari 2cct	Lakhra PP 2π + Lakhra PP-Matiari 2cct, Matiari-Moro and Lakhra PP – Dadu New: Open	Lakhra PP - Matiari 2cct (NTDC's Proposal)
Case (X)		1	2	3	4
Generation	All planned large-scale Power Plant in South Area in Operation (ST X-1)	ST 1-1*	ST 2-1	ST 3-1	ST 4-1
	All of the Large-scale Power Plant in Southern Area but Thar Power Plant are out-of-service (ST X-2)	ST 1-2	ST 2-2	ST 3-2	

Source: JICA Survey Team

<NOTE> * Study on PF 1-1 was excluded in this section since the analysis model and its condition are the same as those used in Section 6.3 and 6.4.

As the severe single contingency condition, a single circuit 3-phase short-circuit fault near the sending end of the 500kV transmission sections which are directly or indirectly connected to the Lakhra CFPP were selected as shown in Table 6.3-4. The cells with "Y" indicate that the sections are relevant to the analysis, while the gray cells indicate that the sections are not applicable for the study case in question. The same fault sequence as shown in Table 6.3-3 was applied to the stability analysis.

Table 6.3-4 Applicable Fault Sections for each Study Case

Fault Section \ Case	ST 1-2	ST 2-1	ST 2-2	ST 3-1	ST 3-2	ST 4-1
JICA Lakhra PP – Dadu New S/S	Y	Y	Y			
JICA Lakhra PP – Matiari S/S		Y	Y	Y	Y	Y
Jamshoro S/S – JICA Lakhra PP	Y	Y	Y	Y	Y	
Jamshoro S/S – Dadu New S/S						Y
Jamshoro S/S – Gadani S/S	Y	Y	Y	Y	Y	Y
Jamshoro S/S – NKI S/S	Y	Y	Y	Y	Y	Y
Jamshoro S/S – Matiari S/S	Y	Y	Y	Y	Y	Y
Coal Gadani PP – Gadani S/S		Y		Y	Y	Y
Matiari S/S – Gadani S/S	Y	Y	Y	Y	Y	Y
Matiari S/S – Moro S/S	Y	Y	Y			Y
K-2/K-3 PP – Matiari S/S		Y		Y	Y	Y
Bin Qasim PP – Matiari S/S		Y		Y	Y	Y
Thar PP – Matiari S/S	Y	Y	Y	Y	Y	Y
Dadu New S/S – Moro S/S	Y	Y	Y	Y	Y	Y
Moro S/S – R. Y. Khan S/S	Y	Y	Y	Y	Y	Y
R. Y. Khan S/S – Multan S/S	Y	Y	Y	Y	Y	Y
Dadu New S/S – Shikarpur S/S	Y	Y	Y	Y	Y	Y
Shikarpur S/S – Guddu S/S	Y	Y	Y	Y	Y	Y
Guddu S/S – Muzaffargarh S/S	Y	Y	Y	Y	Y	Y
Guddu S/S – D. G. Khan S/S	Y	Y	Y	Y	Y	Y
D. G. Khan S/S – Muzaffargarh S/S	Y	Y	Y	Y	Y	Y
Guddu S/S – Guddu New PP	Y	Y	Y	Y	Y	Y
Guddu New PP – Muzaffargarh S/S	Y	Y	Y	Y	Y	Y
Guddu New PP – R. Y. Khan S/S	Y	Y	Y	Y	Y	Y
Muzaffargarh S/S – Multan S/S	Y	Y	Y	Y	Y	Y

Source: JICA Survey Team

(3) Study results

The oscillation waveforms of the generator rotor angle difference between a generator of Muzaffargarh power plant and that of other principal power plants in the south system for all cases were shown in Appendix 6-1 to Appendix 6-6. The analysis results are summarized in Table 6.3-5.

Table 6.3-5 Transient Stability Analysis Results

Fault Section \ Case	ST 1-2	ST 2-1	ST 2-2	ST 3-1	ST 3-2	ST 4-1
JICA Lakhra PP – Dadu New S/S	Stable	Stable	Stable			
JICA Lakhra PP – Matiari S/S		Stable	Stable	Unstable	Stable	Stable
Jamshoro S/S – JICA Lakhra PP	Stable	Unstable	Stable	Unstable	Stable	
Jamshoro S/S – Dadu New S/S						Unstable
Jamshoro S/S – Gadani S/S	Stable	Unstable	Stable	Unstable	Stable	Unstable
Jamshoro S/S – NKI S/S	Stable	Unstable	Stable	Unstable	Stable	Unstable
Jamshoro S/S – Matiari S/S	Stable	Unstable	Stable	Unstable	Stable	Unstable
Coal Gadani PP – Gadani S/S		Unstable		Unstable		Unstable
Matiari S/S – Gadani S/S	Stable	Unstable	Stable	Unstable	Stable	Unstable
Matiari S/S – Moro S/S	Stable	Unstable	Stable			Unstable
K-2/K-3 PP – Matiari S/S		Stable		Stable		Stable
Bin Qasim PP – Matiari S/S		Stable		Stable		Stable
Thar PP – Matiari S/S	Stable	Stable	Stable	Stable	Stable	Stable
Dadu New S/S – Moro S/S	Stable	Stable	Stable	Stable	Stable	Stable
Moro S/S – R. Y. Khan S/S	Stable	Stable	Stable	Stable	Stable	Stable
R. Y. Khan S/S – Multan S/S	Stable	Stable	Stable	Stable	Stable	Stable
Dadu New S/S – Shikarpur S/S	Stable	Stable	Stable	Stable	Stable	Stable
Shikarpur S/S – Guddu S/S	Stable	Stable	Stable	Stable	Stable	Stable
Guddu S/S – Muzaffargarh S/S	Stable	Stable	Stable	Stable	Stable	Stable
Guddu S/S – D. G. Khan S/S	Stable	Stable	Stable	Stable	Stable	Stable
D. G. Khan S/S – Muzaffargarh S/S	Stable	Stable	Stable	Stable	Stable	Stable
Guddu S/S – Guddu New PP	Stable	Stable	Stable	Stable	Stable	Stable
Guddu New PP – Muzaffargarh S/S	Stable	Stable	Stable	Stable	Stable	Stable
Guddu New PP – R. Y. Khan S/S	Stable	Stable	Stable	Stable	Stable	Stable
Muzaffargarh S/S – Multan S/S	Stable	Stable	Stable	Stable	Stable	Stable

Source: JICA Survey Team

As Table 6.3-5 shows, the south power system becomes unstable regardless of the difference in the connection schemes if all of the large-scale planned power plants in the south are in operation. On the other hand, if some of the power plants are assumed to be out-of-service, the 500kV power system is likely to be stable. This result suggests the necessity of further expansion of the trunk transmission system to evacuate the bulk power generated by the planned power plants.

As the consequence of the studies of alternative connection methods on both power flow and transient stability mentioned above, the Case 1 in Figure 6.3-1 (Lakhra PP 2□ connection) was selected for the connection scheme for Lakhra PP in consideration with increase of erection cost of additional transmission line to Matiari S/S for case 2 and 3.

6.4 Conclusions

Table 6.4-1 Summary of Power System Analysis

Case Number		1-1	1-2	2-1	2-2	3-1	3-2	4-1
Case Description	Connection Method	Lakhra PP 2π		Lakhra PP 2π + Lakhra PP - Matiari 2cct		Lakhra PP 2π + Lakhra PP-Matiari 2cct, Matiari-Moro and Lakhra PP – Dadu New: Open		Lakhra PP - Matiari 2cct (NTDC's Proposal)
	Assumed Generation	All planned large scale Power Plant in South Area in Operation	All of the Large scale Power Plant in Southern Area but Thar Power Plant are out-of-service	All planned large scale Power Plant in South Area in Operation	All of the Large scale Power Plant in Southern Area but Thar Power Plant are out-of-service	All planned large scale Power Plant in South Area in Operation	All of the Large scale Power Plant in Southern Area but Thar Power Plant are out-of-service	All planned large scale Power Plant in South Area in Operation
Result of Power Flow Analysis		√ (No Overload)	√ (No Overload)	√ (No Overload)	√ (No Overload)	√ (No Overload)	√ (No Overload)	√ (No Overload)
Result of Transient Stability Analysis		(Unstable)	√ (Stable)	(Unstable)	√ (Stable)	(Unstable)	√ (Stable)	(Unstable)
Construction Cost			Low		high		high	
Evaluation			Selected					

Source: JICA Survey team

Table 6.4-1 shows summary of Power System Analysis in this Chapter. A series of power system analyses for new Lakhra CFPP was carried out in several cases.

No overloading occurred to any section through all simulation cases, 1-1 to 4-1 by power flow analyses, on the other hand, transient stability analyses resulted in instability with all planned power plants as conducted for case 1-1, 2-1 and 3-1.

On the other hands, the connection of new Lakhra power plant in case 1-2, 2-2, and 3-2 concluded steady with specific power plants which we assumed to be installed by 2020 from viewpoint of realization on schedule. Among the stable cases, the case 1 (2π connection to existing 500 kV transmission line between Jamshoro and Dadu New substations) was consequently selected most feasible in consideration with additional erection cost of transmission line to Matiari S/S.

For the reference, additional Study including wind generation and HUBCO extension was studied in Appendix 6-7.