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# NVIRONMENTAL AND SOCIAL SOUNDNESS ASSESSMENT

## VOLUME I
## EXECUTIVE SUMMARY

## LAKHRA COAL MINE AND POWER GENERATION PROJECT

## PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

Sponsored by:
OFFICE OF ENERGY AND ENVIRONMENT
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
MISSION TO PAKISTAN

Prepared by:
ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
and
KBN ENGINEERING AND APPLIED SCIENCES, INC.

March 1987

# EXECUTIVE SUMMARY:

# LAKHRA COAL MINE AND POWER GENERATION PROJECT ENVIRONMENTAL AND SOCIAL SOUNDNESS ASSESSMENT (INCLUDING ENVIRONMENTAL MITIGATION PLAN)

PAKISTAN WATER AND POWER
DEVELOPMENT AUTHORITY
Lahore, Pakistan

Sponsored by:

OFFICE OF ENERGY AND ENVIRONMENT
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
MISSION TO PAKISTAN
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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAQS | Ambient Air Quality Standards |
| ADB | Asian Development Bank |
| Btu | British thermal units |
| Btu/kW | British thermal units per kilowatt |
| CC | combined cycle |
| CT | combustion turbine |
| cusec | cubic foot per second |
| EA | Environmental Assessment |
| EMP | Environmental Mitigation Plan |
| ENERPLAN | Ministry of Energy |
| ESE | Environmental Science and Engineering, Inc. |
| ESP | Electrostatic precipitation |
| FBC | Fluidized bed combustion |
| FGD | Flue gas desulfurization |
| GCII | Gilbert/Commonwealth International, Inc. |
| GOP | Government of Pakistan |
| GSP | Geological Survey of Pakistan |
| ha | hectare |
| KBN | KBN Engineering and Applied Sciences, Inc. |
| km | Kilometer |
| kV | Kilovolt |
| $lb/10^6$ Btu | Pounds per million British thermal units |
| LIMB | Limestone injection multistage burner |
| $m^3$/day | Cubic meters per day |
| $m^3$/year | Cubic meters per year |
| mg/L | Milligrams per liter |
| MH | Ministry of Health |
| MI | Ministry of Industry |
| ML | Ministry of Labor |
| MPD | Ministry of Planning and Development |
| MT/day | Metric tons per day |

| | |
|---|---|
| MT/yr | Metric tons per year |
| MW | Megawatt |
| $NO_x$ | Nitrogen oxide |
| $NO_2$ | Nitrogen dioxide |
| PCSIR | Pakistan Council for Scientific and Industrial Research |
| PEPA | Pakistan Environmental Protection Agency |
| PM | Particulate matter |
| PMDC | Pakistan Mineral Development Corporation |
| $SO_2$ | Sulfur dioxide |
| TLV | Threshold Limit Values |
| $ug/m^3$ | Micrograms per cubic meter |
| USAID | United States Agency for International Development |
| WAPDA | Water and Power Development Authority |

# 1.0 INTRODUCTION

This Executive Summary provides an overview of the significant environmental and social effects, as well as proposed mitigative measures, for a coal mine and power plant project proposed to be located in the Lakhra coal field, Sind Province, Pakistan. The preferred project would consist of a two-unit, 500-megawatt (MW) power plant located at Lakhra; a combination underground/surface mine; and a power plant workers' colony located at Khanot. The purpose of the document is to provide representatives of the host country and donor organizations a clear understanding of the significant impacts of the project to the natural and human environment, as well as the project's benefits in developing the coal resources and the necessary electrical energy for Pakistan. The main report, titled "Environmental and Social Soundness Assessment, Lakhra Coal Mine and Power Generation Project," provides more detailed information on the environmental and social effects of the project.

The Environmental Assessment (EA) was prepared using specific data and information collected for the project through field and site visits by staff from Environmental Science and Engineering, Inc. (ESE) and KBN Engineering and Applied Sciences, Inc. (KBN). Technical and economic information was obtained from J.T. Boyd Company (mining feasibility), Gilbert/Commonwealth International, Inc. (GCII) (power plant feasibility), and ICF Incorporated (economic feasibility). A portion of the EA relied on information developed on the social-cultural feasibility of the project by the Institute for Development Anthropology (Helweg et al., 1985). In addition, environmental representatives from J.T. Boyd Company and GCII assisted in the preparation of the description of the mining and social impacts of the project, respectively.

Preparation of the Environmental and Social Soundness Assessment followed the procedures of:

1. The Government of Pakistan (GOP) Environmental Policy and Regulations (Ordinance No. XXVII of 1983 and Environmental Pro forma),
2. The United States Agency for International Development (USAID) Environmental Policy and Regulations (PD-6, 22CFR216), and
3. The environmental guidelines of the World Bank and Asian Development Bank (ADB).

The preparation of the EA involved a detailed analysis of various alternatives and a detailed environmental assessment of a preferred alternative. Several alternatives were evaluated for power plant and mine combinations:

1. 300-MW, single-unit power plant and associated 1.6 million metric tons/year from an underground and/or surface mine;
2. 500-MW power plant consisting of two units and associated 2.7 million metric tons/year from a combined underground/surface mine; and
3. 700-MW power plant consisting of two units and associated 3.8 million metric tons/year from a combined underground/surface mine.

In addition, three alternative sites were evaluated for the power plant: Lakhra (at mine site), Khanot [about 20 kilometers (km) east of the Lakhra site and about 2.5 km from the Indus River], and Jamshoro (approximately 35 km southeast of the Lakhra site and about 5 km from the Indus River). For a power plant located at the Lakhra site, two alternatives for the workers colony were evaluated: Lakhra and Khanot.



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## 2.0 OBJECTIVES OF THE PROJECT AND THE GOVERNMENT OF PAKISTAN

The shortage of electric power is one of the most serious obstacles to the economic and social development of Pakistan. Under the range of current and potential electrical energy demands, about 800 MW/year in new thermal generating capacity will be required in the early 1990s to assist in alleviating this shortage as well as providing for future energy needs.

The Lakhra Coal Mine and Power Generation Project has been proposed as one facet of a comprehensive energy management plan to provide the needed generation [Pakistan Water and Power Development Authority (WAPDA), 1986]. In addition, the project will also assist the GOP in:

1. Diversifying fuel usage,
2. Increasing energy self-sufficiency and reducing foreign exchange exposure,
3. Developing a coal-fired generation technology base,
4. Mobilizing and developing a modern private sector coal industry, and
5. Providing domestic economic and industrial development.



9'

## 3.0 DESCRIPTION OF PROPOSED PROJECT AND STUDY AREA

The Lakhra coal project will consist of the following two components: (1) a coal mine with associated facilities (e.g., transportation), and (2) a power generation complex. The coal mine and associated facilities will be developed and operated by the private sector, whereas the power plant complex will be operated by WAPDA.

The area that covers the Lakhra coal field, including the proposed coal mine and power plant site at Lakhra and the proposed power plant site at Khanot, are located in the Dadu District of the province of Sind (Figure 3-1). The coal mine and power plant are located in the northern portion of the Lakhra field within about a 80-square-kilometer area which is controlled by the Pakistan Mineral Development Corporation (PMDC) under a series of leases granted by the Sind government. The Indus River runs along the District's eastern boundary. To the east is the Hyderabad District containing the City of Hyderabad. Agriculture is the main economic activity in the Dadu District. The more suitable agricultural lands occur in the Hyderabad District. Grazing and torrent-watered cropping is the primary agriculture activity within the Lakhra area.

Coal mining is a major source of employment and revenue in the area surrounding the Lakhra coal field. The Lakhra coal field is approximately 15 km west of the Indus Highway and currently includes several privately owned mines. These existing mines occur south of the proposed project area. Scattered throughout these mines are a few Khosa Baluch (nomadic tribesmen) villages ranging in size from 20 to 100 people. The main road from the Indus Highway to Lakhra is located approximately 1 km (0.6 mile) below the village of Khanot. This village is composed of about 1,500 people. A major north/south rail line of the Pakistan Railway runs east of the Indus Highway with a rail station at Khanot. A truck stop with shops and a mosque are located at the

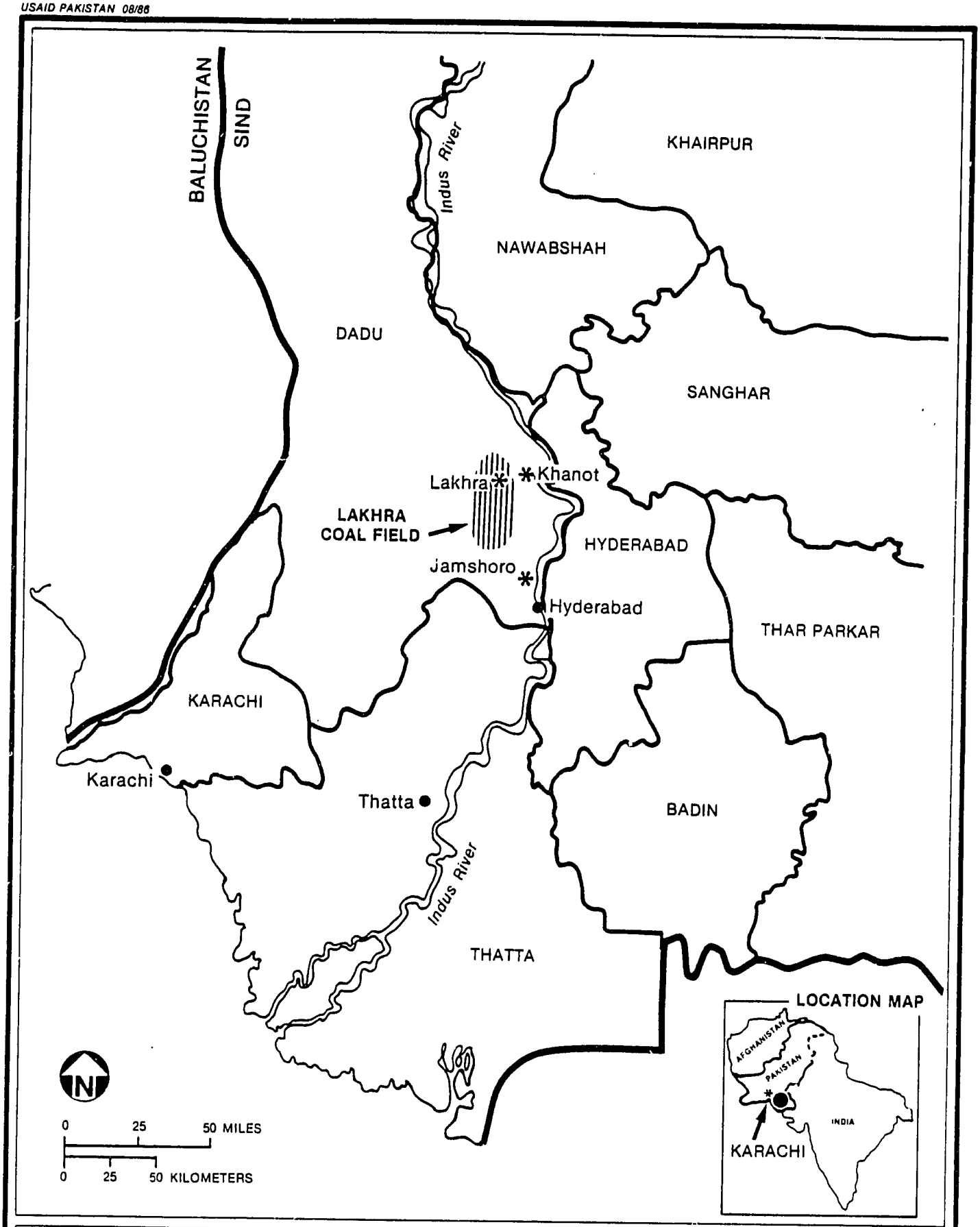


Figure 3-1
LOCATION OF LAKHRA COAL FIELD
AND PROJECT AREA

SOURCES: GOVERNMENT OF PAKISTAN, 1984; ESE, 1986.

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

intersection of the Indus Highway and Lakhra road. Several other Sindhi villages are located in a 5-km (3-mile) radius to the northeast and southeast of the truck stop. The City of Hyderabad, which is located about 30 km (20 miles) south of the intersection of the Lakhra mine road and the Indus Highway, has a population of approximately 750,000.

The coal mining facilities, as developed by J.T. Boyd Company in their feasibility reports, will include:

1. One and/or two open pit mines and possibly one or more underground mine(s) in the Lakhra Coal field to produce 1.6 to 3.8 million metric tons per year ($10^6$ MT/year);
2. Surface coal handling facilities and transportation; and
3. A colony for miners and mine support personnel, along with necessary access roads, utilities, and other necessary equipment and infrastructure.

The actual mining method and facility to supply coal to the Lakhra Power Plant will be those proposed by the successful offerer(s) and may be different from that developed and presented in the feasibility reports.

The power generation facilities, as developed by GCII in their feasibility reports, will include:

1. A coal-fired, steam power plant with a capacity ranging from 250 to 700 MW located in the Province of Sind either at Jamshoro, Khanot, or Lakhra;
2. Coal receiving, storage, and handling facilities;
3. Air pollution control equipment (i.e., electrostatic precipitators and combustion controls) and a space for flue gas desulfurization (FGD) units and for FGD sludge disposal;
4. Ash handling and disposal;
5. Electrical connection facilities to WAPDA's existing 500-kilovolt (kV) transmission network;



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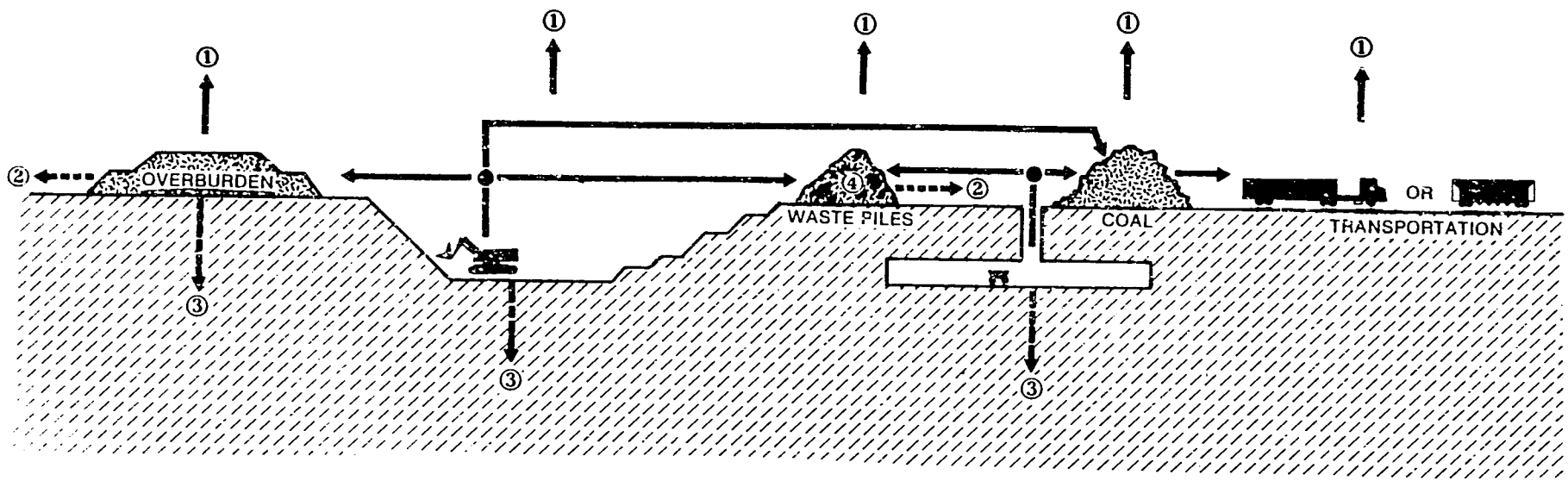
6. An intake water system located on the Indus River, and a water supply line to the power plant of a size sufficient for all plant and colony requirements (with onsite storage ponds at Lakhra);
7. A colony for plant construction, operation, and maintenance personnel;
8. Provision for disposal or use of cooling tower blowdown and low volume wastes;
9. Rail and road access; and
10. Training facilities and secondary infrastructure support.

# 4.0 ENVIRONMENTAL ASSESSMENT PURPOSE AND SCOPE

The purpose of the EA is to provide host country and donor agency decision makers with a full discussion of significant environmental effects of the planned coal-fired power plant and associated mine project. The EA includes an evaluation of alternatives which would avoid or minimize adverse effects or enhance the quality of the environment so that the expected benefits of development objectives can be weighed against any adverse impacts upon the human environment or any irreversible or irretrievable commitment of resources.

From this evaluation, monitoring programs are developed to assess the project's impacts and to provide a mechanism for managing environmental effects as they occur. These monitoring programs provide the basis for WAPDA, the private sector, and GOP agencies to implement an environmental program for the project.

For a coal mine and power generation project, potential environmental impacts may occur to the air, water, and land resources (see Figures 4-1 and 4-2) as well as to the existing socioeconomic infrastructure of the region. These potential impacts have been evaluated in the EA.




KEY
① AIR POLLUTION
② SURFACE WATER DISCHARGE
③ GROUND WATER DISCHARGE
④ SOLID WASTE DISPOSAL

Figure 4-1
GENERIC FLOW DIAGRAM OF SURFACE AND UNDERGROUND MINE AND MAJOR POTENTIAL ENVIRONMENTAL IMPACTS

SOURCE ESE, 1986

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

USAID PAKISTAN 08/86

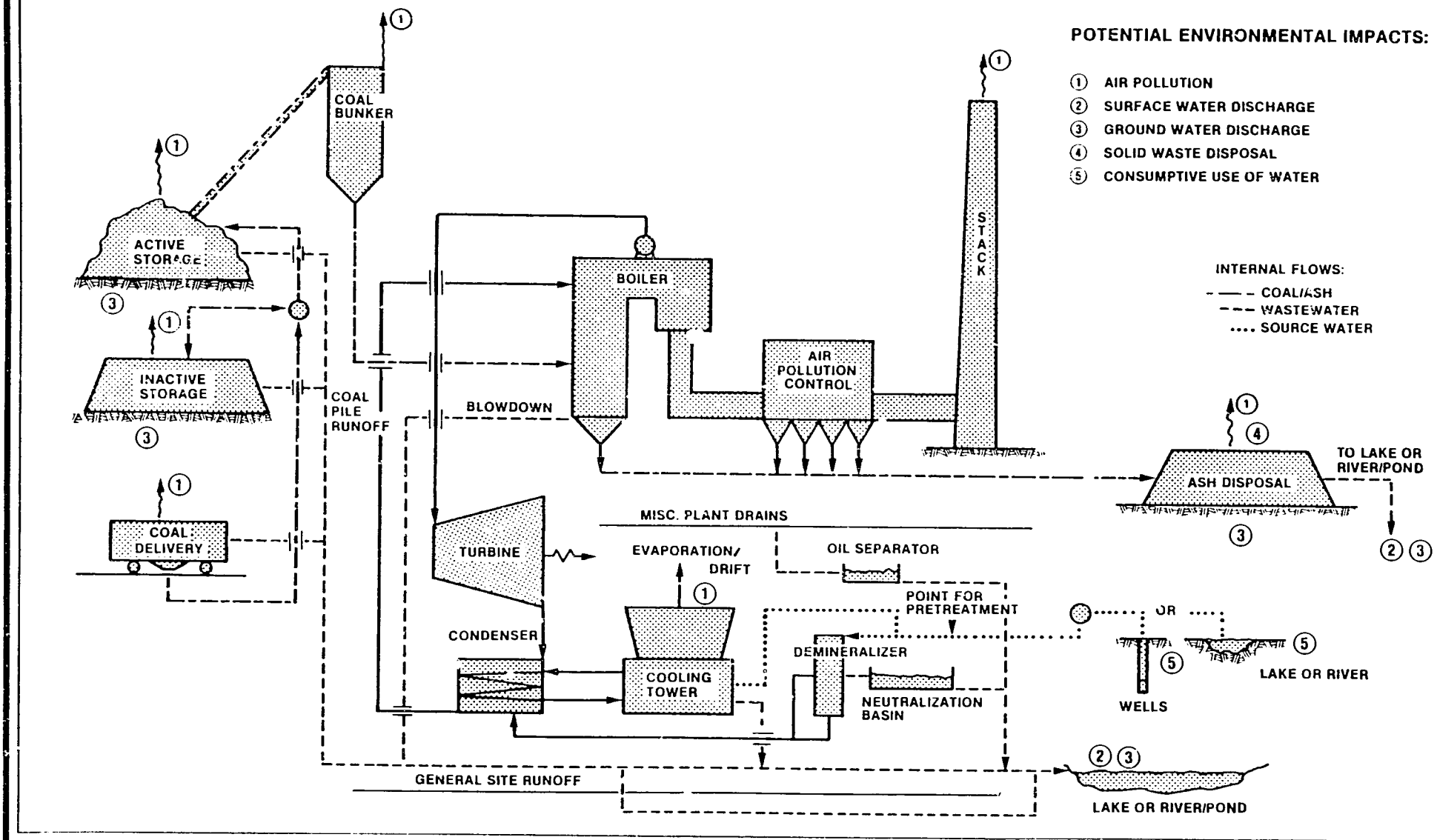



Figure 4-2
GENERIC FLOW DIAGRAM OF COAL-FIRED POWER PLANT AND MAJOR POTENTIAL ENVIRONMENTAL IMPACTS

SOURCE: ESE, 1986

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

Lakhra Coal Mine and Power Generation Feasibility Study

USAID PAKISTAN 08/86

# 5.0 ENVIRONMENTAL POLICY AND REGULATIONS

## 5.1 GOVERNMENT OF PAKISTAN

With the promulgation of the Pakistan Environmental Ordinance of 1983, GOP has initiated the mechanisms for formulating national environmental policy and developing and enforcing national environmental quality standards. Policy and standards approval is the purview of the Pakistan Environmental Council, whereas standards development and enforcement, as well as other environmental programs, are administered by the Environmental and Urban Affairs Division of the Ministry of Housing and Works.

For the Lakhra project, GOP has requested the preparation of an EA via the requirement for an Environmental Pro forma (Ordinance No. XXVII of 1983). Currently, no environmental standards have been adopted by GOP; however, draft standards have been proposed that would restrict the discharge of pollutants into the atmosphere and water. Additionally, GOP and the Sind Government have established legislation governing antiquities, endangered species, national parks, wildlife sanctuaries, game reserves, forestry, and water management.

The major environmental legislation and regulations are presented in Table 5-1.

## 5.2 DONOR ORGANIZATIONS

Multilateral development organizations, such as the World Bank and ADB, have established procedures for the evaluation of potential environmental impacts (i.e., development of EA) and the adequacy of pollution control measures of financed projects (i.e., environmental guidelines). These evaluations are concerned with both the natural and human environment as well as the health and safety of workers. Development of the Lakhra coal project, for which the GOP is seeking a portion of the funding from the

Table 5-1. Major Environmental Legislation and Regulations for Pakistan

| Type | Authority | Administering Agency | Requirements |
|---|---|---|---|
| Comprehensive Environmental Protection | Ordinance No. XXVII of 1983 | Environmental and Urban Affairs Div. Ministry of Housing and Works | Environmental Pro forma |
| Protection of Antiquities | Act No. VI of 1977 | Ministry of Culture, Archaeology, Sports, and Tourism; Dept. of Archaeology | Provides protection and preservation of historically and archaeologically important sites |
| Water Resources | West Pakistan Act of 1958 | WAPDA | Management of water resources |
| | Sind Irrigation Act of 1879 | Government of Sind, Irrigation and Power Department | Granting of water use from Indus River |
| Wildlife | West Pakistan Wildlife Protection Ordinance of 1959 | Zoological Survey; National Council for Conservation of Wildlife; Ministry of Food, Agriculture, and Cooperatives | Promote conservation and establish limits on hunting |
| Wildlife | Sind Wildlife Protection Ordinance | Government of Sind, Ministry of Forest, Wildlife, and Forestry | Promote conservation and limit hunting |

Table 5-1. Major Environmental Legislation and Regulations for Pakistan (Continued, Page 2 of 2)

| Type | Authority | Administering Agency | Requirements |
|---|---|---|---|
| Forests | Forest Act of 1927 No. XVI | Ministry of Food, Agriculture, and Cooperatives; Pakistan Forest Institute; Government of Sind, Ministry of Forest, Wildlife, and Forestry | Protection; regulation of exploitation of forests |

Sources: ESE, 1986.
KBN, 1986.

World Bank, is required to involve consideration of Environmental Guidelines established by the World Bank for developing countries. The preparation of the EA for the Lakhra Coal Project involved direct coordination with, and involvement of, the World Bank Office of Environmental Affairs. This coordination led to a set of environmental criteria for the mine and power plant (Tables 5-2 and 5-3).

Bilateral funding organizations, such as USAID, have established policies for evaluating the environmental consequences of funded projects. For USAID, environmental policies have been included as part of promulgated environmental procedures [see Appendix A for 22 Code of Federal Regulations (CFR) Part 216; § 216.1(b)] and in an official USAID policy determination on Environmental and Natural Resource Aspects of Development Assistance (PD-6, April 26, 1983). An EA, which is a detailed study of potentially significant environmental impacts, must be prepared as part of certain USAID-funded projects. The purpose of the EA is to:

1. Ensure that environmental impacts are identified and considered prior to a final decision and that appropriate safeguards are adopted,
2. Assist the host government in developing effective environmental programs,
3. Identify impacts to the natural and human environment, and
4. Define environmental limiting factors for the project.

The Lakhra coal project EA was conducted in accordance with USAID funding and associated environmental requirements. GOP and the bi- and multi-lateral funding organizations also require an EA for a project of this type. The EA for the Lakhra project considered those requirements and includes:

1. Identification of the potentially affected environment,
2. Identification of environmental issues through a scoping process,
3. Evaluation of project alternatives,
4. Assessment of environmental and social soundness impacts, and
5. Recommendations for mitigation and monitoring programs.

Table 5-2. Applicable Environmental Criteria* for Lakhra Coal Mine

| Environmental Resource | Criteria |
|---|---|
| Air | Ambient Quality for Particulate:<br>100 $\mu g/m^3$ annual geometric mean<br>500 $\mu g/m^3$ maximum 24-hour average. |
| Land | Surface mine reclamation shall be performed to return lands to conditions capable of supporting prior uses or uses that are equal to or better than prior land use.<br><br>Develop a sedimentation and erosion control plan.<br><br>Cover waste piles. |
| Water | Runoff and drainage limitations:<br><br>Total Suspended Solids: 30-100 mg/L<br>Total Iron: 4-7 mg/L<br>pH: 6-9<br>Soluble Toxicants: None<br><br>Apply best practicable commercially available technology to minimize, control, or prevent disturbances to surface or underground water quality and quantity. |
| Noise | Noise levels (yearly average) required for protection of public health and welfare recommended in the World Bank Environmental Guidelines (July 1984). |
| Social and Cultural | Secondary growth effects to the general population shall be addressed and impacts to tribal people shall be mitigated. |
| Occupational | World Bank Occupational Health and Safety Guidelines for Coal Mining; Threshold Limit Values (TLVs) by American Conference of Governmental Industrial Hygienists. |

*These criteria were developed from the World Bank Environmental Guidelines and with coordination between the World Bank Office of Environmental Affairs, USAID, WAPDA, and feasibility contractors.

Notes: $\mu g/m^3$ = Micrograms per cubic meter.
mg/L = Milligrams per liter.

Sources: World Bank, 1986.
ESE, 1986.
KBN, 1986.

Table 5-3. Applicable Environmental Criteria* for Lakhra Coal-Fired Power Plant

| Environmental Resource | Criteria |
|---|---|
| Air | Emissions:<br>1. $SO_2$--454 MT/day/unit (500 tons/day/unit) at 85 percent capacity factor<br>2. Particulate--100 $\mu g/m^3$<br>3. $NO_x$--260 ng/joule (0.6 $lb/10^6$ Btu).<br>Ambient Quality:<br>1. $SO_2$--100 $\mu g/m^3$ annual average<br>500 $\mu g/m^3$ maximum 24-hour average<br>2. Particulate--100 $\mu g/m^3$ annual geometric mean<br>500 $\mu g/m^3$ maximum 24-hour average<br>3. $NO_2$--100 $\mu g/m^3$ annual average |
| Water and Land | No specific limitation but general restrictions on affecting human health and welfare. |
| Noise | Noise levels (yearly average) required for protection of public health and welfare recommended in the World Bank Environmental Guidelines (July 1984). |
| Social and Cultural | Secondary growth effects to the general population shall be addressed and impacts to tribal people shall be mitigated. |
| Occupational | World Bank Occupational Health and Safety Guidelines for Power Plants, Coal, and Fuel Oil; TLVs by American Conference of Governmental Industrial Hygienists. |

*These criteria were developed from the World Bank Environmental Guidelines and with coordination between the World Bank Office of Environmental Affairs, USAID, WAPDA, and the feasibility contractors.

Notes: $SO_2$ = Sulfur dioxide.
MT/day = Metric tons per day.
$\mu g/m^3$ = Micrograms per cubic meter.
$NO_x$ = Nitrogen oxide.
$lb/10^6$ Btu = Pounds per million British thermal units.
$NO_2$ = Nitrogen dioxide.

Sources: World Bank, 1986.
ESE, 1986.
KBN, 1986.

# 6.0 DESCRIPTION OF PROJECT ALTERNATIVES

## 6.1 MANAGEMENT ALTERNATIVES

Pakistan has an installed capacity of about 2,900-MW hydro-power generation and over 3,500-MW [including Karachi Electric Supply Company (KESC)] thermal-power generation. This capacity is insufficient to meet current demand and load shedding has occurred. To meet this existing energy need and alleviate load shedding with associated socioeconomic impacts, as well as provide for future demand, Pakistan is projected to need approximately 800 MW of new capacity each year until the turn of the century. The "no-project" alternative would worsen the current shortage of electrical energy and result in significant social/economic impacts.

WAPDA and KESC are the major bulk electrical suppliers in Pakistan. KESC serves Karachi City and surrounding areas, and WAPDA serves the rest of the country. Limited transfers of power from one system to the other are possible through a double circuit 220-kV transmission system linking Karachi with the WAPDA system. Several projects, including the KESC projects, are currently included in the generation plan; however, the proposed gas and oil-fired projects are insufficient to eliminate the need for additional generation. Energy conservation would produce benefits; however, in itself energy conservation would not lower demand sufficiently to eliminate the need for additional generation.

Postponing unit retirements would not substantially increase electrical supply. Rehabilitation of older plants is currently a part of WAPDA's expansion program. Nine units at seven existing generating stations (Multan, Faisalabad, Guddu, Sukkur, Quetta, Shahdara, and Kotri) are scheduled for upgrades with an in-service rehabilitation date of about June 1989; however, an increase of about 126 MW is anticipated from these upgrades.

The range of project alternatives considered in the preparation of the EA include generating units from 250- to 700-MW. The range of sizes was based upon available reserves in the Lakhra field and economic viability of the different-sized units. Depending on the coal supply offered by the successful proposer, units smaller than these alternatives (i.e., 250- to 700-MW) may be considered.

## 6.2 ALTERNATIVE PROJECTS

The current electrical generation plan for Pakistan (WAPDA, 1986) includes provisions for a variety of generation projects including hydro, steam, and combustion turbine combined-cycle generation (see Table 6-1). A number of these projects have been committed to (and in some cases initiated or already completed), whereas others on the list, including the Lakhra project, are in a proposed or conceptual stage. Generation studies sponsored by USAID and coordinated with WAPDA have identified the need for additional baseload capacity to meet 1991-1993 demand. Viable alternatives for increased power generation include plants fired with domestic (Lakhra) coal, imported coal, or imported oil; therefore, all three types of plants are included in the generation plan.

An environmental/social soundness analysis of these alternatives was performed. This analysis was based upon a domestic coal-fired plant located in the general Lakhra area, an imported oil-fired plant, and an imported coal-fired plant. The size of the power plant was considered the same for all plant alternatives. Sulfur content was 0.6 percent for imported coal (GCII, 1986), 3.2 percent for imported oil, and 5 percent for Lakhra coal. Because of the lack of site-specific design and environmental information for the imported fuel alternatives, the analysis considered impacts from a regional perspective. Four environmental disciplines (i.e., air, land, socieconomic, and water resources) were used to evaluate the differences in environmental impacts for the three candidate fuels. The results of this analysis (see

Table 6-1. Summary of Pakistan's Power Generation Program (After April 1986)

| Station/Project Designation* | Unit Number(s) | Total Capacity (MW) | In-Service Dates |
|---|---|---|---|
| Kot Addu CT | 1-8 | 800 | From Nov 86 to Feb 89 |
| CC | 9-10 | 200 | Jun 89 |
| Guddu CC | 5,6 | 200 | Dec 87 and Jun 88 |
| Jamshoro Imported Oil | 1-6 | 1,570 | From Dec 88 to Dec 93 |
| KESC Steam | D-3,D-4,D-5 | 630 | From Feb 89 to Dec 89 |
| Mangla | 9 and 10 | 200 | Sept 89 |
| Undesignated CT | 1,2 | 200 | Dec 89 |
| Tarbela | 11-17 | 2,928 | From Jun 90 to Dec 95 |
| Faisalabad CC | 9 and 10 | 80 | Feb 90 |
| Kotri CC | 7 and 8 | 40 | Feb 90 |
| Multan | 1-3 | 630 | From Oct 90 to Oct 91 |
| Lowhead Hydro | † | 420 | From Dec 90 to Dec 92 |
| Lakhra Coal | 1 and 2 | 600 | From Mar 92 to Dec 92 |
| Undesignated Imported Coal | 1-3 | 1,200 | From Dec 93 to Dec 95 |
| Kalabagh | 1-5 | 1,500 | From Sep 94 to Sep 95 |

*CT = combustion turbine; CC = combined cycle.
†Chashma, Taunsa, and Jinnah.

Source: WAPDA, 1986.

Table 6-2) suggests that a domestic coal-fired power plant using Lakhra coal would fit into an overall generation program which also includes imported coal and oil generating facilities.

## 6.3 PLANT-SPECIFIC ALTERNATIVES

The project-specific alternatives include three basic plant configurations: one 300-MW unit; two 250-MW units; and two 350-MW units. The basic design specifications of these alternatives are listed in Table 6-3. The ultimate size of the power plant will depend on the scale of the coal supply that is offered by the successful private-sector proposers.

Each alternative size was evaluated on the basis of economic and environmental criteria. Because of the low heating value of the Lakhra coal and the advantages of using open pit mining to effectively utilize the coal resources, a 250- to 300-MW plant may not be as economically viable as a larger plant. Projected costs for supplying coal for a 300-MW plant were estimated to be about 18 percent higher on a per-ton-of-coal-fired basis than for a 700-MW plant using comparable mining techniques. In addition, a 300-MW plant would provide only a portion of the needed generation.

The principal environmental design criterion for the plant will allow each unit an $SO_2$ emission limit of 454 MT (500 tons) per day when operating at 85 percent of rated capacity. Based on the above design criterion, a plant consisting of two 250-MW units would achieve this criterion and on an annual average basis have the $SO_2$ emissions of approximately 340 MT (370 tons) per day per unit at the projected annual average operating capacity factor of 70 percent. This environmental design criterion has been found acceptable to the World Bank, provided emissions at this level are demonstrated not to cause significant impacts to local, regional, and global environments.



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Table 6-2. Summary of Alternative Project Evaluation

| Alternative Project | Environmental Score* | Environmental Rank |
|---|---|---|
| Domestic Coal (Lakhra) | 35 | First |
| Imported Coal | 33 | Second |
| Imported Oil | 33 | Second |

*Refer to table below.

NOTE: The environmental evaluation of alternative projects was performed by calculating rating coefficients with respect to four environmental criteria (air, land, socioeconomics, and water resources). To develop rating coefficients, sites were compared two at a time against each environmental criterion. The environmental analysis is summarized below:

| | Environmental Resource Rating* | | | | |
|---|---|---|---|---|---|
| Site | Air | Land | Socio-economic | Water | Sum |
| Lakhra-Coal | 0 | 0 | 23 | 12 | 35 |
| Imported-Coal | 10 | 5 | 6 | 12 | 33 |
| Imported-Oil | 5 | 10 | 6 | 12 | 33 |

*Higher ratings denote a more environmentally favorable alternative.

Sources: ESE, 1986.
KBN, 1986.



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Table 6-3. General Design Specifications and Environmental Discharges for Power Plant Alternatives (at 100 Percent Capacity Factor)

| Design Specification/ Environmental Discharges | Plant Size (MW) | | | |
|---|---|---|---|---|
| | 300 | Two 250* | Two 350 w/o FGD | Two 334 w/FGD† |
| Heat Rate (Btu/kWH) | 11,120 | 11,016 | 11,200 | 11,730 |
| Heat Input ($10^6$ Btu/hr) | 3,336 | 5,508 | 7,834 | 7,834 |
| Average Annual Coal Consumption ($10^6$ MT) | 1.6 | 2.7 | 3.8 | 3.8 |
| Air | | | | |
| Sulfur Dioxide Emissions | | | | |
| Maximum (MT/day) | 585 | 967 | 1,373 | 137 |
| Annual Average (1,000 MT) | 149 | 247 | 351 | 35 |
| Particulate Matter | | | | |
| Maximum (MT/day) | 5.8 | 9.8 | 13.9 | 13.9 |
| Annual Average (1,000 MT) | 1.5 | 2.5 | 3.5 | 3.5 |
| Nitrogen Oxides | | | | |
| Maximum (MT/day) | 21.8 | 36.0 | 51.2 | 51.2 |
| Annual Average (1,000 MT) | 5.6 | 9.2 | 13.1 | 13.1 |
| Water | | | | |
| Consumptive Use (1,000 $m^3$/day) | 33 | 55 | 77 | 86 |
| Cooling Tower Blowdown (1,000 $m^3$/day) | 1.8 | 2.9 | 4.1 | 4.1 |
| Filter Backwash (1,000 $m^3$/day) | 2.0 | 3.3 | 4.6 | 4.6 |
| Fly Ash Transport (1,000 $m^3$/day) | 14 | 24 | 33 | 33 |
| Bottom Ash Sluice (1,000 $m^3$/day) | 12 | 20 | 28 | 28 |
| FGD System (1,000 $m^3$/yr) | -- | -- | -- | 9 |
| Solid Waste | | | | |
| Bottom Ash (1,000 MT/yr) | 135 | 224 | 318 | 318 |
| Fly Ash (1,000 MT/yr) | 203 | 336 | 478 | 478 |
| Water Treatment Sludge (1,000 $m^3$/yr) | 218 | 363 | 508 | 508 |
| FGD Sludge (1,000 $m^3$/yr) | -- | -- | -- | 237 |

*Except for heat rate and input, a single 250-MW unit would have ½ the values shown in the table.
†Assumes 90 percent $SO_2$ removal; lower net capacity due to auxiliary power requirement of FGD.

Notes: MT = Metric tons.
Btu/kWH = British thermal units per kilowatt hour.
$10^6$ Btu/hr = Million British thermal units per hour.
$m^3$/day = Cubic meters per day.
$m^3$/yr = Cubic meters per year.

Sources: GCII, 1986.
ESE, 1986.
KBN, 1986.

A plant consisting of two 350-MW units would be required to install FGD equipment to reduce $SO_2$ emissions to levels satisfying World Bank limits. The addition of FGD equipment would result in significant economic penalties that would make a two 350-MW project economically unattractive. Operation of FGD would also create additional environmental effects from disposal of sludge. Therefore, based upon a balance of current economic and environmental criteria, a plant consisting of two 250-MW units is the preferred alternative.

## 6.4 POWER PLANT SITE ALTERNATIVES

Three potential sites were evaluated for the power plant complex: Jamshoro, Khanot, and Lakhra (Figure 6-1). An evaluation of these sites was performed by considering the air, land, socioeconomic, and water resource effects pertaining to each site. The power plant size was considered the same (i.e., 500-MW) in the evaluation. Mine development impacts were not considered as synergistic effects; however, linear facilities such as coal transportation were considered. The results (see Table 6-4) indicate that the Lakhra site is environmentally superior to either the Jamshoro or Khanot sites. Although the Jamshoro site was ranked second environmentally, potential air quality impacts from a Lakhra coal-fired power plant to sensitive receptors such as Mehran University, the Sind University, the Liaquat Medical College and Hospital, and Hyderabad City make this site unacceptable for a Lakhra coal-fired power plant.

Further analysis of specific environmental impacts of two 250-MW units located at Lakhra or Khanot was performed. The results of this analysis indicated the potential for significant air pollution impacts to the population and agriculture of the Indus Valley from a plant located at the Khanot site. At the Lakhra site, however, the potential for significant air quality impacts is small (see Figure 6-2) because the site is located over 20 km (12 miles) from the Indus Valley agricultural areas and is very sparsely populated, with only a few torrent-watered cropping areas.

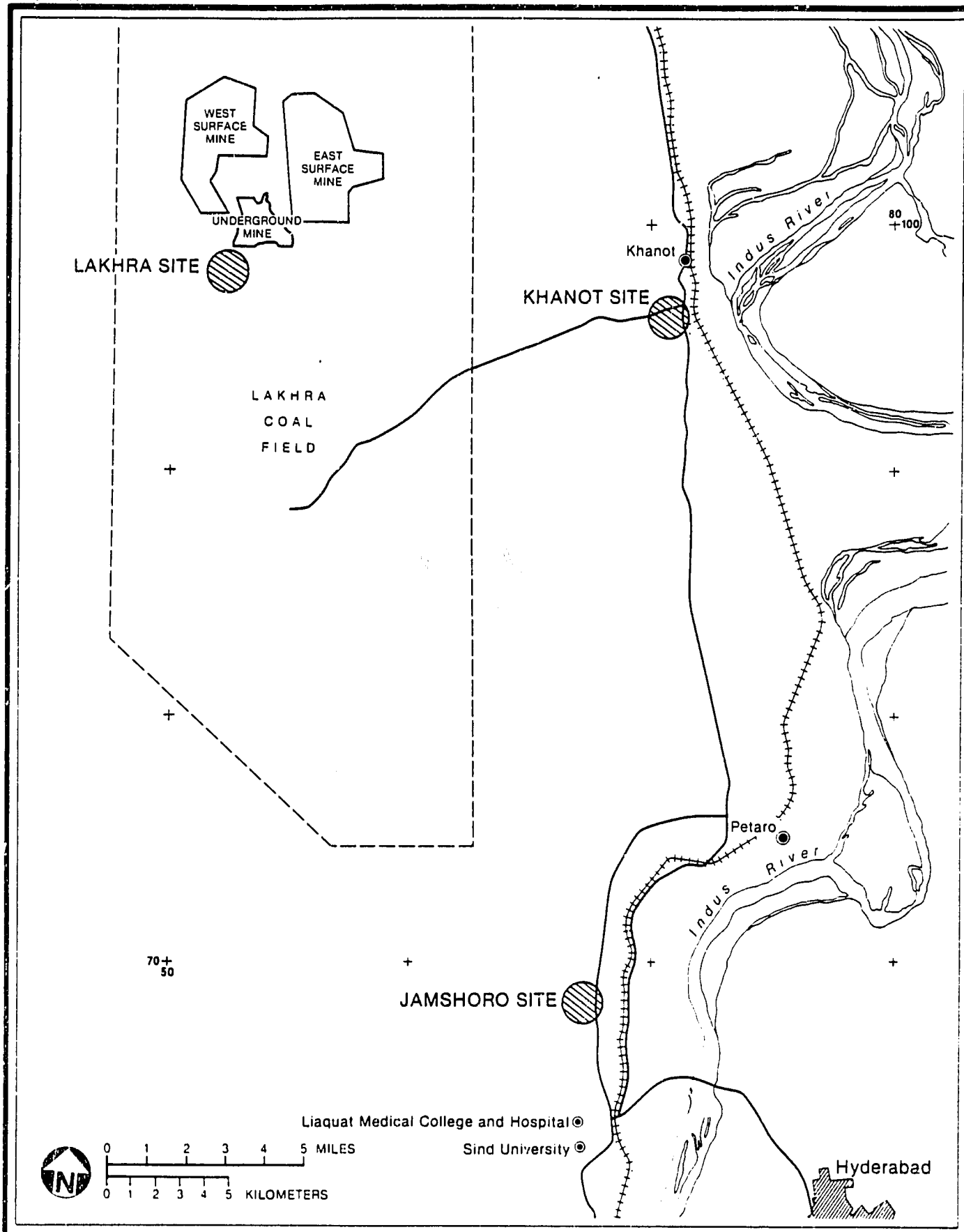


Figure 6-1
LOCATION OF CANDIDATE POWER PLANT SITES AND PROPOSED LAKHRA MINE

SOURCE: ESE, 1986.

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Table 6-4. Summary of Power Plant Site Alternatives Analysis

| Alternative Project | Environmental Score* | Environmental Rank |
|---|---|---|
| Lakhra | 48 | First |
| Khanot | 22 | Third |
| Jamshoro | 29 | Second† |

*Refer to table below.
†Potentially unacceptable air quality impacts to local sensitive receptors would make this site environmentally inferior to other sites for a Lakhra coal-fired power plant. These impacts are due to $SO_2$ emissions resulting from firing Lakhra coal which has both high sulfur and low Btu content that produce high $SO_2$ emissions relative to other types of fuel.

NOTE: The environmental evaluation of alternative projects was performed by calculating rating coefficients with respect to four environmental criteria (air, land, socioeconomics, and water resources). To develop rating coefficients, sites were compared two at a time against each environmental criterion. The environmental analysis is summarized below:

| Site | Environmental Rescurce Rating** | | | | |
|---|---|---|---|---|---|
| | Air | Land | Socioeconomic | Water | Sum |
| Lakhra | 17 | 3 | 5 | 23 | 48 |
| Khanot | 8 | 3 | 5 | 6 | 22 |
| Jamshoro | 0 | 3 | 20 | 6 | 29 |

**Higher ratings denote a more environmentally favorable alternative.

Sources: ESE, 1986.
KBN, 1986.

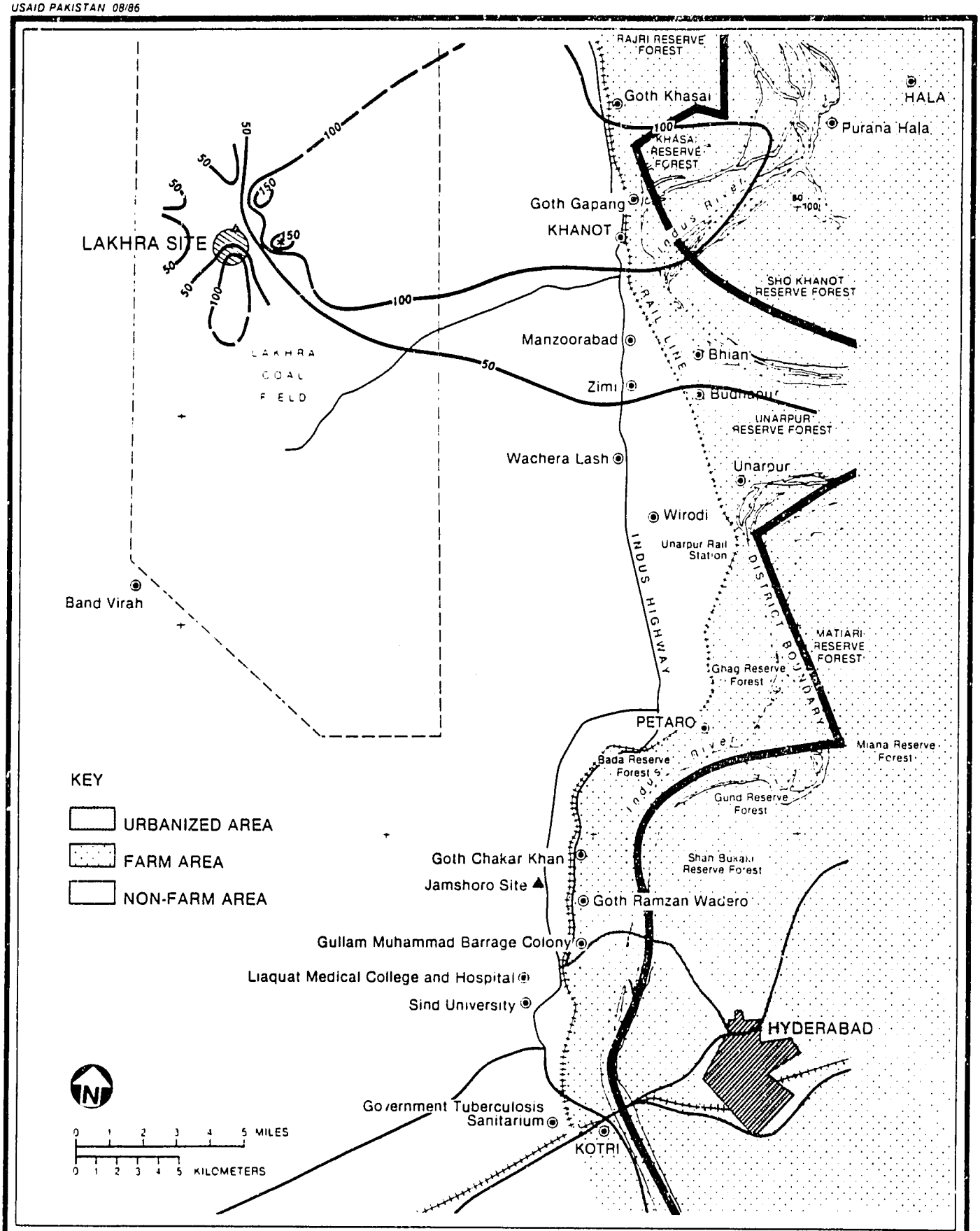


Figure 6-2
MAXIMUM PREDICTED 24-HOUR $SO_2$ CONCENTRATION (ug/m³) DUE TO THE PROPOSED FACILITY

SOURCES: GCII, 1985; ESE, 1986.

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The remoteness of the Lakhra site, which is an advantage in relation to affecting existing human populations, agriculture, and the natural environment, makes this site much less suitable as a site for a power plant workers colony. As a result, WAPDA has decided to locate the power plant workers colony near Khanot, where living conditions are more customary and acceptable. Worker transportation, if provided by buses and traveling on an improved road, will not extend the workday by more than approximately one hour.

## 6.5 MINING TECHNOLOGY ALTERNATIVES

Based on studies and the results of the field programs, the demonstrated recoverable lignite reserves underlying the 62-$km^2$ area studied by J.T. Boyd Company are estimated to range from 143 to 174 million run-of-mine (ROM) metric tons (J.T. Boyd Company, 1986). The quantity of estimated reserve varies according to mining method and average mining recovery assigned to the underground reserves. Overall mining recoveries of 85 percent for surface and 50 percent to 60 percent for underground methods are applied.

To supply from 1.6 to 3.8 x $10^6$ MT/year (48 to 114 x $10^6$ metric tons over a 30-year plant life) of Lakhra coal, various mining alternatives have been proposed, including an underground mine, a surface mine, or a combination of an underground and surface mine (see Table 6-5).

The preferred mining alternative developed by J.T. Boyd Company is a combination of surface and underground mines which considers the following factors:

1. The economy of a large surface mine,
2. The use of an underground mine that utilizes existing technology with improved modern techniques,
3. Maximizing the recoverable resources, and
4. Providing fuel supply reliability.

Table 6-5. Mining Alternatives

| Output ($10^6$ MT/yr) | Plant Size | Underground ($10^6$ MT/yr) | Surface ($10^6$ MT/yr) | No. of Surface Mines | Topsoil Over-burden Removed ($10^6$ BCM) | Surface Area Impacted (ha) |
|---|---|---|---|---|---|---|
| 1.6 | 300 | 0.9 | 0.7 | 1 | 9 | 390 |
| 1.6 | 300 | 0.0 | 1.6 | 1 | 21 | 910 |
| 1.6 | 300 | 1.6 | 0.0 | 0 | 0 | <100 |
| 2.7 | 500 | 0.3 | 2.4 | 2 | 32 | 1,360 |
| 3.8 | 700 | 0.3 | 3.5 | 2 | 46 | 1,990 |

Notes: $10^6$ MT/yr = Million metric tons per year.
BCM = Bank cubic meters.
ha = hectares.

Sources: J.T. Boyd, 1986.
ESE, 1986.
KBN, 1986.

The actual methods and facilities used to mine Lakhra coal will, however, depend on the successful private-sector proposer. While the methods used by the successful proposer may be quite different than those developed by J.T. Boyd Company, the mining alternatives evaluated in this report are expected to cover the range in expected environmental impacts for this portion of the Lakhra coal project.

The mining plan proposed by the successful proposer must comply with the World Bank environmental and occupational health and safety guidelines for surface and underground mining. In addition, the successful proposer's mine plan must conform to internationally recognized standards for environmental protection, mining technology, occupational health and safety, and resource recovery. The mines will also be required to have properly designed programs for emergency prevention, planning, and management. The power plant will be authorized to obtain indigenous coal only from other sources which have been found by an inspector qualified in modern mining practices, to comply with guidelines used for project-supported surface and underground mines for environmental protection, mining technology, occupational health and safety, and resource recovery.

## 6.6 COAL TREATMENT ALTERNATIVES

The process of physically cleaning coal, to reduce ash-forming impurities and improve British thermal units (Btu) content, has been practiced for many years. More recently, coal washing has been used to reduce the sulfur content of coals. Sulfur occurs in coal in three forms: organic, sulfate, and pyritic sulfur. Organic sulfur, in which the sulfur is chemically bound to the coal, cannot be removed by mechanical means. Sulfate and pyritic sulfur, which are not chemically bound, may be removed from the coal in varying degrees. Processes are available for chemically removing organic sulfur (solvent-refined coal), but these processes have not been demonstrated commercially.

Coal washability tests, sponsored by USAID and performed under the direction of GCII and J.T. Boyd Company, indicated that $SO_2$ and particulate matter (PM) emissions could be reduced by about 40 and 50 percent, respectively. In addition, the Btu content would be improved by approximately 20 percent; however, there is a concomitant loss of about 22 percent in net energy by coal washing, which would result in a significant increase in coal costs. Therefore, this alternative was found not to be economically viable and was rejected from further consideration.

Blending high quality imported coal with Lakhra coal could increase the heat content and lower the sulfur and ash content of composite fuel; however, current coal imports are limited to metallurgical coal for the Pakistan Steel Mills Corporation located in Karachi. Because of the limited transportation system (ocean facilities and then rail to Lakhra) and the lack of suitable sources of alternative coals in Pakistan, blending is not considered a viable alternative for the project.

## 6.7 AIR EMISSIONS CONTROL ALTERNATIVES

An evaluation of air pollution emission control alternatives included FGD for $SO_2$ removal, electrostatic precipitation (ESP) or fabric filters for particulate removal, and combustion controls for $NO_x$ reduction.

An evaluation of FGD systems based on consideration of uncontrolled emissions, $SO_2$ removal efficiency required, availability of reagents, availability and quality of raw water make up, byproduct disposal, and potential for salable FGD byproducts determined that a wet limestone slurry FGD system producing a throwaway gypsum byproduct would be a preferred alternative for the project if $SO_2$ removal is required. The wet FGD system would be more economical than a dry or regenerable system and would achieve the same desired efficiency.

As previously discussed, in order to meet the project's environmental criteria, the application of an FGD system would be required for two 350-MW units, and this requirement makes this alternative economically unattractive (see Table 6-6). For two 250-MW units, an FGD system would not be necessary to meet project criteria. Although an FGD system could be installed to reduce $SO_2$ emissions from a 500-MW plant, the economic impacts would still be significant and make this alternative economically unattractive. Furthermore, for any FGD system evaluated, the net air quality benefit would not be as great as the emission reduction. For example, a 45 percent reduction in emissions using partial FGD would reduce maximum ambient air quality concentrations of $SO_2$ by 27 percent; a 90 percent emission reduction would reduce maximum ambient air quality concentrations of $SO_2$ by 78 percent. In addition, an FGD system would also increase water consumption by about 12 percent. Therefore, because of the economic penalty, water usage, and the relatively lower air quality benefit associated with FGD systems, the preferred alternative for two 250-MW units would not include the construction and operation of an FGD system; however, space for an FGD system would be provided in the event air quality monitoring indicated a serious $SO_2$ impact after plant startup.

Fluidized bed combustion (FBC) boilers and limestone injection multistage burners (LIMB) were considered as alternative technologies for reducing $SO_2$ emissions. Because of the specific requirements for burning Lakhra coal and the need to construct new generation by the mid-1990s, conventional steam generator technology was considered most appropriate for the Lakhra project.

For particulate control, ESPs are the preferred alternative over fabric filters. The abrasive nature of fly ash generated by burning Lakhra lignite, as determined from combustion tests, would make fabric filters unsuitable for particulate control. The design parameters for the ESP are:



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Table 6-6. Air Pollution Control Alternatives Comparison for $SO_2$ Removal

| | Emissions* | Air Quality Impact† | | Annualized Cost** |
|---|---|---|---|---|
| | | 24-Hour | Annual Average | |
| Base--No $SO_2$ Reduction | 2.0 | 0.41 | 0.20 | -0- |
| 22.5% Removal | 1.5 | 0.46†† | 0.22†† | 0.25-0.46 |
| 45% Removal | 1.3 | 0.54 | 0.27 | 0.44-0.74 |
| 67.5% Removal | 0.6 | 0.70†† | 0.41†† | 0.52-0.88†† |
| 90% Removal | 0.2 | 0.91 | 0.59 | 0.60-1.01 |

*Normalized to MT/day/MW.
†Normalized to $\mu g/m^3$/MT emission for 24-hour and $\mu g/m^3$/1,000 MT emission for annual average.
**Normalized to $/kWh for 5 and 10 percent discount rates.
††Estimated from data.

Sources: ESE, 1986.
KBN, 1986.
ICF, 1986.

1. Rigid discharge electrode and rigid collection electrode type;
2. Minimum specific collection area, 100 $m^2/m^3/sec$;
3. Maximum effective collecting electrode height, 12.8 m;
4. Minimum gas passage width, 305 mm;
5. Maximum gas velocity at ID for test block flow, 1.37 mls;
6. Alignment tolerance on discharge electrodes, $\pm 6$ mm;
7. Aspect ratio of 2 to 1;
8. Number of electric fields, 6;
9. Number of sets per electrical bus station, 1;
10. Number of hoppers per electrical bus station, 1; and
11. Maximum coefficient of variation, $\pm 18$ percent.

$NO_x$ emissions will be controlled through combustion techniques that may include low excess air burners and staged combustion. Final design will depend upon the boiler vendor selected.

The alternatives for controlling fugitive dust emissions from mining and lignite handling include paving (for roads only), chemical stabilization, and watering. Watering is the preferred alternative because low quality water (cooling tower and boiler blowdown) will be readily available and lower in cost than paving and chemical stabilization. Also, the latter two alternatives cannot be easily adapted to the evolving nature of the surface mine.

## 6.8 INFRASTRUCTURE ALTERNATIVES

The power plant worker's colony will be designed and built by WAPDA, based on WAPDA's standard practices and procedures for layout and construction of such colonies. The mine worker's colony will be built by the private company or companies responsible for supply of coal to the power plant and will follow WAPDA specifications. Because of the different working patterns and requirements of the mining and plant workers, the residential and mosque facilities for the two groups could be separate, whereas common facilities could include schools (depending

on final economics), clinics, market areas, and utility systems (water, sewer, electric), as well as public services (police and fire protection).

The mine and power plant workers colony will each include provisions for:

1. Housing;
2. Utilities, including potable water, electricity, sewage disposal, and municipal refuse;
3. Primary and secondary education facilities;
4. Mosque;
5. Recreational facilities;
6. Fire and police protection;
7. Stores;
8. Training facilities;
9. Transportation;
10. Medical facilities;
11. Telecommunications;
12. Bank;
13. Post Office; and
14. Shopping Center

The specific site for each colony was evaluated under two alternative scenarios: Khanot or Lakhra.

The construction and operational activities of the mine and power plant will cause a number of potential direct impacts to cultural resources of the area and require consideration for secondary infrastructure development. These impacts include:

1. Increased demand upon existing facilities and services,
2. Induced development in the surrounding area associated with construction of the mine and power plant,
3. Disruption of existing transportation and communication systems,
4. Change in employment and economic patterns, and
5. Disruption of existing cultural patterns and values.

The areas most affected by these impacts include all the villages of the Lakhra area and those villages in the vicinity of the junction of the Indus Highway and Lakhra Road (such as Khanot and Manzoorabad). The results of the infrastructure evaluation suggest that the Khanot area is the preferred location for both mine and power plant worker's colonies. The major reasons for this ranking are:

1. Significant air quality impacts in the Lakhra area,
2. Proximity of Khanot to urban areas,
3. Ability of the Khanot area to support cottage industries, and
4. Employee acceptance.

Secondary infrastructure development should consist of a series of community and infrastructure improvements brought about by the project. In addition, certain services provided to the workers also should be made available on a limited basis to the local inhabitants. Such services might be:

1. Improvement/upgrading of Indus Highway from Kotri to Khanot,
2. Public availability of potable water at selected stations, and
3. Coordination with local governments (Sind Province and Dadu District) for areawide infrastructure improvements.

## 6.9 EMPLOYMENT ALTERNATIVES

The construction and operation of the mine and power plant complex would require skilled and unskilled workers. The surface and underground mine activities would require about 2,000 employees including about 150 employees needed directly for the colony (J.T. Boyd, 1986). Operation of the power plant would also require about 1,500 employees with a similar number of colony personnel (GCII, 1986). During the initial stages of the project, a large number of construction and operation workers would be needed to build and operate the mines, power plant, and workers colonies. J.T. Boyd Company estimates that the work force for the mine would increase to peak employment in Year 7 of about

1,750 workers. Total mine, colony, and other workers associated directly with the mine are estimated to be about 2,900. The power plant construction and operation labor force, as estimated by GCll, would increase in Year 3 from 200 workers, peak in Year 5 with 6,136 workers, and level off in Year 8 to about 1,500 workers. Overall, the work force is expected to peak in Years 5 and 6 with over 7,000 workers. After construction is complete, employment would decline to operational levels. To ensure that adequate facilities are available, an implementation plan for infrastructure development for construction workers, many of whom will arrive in the Lakhra/Khanot area prior to operational workers, is needed. Alternatives for obtaining the necessary employees are listed in Table 6-7.

During the construction and initial phases of operation, most management and technical advisors would likely be expatriate; however, their numbers are expected to be small (i.e., less than 100). Skilled construction workers would likely come from the Hyderabad area, whereas unskilled workers would come from the rural Dadu District population as well as the Khosa Baluch (nomadic villagers of the Lakhra area). It is WAPDA's policy to hire all local people for positions through Grade 16. Underground miners may be recruited from the existing mines. These miners are generally Swati of Kashmiri immigrants who work existing mines for 4 to 6 months out of the year; however, the existing number of miners, about 9,000, may not be sufficient to support the existing mines and the Lakhra project together and additional miners would have to be recruited. Providing improved working and living conditions in the Lakhra project area should, however, attract a more stable and permanent employment force.



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Table 6-7. Employment Alternatives

| General Job Classifications | Existing Employment Sources | | | |
|---|---|---|---|---|
| | Dadu District | Hyderabad District | Other Pakistani | Ex-Patriate |
| Construction/ Development | | | | |
| Management | | PS | SS* | PS† |
| Technical | | PS | SS | PS |
| Skilled Craft | | PS | SS | |
| Laborers | PS** | PS** | SS | |
| Operation†† | | | | |
| Advisors-- Tech/Mgt | | | | PS*** |
| Management | | PS | SS | |
| Technical | | PS | PS | |
| Skilled Craft | | PS | SS | |
| Laborers | PS** | PS** | SS | |

*SS = Secondary source of employees.
†PS = Primary source of employees.
**Labor source expected to be split evenly between Dadu and Hyderabad districts.
††After training of Pakistani staff.
***As needed by the project.

Sources: ESE, 1986.
KBN, 1986.

# 7.0 PROPOSED ACTION AND IMPACTS

The preferred project alternative consists of a colocated power plant (two 250-MW units) and associated surface/underground mine located at Lakhra and a power plant workers colony located at Khanot. The potential effects associated with the construction and operation of the project are summarized in Table 7-1. Impacts to the physical, biological, and social environments are presented in Tables 7-2, 7-3, and 7-4. A majority of these impacts, however, will not be significant. Potentially significant impacts are discussed in the following sections.

## 7.1 PHYSICAL IMPACTS

The establishment of a large surface mine and the degradation in air quality from mining and power plant emissions are potentially the most significant impacts to the physical environment.

The mining impacts will have two major components: (1) the physical disruption of mining activities, and (2) utilization of non-renewable resources (i.e., lignite). The physical disruption of the surface, which involves up to approximately 2,000 ha (5,000 acres), will change the land use, drainage, surface water, and limited ground water resources. The magnitude of these effects will primarily be confined directly to the mining area provided that appropriate management of spoil piles, highwalls, acid-producing materials, and runoff impoundments is practiced. Land within the mining area will be temporarily disrupted; however, through reclamation practices the land will be returned to conditions similar to those prior to mining. Use of the non-renewable resources will be irretrievable; however, this use is offset by the country's need to supply the required electrical power. For recovering a major portion of the lignite resources, surface mining is preferred; with a surface mine, about 80 to 90 percent of the available lignite resource is recovered, whereas for an underground mine, only about 50 percent is recovered.

Table 7-1. Potential Environmental Effects Evaluated for the Construction and Operation of Lakhra Coal-Fired Plant and Coal Mine

| |
|---|
| CONSTRUCTION |
| Change of Land Use |
| Vegetation Removal and Loss of Habitat |
| Increased Soil Erosion and Runoff |
| Change in Drainage |
| Change in Surface Water Quality |
| Spills and Chemical Usage |
| Road Traffic and Road Kills |
| Noise and Vibration |
| Air Emissions--Fugitive Dust from Construction and Overburden Removal |
| Induced Development--associated with mine power plant |
| Change in Employment and Economic Patterns |
| Increased Demand upon Existing Facilities and Services |
| Disruption of Cultural Values and Patterns |
| Loss of Cultural, Historical, and Archaeological Resources |
| OPERATION |
| Thermal Discharge |
| Discharge of Blowdown Chemicals |
| Change in Surface Water Flow and Quality |
| Change in Ground Water Table Quality |
| Maintenance Dredging |
| Entrainment of Aquatic Organisms |
| Fog Formation |
| Formation of Biological Barriers and Corridors |
| Loss of Future Biological Productivity |
| Chemical Spills and Nonpoint Source |
| Domestic Wastes Discharge |
| Air Emissions-includes emissions from stacks, fugitive dust from coal handling, and reclamation |
| Atmospheric Deposition |
| Noise and Vibration |
| Crop Loss |
| Avian Hazards--from stacks, transmission, etc. |
| Increased Access--i.e., opening up otherwise less accessible natural areas |
| Consumptive Water Use |

Sources: Argonne National Laboratory, 1978.
ESE, 1985.
KBN, 1986.

Table 7-2. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Physical Impacts

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Construction | |
| Change of Land Use | Site specific/long-term/not significant. |
| Increased Soil Erosion and Runoff | Site specific/long-term/not significant. |
| Change in Drainage | Site specific/long-term/not significant. |
| Change in Surface Water Quality | Site specific/long-term/not significant.† |
| Spills and Chemical Usage | Site specific/short-term/easily mitigated by prevention. |
| Air Emissions | Regional/short-term/moderately significant near source, not significant after about 5 km. |
| Operation | |
| Thermal Discharge | Site specific/long-term/not significant. |
| Change in Surface Water Flow and Quality | Site specific/long-term/not significant.** |
| Change in Ground Water Quality | Site specific/long-term/minor effects; pond leachate may degrade ground water quality; acid mine waste may further degrade ground water quality; low impacts due to limited quantity and low quality of existing ground water.†† |
| Maintenance Dredging of Ponds and Land or Mine Disposal of Solid Wastes | Site specific/long-term/not significant; will likely improve quality of leachate from settling/evaporation ponds.*** |



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Table 7-2. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Physical Impacts (Continued, Page 2 of 2)

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Chemical Spills and Nonpoint Sources | Site specific/short-term/not significant; little or no impact due to low rainfall and high evaporation rates in region. |
| Domestic Wastes Discharges | Site specific/long-term/minor impacts. |
| Consumptive Water Use | Site specific/long term/minor impacts; downstream water availability reduced by about 25 cubic feet per second (cusecs), which is a small amount compared to available supplies from the Indus River. |
| Air Emissions | Regional/long-term/moderately significant near source, minor after 20 km. Transboundary impacts are not predicted to be significant. |

*In terms of impacts, the following definitions are used:
1. Extent refers to the areal effect of the impact, e.g., whether the impact is confined to the site only or extends some distance from the site;
2. Duration refers to the length of time the impact will last, e.g., whether the impact is short-term, lasts for several years, or for much longer periods; and
3. Significance refers to the magnitude of the impact in relation to the type of resource being impacted.

†Indus River is only perennial surface water in region.

**No perennial surface water bodies on or adjacent to the Lakhra site.

††If local wells are degraded, impacts can be mitigated by supplying treated water from power plant. Lakhra site is about 20 km in distance to the Indus River and a limited number of wells currently exist in the area.

***Mine disposal of all solid wastes (ash) at Lakhra is preferred.

Source: ESE, 1986.

Table 7-3. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Biological Resources

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Construction | |
| Vegetation Removal and Loss of Habitat | Site-specific/long-term/moderately significant; loss of some acreage of tropical scrub forest vegetation and tropical plain thorn forest habitat, including desert monitor habitat; no significant loss given the small amount lost versus amount available. |
| Spills and Chemical Usage | Site-specific/short-term/not significant: no aquatic habitat; no effects. |
| Road Traffic and Road Kills | Regional/short-term/not significant: increased probability of wildlife road kills. |
| Air Emissions--Fugitive Dust from Overburden Removal Effects on Vegetation | Regional/short-term/minor effects: vegetation will adapt to conditions. |
| Operation | |
| Entrainment | Site-specific/long-term/minor impacts: minimal larval and fish populations expected to be impacted. |
| Formation of Biological Barriers and Corridors | Site-specific/long-term/not significant. |
| Loss of Future Biological Productivity | Site-specific/long-term/not significant: small area. |
| Air Emissions--includes emissions from stacks, fugitive dust from coal handling, and reclamation | Regional/long-term/minor impacts: no major effects to natural vegetation. |

Table 7-3. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Biological Resources (Continued, Page 2 of 2)

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Avian Hazards--from stacks, transmission, etc. | Site-specific/long-term/minor impacts. |
| Increased Access--i.e., opening up otherwise less accessible natural areas | Site-specific/long-term/minor impacts: no special biological resources in vicinity. |

*In terms of impacts, the following definitions are used:

1. Extent refers to the areal effect of the impact, e.g., whether the impact is confined to the site only or extends some distance from the site;
2. Duration refers to the length of time the impact will last, e.g., whether the impact is short-term, lasts only several years, or for much longer periods; and
3. Significance refers to the magnitude of the impact in relation to the type of resource being impacted.

Sources: ESE, 1986.
KBN, 1986.



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Table 7-4. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Social Impacts

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Construction and Operation | |
| Loss of Land Use | Site-specific/long-term/significant locally. |
| Loss of Future Agricultural Productivity | Site-specific/long-term/not significant. |
| Road Traffic | Regional/short-term/moderately significant, traffic increase.† |
| Change in Ground Water Table and Aquifer Quality | Site-specific/long-term/not significant: lower quality but not extensively used for potable supplies. |
| Air Emissions--includes emisssions from stacks, fugitive dust from coal handling, and reclamation | Regional/long-term/moderately significant to existing mining population; however, no major agricultural areas nearby. |
| Noise and Vibration | Site-specific/long-term/not significant. |
| Induced Development--associated with mine and power plant in surrounding area including facilities and services demand | Regional/long-term/significant: workers colony will require significant development of infrastructure facilities and services. |
| Change in Employment and Economic Patterns | Regional/long-term/significant: cyclic boom economy will occur probably during years 5 and 6. |
| Increased Demand upon Existing Facilities and Services | Regional/long-term/significant: facilities and services provided for needs of operation workers, construction workers, and other inhabitants. |
| Disruption of Cultural Values and Patterns | Site-specific/long-term/ significant effects to local Khosa Baluch: major changes to rural life will occur in the vicinity of the site, both positive and negative. Regional impacts are likely to be minor. |



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Table 7-4. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Social Impacts (Continued, Page 2 of 2)

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Loss of Cultural, Historical, and Archaeological Resources | Site-specific/long-term/not significant based on current data. |

*In terms of impacts, the following definitions are used:

1. Extent refers to the areal effect of the impact, e.g., whether the impact is confined to the site only or extends some distance from the site;
2. Duration refers to the length of time the impact will last, e.g., whether the impact is short-term, lasts only several years, or for much longer periods; and
3. Significance refers to the magnitude of the impact in relation to the type of resource being impacted.

†Road improvement of Indus Highway already planned.

Sources: ESE, 1986.
KBN, 1986.



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The impacts to air quality, resulting from the use of the high-sulfur, low-Btu Lakhra lignite at the power plant coupled with fugitive dust emissions from the mining activities, are potentially significant; however, analyses have shown that the combination of site location and atmospheric dispersion will confine potentially significant air quality impacts to the immediate Lakhra area. In addition, offsite air quality impacts are projected to meet the World Bank and World Health Organization's guidelines for air quality and not significantly impact human health.

## 7.2 BIOLOGICAL IMPACTS

The adverse impacts associated with construction of the mine and power plant include the loss of up to approximately 2,000 ha (5,000 acres) of scrub forest vegetation and associated tropical plain forest wildlife habitat. There is the potential for the desert monitor lizard, classified as endangered, to be affected onsite by these activities; however, the status of the population in the region will not be significantly affected. In addition, in cooperation with GOP, the U.S. Fish and Wildlife Service is sponsoring specific studies on the desert monitor (see mitigation plan).

Adverse impacts of the operation of the power plant on ecological resources include potential effects on vegetation and wildlife from air emissions, including atmospheric deposition, entrainment of aquatic organisms during cooling water intake, and increased mortality of wildlife due to highway traffic. The impacts from air emissions are not likely to affect local and regional wildlife and native vegetation. These impacts would be considered significant only if acute effects from air emissions occur. The desert monitor will likely be affected by the operational activities of the mine, but no effect to the regional population is expected. Impacts to other endangered species occurring in the Lakhra area are not projected. Avian mortality due to collisions with stacks is not likely to be significant at the Lakhra site. Impacts



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to agricultural crops are not considered significant because of the distance of a power plant located at Lakhra and the concomitant lower air pollutant concentrations.

## 7.3 SOCIAL IMPACTS

Impacts to the social environment in Kotri Taluka due to the construction and operation of the project are unavoidable. These unavoidable impacts vary in their magnitude and extent. The loss of existing land use is considered significant for local Khosa Baluch with agricultural plots in mine areas. The change in employment and economic patterns is considered a positive impact, but will be cyclic and result in a "boom" period during construction and then lesser levels of employment during operations. The disruption of cultural patterns and values and increased demand for facilities and services, however, are considered significant adverse impacts which cannot be avoided. Development of secondary infrastructure alternatives will partially mitigate these impacts. Impacts to local inhabitants will be significant on a site-specific basis; however, tne number of local inhabitants (Khosa Baluch) affected is small (about 50) and their residence is seasonal. Regional impacts to the Khosa Baluch are considered minor. The disruption of transportation systems is not considered significant. Impacts to historical and archaeological resources are not expected, based on a survey performed by the Pakistan Department of Archaeology.

The major operational adverse impacts include a drop in employment and the local economy at the end of construction; potential labor productivity problems between local inhabitants and workers, between construction and operation workers, and between power plant workers and the coal miners; and disruption of existing transportation systems. Adverse effects to man and agriculture in the vicinity of the Indus Valley from air emissions are not considered significant because of the distance of human settlements and sensitive agricultural crops from the Lakhra area.

# 8.0 ENVIRONMENTAL MITIGATION PLAN

The feasibility studies performed by GCII and J.T. Boyd Company for the Lakhra Coal Mine and Power Generation Project, have, for the most part, incorporated design features that would mitigate environmental impacts (see Table 8-1). Nonetheless, unavoidable environmental impacts will occur for which a mitigation plan must be developed and properly managed. Based on the evaluations and analyses performed through the EA process, an environmental mitigation plan (EMP) has been developed by USAID in conjunction with the World Bank environmental representatives and feasibility consultants (i.e., ESE, KBN, GCII, and Boyd). When finalized, the EMP will be colloboratively adopted by GOP and the international development organizations (i.e., World Bank and ADB) prior to project implementation. The purpose of the EMP is to promulgate those activities that will be taken to avoid, reduce, or otherwise mitigate adverse environmental impacts associated with the Lakhra project. The mitigation activities proposed in the EMP are consistent with GOP, USAID, World Bank, and ADB environmental policies. A summary of the EMP is provided in Table 8-2 and includes mitigation activities that are national, regional, and site-specific in scope (refer to Draft Environmental Mitigation Plan, May 1986, USAID, for more details).

Environmental monitoring programs are a critical management tool in assessing the magnitude and extent of environmental impacts. Table 8-3 presents an outline of the suggested monitoring programs that should be considered for the project as well as the appropriate organization that should implement the programs.

The implementation of Lakhra Coal Mine and Power Generation Project will have a profound effect on the social environment of the Kotri Taluka. An analysis of the social soundness of the project that evaluated the significance of social impacts suggested various ways that would enhance

Table 8-1. Major Environmental Design Features of the Lakhra Coal Mine and Power Plant Project

| Environmental Impact | Design Features |
|---|---|
| Physical | |
| Air Quality | Electrostatic precipitators and combustion techniques; construction of Good Engineering Practice stack height; fugitive dust control (e.g., watering haul roads, storage piles) |
| Water Quality | Treatment of chemical and sewage wastes; construction of evaporation ponds |
| Biological (including agricultural) | Location of power plant at Lakhra; reduced design velocity of intake water (impingement) and evaluate the need for fine mesh screens |
| Social | Construction of workers colonies; institutional development and training |

Sources: GCII, 1986.
J.T. Boyd Company, 1986.
ESE, 1986.
KBN, 1986.



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the benefits of the project and minimize the social impacts of the project. Many of these recommendations are presented in Table 8-2. Those recommendations most important to the success of the project include maximization of local employment, careful planning and integration of workers colonies, development and implementation of a public information program, coordination and integration of construction and operation activities to assure a smooth transition, and coordination with local governments (Dadu District and Sind Province) on secondary infrastructure development. Implementation of these recommendations would greatly ameliorate any adverse impacts to the social environment of the Kotri Taluka.

Table 8-2. Summary of Environmental Mitigation Plan (Draft)

| Mitigation Description | Need or Impact | Proposed Mitigation Activity | Implementation Organization* |
|---|---|---|---|
| I. National Coal Development<br>A. Environmentally Sound Coal Development Strategy | GOP policy needed to evaluate/ mitigate environmental impacts of coal development in Pakistan | Develop plan and associated regulations for modern mining and utilization practices | GOP organizations: PEPA, GSP, PMDC, ENERPLAN, MH, MPD, MI and WAPDA. Assistance from international consultant |
| B. Ambient Air Quality Standards (AAQS) | Use of coal and associated air emissions from its use requires development and implementation of AAQS | Develop AAQS and institutional structure to implement standards | GOP organizations: PEPA, PCSIR, PMDC, ENERPLAN, MH, MPD, MI and WAPDA. Assistance from international consultant |
| II. Lakhra Coal Mine<br>A. Environmental, Safety, and Health Management Staff | Mine staff needed to manage potentially significant impacts | Development including training of professional staff | Coal mine operator. Oversight by PEPA and ML |
| B. Environmental Monitoring Program | Detection of potentially significant environmental impacts | Develop long-term monitoring program including monitoring of environment (air, water, etc.), reclamation program, and waste materials (see Table 6-2) | Coal mine operator with oversight by PEPA and Sind Mine Inspectorate |
| C. Mine Reclamation | Disruption of land causing air, water, safety, and social impacts | Develop and implement mitigation plan | Coal mine operator with oversight from PEPA and Sind Mine Inspectorate |
| D. Occupational Safety and Health | Potential serious injuries and fatalities from mining activities | Preparation and implementation of health and safety plan that conforms to World Bank guidelines and Boyd recommendations (see Volume 10 of J.T. Boyd Company Feasibility Report) | Coal mine operator as well as existing private sector mines if coal is received from these sources. Oversight by ML, Sind Mine Inspectorate, and donor organizations |



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Table 8-2. Summary of Environmental Mitigation Plan (Draft) (Continued, Page 2 of 3)

| Mitigation Description | Need or Impact | Proposed Mitigation Activity | Implementation Organization* |
|---|---|---|---|
| E. Emergency Prevention Planning and Management | Potential emergency situations caused by mining activities; the need to respond in a timely manner to ameliorate emergency condition | Preparation and implementation of plan | Coal mine operator with assistance from GOP and Sind organizations, as necessary. Oversight by ML, Sind Mine Inspectorate, and donor organizations |
| III. Lakhra Power Plant<br>A. Construction Safety Program | Construction accidents causing serious injuries or fatalities | Preparation and implementation of plan | Power plant contractors. Oversight by ML, WAPDA, and donor organizations |
| B. Environmental, Safety, and Health Management Staff | Potentially adverse impacts of power plant operation | Development of professional staff including training | WAPDA with oversight by PEPA and ML |
| C. Environmental Monitoring Program | Detection of potentially adverse environmental impacts | Obtain equipment and develop operation measures to implement program (see Table 16) | WAPDA with oversight from PEPA and donor organizations |
| D. Occupational Safety and Health Plan | Potential serious injuries and fatalities from power plant operation | Preparation and implementation of plan that conforms with World Bank guidelines and OCII recommendations | WAPDA with oversight from ML and donor organizations |
| E. Emergency Prevention, Planning, and Management | The need to ameliorate potentially serious injuries during emergencies | Preparation and implementation of plan | WAPDA with assistance from GOP and Sind organizations |
| IV. Solid Waste Master Plan | Potentially adverse environmental impacts from power plant and mine solid wastes | Develop and implement plan. Plan to comply with PEPA and project criteria | International consultant with input from coal mine operator and WAPDA. Oversight provided by PEPA, MH, MH and Sind Mine Inspectorate |

Table 8-2. Summary of Environmental Mitigation Plan (Draft) (Continued, Page 3 of 3)

| Mitigation Description | Need or Impact | Proposed Mitigation Activity | Implementation Organization* |
|---|---|---|---|
| V. Waste Product Utilization | Potentially beneficial and economic uses of waste products (e.g., power plant fly ash) | Perform feasibility study and research into waste product utilization | PCSIR and universities with assistance of WAPDA and coal mine operator |
| VI. Infrastructure and Public Services | Potentially significant impacts to primary and secondary infrastructures and existing public services | Perform the following activities*:<br>A. Upgrading and improvement of Lakhra Highway<br>B. Planning and management of primary infrastructure development<br>C. Planning and management of secondary infrastructure development<br>D. Potable water stations in Khanot<br>E. Local official coordination for increasing public services<br>F. Local official coordination for development of secondary infrastructure | All potentially affected parties:<br>Coal mine operator<br>WAPDA<br>GOP<br>Sind<br>Dadu District<br>Local governments |
| VII. Grazing and Runoff Cropping | Removal of areas currently used for seasonal grazing and crops using runoff | Develop alternate areas | Coal mine operator |
| VIII. Endangered Animal Species | Loss of habitat for desert monitor (Varanus griseus) | Study of the ecology of the species in Sind/Lakhra area† | GOP Zoological Survey; Sind Ministry of Forest, Wildlife, and Forestry; US FWS |
| IX. Archeological and Historical Sites | Potential loss of significant archeological and historical sites not found in initial survey | Implementation of "Chance Find" Procedures | Coal mine operator with oversight from the GOP Department of Archeology |

*Refer to Section 4.2.3 and Appendix D.7 for more information and recommendations on infrastructure development. A public information program is also recommended.
† Study presently being conducted.
ENERPLAN = Ministry of Energy.
GSP = Geological Survey of Pakistan.
MI = Ministry of Industry.
MH = Ministry of Health.
ML = Ministry of Labor.
MPD = Ministry of Planning and Development.
PCSIR = Pakistan Council for Scientific and Industrial Research.
PEPA = Pakistan Environmental Protection Agency.
PMDC = Pakistan Mineral Development Corporation.
AAQS = Ambient Air Quality Standards.

Source: USAID, 1986.



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Table 8-3. Suggested Environmental Monitoring Programs

| Type of Monitoring | Parameters | Frequency | Number of Monitoring Stations and Location |
|---|---|---|---|
| Physical | | | |
| Air Quality | $SO_2$/Particulate | Continuous | Two stations located: (1) north-east near Indus agricultural areas (near the Rajri Reserve Forest) and (2) 1 to 2 km south of the power plant site. |
| Air Emissions | $SO_2$/Particulate/ $NO_x$ | Performance--annual | Testing of emissions at flue of each unit. Such tests should be performed annually. |
| | Meteorology | Continuous--wind speed and direction, stability (indirect methods) | One station at or near plant site. |
| Ground Water Quality | Total suspended solids, pH, temp., iron, arsenic, chromium, and selenium | Quarterly | Six to eight stations near ash/wastewater disposal areas; samples could also be obtained from existing underground mines. |

Table 8-3. Suggested Environmental Monitoring Programs
(Continued, Page 2 of 2)

| Type of Monitoring | Parameters | Frequency | Number of Monitoring Stations and Location |
|---|---|---|---|
| Biological | Vegetation | Semi-annual | Survey of Indus agricultural areas northeast of plant for possible air pollution impacts. |
| | Monitor Lizard | Single 6-month study | Determine status of endangered species and ecology. Note: A project is currently funded by US Fish and Wildlife Service with cooperation of GOP to investigate the habitat of the monitor lizard. |
| Social | Infrastructure Development | Annually | Discussions with local/community leaders for planning and implementation of secondary infrastructure development. |

Sources: ESE, 1986.
KBN, 1986.



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# 9.0 BIBLIOGRAPHY

Boyd (John T.) Company. 1986. Technical Report, Environmental Assessment Lakhra Coal Project Sind Province, Pakistan; and Interim Report, Transportation Study, Lakhra Coal Mine Study, Sind Province, Pakistan. Prepared for USAID/Pakistan (Contract No. 391-0478-C-00-5006-00) and Water & Power Development Authority, Government of Pakistan. Pittsburgh, Pennsylvania.

Environmental Science and Engineering, Inc. 1986. Air Quality and Land and Water Data and Analyses. Gainesville, Florida.

Gilbert/Commonwealth International, Inc. (GCII). 1986. Lakhra Coal Mine and Power Generation Feasibility Study: Power Plant Feasibility. Vols. I-IX. Submitted to U.S. Agency for International Development and Pakistan Water and Power Development Authority. Jackson, Michigan.

Helweg, A.W. 1985. Social Soundness Assessment of the Lakhra Coal Mine and Power Generation Project. USAID, Islamabad.

ICF, Inc. 1986. Lakhra Coal Mine and Power Generation Project--Economic Feasibility. Washington, D.C.

KBN Engineering and Applied Services, Inc. 1986. Air Quality, Noise, Biological, and Socioeconomic Data and Analyses. Gainesville, Florida.

Water and Power Development Authority (WAPDA). 1986. Power Development Plan for Elimination of Load-Shedding by 1990. Lahore, Pakistan.

World Bank, Office of Environmental Affairs. 1986. Environmental Guidelines.

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# ENVIRONMENTAL AND SOCIAL SOUNDNESS ASSESSMENT

## VOLUME II - MAIN REPORT
## VOLUME III - APPENDICES

## LAKHRA COAL MINE AND POWER GENERATION PROJECT

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

Sponsored by:
OFFICE OF ENERGY AND ENVIRONMENT
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
MISSION TO PAKISTAN

Prepared by:
ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
and
KBN ENGINEERING AND APPLIED SCIENCES, INC.

March 1987

# ENVIRONMENTAL AND SOCIAL SOUNDNESS ASSESSMENT
# LAKHRA COAL MINE AND POWER GENERATION PROJECT

PAKISTAN WATER AND POWER
DEVELOPMENT AUTHORITY
LAHORE, PAKISTAN

VOLUME II
MAIN REPORT

Sponsored by:

OFFICE OF ENERGY AND ENVIRONMENT
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
MISSION TO PAKISTAN
Islamabad, Pakistan

Prepared by:

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
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| | |
|---|---|
| AAQS | Ambient Air Quality Standards |
| ADB | Asian Development Bank |
| BCM | bank cubic meters |
| $BOD_5$ | biochemical oxygen demand (5-day) |
| Btu | British thermal units |
| Btu/kW | British thermal units per kilowatt |
| $^oC$ | degrees Celsius |
| CC | combined cycle |
| CFR | Code of Federal Regulations |
| cfs | cubic feet per second |
| CITES | Convention on International Trade of Endangered Species |
| $Cl^-$ | chloride |
| cms | cubic meters per second |
| cm/sec | centimeters per second |
| CT | combustion turbine |
| cusec | cubic feet per second |
| dBA | A-weighted decibel |
| EA | Environmental Assessment |
| EEI | Edison Electric Institute |
| EMP | Environmental Mitigation Plan |
| ENERPLAN | Ministry of Energy |
| ESE | Environmental Science and Engineering, Inc. |
| ESP | electrostatic precipitation |
| $^oF$ | degrees Fahrenheit |
| FBC | fluidized bed combustion |
| FGD | flue gas desulfurization |
| ft | foot |
| FTU | Formaxin Turbidity Units |
| gal | gallon |
| GCII | Gilbert/Commonwealth International, Inc. |
| GOP | Government of Pakistan |

| | |
|---|---|
| GSP | Geological Survey of Pakistan |
| ha | hectare |
| JICA | Japan International Cooperative Agency |
| KBN | KBN Engineering and Applied Sciences, Inc. |
| KESC | Karachi Electric Supply Company |
| km | kilometer |
| $km^2$ | square kilometer |
| kV | kilovolt |
| kW | kilowatt |
| $lb/10^6$ Btu | pounds per million British thermal units |
| LIMB | limestone injection multistage burner |
| m | meter |
| $m^3$/day | cubic meters per day |
| $m^3$/year | cubic meters per year |
| m/s | meters per second |
| mb | millibar |
| mg/L | milligrams per liter |
| MH | Ministry of Health |
| MI | Ministry of Industry |
| ML | Ministry of Labor |
| mm | millimeter |
| MPD | Ministry of Planning and Development |
| MT/day | metric tons per day |
| MT/yr | metric tons per year |
| MW | Megawatt |
| NCCW | National Council for Conservation of Wildlife |
| $NO_x$ | nitrogen oxide |
| $NO_2$ | nitrogen dioxide |
| NTU | Nephelometric Turbidity Units |
| NWFP | North-West Frontier Province |
| PCSIR | Pakistan Council for Scientific and Industrial Research |
| PEPA | Pakistan Environmental Protection Agency |
| PM | particulate matter |
| PMDC | Pakistan Mineral Development Corporation |
| PMS | Pakistan Meteorological Society |



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| | |
|---|---|
| ROM | run-of-mine |
| Rs | Pakistan rupees |
| $SO_2$ | sulfur dioxide |
| $SO_4^{-2}$ | sulfate |
| SWEC | Stone and Webster Engineering Corporation |
| TAMS | Tippetts-Abbett-McCarthy-Stratton |
| TLV | Threshold Limit Values |
| TSP | total suspended particulate |
| T&T | Telephone and Telegraph Authority of Pakistan |
| µs/cm | $10^{-6}$ siemens per centimeter |
| $\mu g/m^3$ | micrograms per cubic meter |
| USAID | United States Agency for International Development |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| WAPDA | Water and Power Development Authority |

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# 1.0 INTRODUCTION

## 1.1 BACKGROUND

This document, titled "Environmental and Social Soundness Assessment Lakhra Coal Mine and Power Generation Project," provides a discussion of the significant environmental and social effects, as well as proposed mitigative measures, for a coal mine and power plant project proposed to be located in the Lakhra coal field, Sind Province, Pakistan. The preferred project would consist of a two unit, 500-megawatt (MW) power plant located at Lakhra, a combination underground/surface mine, and a power plant workers' colony located at Khanot. The purpose of the document is to provide representatives of the host country and donor organizations a clear understanding of the significant impacts of the project to the natural and human environment, as well as the project's benefits in developing the coal resources and the necessary electrical energy for Pakistan.

Pakistan has coal resources which heretofore have not been used to provide new thermal generating capacity; however, existing mining techniques, which use relatively primitive methods, do not produce substantial quantities of coal and resource utilization is poor. Currently, nearly all of the coal mined in Pakistan is used in the brick kiln industry. The Lakhra coal field is one of the major coal resources of Pakistan and has recently undergone extensive study. In the late 1970's, the Japan International Cooperative Agency (JICA) performed limited field studies of reserves and evaluated the construction and operation of a 300-MW plant fueled by coal from both surface and underground mines. Subsquently, the Water and Power Development Authority (WAPDA), Pakistan Mineral Development Corporation (PMDC), and Stone and Webster Engineering Corporation (SWEC) reviewed the 1981 feasibility study published by JICA and extended the evaluation. Based

on the results of the WAPDA-PMDC-SWEC Report (1983), the U.S. Agency for International Development (USAID), in coordination with WAPDA, initiated a series of feasibility studies to develop more detailed information on the Lakhra field and to perform engineering and economic evaluations on the coal mine and power plant project.

The feasibility studies and their contractors are:

Mining Feasibility - J. T. Boyd Company

Power Plant Feasibility - Gilbert/Commonwealth International, Inc. (GCII)

Economic Feasibility - ICF, Incorporated

For the environmental feasibility study, Environmental Science and Engineering, Inc. (ESE) is the prime contractor and KBN Engineering and Applied Sciences, Inc. (KBN) is a subcontractor.

The Environmental Assessment (EA) was prepared using specific data and information collected for the project through field and site visits by staff from ESE and KBN. Field and site visits were made in August 1985 and February 1986. Environmental evaluations and analyses were performed from October 1985 through June 1986. In addition, the EA was prepared using information developed on the social-cultural feasibility of the project by the Institute for Development Anthropology who prepared a report titled Social Soundness Assessment of the Lakhra Coal Mine and Power Generation Project. This report was prepared by a three member team of social scientists (Dr. Arthur Helweg, M. Iqbal A. Niazi, and Saskia Vleer) during January to May 1985. Engineering and economic information was obtained from J.T. Boyd Company (mining feasibility), GCII (power plant feasibility), and ICF Incorporated (economic feasibility). Also, environmental representatives from J.T. Boyd Company and GCII assisted in the preparation of the mining and social impacts of

the project, respectively (see list of preparers for more information). Preparation of the Environmental and Social Soundness Assessment followed the procedures of:

1. The Government of Pakistan (GOP) Environmental Policy and Regulations (Ordinance No. XXVII of 1983 and Environmental Pro forma),
2. The United States Agency for International Development (USAID) Environmental Policy and Regulations (PD-6, 22CFR216), and
3. The environmental guidelines of the World Bank and Asian Development Bank (ADB).

The preparation of the EA involved a detailed analysis of various alternatives and a detailed environmental assessment of a preferred alternative. The results of this work are presented in eight major sections. This section (1.0) provides an overview of the preferred project alternative and environmental requirements. Section 2.0 presents a description of the project alternatives which were evaluated during the course of EA preparation. Several alternatives were evaluated for power plant and mine combinations:

1. 300-MW, single-unit power plant and associated 1.6 million metric tons/year from an underground and/or surface mine;
2. 500-MW power plant consisting of two units and associated 2.7 million metric tons/year from a combined underground/surface mine; and
3. 700-MW power plant consisting of two units and associated 3.8 million metric tons/year from a combined underground/surface mine.

In addition, three alternative sites were evaluated for the power plant: Lakhra (at mine site), Khanot [about 20 kilometers (km) east of the Lakhra site and about 2.5 km from the Indus River], and Jamshoro (approximately 35 km southeast of the Lakhra site and about 5 km from the Indus River). For a power plant located at the Lakhra site, two alternatives for the workers colony were evaluated: Lakhra and Khanot.

A detailed description of the physical, biological, and social environments affected by the project is presented in Section 3.0. Sections 4.0 through 8.0 present the detailed analysis of environmental impacts and proposed mitigation plans for the preferred alternative. This preferred alternative consisted of a 500-MW power plant located at Lakhra, a combination underground/surface mine, and a power plant workers colony located at Khanot. Environmental impacts of the mine and power plant as well as workers colonies are presented in Section 4.0.

Adverse environmental effects that cannot be avoided are contained in Section 5.0. Section 6.0 presents a summary of the Draft Environmental Mitigation Plan developed by USAID in conjunction with World Bank and feasibility contractors. The final two sections, 7.0 and 8.0, present short-term uses versus long-term productivity and irretrievable commitments of resources. The index for the GOP Environmental Pro forma for the Lakhra Project is presented as Attachment I. Attachment II contains the record of the scoping session for the Lakhra project which was held on 6 October 1986. During this scoping session, a brief overview of the results of the EA was presented and a dialogue established on the major areas of interest by attendees. Appendices A through J are contained in a separate technical document and present more detailed environmental baseline and impact information.

## 1.2 OBJECTIVES OF THE PROJECT AND THE GOVERNMENT OF PAKISTAN

The shortage of electric power is one of the most serious obstacles to the economic and social development of Pakistan. Under the range of current and potential electrical energy demands, about 800 MW/year in new thermal generating capacity will be required in the early 1990s to assist in alleviating this shortage as well as providing for future energy needs. In the latest power development plan (WAPDA, 1986), eight major areas of actions are specified:

1. Electrification of 90 percent (40,700) of the villages in Pakistan by June 1990;



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2. Complete elimination of load shedding by January 1990;
3. Addition of 2,900 MW of generation by December 1989 and 11,198 MW by December 1995;
4. Addition of about 1,900 km of 500-kilovolt(kV) and 220-kV transmission lines by 1990-1991;
5. Implementation of load management and tariff rationalization measures;
6. Continuation of electrical loss reduction program;
7. A total investment outlay (excluding Kalabagh project) of about Pakistan rupees (Rs) 116 billion by 1991; and
8. To ensure a self-financing ratio of 40 percent, a suitable annual increase in average energy sale price in future years.

The Lakhra Coal Mine and Power Generation Project has been proposed as one facet of this comprehensive energy management plan to provide the needed generation. In addition, the project will also assist the GOP in:

1. Diversifying fuel usage,
2. Increasing energy self-sufficiency and reducing foreign exchange exposure,
3. Developing a coal-fired generation technology base,
4. Mobilizing and developing a modern private sector coal industry, and
5. Providing domestic economic and industrial development.

## 1.3 DESCRIPTION OF PROPOSED PROJECT AND STUDY AREA

The Lakhra coal project will consist of the following two components: (1) a coal mine with associated facilities (e.g., transportation), and (2) a power generation complex. The coal mine and associated facilities will be developed and operated by the private sector, whereas the power plant complex will be operated by WAPDA.

The area that covers the Lakhra coal field, including the proposed coal mine and power plant site at Lakhra and the proposed power plant site at Khanot, are located in the Dadu District of the province of Sind (Figure 1-1). The coal mine and power plant are located in the northern portion of the Lakhra field within about a 80 square kilometer area which is controlled by the PMDC under a series of leases granted by the Sind government. The Indus River runs along the District's eastern boundary. To the east is the Hyderabad District containing the city of Hyderabad. Agriculture is the main economic activity in the Dadu District. The more suitable agricultural lands occur in the Hyderabad District. Grazing and torrent-watered cropping is the primary agriculture activity within the Lakhra area.

Coal mining is a major source of employment and revenue in the area surrounding the Lakhra coal field. The Lakhra coal field is approximately 15 km west of the Indus Highway and currently includes several privately owned mines. These existing mines occur south of the proposed project area. Scattered throughout these mines are a few Khosa Baluch (nomadic tribesmen) villages ranging in size from 20 to 100 people. The main road from the Indus Highway to Lakhra is located approximately 1 km (0.6 mile) below the village of Khanot. This village is composed of about 1,500 people. A major north/south rail line of the Pakistan Railway runs east of the Indus Highway with a rail station at Khanot. A truck stop with shops and a mosque are located at the intersection of the Indus Highway and Lakhra road. Several other Sindhi villages are located in a 5-km (3-mile) radius to the northeast and southeast of the truck stop. The City of Hyderabad, which is located about 30 km (20 miles) south of the intersection of the Lakhra mine road and the Indus Highway, has a population of approximately 750,000.

The coal mining facilities, as developed by the J.T. Boyd Company in their feasibility reports, will include:

1. One and/or two open pit mines and possibly one or more underground mine(s) in the Lakhra Coal field to produce 1.6 to 3.8 million metric tons per year ($10^6$ MT/year);



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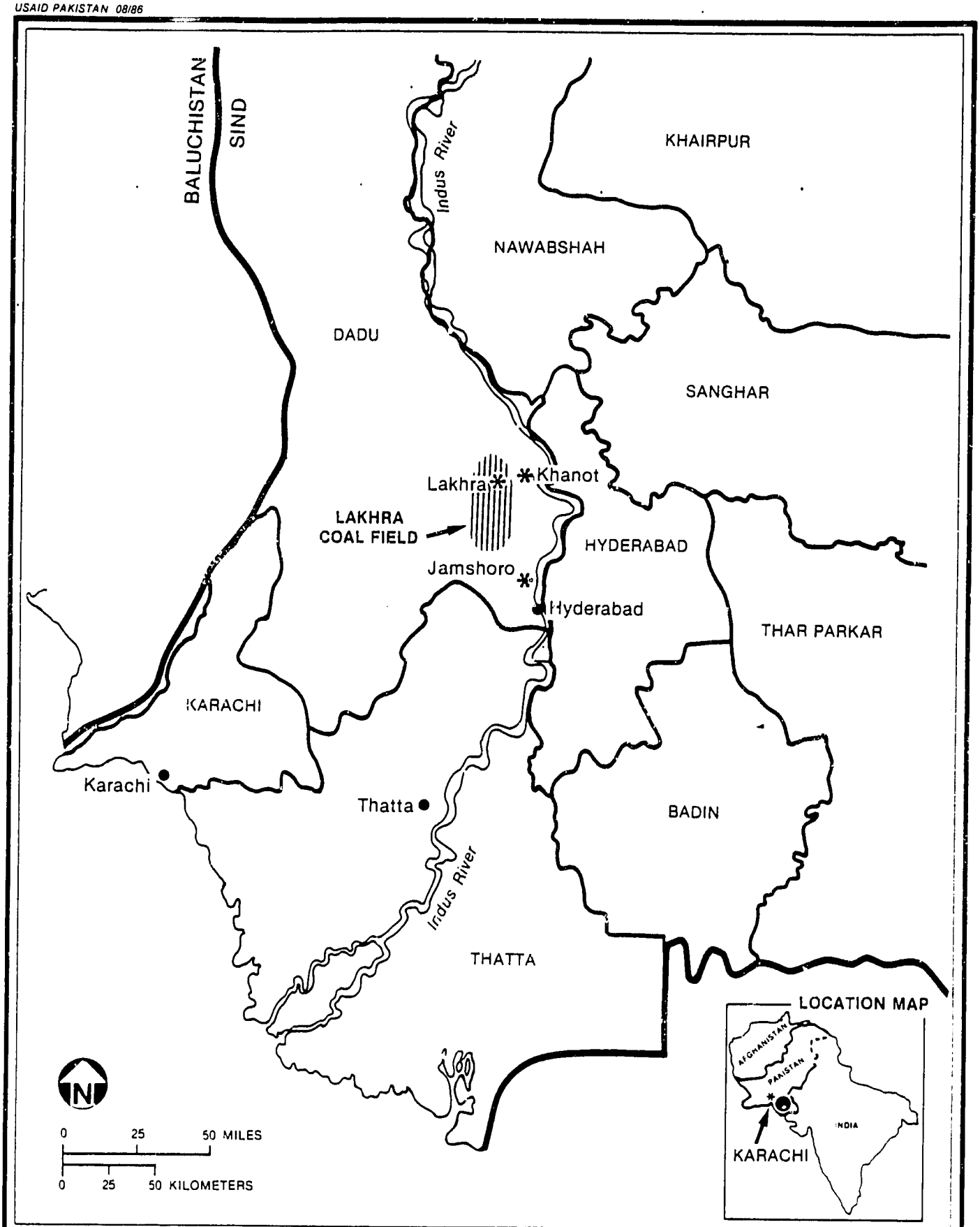


Figure 1-1
LOCATION OF LAKHRA COAL FIELD
AND PROJECT AREA

SOURCES: GOVERNMENT OF PAKISTAN, 1984; ESE, 1986.

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

2. Surface coal handling facilities and transportation; and
3. A colony for miners and mine support personnel, along with necessary access roads, utilities, and other necessary equipment and infrastructure.

The actual mining method and facility to supply coal to the Lakhra Power Plant will be those proposed by the successful offerer(s) and may be different to that developed and presented in the feasibility reports.

The power generation facilities, as developed by GCII in their feasibility reports, will include:

1. A coal-fired, steam power plant with a capacity ranging from 250 to 700 MW located in the Province of Sind either at Jamshoro, Khanot, or Lakhra;
2. Coal receiving storage and handling facilities;
3. Air pollution control equipment (i.e., electrostatic precipitators and combustion controls) and a space for flue gas desulfurization (FGD) units and for FGD sludge disposal;
4. Ash handling and disposal;
5. Electrical connection facilities to WAPDA's existing 500-kV transmission network;
6. An intake water system located on the Indus River, and a water supply line to the power plant of a size sufficient for all plant and colony requirements (with onsite storage ponds at Lakhra);
7. A colony for plant construction, operation, and maintenance personnel;
8. Provision for disposal or use of cooling tower blowdown and low volume wastes;
9. Rail and road access; and
10. Training facilities and secondary infrastructure support.

## 1.4 ENVIRONMENTAL ASSESSMENT PURPOSE AND SCOPE

The purpose of the EA is to provide host country and donor agency decision makers with a full discussion of significant environmental effects of the planned coal-fired power plant and associated mine project. The EA includes an evaluation of alternatives which would avoid or minimize adverse effects or enhance the quality of the environment so that the expected benefits of development objectives can be weighed against any adverse impacts upon the human environment or any irreversible or irretrievable commitment of resources.

From this evaluation, monitoring programs are developed to assess the project's impacts and to provide a mechanism for managing environmental effects as they occur. These monitoring programs provide the basis for WAPDA, the private sector, and GOP agencies to implement an environmental program for the project.

For a coal mine and power generation project, potential environmental impacts may occur to the air, water, and land resources (see Figures 1-2 and 1-3) as well as to the existing socioeconomic infrastructure of the region. These potential impacts have been evaluated in the EA.

## 1.5 ENVIRONMENTAL POLICY AND REGULATIONS

### 1.5.1 GOVERNMENT OF PAKISTAN

With the promulgation of the Pakistan Environmental Ordinance of 1983, GOP has initiated the mechanisms for formulating national environmental policy and developing and enforcing national environmental quality standards. Policy and standards approval is the purview of the Pakistan Environmental Council, whereas standards development and enforcement, as well as other environmental programs, are administered by the Environmental and Urban Affairs Division of the Ministry of Housing and Works.



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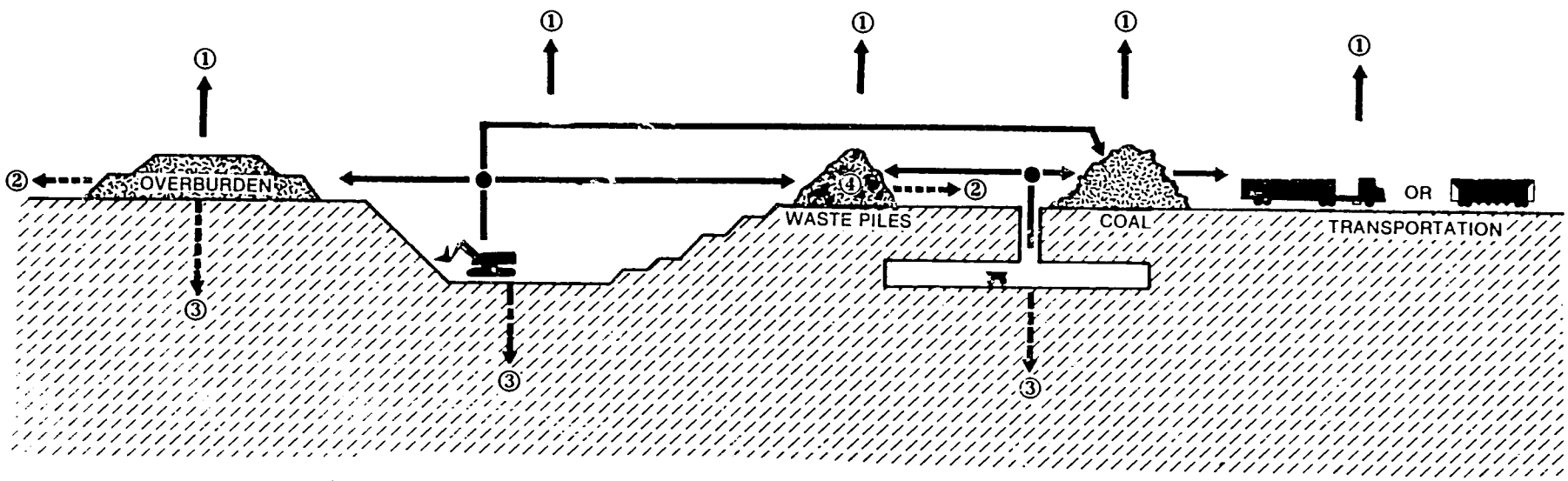


KEY
① AIR POLLUTION
② SURFACE WATER DISCHARGE
③ GROUND WATER DISCHARGE
④ SOLID WASTE DISPOSAL

Figure 1-2
GENERIC FLOW DIAGRAM OF SURFACE AND UNDERGROUND MINE AND MAJOR POTENTIAL ENVIRONMENTAL IMPACTS

SOURCE. ESE, 1986

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**Lakhra Coal Mine and Power Generation Feasibility Study**

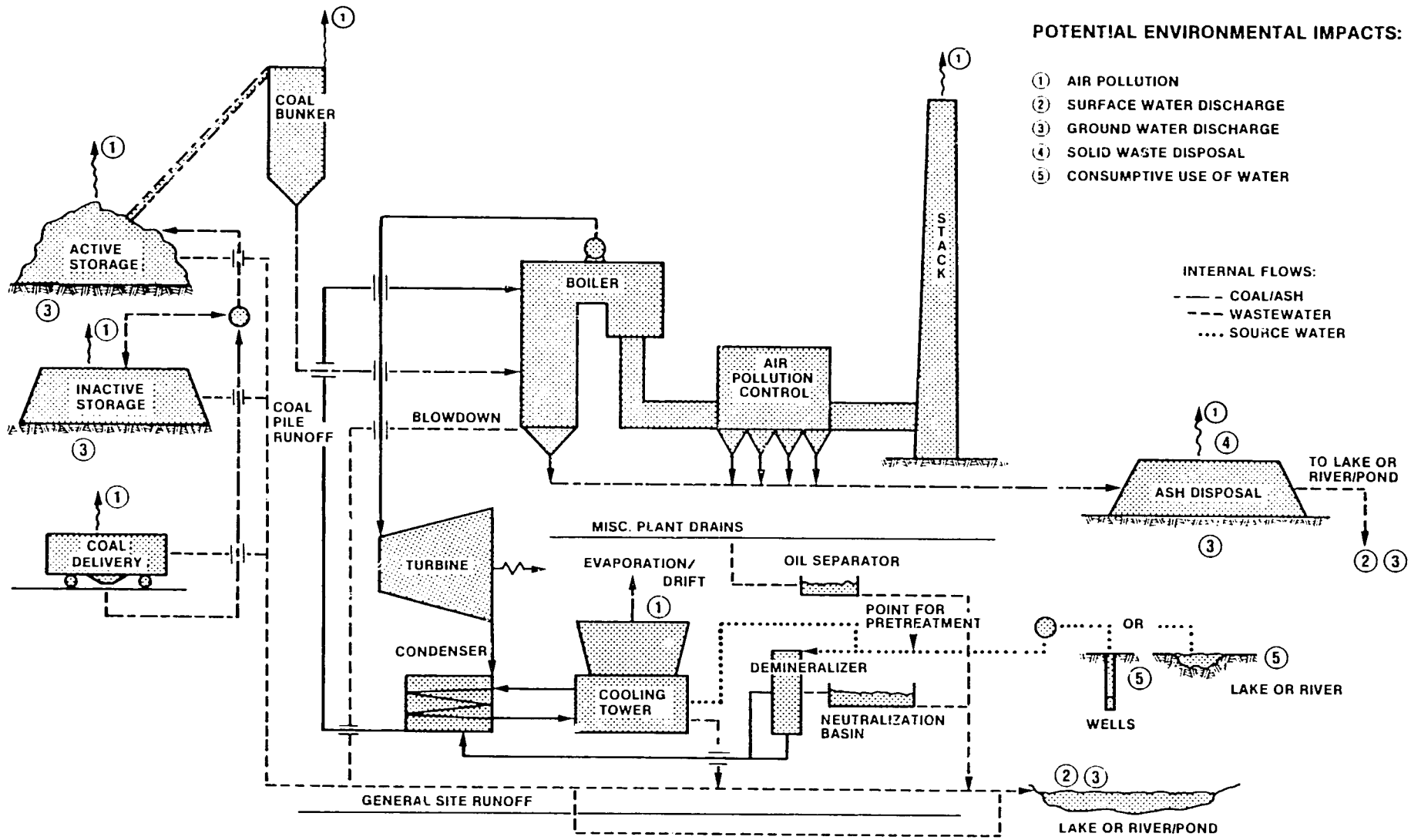


Figure 1-3
GENERIC FLOW DIAGRAM OF COAL-FIRED POWER PLANT AND MAJOR POTENTIAL ENVIRONMENTAL IMPACTS

SOURCE ESE, 1986

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

Lakhra Coal Mine and Power Generation Feasibility Study

USAID PAKISTAN 06/86

For the Lakhra project, GOP has requested the preparation of an EA via the requirement for an Environmental Pro forma (Ordinance No. XXVII of 1983). The details of the Pro forma are contained as Attachment A. Currently, no environmental standards have been adopted by GOP; however, draft standards have been proposed that would restrict the discharge of pollutants into the atmosphere and water.

Additionally, GOP and the Sind Government have established legislation governing antiquities, endangered species, national parks, wildlife sanctuaries, game reserves, forestry, and water management.

The major environmental legislation and regulations are presented in Table 1-1.

### 1.5.2 DONOR ORGANIZATIONS

Multilateral development organizations, such as the World Bank and ADB, have established procedures for the evaluation of potential environmental impacts (i.e. EA) and the adequacy of pollution control measures of financed projects (i.e. environmental guidelines). These evaluations are concerned with both the natural and human environment as well as the health and safety of workers. The Lakhra coal project, for which the GOP is seeking a portion of the funding from the World Bank, will be required to consider and evaluate, based on project-specific needs, Environmental Guidelines established by the World Bank for developing countries. The preparation of the EA for the Lakhra Coal Project involved direct coordination with, and involvement of, the World Bank Office of Environmental Affairs. This coordination led to a set of environmental criteria for the mine and power plant (Tables 1-2 and 1-3).

Bilateral funding organizations, such as USAID, have established policies for evaluating the environmental consequences of funded projects. For USAID, environmental policies have been included as part of promulgated environmental procedures [see Appendix A for 22 Code of Federal Regulations (CFR) Part 216; § 216.1(b)]



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Table 1-1. Major Environmental Legislation and Regulations for Pakistan

| Type | Authority | Administering Agency | Requirements |
|---|---|---|---|
| Comprehensive Environmental Protection | Ordinance No. XXVII of 1983 | Environmental and Urban Affairs Div. Ministry of Housing and Works | Environmental Pro forma |
| Protection of Antiquities | Act No. VI of 1977 | Ministry of Culture, Archaeology, Sports, and Tourism; Dept. of Archaeology | Provides protection and preservation of historically and archaeologically important sites |
| Water Resources | West Pakistan Act of 1958 | WAPDA | Management of water resources |
| | Sind Irrigation Act of 1879 | Government of Sind, Irrigation and Power Department | Granting of water use from Indus River |
| Wildlife | West Pakistan Wildlife Protection Ordinance of 1959 | Zoological Survey; National Council for Conservation of Wildlife; Ministry of Food, Agriculture, and Cooperatives | Promote conservation and establish limits on hunting |
| Wildlife | Sind Wildlife Protection Ordinance | Government of Sind, Ministry of Forest, Wildlife, and Forestry | Promote conservation and limit hunting |



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Table 1-1. Major Environmental Legislation and Regulations for Pakistan (Continued, Page 2 of 2)

| Type | Authority | Administering Agency | Requirements |
|---|---|---|---|
| Forests | Forest Act of 1927 No. XVI | Ministry of Food, Agriculture, and Cooperatives; Pakistan Forest Institute; Government of Sind, Ministry of Forest, Wildlife, and Forestry | Protection; regulation of exploitation of forests |

Sources: ESE, 1986.
KBN, 1986.



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Table 1-2. Applicable Environmental Criteria* for Lakhra Coal Mine

| Environmental Resource | Criteria |
|---|---|
| Air | Ambient Quality for Particulate:<br>100 $\mu g/m^3$ annual geometric mean<br>500 $\mu g/m^3$ maximum 24-hour average. |
| Land | Surface mine reclamation shall be performed to return lands to conditions capable of supporting prior uses or uses that are equal to or better than prior land use.<br><br>Develop a sedimentation and erosion control plan.<br><br>Cover waste piles. |
| Water | Runoff and drainage limitations:<br><br>Total Suspended Solids: 30-100 mg/L<br>Total Iron: 4-7 mg/L<br>pH: 6-9<br>Soluble Toxicants: None<br><br>Apply best practicable commercially available technology to minimize, control, or prevent disturbances to surface or underground water quality and quantity. |
| Noise | Noise levels (yearly average) required for protection of public health and welfare recommended in the World Bank Environmental Guidelines (July 1984). |
| Social and Cultural | Secondary growth effects to the general population shall be addressed and impacts to tribal people shall be mitigated. |
| Occupational | World Bank Occupational Health and Safety Guidelines for Coal Mining; Threshold Limit Values (TLVs) by American Conference of Governmental Industrial Hygienists. |

*These criteria were developed from the World Bank Environmental Guidelines and with coordination between the World Bank Office of Environmental Affairs, USAID, WAPDA, and feasibility contractors.

Notes: $\mu g/m^3$ = Micrograms per cubic meter.
mg/L = Milligrams per liter.

Sources: World Bank, 1986.
ESE, 1986.
KBN, 1986.



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Table 1-3. Applicable Environmental Criteria* for Lakhra Coal-Fired Power Plant

| Environmental Resource | Criteria |
|---|---|
| Air | Emissions:<br>1. $SO_2$--454 MT/day/unit (500 tons/day/unit) at 85 percent capacity factor<br>2. Particulate--100 $\mu g/m^3$<br>3. $NO_x$--260 ng/joule (0.6 $lb/10^6$ Btu).<br>Ambient Quality:<br>1. $SO_2$--100 $\mu g/m^3$ annual average<br>500 $\mu g/m^3$ maximum 24-hour average<br>2. Particulate--100 $\mu g/m^3$ annual geometric mean<br>500 $\mu g/m^3$ maximum 24-hour average<br>3. $NO_2$--100 $\mu g/m^3$ annual average |
| Water and Land, | No specific limitation but general restrictions on affecting human health and welfare. |
| Noise | Noise levels (yearly average) required for protection of public health and welfare recommended in the World Bank Environmental Guidelines (July 1984). |
| Social and Cultural | Secondary growth effects to the general population shall be addressed and impacts to tribal people shall be mitigated. |
| Occupational | World Bank Occupational Health and Safety Guidelines for Power Plants, Coal, and Fuel Oil; TLVs by American Conference of Governmental Industrial Hygienists. |

*These criteria were developed from the World Bank Environmental Guidelines and with coordination between the World Bank Office of Environmental Affairs, USAID, WAPDA, and the feasibility contractors.

Notes: $SO_2$ = Sulfur dioxide.
MT/day = Metric tons per day.
$\mu g/m^3$ = Micrograms per cubic meter.
$NO_x$ = Nitrogen oxide.
$lb/10^6$ Btu = Pounds per million British thermal units.
$NO_2$ = Nitrogen dioxide.

Sources: World Bank, 1986.
ESE, 1986.
KBN, 1986.

and in an official USAID policy determination on Environmental and Natural Resource Aspects of Development Assistance (PD-6, April 26, 1983). An EA, which is a detailed study of potentially significant environmental impacts, must be prepared as part of certain USAID-funded projects. The purpose of the EA is to:

1. Ensure that environmental impacts are identified and considered prior to a final decision and that appropriate safeguards are adopted,
2. Assist the host government in developing effective environmental programs,
3. Identify impacts to the natural and human environment, and
4. Define environmental limiting factors for the project.

The Lakhra coal project EA was conducted in accordance with USAID funding and associated environmental requirements. GOP and the bi- and multi-lateral funding organizations also require an EA for a project of this type. The EA for the Lakhra project considered those requirements and includes:

1. Identification of the potentially affected environment,
2. Identification of environmental issues through a scoping process,
3. Evaluation of project alternatives,
4. Assessment of environmental and social soundness impacts, and
5. Recommendations for mitigation and monitoring programs.



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# 2.0 DESCRIPTION OF PROJECT ALTERNATIVES

## 2.1 MANAGEMENT ALTERNATIVES

### 2.1.1 NO-ACTION ALTERNATIVE

Pakistan has an installed capacity of about 2,900-MW hydro-power generation and over 3,500-MW [including Karachi Electric Supply Company (KESC)] thermal-power generation. This capacity is insufficient to meet current demand and load shedding has occurred. To meet this existing energy need and alleviate load shedding with associated socioeconomic impacts, as well as provide for future demand, Pakistan is projected to need approximately 800 MW of new capacity each year until the turn of the century. The "no-project" alternative would worsen the current shortage of electrical energy and result in significant social/economic impacts.

### 2.1.2 PURCHASES OF REQUIRED ENERGY FROM OTHER SOURCES/JOINT PROJECTS

WAPDA and KESC are the major bulk electrical suppliers in Pakistan. KESC serves Karachi City and surrounding areas and WAPDA serves the rest of the country. Limited transfers of power from one system to the other are possible through a double circuit 220-kV transmission system linking Karachi with the WAPDA system. Several projects, including the KESC projects, are currently included in the generation plan; however, the proposed gas and oil-fired projects are insufficient to eliminate the need for additional generation.

Energy conservation would produce benefits; however, in itself energy conservation would not lower demand sufficiently to eliminate the need for additional generation.

### 2.1.3 POSTPONING UNIT RETIREMENTS, REACTIVATING, AND/OR UPGRADING EXISTING PLANTS

Postponing unit retirements would not substantially increase electrical supply. Rehabilitation of older plants is currently a part of WAPDA's expansion program. Nine units from seven existing generating stations (Multan, Faisalabad, Guddu, Sukkur, Quetta, Shahdara, and Kotri) are scheduled for upgrades with an in-service rehabilitation date of about June 1989; however, an increase of about 126 MW is anticipated from these upgrades.

### 2.1.4 CONSTRUCTION OF UNITS SMALLER THAN THE PROPOSED FACILITIES

The range of project alternatives considered in the preparation of the EA include generating units from 250- to 700-MW. The range of sizes was based upon available reserves in the Lakhra field and economic viability of the different-sized units. Depending on the coal supply offered by the successful proposer, units smaller than these alternatives (i.e., 250- to 700-MW) may be considered (see also Sections 2.3 and 2.5).

## 2.2 ALTERNATIVE PROJECTS

The current electrical generation plan for Pakistan (WAPDA, 1986) includes provisions for a variety of generation projects including hydro, steam, and combustion turbine combined-cycle generation (see Table 2-1). A number of these projects have been committed to (and in some cases initiated or already completed), whereas others on the list, including the Lakhra project, are in a proposed or conceptual stage. Generation studies sponsored by USAID and coordinated with WAPDA have identified the need for additional baseload capacity to meet 1991-1993 demand. Viable alternatives for increased power generation include plants fired with domestic (Lakhra) coal, imported coal, or imported oil; therefore, all three types of plants are included in the generation plan.



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Table 2-1. Summary of Pakistan's Power Generation Program (After April 1986)

| Station/Project Designation* | Unit Number(s) | Total Capacity (MW) | In-Service Dates |
|---|---|---|---|
| Kot Addu CT | 1-8 | 800 | From Nov 86 to Feb 89 |
| CC | 9-10 | 200 | Jun 89 |
| Guddu CC | 5,6 | 200 | Dec 87 and Jan 88 |
| Jamshoro Imported Oil | 1-6 | 1,570 | From Dec 88 to Dec 93 |
| KESC Steam | D-3,D-4,D-5 | 630 | From Feb 89 to Dec 89 |
| Mangla | 9 and 10 | 200 | Sept 89 |
| Undesignated CT | 1,2 | 200 | Dec 89 |
| Tarbela | 11-17 | 2,928 | From Jan 90 to Dec 95 |
| Faisalabad CC | 9 and 10 | 80 | Feb 90 |
| Kotri CC | 7 and 8 | 40 | Feb 90 |
| Multan | 1-3 | 630 | From Oct 90 to Oct 91 |
| Lowhead Hydro | † | 420 | From Dec 90 to Dec 92 |
| Lakhra Coal | 1 and 2 | 600 | From Mar 92 to Dec 92 |
| Undesignated Imported Coal | 1-3 | 1,200 | From Dec 93 to Dec 95 |
| Kalabagh | 1-5 | 1,500 | From Sep 94 to Sep 95 |

*CT = combustion turbine; CC = combined cycle.
†Chashma, Taunsa, and Jinnah.

Source: WAPDA, 1986.



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An environmental/social soundness analysis of these alternatives was performed. This analysis was based upon a domestic coal-fired plant located in the general Lakhra area, an imported oil-fired plant, and an imported coal-fired plant. The size of the power plant was considered the same for all plant alternatives. Sulfur content was 0.6 percent for imported coal (GCII, 1986), 3.2 percent for imported oil, and 5 percent for Lakhra coal. Because of the lack of site-specific design and environmental information for the imported fuel alternatives, the analysis considered impacts from a regional perspective. Four environmental disciplines (i.e., air, land, socieconomic, and water resources) were used to evaluate the differences in environmental impacts for the three candidate fuels. The results of this analysis (see Table 2-2) suggests that a domestic coal-fired power plant using Lakhra coal would fit into an overall generation program which also includes imported coal and oil generating facilities. A more detailed discussion of the analysis technique and results is presented in Appendix B.

## 2.3 PLANT-SPECIFIC ALTERNATIVES

The project-specific alternatives include three basic plant configurations: one 300-MW unit; two 250-MW units; and two 350-MW units. The basic design specifications of these alternatives are listed in Table 2-3. The ultimate size of the power plant will depend on the size of the coal supply that is offered by the successful private-sector proposers.

Each alternative size was evaluated on the basis of economic and environmental criteria. Because of the low heating value of the Lakhra coal and the advantages of using open pit mining to effectively utilize the coal resources, a 250- 300-MW plant may not be as economically viable as a larger plant. Projected costs for supplying coal for a 300-MW plant were estimated to be about 18 percent higher on a per-ton-of-coal-fired basis than for a 700-MW plant using comparable mining techniques. In addition, a 300-MW plant would only provide a portion of the needed generation.



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Table 2-2. Summary of Alternative Project Evaluation

| Alternative Project | Environmental Score* | Environmental Rank |
|---|---|---|
| Domestic Coal (Lakhra) | 35 | First |
| Imported Coal | 33 | Second |
| Imported Oil | 33 | Second |

*Refer to table below

NOTE: The environmental evaluation of alternative projects was performed by calculating rating coefficients with respect to four environmental criteria (air, land, socioeconomics, and water resources). To develop rating coefficients, sites were compared two at a time against each environmental criterion (refer to Appendix B for more information). The environmental analysis is summarized below:

| Site | Environmental Resource Rating † | | | | |
|---|---|---|---|---|---|
| | Air | Land | Socioeconomic | Water | Sum |
| Lakhra-Coal | 0 | 0 | 23 | 12 | 35 |
| Imported-Coal | 10 | 5 | 6 | 12 | 33 |
| Imported-Oil | 5 | 10 | 6 | 12 | 33 |

†Higher ratings denote a more environmentally favorable alternative.

Sources: ESE, 1986.
KBN, 1986.



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Table 2-3. General Design Specifications and Environmental Discharges for Power Plant Alternatives (at 100 Percent Capacity Factor)

| Design Specification/ Environmental Discharges | Plant Size (MW) 300 | Two 250* | Two 350 w/o FGD | Two 334 w/FGD† |
|---|---|---|---|---|
| Heat Rate (Btu/kWH) | 11,120 | 11,016 | 11,200 | 11,730 |
| Heat Input ($10^6$ Btu/hr) | 3,336 | 5,508 | 7,834 | 7,834 |
| Average Annual Coal Consumption ($10^6$ MT) | 1.6 | 2.7 | 3.8 | 3.8 |
| Air | | | | |
| Sulfur Dioxide Emissions | | | | |
| Maximum (MT/day) | 585 | 967 | 1,373 | 137 |
| Annual Average (1,000 MT) | 149 | 247 | 351 | 35 |
| Particulate Matter | | | | |
| Maximum (MT/day) | 5.8 | 9.8 | 13.9 | 13.9 |
| Annual Average (1,000 MT) | 1.5 | 2.5 | 3.5 | 3.5 |
| Nitrogen Oxides | | | | |
| Maximum (MT/day) | 21.8 | 36.0 | 51.2 | 51.2 |
| Annual Average (1,000 MT) | 5.6 | 9.2 | 13.1 | 13.1 |
| Water | | | | |
| Consumptive Use (1,000 $m^3$/day) | 33 | 55 | 77 | 86 |
| Cooling Tower Blowdown (1,000 $m^3$/day) | 1.8 | 2.9 | 4.1 | 4.1 |
| Filter Backwash (1,000 $m^3$/day) | 2.0 | 3.3 | 4.6 | 4.6 |
| Fly Ash Transport (1,000 $m^3$/day) | 14 | 24 | 33 | 33 |
| Bottom Ash Sluice (1,000 $m^3$/day) | 12 | 20 | 28 | 28 |
| FGD System (1,000 $m^3$/yr) | -- | -- | -- | 9 |
| Solid Waste | | | | |
| Bottom Ash (1,000 MT/yr) | 135 | 224 | 318 | 318 |
| Fly Ash (1,000 MT/yr) | 203 | 336 | 478 | 478 |
| Water Treatment Sludge (1,000 $m^3$/yr) | 218 | 363 | 508 | 508 |
| FGD Sludge (1,000 $m^3$/yr) | -- | -- | -- | 237 |

*Except for heat rate and input, a single 250-MW unit would have ½ the values shown in the table.
†Assumes 90 percent $SO_2$ removal; lower net capacity due to auxiliary power requirement of FGD.

Notes: MT = Metric tons.
Btu/kWH = British thermal units per kilowatt hour.
$10^6$ Btu/hr = Million British thermal units per hour.
$m^3$/day = Cubic meters per day.
$m^3$/yr = Cubic meters per year.

Sources: GCII, 1986.
ESE, 1986.
KBN, 1986.



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The principal environmental design criterion for the plant will allow each unit an $SO_2$ emission limit of 454 MT (500 tons) per day when operating at 85 percent of rated capacity. Based on the above design criterion, a plant consisting of two 250-MW units would achieve this criterion and on an annual average basis have the $SO_2$ emissions of approximately 340 MT (370 tons) per day per unit at the projected annual average operating capacity factor of 70 percent. This environmental design criterion has been found acceptable to the World Bank, provided emissions at this level are demonstrated not to cause significant impacts to local, regional, and global environments.

A plant consisting of two 350-MW units would be required to install FGD equipment to reduce $SO_2$ emissions to levels satisfying to World Bank limits. The addition of FGD equipment would result in significant economic penalties (see Section 2.7, Air Emission Control Alternatives) that would make a two 350-MW project economically unattractive. Operation of FGD will also create additional environmental effects from disposal of sludge. Therefore, based upon a balance of current economic and environmental criteria, a two 250-MW plant is the preferred alternative.

## 2.4 POWER PLANT SITE ALTERNATIVES

Three potential sites were evaluated for the power plant complex: Jamshoro, Khanot, and Lakhra (Figure 2-1). An evaluation of these sites was performed by considering the air, land, socioeconomic, and water resource effects pertaining to each site. The power plant size was considered the same (i.e., 500-MW) in the evaluation. Mine development impacts were not considered as synergistic effects; however, linear facilities such as coal transportation were considered. A detailed description of the alternative evaluation methodology, assumptions, and results is presented in Appendix B. Descriptions of the engineering requirements of each of the three sites are presented in Appendix C, and



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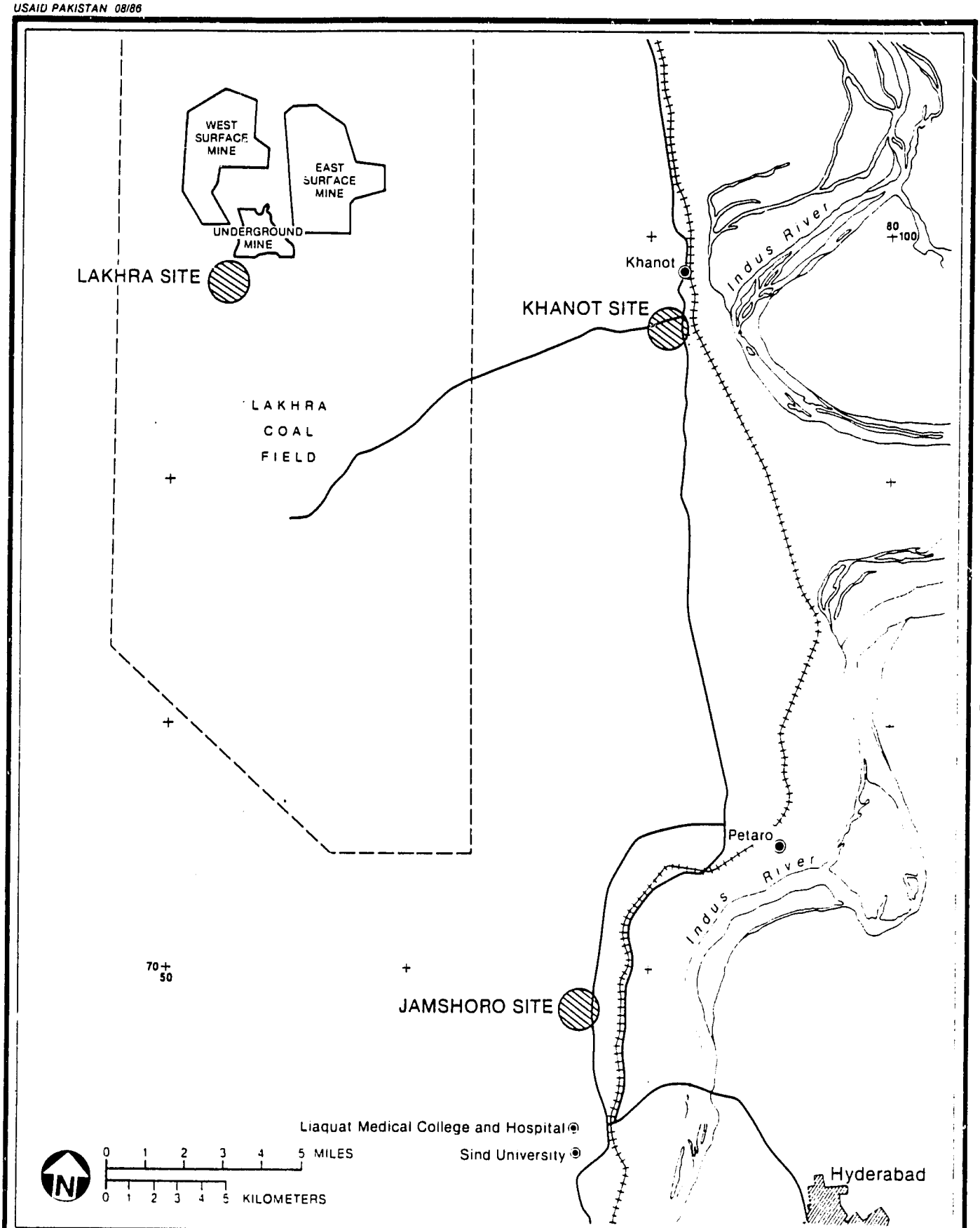


Figure 2-1
LOCATION OF CANDIDATE POWER PLANT SITES AND PROPOSED LAKHRA MINE

SOURCE. ESE. 1986.

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a description of the plant design is presented in Appendix D. The results (see Table 2-4) indicate that the Lakhra site is environmentally superior to either the Jamshoro or Khanot sites. Although the Jamshoro site was ranked second environmentally, potential air quality impacts from a Lakhra coal-fired power plant to sensitive receptors such as Mehran University, the Sind University, the Liaquat Medical College and Hospital, and Hyderabad City make this site unacceptable for a Lakhra coal-fired power plant.

Further analysis of specific environmental impacts of two 250-MW units located at Lakhra or Khanot was performed. The results of this analysis indicated the potential for significant air pollution impacts to the population and agriculture of the Indus Valley from a plant located at the Khanot site. At the Lakhra site, however, the potential for significant air quality impacts is small (see Figure 2-2) because the site is located over 20 km (12 miles) from the Indus Valley agricultural areas and is very sparsely populated, with only a few torrent-watered cropping areas.

The remoteness of the Lakhra site, which is an advantage in relation to affecting existing human populations, agriculture, and the natural environment, makes this site much less suitable as a site for a power plant workers colony. As a result, WAPDA has decided to locate the power plant workers colony near Khanot, where living conditions are more customary and acceptable. (See Section 2.8, Infrastructure Alternatives section). Worker transportation, if provided by buses and traveling on an improved road, will not extend the workday by more than approximately one hour.



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Table 2-4. Summary of Power Plant Site Analysis

| Alternative Project | Environmental Score* | Environmental Rank |
|---|---|---|
| Lakhra | 48 | First |
| Khanot | 22 | Third |
| Jamshoro | 29 | Second† |

*Refer to table below.
†Potentially unacceptable air quality impacts to local sensitive receptors would make this site environmentally inferior to other sites for a Lakhra coal-fired power plant. These impacts are due to $SO_2$ emissions resulting from firing Lakhra coal which has both high sulfur and low Btu content that produce high $SO_2$ emissions relative to other types of fuel.

NOTE: The environmental evaluation of alternative projects was performed by calculating rating coefficients with respect to four environmental criteria (air, land, socioeconomics, and water resources). To develop rating coefficients, sites were compared two at a time against each environmental criterion (refer to Appendix B for more information). The environmental analysis is summarized below:

| Site | Environmental Resource Rating** | | | | |
|---|---|---|---|---|---|
| | Air | Land | Socioeconomic | Water | Sum |
| Lakhra | 17 | 3 | 5 | 23 | 48 |
| Khanot | 8 | 3 | 5 | 6 | 22 |
| Jamshoro | 0 | 3 | 20 | 6 | 29 |

**Higher ratings denote a more environmentally favorable alternative.

Sources: ESE, 1986.
KBN, 1986.



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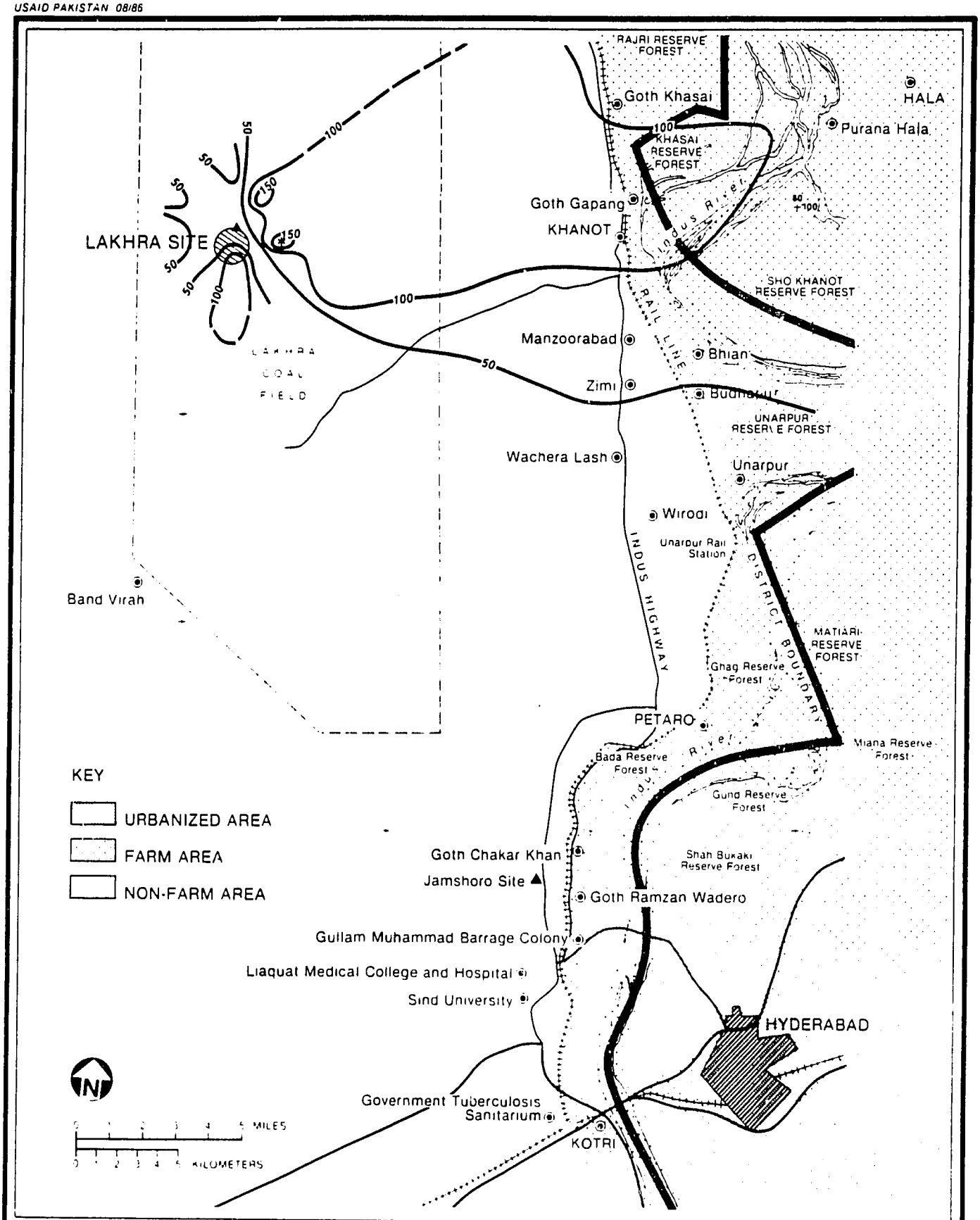


Figure 2-2
MAXIMUM PREDICTED 24-HOUR $SO_2$ CONCENTRATION (ug/m³) DUE TO THE PROPOSED FACILITY

SOURCES GCII. 1985. ESE. 1986

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## 2.5 MINING TECHNOLOGY ALTERNATIVES

### 2.5.1 OVERVIEW

The Lakhra Coal Project designated area covers a contiguous area of approximately 62 square kilometers ($km^2$) of a 79-$km^2$ area currently under prospecting lease by the PMDC from the Province of Sind. The project area, located approximately 50 km (31 miles) north-northwest of the town of Hyderabad, is situated in the Dadu District of Sind Province.

Access to the project area is by a combination of paved and unpaved roads which serve the existing private underground mines to the south. A paved road (Indus Highway) adjoins the western side of the Indus River extending from Hyderabad to Khanot and northward. The closest rail service is a single-line, broad-gauge track of Pakistan Railways which also adjoins the west bank of the Indus River, passing through Khanot.

The Laki Limestone Member forms a cap rock over the western two-thirds of the study area, producing relatively flat to gently rolling terrain. Intermittent streams (e.g., the Kath Buthi) have eroded the cap rock in the eastern portion of the area, exposed the underlying Laki laterite, and resulted in moderate relief. Surface elevations range from 110 to 150 meters (m) (360 to 500 ft) above sea level, as compared to less than 30 m (100 ft) along the Indus River, located approximately 20 km (12 miles) to the east.

Based on studies and the results of the field programs, the demonstrated recoverable lignite reserves underlying the 62-$km^2$ area studied by J.T. Boyd Company are estimated to range from 143 to 174 million run-of-mine (ROM) metric tons (J.T. Boyd Company, 1986). The quantity of estimated reserve (see Table 2-5 and Figure 2-3) varies according to mining method and average mining recovery assigned to the underground reserves. Overall mining recoveries of 85 percent for surface and 50 percent to 60 percent for underground methods are applied.



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Table 2-5. Recoverable Reserves for the Lakhra Study Area

| | ROM Metric Tons (Millions) Reservation Classification | | |
|---|---|---|---|
| | Measured | Indicated* | Total |
| Total Reserves | 143.3 | 30.8 | 174.1 |
| Total Underground Mineable Reserves | 26.0 | 4.7 | 30.7 |
| Master Mine Plan | 110.5 | 12.4 | 122.9 |
| Surface Mineable Reserves (East and West Pits) | 105.2 | 10.6 | 115.8 |
| Underground Reserves (Central and Southeast Only) | 5.3 | 1.8 | 7.1 |

*Amount inferred from topography.

Source: J.T. Boyd Company, 1986.

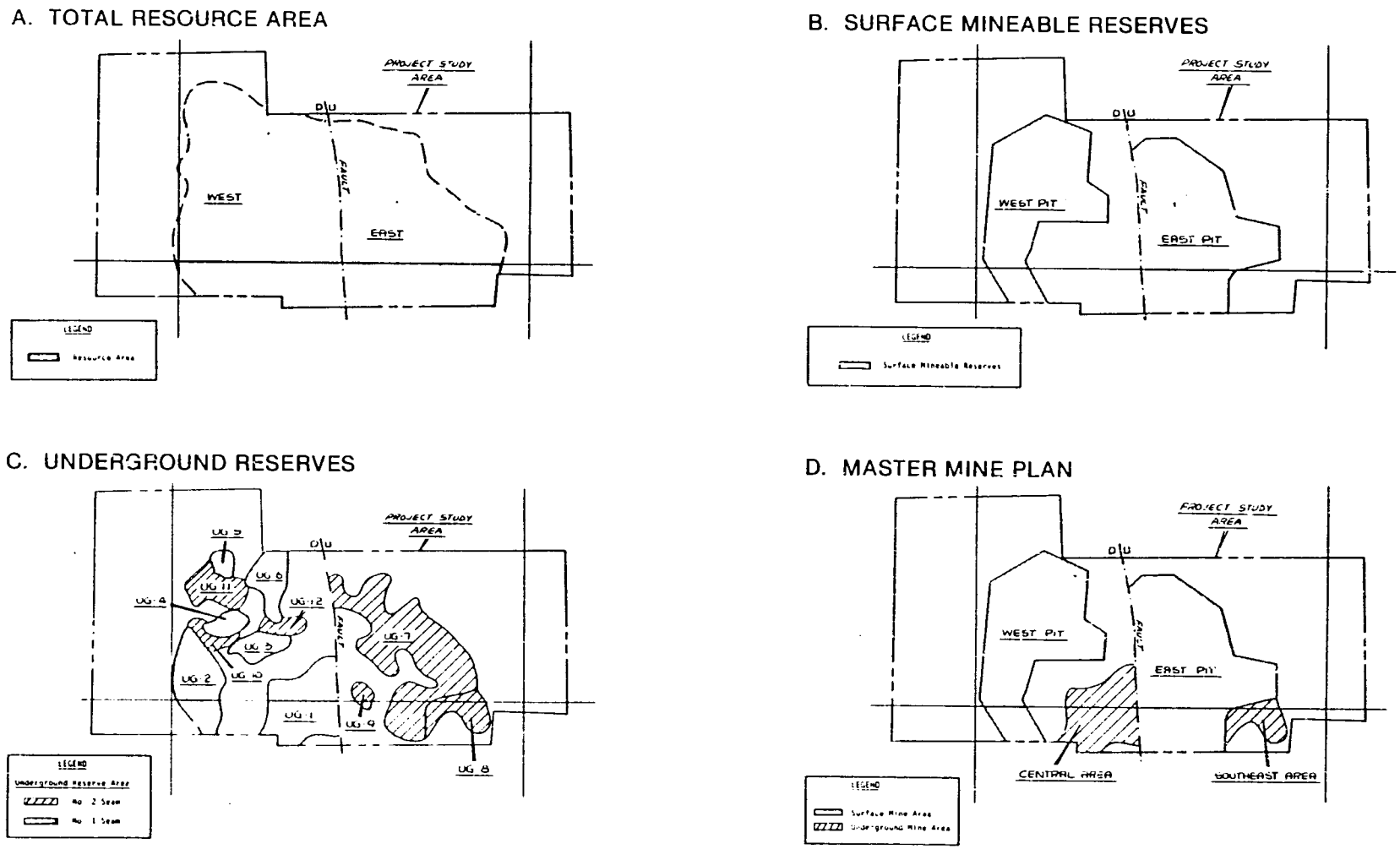


Figure 2-3
RECOVERABLE COAL RESOURCE AREAS WITHIN PMDC TRACT

SOURCE: JOHN T. BOYD COMPANY, 1986.

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**Lakhra Coal Mine and Power Generation Feasibility Study**

To supply from 1.6 to 3.8 x $10^6$ MT/year (48 to 114 x $10^6$ metric tons over a 30-year plant life) of Lakhra coal, various mining alternatives have been proposed, including an underground mine, a surface mine, or a combination of an underground and surface mine (see Table 2-6).

### 2.5.2 UNDERGROUND MINING

Underground mining methods are typically employed where the coal is too deep to be surface mined economically. The proposed continuous underground mining method of Lakhra involves long wall mining and a sequence of labor-intensive operations. A typical mine crew would consist of about 22 workers on each shift including seven cutters, seven loaders, seven roof support men, and one boom man at the face of the conveyor drive station. Each crew would have two section foremen. The 22-man crew would operate as a team for moving, roof support, digging, loading, and separation of impurities.

At the longwall face, the lignite would be broken with pneumatic picks. Lignite would then be hand shoveled onto a chain-type conveyor which is positioned adjacent to the face. During loading of the belt conveyor, which transports lignite out of the mine, in-seam separable parting material (clay and shale) would be removed manually. To minimize spontaneous combustion of the reject material, the material would be either hauled to the surface (approximately once per week) or transported to a mined-out section of the mine and sealed in a disposal area.

The roof along the longwall face would be supported by hydraulic props with sliding steel bars and supplemented with wooden posts and cribs. Approximately 160 hydraulic props would be used along each face, and the hydraulic props would be advanced as close as possible toward the face conveyor as the longwall retreats. The wooden posts would normally not recovered as the roof collapses by the face. Figure 2-4 shows the proposed longwall face, along with worker positions along the face, for the Lakhra underground mine.

Table 2-6. Mining Alternatives

| Output ($10^6$ MT/yr) | Plant Size | Underground ($10^6$ MT/yr) | Surface ($10^6$ MT/yr) | No. of Surface Mines | Topsoil Over-burden Removed ($10^6$ BCM) | Surface Area Impacted (ha) |
|---|---|---|---|---|---|---|
| 1.6 | 300 | 0.9 | 0.7 | 1 | 9 | 390 |
| 1.6 | 300 | 0.0 | 1.6 | 1 | 21 | 910 |
| 1.6 | 300 | 1.6 | 0.0 | 0 | 0 | <100 |
| 2.7 | 500 | 0.3 | 2.4 | 2 | 32 | 1,360 |
| 3.8 | 700 | 0.3 | 3.5 | 2 | 46 | 1,990 |

Notes: $10^6$ MT/yr = Million metric tons per year.
BCM = Bank cubic meters.
ha = hectares.

Sources: J.T. Boyd, 1986.
ESE, 1986.
KBN, 1986.

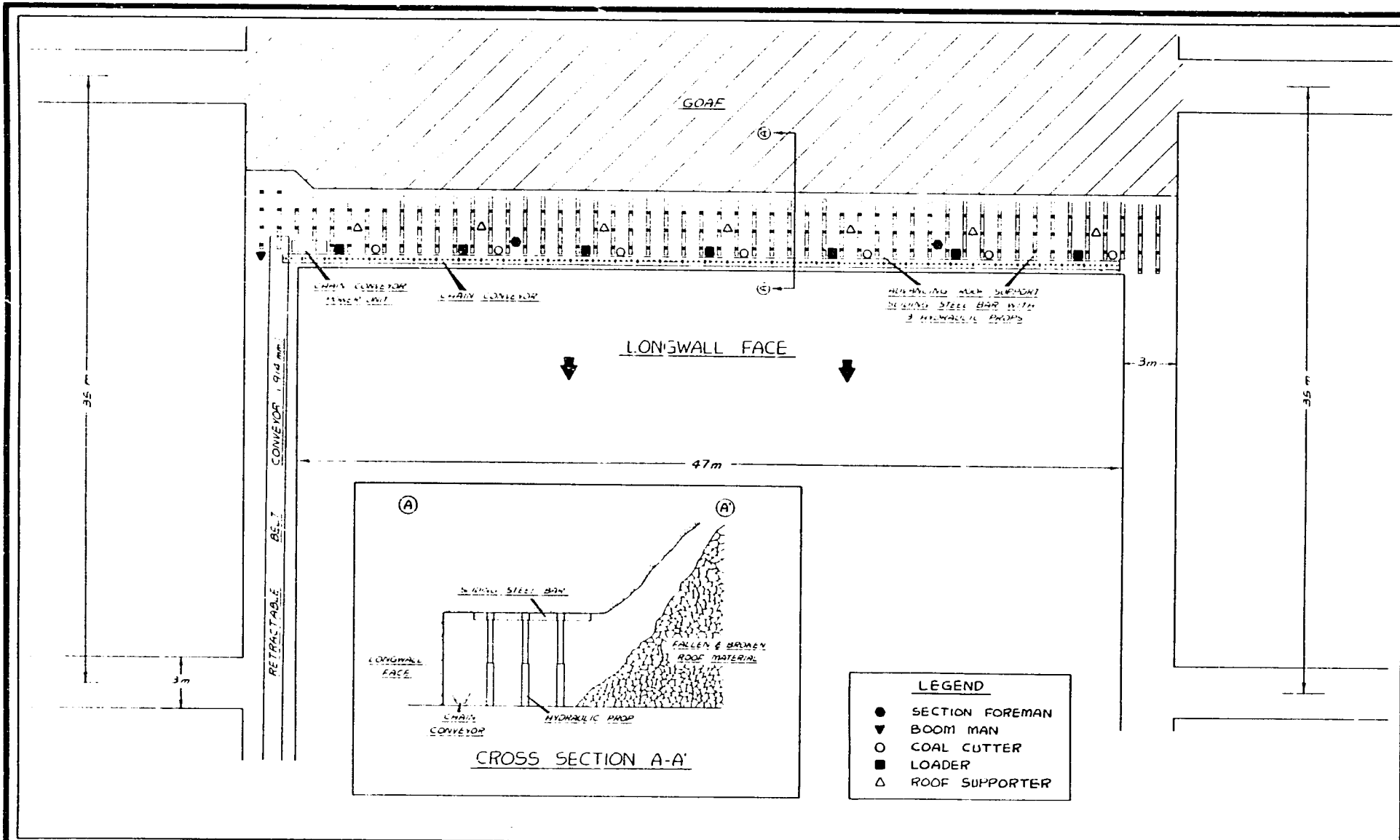


Figure 2-4
PROPOSED LONGWALL FACE: MINE NO. 1, SEAM NO. 2

SOURCE: JOHN T. BOYD COMPANY, 1985.

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Surface facilities for the underground mine would be arranged in proximity to the primary mine entrance, as shown in Figure 2-5. Surface facilities would include a main building (combination office-repair shop-warehouse), bathhouse, training facilities, supply yard (fuel, lubricant, and rock-dust), and water storage. Located at the discharge end of the incline belt conveyor would be the rock picking station, screen, crushers, and stacker for open lignite storage.

### 2.5.3 SURFACE MINING

Surface mining techniques would be employed where the coal is close enough to the overburden (the soil and rock above the coal) to be removed with subsequent replacement and regrading of the overburden. The ability to rapidly develop the two surface mines is constrained by the absence of shallow cover access, substantial depth of cover [averaging 65 meters (215 ft) of overburden depth to the top of the lowermost No. 1 seam], and the multiple seam/split nature of the lignite reserve (J.T. Boyd Company, 1985). Consequently, a significant amount of prestripping would be required to develop the pits to the point where the full annual tonnage requirement could be consistently mined.

The Lakhra Coal Project area is a relatively flat area interspersed with hills, ridges, and valleys; consequently, conventional surface mining methods are applicable using "area type" surface mining, i.e., excavation of a sequence of parallel pits extending several thousand meters in length. Types of equipment that would be used for conventional surface mining to remove overburden include draglines, shovels, backhoes, front-end loaders and trucks, and scraper-dozer units. Figure 2-3 shows the configurations of the two surface mines proposed at Lakhra.

With the proposed area to be mined at Lakhra, spoil from the initial cut (box cut) would be placed on virgin ground. The overburden from each succeeding pit would be spoiled on the previous pit where the spoil has been removed. Reclamation operations would follow closely behind the mining front. The final highwall and entire mined area would approximate the existing terrain contours.



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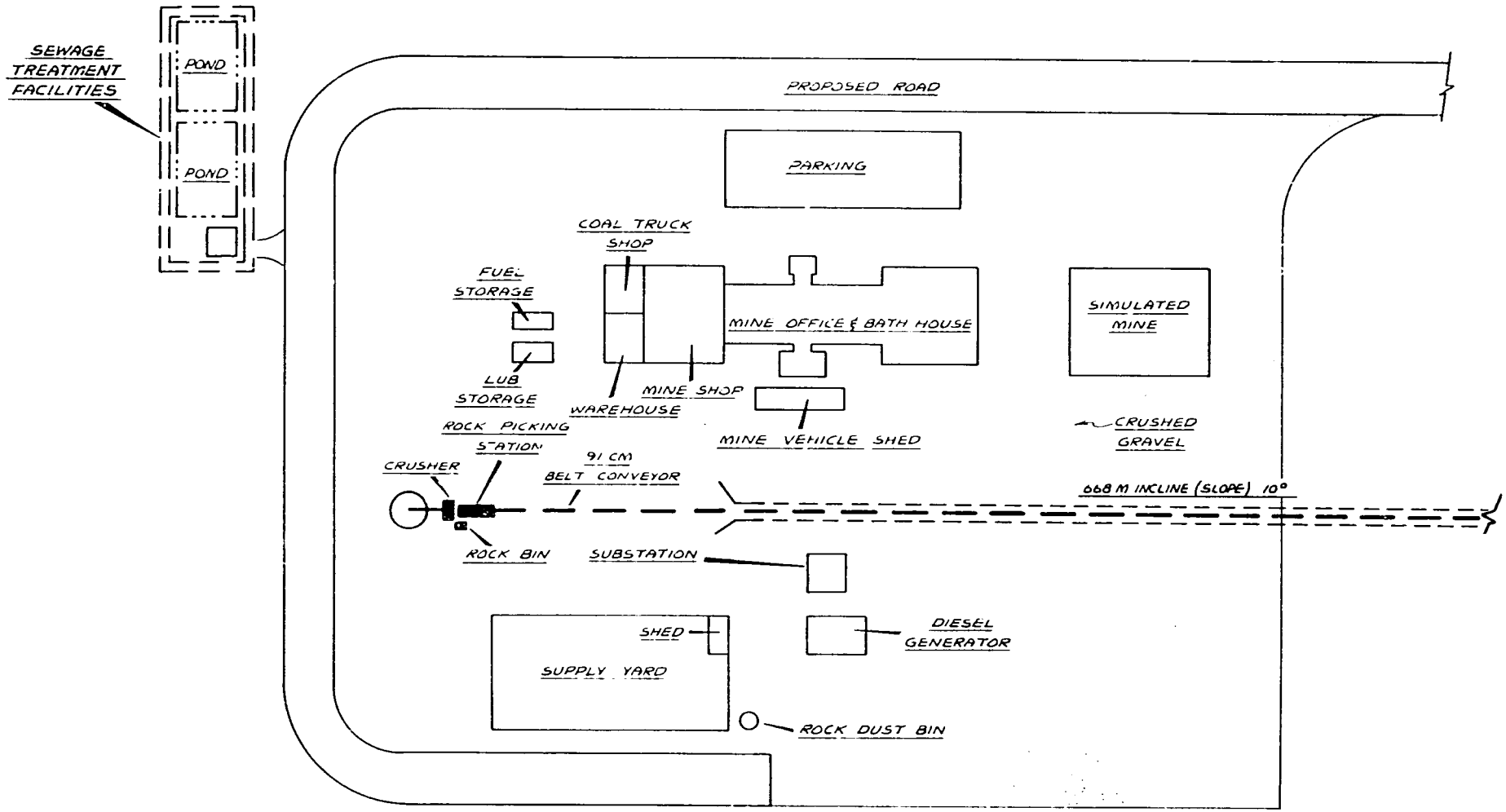


Figure 2-5
UNDERGROUND MINE PLAN: PLOT PLAN OF SURFACE FACILITIES

SOURCE: JOHN T. BOYD COMPANY, 1985.

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Due to the geometry of the Lakhra deposit and the need to establish adequate dragline working room, approximately 135 million bank cubic meters (BCM) of preproduction stripping is required. The prestripping operations, which might require up to 5-years to complete, would initially require the use of scrapers and backhoes to make a box cut to allow movement of the first dragline and permit an orderly sequenced mining cycle. When dragline operations begin, the excavated material would either be leveled to provide a working bench for the dragline or be cast into the cut provided by the previous dragline or scraper. Dragline operations would begin during the latter part of the prestripping period and continue through the 30-year production period. The proposed reclamation plan would include leveling off the tops of spoil windows, rough grading, and replacement of topsoil material which is stockpiled during excavation operations (J.T. Boyd Company, 1985).

### 2.5.4 EXISTING MINING TECHNOLOGY

In addition to an underground and surface mines on the PMDC tract, the existing private sector mines may provide some supplementary coal. A number of existing mines are located in the Lakhra area:

Amin Mines
Baluchistan Coal Company
Faiz Coal Mines
Habibullah Mines Limited
Indus Coal Mines
Iqbal Coal Mines
National Mines Ltd.
PMDC

Existing coal mines in the Lakhra coalfield are small-shaft, deep mines using labor-intensive mining methods. Manual labor is used in the process by which coal is cut (picked), shoveled, carried in burlap bags, and sorted to remove rock impurities. The only mechanization is a motorized wire rope hoisting at all the existing mines. The mines

reflect the minimal capital investment and low production cost (estimated 150 to 170 Rs/MT at the mine site stockpile) necessary to operate in the competitive coal market. Reliable production figures are not available, but the current annual production of the Lakhra coalfield is estimated at 800,000 MT. A typical mine produces 100 MT daily on a two-shift basis and employs approximately 150 men. Average productivity of the field is reported to be 0.66 MT per manshift. Lack of committed markets results in minimal capital for modernization and constrains overall production.

Coal prices are determined by market demand, available supply coal quality (age of coal), and transportation and production costs. As compared to the northern coal mining regions, Lakhra coals are cheaper to produce but are inferior in quality (primarily heat value). Normal marketing practice is for mining companies to advance sell production to independent agents (coal brokers). Lack of an efficient, integrated railroad system results in all Lakhra coal being trucked to market.

### 2.5.5 PREFERRED MINING ALTERNATIVE (J.T. BOYD COMPANY)

The preferred mining alternative developed by J.T. Boyd Company is a combination of surface and underground mines which considers the following factors:

1. The economy of a large surface mine,
2. The use of an underground mine that utilizes existing technology with improved modern techniques,
3. Maximizing the recoverable resources, and
4. Providing fuel supply reliability.

The actual methods and facilities used to mine Lakhra will, however, be dependent on the successful private-sector proposer. While the methods used by the successful proposer may be quite different than those developed by J.T. Boyd Company (and those presented in Section 2.5), the mining alternatives evaluated in this report are expected to cover the range in expected environmental impacts for this portion of the Lakhra coal project.

The mining plan proposed by the successful proposer must comply with the World Bank environmental and occupational health and safety guidelines for surface and underground mining. In addition, the successful proposer's mine plan must conform to internationally recognized standards for environmental protection, mining technology, occupational health and safety, and resource recovery. The mines will also be required to have properly designed programs for emergency prevention, planning, and management. The power plant will be authorized to obtain indigenous coal only from other sources which have been found by an inspector qualified in modern mining practices, to comply with guidelines used for project-supported surface and underground mines for environmental protection, mining technology, occupational health and safety, and resource recovery.

## 2.6 COAL TREATMENT ALTERNATIVES

### 2.6.1 COAL WASHING

The process of physically cleaning coal, to reduce ash-forming impurities and improve British thermal units (Btu) content, has been practiced for many years. More recently, coal washing has been used to reduce the sulfur content of coals. Sulfur occurs in coal in three forms: organic, sulfate, and pyritic sulfur. Organic sulfur, in which the sulfur is chemically bound to the coal, cannot be removed by mechanical means. Sulfate and pyritic sulfur, which are not chemically bound, may be removed from the coal in varying degrees. Processes are available for chemically removing organic sulfur (solvent-refined coal), but these processes have not been demonstrated commercially.

Coal washability tests, sponsored by USAID and performed under the direction of GCII and J.T. Boyd Company, indicated that $SO_2$ and particulate matter (PM) emissions could be reduced by about 40 and 50 percent, respectively. In addition, the Btu content would be improved

by approximately 20 percent; however, there is a concomitant loss of about 22 percent in net energy by coal washing, which would result in a significant increase in coal costs. Therefore, this alternative was found not to be economically viable and was rejected from further consideration.

### 2.6.2 BLENDING

Blending high quality imported coal with Lakhra coal could increase the heat content and lower the sulfur and ash content of the composite fuel; however, current coal imports are limited to metallurgical coal for the Pakistan Steel Mills Corporation located in Karachi. Because of the limited transportation system (ocean facilities and then by rail to Lakhra) and the lack of suitable sources of alternative coals in Pakistan, blending is not considered a viable alternative for the project.

## 2.7 AIR EMISSIONS CONTROL ALTERNATIVES

An evaluation of air pollution emissions control alternatives included FGD for $SO_2$ removal, electrostatic precipitation (ESP) or fabric filters for particulate removal, and combustion controls for $NO_x$ reduction. Appendix E contains a full description of the alternatives evaluated.

An evaluation of FGD systems based on consideration of uncontrolled emissions, $SO_2$ removal efficiency required, availability of reagents, availability and quality of raw water make up, by-product disposal, and potential for salable FGD by-products determined that a wet limestone slurry FGD system producing a throwaway gypsum by-product would be a preferred alternative for the project if $SO_2$ removal is required. The wet FGD system would be more economical than a dry or regenerable system and would achieve the same desired efficiency.

As previously discussed, in order to meet the project's environmental criteria, the application of an FGD system would be required for two 350-MW units, and this requirement makes this alternative economically unattractive (see Table 2-7). For two 250-MW units, an FGD system would not be necessary to meet project criteria. Although an FGD system could be installed to reduce $SO_2$ emissions from a 500-MW plant, the economic impacts would still be significant and make this alternative economically unattractive. Furthermore, for any FGD system evaluated, the net air quality benefit would not be as great as the emission reduction. For example, a 45 percent reduction in emissions using partial FGD would reduce maximum ambient air quality concentrations of $SO_2$ by 27 percent; a 90 percent emission reduction would reduce maximum ambient air quality concentrations of $SO_2$ by 78 percent. In addition, an FGD system would also increase water consumption by about 12 percent. Therefore, because of the economic penalty, water usage, and the relatively lower air quality benefit associated with FGD systems, the preferred alternative for two 250-MW units would not include the construction and operation of an FGD system; however, space for an FGD system would be provided in the event air quality monitoring indicated a serious $SO_2$ impact after plant startup.

Fluidized bed combustion (FBC) boilers and limestone injection multistage burners (LIMB) were considered as alternative technologies for reducing $SO_2$ emissions. Because of the specific requirements for burning Lakhra coal and the need to construct new generation by the mid-1990s, conventional steam generator technology was considered most appropriate for the Lakhra project.

For particulate control, ESPs are the preferred alternative over fabric filters. The abrasive nature of fly ash generated by burning Lakhra

Table 2-7. Air Pollution Control Alternatives Comparison for $SO_2$ Removal

| | Emissions* | Air Quality Impact† 24-Hour | Air Quality Impact† Annual Average | Annualized Cost** |
|---|---|---|---|---|
| Base--No $SO_2$ Reduction | 2.0 | 0.41 | 0.20 | -0- |
| 22.5% Removal | 1.5 | 0.46†† | 0.22†† | 0.25-0.46 |
| 45% Removal | 1.3 | 0.54 | 0.27 | 0.44-0.74 |
| 67.5% Removal | 0.6 | 0.70†† | 0.41†† | 0.52-0.88†† |
| 90% Removal | 0.2 | 0.91 | 0.59 | 0.60-1.01 |

*Normalized to MT/day/MW.
†Normalized to $\mu g/m^3$/MT emission for 24-hour and $\mu g/m^3$/1,000 MT emission for annual average.
**Normalized to $/kWh for 5 and 10 percent discount rates.
††Estimated from data.

Sources: ESE, 1986.
KBN, 1986.
ICF, 1986.

lignite, as determined from combustion tests, would make fabric filters unsuitable for particulate control. The design parameters for the ESP are:

1. Rigid discharge electrode and rigid collection electrode type;
2. Minimum specific collection area, 100 $m^2/m^3/sec$;
3. Maximum effective collecting electrode height, 12.8 m;
4. Minimum gas passage width, 305 mm;
5. Maximum gas velocity at ID for test block flow, 1.37 mls;
6. Alignment tolerance on discharge electrodes, $\pm 6$ mm;
7. Aspect ratio of 2 to 1;
8. Number of electric fields, 6;
9. Number of sets per electrical bus station, 1;
10. Number of hoppers per electrical bus station, 1; and
11. Maximum coefficient of variation, $\pm 18$ percent.

$NO_x$ emissions will be controlled through combustion techniques that may include low excess air burners and staged combustion. Final design will depend upon the boiler vendor selected.

The alternatives for controlling fugitive dust emissions from mining and lignite handling include paving (for roads only), chemical stabilization, and watering. Watering is the preferred alternative because low quality water (cooling tower and boiler blowdown) will be readily available and lower in cost than paving and chemical stabilization. Also, the latter two alternatives cannot be easily adapted to the evolving nature of the surface mine.

## 2.8 INFRASTRUCTURE ALTERNATIVES

The power plant worker's colony will be designed and built by WAPDA, based on WAPDA's standard practices and procedures for layout and construction of such colonies. The mine worker's colony will be built by the private company or companies responsible for supply of coal to the

power plant and will follow WAPDA specifications. Because of the different working patterns and requirements of the mining and plant workers, the residential and mosque facilities for the two groups could be separate, whereas common facilities could include schools (depending on final economics), clinics, market areas, and utility systems (water, sewer, electric), as well as public services (police and fire protection).

The mine and power plant workers colony will each include provisions for:

1. Housing;
2. Utilities, including potable water, electricity, sewage disposal, and municipal refuse;
3. Primary and secondary education facilities;
4. Mosque;
5. Recreational facilities;
6. Fire and police protection;
7. Stores;
8. Training facilities;
9. Transportation;
10. Medical facilities;
11. Telecommunications;
12. Bank;
13. Post Office; and
14. Shopping Center

The specific site for each colony was evaluated under two alternative scenarios: Khanot or Lakhra.

The construction and operational activities of the mine and power plant will cause a number of potential direct impacts to cultural resources of the area and require consideration for secondary infrastructure development. These impacts include:

1. Increased demand upon existing facilities and services,
2. Induced development in the surrounding area associated with construction of the mine and power plant,
3. Disruption of existing transportation and communication systems,
4. Change in employment and economic patterns, and
5. Disruption of existing cultural patterns and values.

The areas most affected by these impacts include all the villages of the Lakhra area and those villages in the vicinity of the junction of the Indus Highway and Lakhra Road (such as Khanot and Manzoorabad). The results of the infrastructure evaluation (see Appendix B) suggest that the Khanot area is the preferred location for both mine and power plant worker's colonies. The major reasons for this ranking are:

1. Significant air quality impacts in the Lakhra area,
2. Proximity of Khanot to urban areas,
3. Ability of the Khanot area to support cottage industries, and
4. Employee acceptance.

Secondary infrastructure development should consist of a series of community and infrastructure improvements brought about by the project. In addition, certain services provided to the workers also should be made available on a limited basis to the local inhabitants. Such services might be:

1. Improvement/upgrading of Indus Highway from Kotri to Khanot,
2. Public availability of potable water at selected stations, and
3. Coordination with local governments (Sind Province and Dadu District) for areawide infrastructure improvements (refer to Section 4.2.3).



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## 2.9 EMPLOYMENT ALTERNATIVES

The construction and operation of the mine and power plant complex would require skilled and unskilled workers. The surface and underground mine activities would require about 2,000 employees including about 150 employees needed directly for the colony (J.T. Boyd, 1986). Operation of the power plant would also require about 1,500 employees with a similar number of colony personnel (GCII, 1986). During the initial stages of the project, a large number of construction and operation workers would be needed to build and operate the mines, power plant, and workers colonies. J.T. Boyd Company estimates that the work force for the mine would increase to a peak employment in Year 7 of about 1,750 workers. Total mine, colony, and other workers associated directly with the mine are estimated to be about 2,900. The power plant construction and operation labor force, as estimated by GCII, would increase in Year 3 from 200 workers peaking in Year 5 with 6,136 workers and leveling off in Year 8 to about 1,500 workers. Overall, the work force is expected to peak in Years 5 and 6 with over 7,000 workers. After construction is complete, employment would decline to operational levels. To ensure that adequate facilities are available, an implementation plan for infrastructure development for construction workers, many of whom will arrive in the Lakhra/Khanot area prior to operational workers, is needed. Alternatives for obtaining the necessary employees are listed in Table 2-8.

During the construction and initial phases of operation, most management and technical advisors would likely be expatriate; however, their numbers are expected to be small (i.e. less than 100). Skilled construction workers would likely come from the Hyderabad area, whereas unskilled workers would come from the rural Dadu District population as well as the Khosa Baluch (nomadic villagers of the Lakhra area). It is WAPDA's policy to hire all local people for positions through Grade 16. Underground miners may be recruited from the existing mines. These miners are generally Swati of Kashmiri immigrants who work existing mines



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Table 2-8. Employment Alternatives

| General Job Classifications | Existing Employment Sources | | | |
|---|---|---|---|---|
| | Dadu District | Hyderabad Urban | Other Pakistani | Ex-Patriate |
| Construction/ Development | | | | |
| Management | | PS | SS* | PS† |
| Technical | | PS | SS | PS |
| Skilled Craft | | PS | SS | |
| Laborers | PS** | PS** | SS | |
| Operation†† | | | | |
| Advisors-- Tech/Mgt | | | | PS*** |
| Management | | PS | SS | |
| Technical | | PS | PS | |
| Skilled Craft | | PS | SS | |
| Laborers | PS** | PS** | SS | |

*SS = Secondary source of employees.
†PS = Primary source of employees.
**Labor source expected to be split evenly between Dadu and Hyderabad districts.
††After training of Pakistani staff.
***As needed by the project.

Sources: ESE, 1986.
KBN, 1986.



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for 4 to 6 months out of the year; however, the existing number of miners, about 9,000, may not be sufficient to support the existing mines and the Lakhra project together and additional miners would have to recruited. Providing improved working and living conditions in the Lakhra project area should, however, attract a more stable and permanent employment force. To accommodate the projected construction and operation labor force, the infrastructure alternatives presented in Section 2.8 would be required.

# 3.0 DESCRIPTION OF THE AFFECTED ENVIRONMENT

## 3.1 PHYSICAL ENVIRONMENT

### 3.1.1 AIR RESOURCES

#### 3.1.1.1 CLIMATOLOGY

Pakistan is oriented in a general southwest to northeast direction, extending from 24 to 37 degrees north (°N) latitude and 60 to 77 degrees east (°E) longitude. Pakistan lies on the western boundary of the monsoon region, which is one of the major climate regions of the earth. This climate region extends from Pakistan to Japan and northern Australian in the east. The word monsoon is derived from an Arabic word meaning "season"; in meteorology it has come to be associated with prevailing winds and wet or dry weather which reverse with the seasons. Generally, monsoon is used to describe wind systems where the seasonal reversal is pronounced and exceeds a minimum number of degrees. For example, Nieuwolt (1977) has defined a monsoon as a system which shares a seasonal change of wind direction of at least 120 degrees, and both winds must have a constancy higher than 40 percent and mean resultant speed of more than 3 meters per second (m/s).

In Pakistan, the winds are generally from a northerly direction in winter and from the southwest in summer. The causes of the reversal of the wind system are related to the large sizes of the Asian continent and adjacent oceans and the very high and extensive mountain ranges of the continent. These ranges are oriented in an east-west direction and form a barrier between tropical and polar air masses.

The climate of Pakistan is more continental than that of other parts of the Indian subcontinent which come under a more typical monsoon regime. The summer monsoon brings maritime influences and rain, but the strength of the winds fluctuates on an annual basis. Cyclones in the monsoon season cause significant rainfall, but their frequency is variable.

Rainfall throughout Pakistan is minimal because the rainfall occurs coincidentally with high temperatures, and the majority of rainfall evaporates, causing extremely arid conditions.

Pakistan has four well-defined seasons, similar to the remainder of the subcontinent, with variations to their duration. The description and duration of the seasons are:

1. Cold Weather Season: mid-December through March,
2. Hot Weather Season: April through June,
3. Monsoon Season: July through September, and
4. Post-Monsoon Season: October through mid-December.

The cold weather season is characterized by high barometric pressure [e.g., mean monthly pressure greater 1,015 millibar (mb)], relatively low temperatures, and low amounts of precipitation. The mean monthly temperature varies from below 4 degrees Celsius (°C) [40 degrees Fahrenheit (°F)] in the mountain areas, to approximately 10°C (50°F) north of the plain area and to approximately 18°C (65°F) in the south. Rainfall during this season increases northward and westward, with 25 millimeters (mm) (1 inch) or less in the middle and lower Indus Plain, 76 to 127 mm (3 to 5 inches) in the upper Indus Plain, and 250 mm (10 inches) or more in the north and northwest.

The hot weather season is characterized by high temperature and low rainfall amounts. The mean maximum daily temperature varies from 40 to 46°C (104 to 115°F). The highest temperatures have been recorded in the south and southwestern parts of Pakistan. Rainfall amounts are low, varying from approximately 25 to 76 mm (1 to 3 inches) over the plains to approximately 102 to 127 mm (4 to 5 inches) in the mountainous areas. The rainfall is associated with western disturbances which occur in more northerly latitudes, causing thunderstorms over the hills and widespread dust-storms over the plains.

The monsoon season is characterized by moderate temperatures, large rainfall amounts, and persistent southwest winds. The winds are due to the establishment of low-pressure systems over the Indo-Pakistan subcontinent in May and June. The monsoon current in Pakistan is well established by July and remains constant through August. In some years, the monsoon remains active into September. During July, the mean monthly temperature exceeds 32°C (90°F) through the majority of the Indus Plain and western Pakistan. The average rainfall during the season decreases from approximately 1,000 mm (25 inches) in the north Indus Plain to approximately 127 mm (5 inches) or less in the south.

The post-monsoon season is characterized by retreat of monsoon regime and is a transitional period between the monsoon regime and cool-season conditions. The high-pressure system begins to establish itself over Pakistan in mid-November. Without any active wind system, the weather produces generally dry conditions, with the least rainfall amounts in October and November.

The proposed sites are located in southeast Pakistan and exhibit an arid climate that is influenced by the monsoon season. Data taken by the Pakistan Meteorological Service (PMS) in Hyderabad during 1931 through 1960 (see Table 3.1-1) demonstrate the influence of the monsoon season and the generally arid nature of the area.

### 3.1.1.2 SITE METEOROLOGY

WAPDA currently is operating air quality and meteorological stations at the Jamshoro and Lakhra sites. A complete description of these stations is presented in Environmental Baseline Monitoring System and Program for the Lakhra Coal Mining and Power System Project (TAMS, 1985).

The Jamshoro monitoring station is located approximately 4 km (2.4 miles) west of the Indus River and approximately 5 km (3 miles) north of Liaquat Medical College. The station is located on a small hill (30 m in height)



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Table 3.1-1. Hyderabad Climatological Data (1931 to 1960)

| Month | Average Wind Speed (m/s) | Average Wind Direction | Temperature (°C) | | | Precipitation (mm) | | | Evaporation From Water Surfaces | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Minimum Daily | Maximum Daily | Mean | Maximum (Monthly) | Maximum (24 Hour) | mm | (inches) |
| January | 1.6 | N | 17.1 | 10.1 | 24.2 | 4.1 | 30.0 | 17.8 | 152.4 | (6.0) |
| February | 1.6 | N | 20.6 | 12.8 | 28.6 | 4.8 | 35.1 | 33.0 | 154.9 | (6.1) |
| March | 2.0 | SW | 25.9 | 17.7 | 34.2 | 1.0 | 12.2 | 6.1 | 226.1 | (8.9) |
| April | 2.5 | SW | 30.8 | 22.2 | 39.4 | 1.5 | 17.0 | 17.0 | 393.7 | (15.5) |
| May | 4.0 | SW | 34.1 | 25.9 | 42.3 | 4.1 | 27.9 | 14.0 | 406.4 | (16.0) |
| June | 5.3 | SW | 34.3 | 27.9 | 40.6 | 6.3 | 47.5 | 38.4 | 434.3 | (17.1) |
| July | 4.8 | SW | 32.5 | 27.5 | 37.5 | 68.1 | 273.6 | 109.5 | 302.3 | (11.9) |
| August | 4.7 | SW | 31.3 | 26.5 | 36.1 | 43.7 | 276.6 | 118.4 | 274.3 | (10.8) |
| September | 4.0 | SW | 30.9 | 25.1 | 36.8 | 14.7 | 192.5 | 78.0 | 254.0 | (10.0) |
| October | 2.0 | SW/N | 29.3 | 21.5 | 37.1 | 2.8 | 26.2 | 34.3 | 233.7 | (9.2) |
| November | 1.3 | N | 24.2 | 16.2 | 32.2 | 1.0 | 13.7 | 13.7 | 182.9 | (7.2) |
| December | 1.5 | N | 19.1 | 11.8 | 26.4 | 2.5 | 26.4 | 26.4 | 203.2 | (8.0) |
| Annual | 2.9 | | 27.5 | 20.4 | 34.6 | 154.7 | 526.5 | 118.4 | 3,218.[illegible] | (126.7) |

Sources: Pakistan Meteorological Service, 1985.
ESE, 1986.

and consists of a small air-conditioned building housing instrumentation, with a 19-KVA generator, and a guyed 10-m meteorological tower. The meteorological parameters measured are wind speed, wind direction, ambient temperature, precipitation, and solar radiation. Air quality instrumentation includes ambient continuous analyzers for $NO_x$, $SO_2$, and CO and two TSP monitors. A calibration system is present for these analyzers. Both the meteorological and air quality data are fed into a data acquisition system. There is also an acoustic radar (monostatic) at this site for mixing height detection.

The Lakhra site is located approximately 20 km (12 miles) west of the village of Khanot, and data collected here are also indicative of the Khanot site. Wind speed, wind direction, temperature, precipitation, and solar radiation data are gathered continuously. TSP data (2 monitors) are also collected.

The meteorological data from Lakhra were processed to obtain a set of site-specific meteorological data that can be used to:

1. Characterize the meteorology of the Lakhra area, and
2. Estimate in an atmospheric dispersion model the air quality impacts of the power plant and mine on the surrounding area.

In evaluating air pollution emissions from a power plant or mine, site-specific meteorology is important in characterizing the conditions under which pollutants disperse in the atmosphere. Five meteorological parameters are needed to characterize the dispersion meteorology of an area:

1. Wind Direction--determines the transport directions toward which the plume will travel and potentially affect receptors downwind of the plant;
2. Wind Speed--determines the amount of dilution of plume concentration and height to which the plume will rise;

3. Temperature--affects the height to which the plume will rise and also is used in estimating afternoon mixing heights;
4. Atmospheric Stability--determines the extent of plume spread or dispersion in the vertical and horizontal directions;
5. Mixing Height--determines the maximum vertical extent or volume of air in which the plume can disperse.

Wind speed, wind direction, and temperature were measured directly at the Lakhra site. Atmospheric stability can be determined using various techniques but is usually determined using a technique that incorporates wind speed, cloud cover, and cloud ceiling values as well as recognition of day or night time conditions. This technique, referred to as the "Turner Stability Scheme," was used to develop atmospheric stabilities for the Lakhra area. Mixing depth is generally calculated from a technique suggested by Holzworth (1972), which determines hourly mixing depths based on an interpolation scheme using morning and afternoon mixing depths calculated from radiosonde data (meteorological soundings made from a free-released balloon). For the Lakhra area, radiosonde data are not taken by the PMS in Hyderabad; however, seasonal mixing heights were inferred from radiosonde data obtained from the PMS station in Karachi.

Meteorological data on the air pollution sources are used in an atmospheric dispersion model, and incorporated to estimate concentrations of pollutants over a wide area. An atmospheric dispersion model is a series of mathematical formulae that calculate temporal and spacial concentrations of pollutants, using the meteorological data to determine the direction pollutants will travel (wind direction), the dilution of the plume (wind speed), the dispersion or mixing of the plume in the atmosphere (stability), and the height to which further dispersion of pollutants can take place (mixing depth). Information from the source includes the stack height, stack diameter, volumetric flow rate, exit gas velocity, exit gas temperature, and pollutant emission rate. These data



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are used to calculate the height to which the plume will rise in the atmosphere, and the concentrations of pollutants in the plume. These concepts of a dispersion model are presented in Figure 3.1-1, and are discussed in more detail in Appendix F.

The meteorological data from the Lakhra Field and Jamshoro are summarized in Table 3.1-2 for wind speed, direction, and temperature. The frequencies of wind direction and wind speed classes and a description of the processing methods are presented in Appendix F.

3.1.1.3 EXISTING AIR POLLUTION SOURCES

Within the Hyderabad area, there are only a few major existing point sources of air pollutants. These point sources, shown in Figure 3.1-2, include the Kotri Gas Turbine Power Station, the Hyderabad Thermal Power Station, and the Zeal Pak Cement Plant. Technical information on these units is presented in Appendix F. In addition to these sources, WAPDA plans to construct an oil-fired power station located at the Jamshoro site. Although this station is not constructed, development plans are underway and these units will likely be in existence prior to the operation of the Lakhra plant.

Area sources in the Hyderabad vicinity include vehicular traffic and other emission from anthropogenic activities (e.g., open burning of refuse, fugitive dust from construction and demolition, and agricultural activity). These area sources are generally small and associated with the City of Hyderabad.

The most potentially significant source of air pollution that can interact with the emissions from the Lakhra plant is the proposed Jamshoro oil-fired power station. This plant will consist of one 250-MW unit and three 210-MW units firing low grade fuel oil with a sulfur content of approximately 3.5 percent. In addition, the engineering feasibility of three 350-MW units is currently being evaluated (Bechtel, 1987). Stack parameters and estimated emissions for a single 250-MW unit which were used in the modeling analysis are presented in Appendix F.



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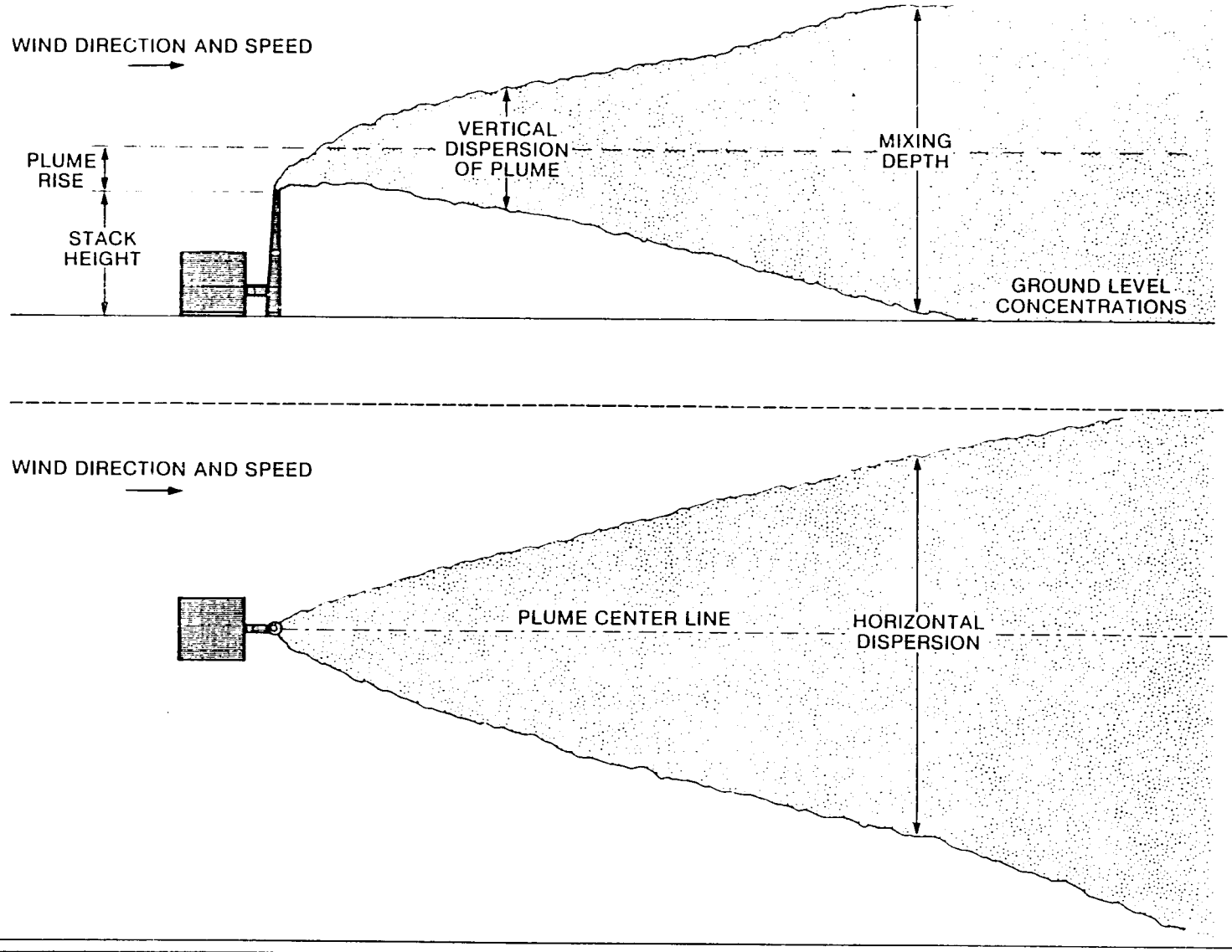


Figure 3.1-1
PRIMARY CONCEPTS OF POLLUTANT DISPERSION FROM STACKS

SOURCES: KBN, 1986; ESE, 1986

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Table 3.1-2. Meteorological Data Collected at the Lakhra and Jamshoro Monitoring Stations from May 1985 to April 1986

| Month | Number of Observations | Temperature (°C) | | | Prevailing Direction | Wind Data (mph) | | |
|---|---|---|---|---|---|---|---|---|
| | | Average | Minimum | Maximum | | Average | Minimum | Maximum |
| Lakhra | | | | | | | | |
| May 1985 | 367 | 43 | 29 | 58 | North-northeast | 20 | 3 | 41 |
| June | 720 | 39 | 32 | 55 | West | 31 | 5 | 53 |
| July | 744 | 37 | 27 | 49 | West-southwest | 27 | 5 | 46 |
| August | 721 | 35 | 26 | 48 | West-southwest | 24 | 2 | 46 |
| September | 84 | 34 | 29 | 43 | West | 25 | 12 | 38 |
| October | 108 | 33 | 21 | 46 | West-southwest | 17 | 6 | 31 |
| November | 720 | 28 | 15 | 45 | North-northeast | 12 | 2 | 29 |
| December | 659 | 20 | 5 | 37 | North-northeast | 13 | 1 | 34 |
| January 1986 | 698 | 17 | 3 | 29 | North-northeast | 15 | 2 | 30 |
| February | 168 | 19 | 9 | 29 | West-southwest | 13 | 3 | 24 |
| Jamshoro | | | | | | | | |
| January 1986 | 324 | 17 | 10 | 24 | North-northeast | 13 | 3 | 24 |
| February | 555 | 19 | 11 | 28 | Northeast | 11 | 2 | 28 |
| March | 637 | 24 | 14 | 34 | North-northeast | 11 | 2 | 34 |
| April | 512 | 30 | 18 | 41 | North-northeast | 15 | 1 | 41 |

Source: ESE, 1986.



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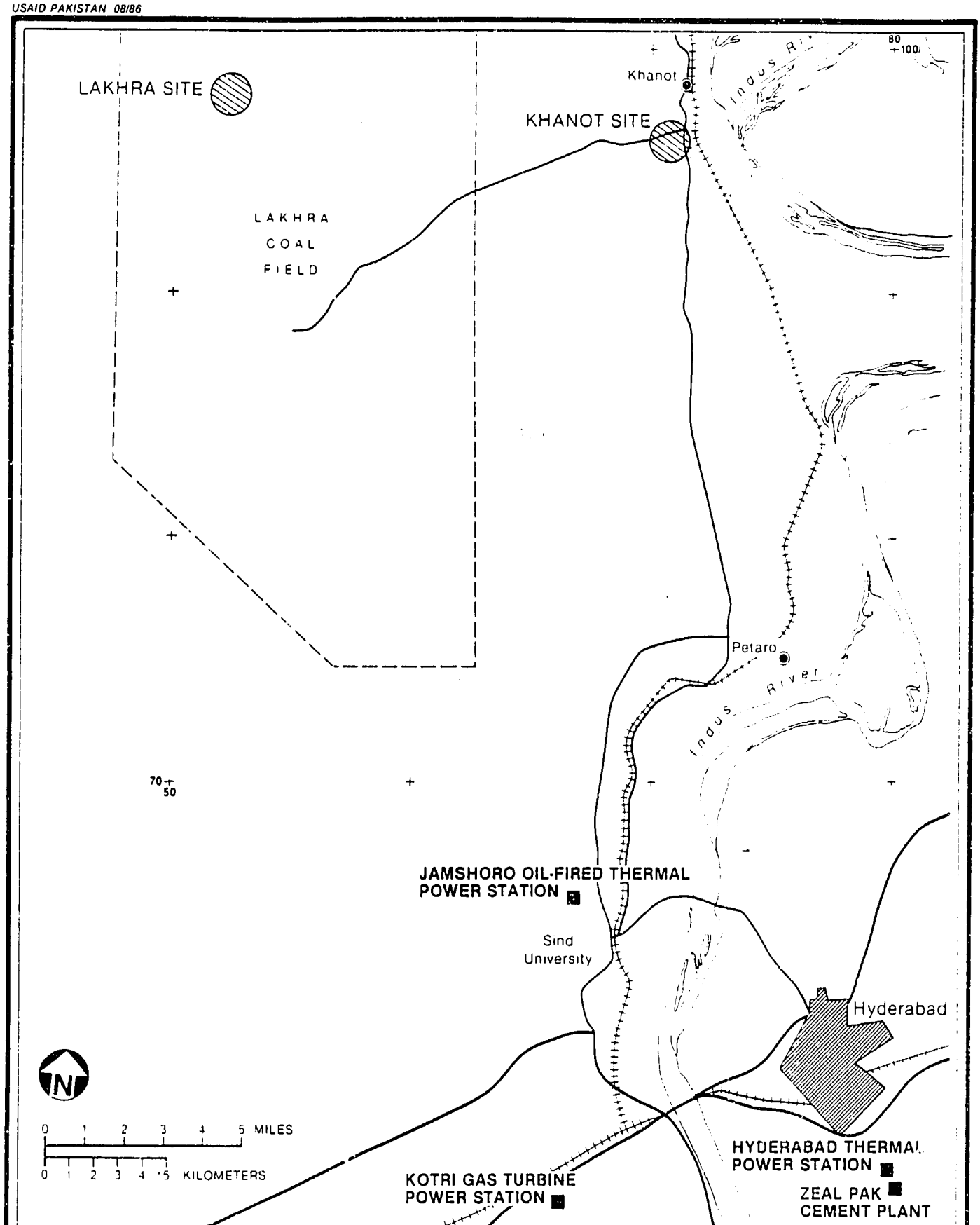


Figure 3.1-2
EXISTING AND PROJECTED POINT SOURCES IN THE PROJECT AREA

SOURCE: ESE, 1986

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Because of the potential interaction with the Lakhra units, impacts from both the Jamshoro and a Lakhra coal-fired plant located at either the Lakhra or Khanot sites were evaluated. (Note: Four 250-MW units were used in the analysis to conservatively evaluate impacts at the Lakhra plant.) Other sources were considered insignificant and were not evaluated in the modeling analysis.

3.1.1.4 AMBIENT AIR QUALITY

Ambient air quality data obtained from the monitoring equipment were evaluated to determine the general background concentrations of air pollutants in the area. A summary of the TSP data collected at the Lakhra and Jamshoro sites is presented in Table 3.1-3. The relatively high average TSP concentration in the Lakhra area is primarily due to the arid nature of the region and the suspension of wind-borne dusts. Because most of the particles are considered above a respirable range (i.e., >10 μ) and are most likely native soil, the health significance of the observed levels is low. For $SO_2$, CO, and $NO_2$, maximum concentrations were generally less than 0.01 ppm (26 $\mu g/m^3$), 0.5 ppm (600 $\mu g/m^3$), and 0.01 ppm (19 $\mu g/m^3$), respectively. These concentration levels are generally indicative of a relatively clean, non-polluted environment.

The recognition of ambient air quality as an important environmental resource has brought about the promulgation in some countries of ambient air quality standards (AAQS) designed to protect human health and welfare (i.e., the potential effects to materials and agricultural activities), and to a lesser degree, natural vegetation and wildlife. In some countries, standards reflect the general social value of ambient air quality and the desire to inhibit air quality deterioration.

Currently, the Government of Pakistan has not promulgated AAQS; however, there are guidelines that allow an evaluation of the impacts predicted from the Lakhra Coal Power Project. Such guidelines are promulgated by the World Bank and World Health Organization (WHO) and are generally accepted as measures necessary to protect human health and welfare. The evaluation of ambient air quality, as it relates to such promulgated

Table 3.1-3. Summary of Total Suspended Particulate Matter Concentrations for Jamshoro and Lakhra Monitoring Stations; May 1985 through September 1986

| Site Location | Station Number | Number of Observations | Concentrations ($\mu g/m^3$) | | | Standard Deviation |
|---|---|---|---|---|---|---|
| | | | Maximum | Minimum | Mean | |
| Jamshoro | J-1 | 37 | 478 | 64 | 213 | 103 |
| | J-2 | 89 | 661 | 7.4 | 180 | 110 |
| Lakhra | I-1 | 23 | 553 | 35 | 180 | 110 |
| | L-2 | 19 | 537 | 56 | 219 | 12 |

Note: $\mu g/m^3 = 10^{-6}\ g/m^3$.

Standard deviation (SD) provides a measure of the variability in the observed data around the mean and is given by the formula:

$$SD = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1}$$

where: x = concentration, xi = individual $i^{th}$ concentration, $\bar{x}$ = average concentration, and n = number of observations.

Sources: WAPDA, 1985.
ESE, 1986.



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guidelines, is primarily based on observed air monitoring data for those areas where existing pollution sources are located and on atmospheric dispersion modeling for those areas where future sources are proposed.

Table 3.1-4 presents AAQS for the World Bank. These standards are for 24-hour and annual averaging times for $NO_2$, TSP, and $SO_2$.

### 3.1.2 LAND AND WATER RESOURCES

#### 3.1.2.1 SURFACE WATER RESOURCES

The major surface water feature of the region is the Indus River which is the major freshwater supply for agricultural, domestic, and industrial water uses in the region.

Several non-perennial river beds or streams located in the region transport water during short periods of the rainy season or following heavy rainfall events. Surface drainage in the region generally flows east to the Indus River. During heavy rains, the nonperennial stream beds are filled with sufficient water to wash away sections of the Dadu Highway and collapse bridges between Hyderabad and Khanot (JICA, 1981).

Monthly climatic conditions for the Hyderabad area are shown in Table 3.1-1. Average annual rainfall for the area is about 155 millimeters (mm) [6 inches], with about 80 percent of the total rainfall occurring in the wet season between July and September. Evaporation rates from open water surfaces for the region were calculated from meteorological data to be about 3,218 mm (127 inches) per year. At Lakhra and Khanot, temperatures are likely higher and rainfall lower than at Hyderabad, resulting in potentially higher evaporation rates at the Lakhra and Khanot sites.

Water levels in the Indus River are controlled by a series of barrages constructed to control flooding and to provide a supply of water during the dry season. A cross section of the Indus River at Khanot indicates



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Table 3.1-4. Air Quality Standards and Guidelines ($\mu g/m^3$) for TSP, $SO_2$, and $NO_2$ for the World Bank

| Pollutant | Averaging Time | |
|---|---|---|
| | 24-hour | Annual |
| TSP | 500 | 100 |
| $SO_2$ | | |
| ambient | 500 | 100 |
| in-plant | 1,000 | 100 |
| $NO_2$ | -- | 100 |

Source: World Bank, 1984.



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that the river is about 230 m (750 ft) across and up to 9 m (30 ft) deep (see Figure 3.1-3). Flow upstream of the Kotri Barrage increases significantly during the rainy season between July and September with approximately 80 percent of the flow occurring during these months. The highest flows between 1981 and 1983 during this rainy season are generally above 300,000 cubic meters per second (cms) [10,600,000 cubic feet per secs (cfs)]. The lowest flow upstream of the Kotri Barrage for the period between 1981 and 1983, was 1,013 cms (35,770 cfs). At Sehwan, approximately 85 km (53 miles) north of Khanot, the extreme daily minimum flow was 895 cms (32,000 cfs) which was recorded for 7 consecutive days in April 1975. The average of the extreme daily minimums for the recording period at Sehwan was 1,363 cms (48,000 cfs). Appendix G contains discharge flow rates upstream and downstream of the Kotri Barrage (1981-1983) and discharge characteristics at Sehwan (1972-1975 and 1979).

Water quality data for the Indus River at the Kotri Barrage have been obtained from an ongoing monitoring program conducted by the Public Health Engineering and Research Laboratory in Pakistan between February 1979 and February 1985. In May 1985, a water quality monitoring program was initiated by WAPDA, USAID, and USAID's contractor, TAMS, to obtain water quality data relevant to the Lakhra Coal Project. Monthly samples are collected from six sample locations between Khanot and Hyderabad. Samples are collected and analyzed by WAPDA personnel. Results of available water quality data are summarized in Table 3.1-5 and presented in detail in Appendix G. The results of these monitoring programs show that the river contains levels of suspended solids higher than 1,000 mg/L at certain times, particularly during periods of high flow. Concentrations of sulfate ($SO_4^{-2}$) and chloride ($Cl^-$) are generally below 50 mg/L with average values near 20 mg/L. These $SO_4^{-2}$ and $Cl^-$ concentrations are substantially below the WHO Guidelines of 400 and 250 mg/L, respectively. Iron concentrations are generally less than 5 mg/L with mean values well below 1 mg/L; concentrations above the WHO



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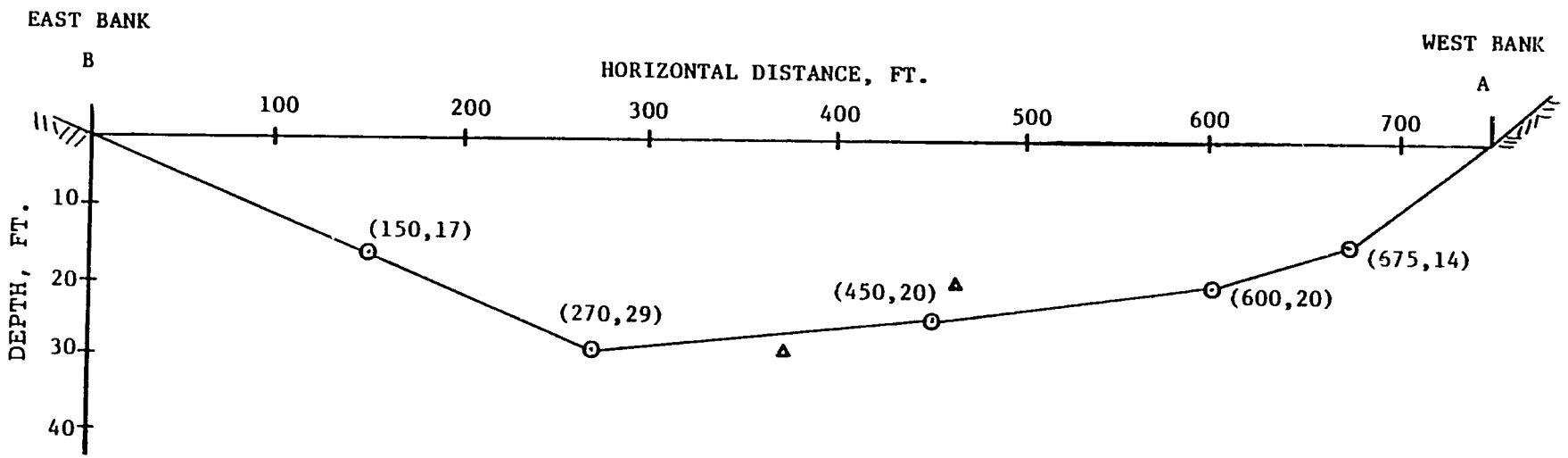


LEGEND

⊙ SOUNDING TAKEN EAST TO WEST ACROSS INDUS

△ CHECK; SOUNDING TAKEN WEST TO EAST ACROSS INDUS

Figure 3.1-3
SOUNDINGS OF INDUS RIVER AT KHANOT

SOURCE GCII, 1985

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Table 3.1-5. Summary of Indus River Water Quality Upstream of Kotri Barrage

| Parameter | 1980-1984 from Public Health Engineering Research Laboratory, Hyderabad* | | | | 1985-1986 from WAPDA† | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Maximum | Minimum | Std. Dev. | Mean | Maximum | Minimum | Std. Dev. |
| Temperature (°C) | 26.4 | 40 | 14 | 6.3 | 25.1 | 32.8 | 19 | 5.24 |
| pH | 7.5 | 7.8 | 7.2 | 0.09 | 7.8 | 8.5 | 7.1 | 0.36 |
| Alkalinity (mg/L) | 102 | 140 | 40 | 24.5 | 107.8 | 227 | 70 | 38.1 |
| Conductivity (μs/cm)** | 335 | 510 | 230 | 48.5 | 327 | 1,100 | 100 | 175 |
| Suspended Solids (mg/L) | 487 | 2,200 | 10 | 811 | 410 | 1,800 | 1 | 374 |
| D.O. (mg/L) | 9.7 | 24 | 4 | 4.2 | 8.0 | 16.5 | 5.9 | 1.4 |
| C.O.D. (mg/L) | 20 | 720 | 2 | 64 | | | | |
| B.O.D. (mg/L) | 6.3 | 12.8 | 1 | 2.8 | | | | |
| $Cl^-$ (mg/L) | 51.6 | 100 | 30 | 12.5 | 18.5 | 50 | 6 | 8.9 |
| $SO_4^{-2}$ (mg/L) | 98.5 | 149 | 64 | 11.8 | 40.9 | 120 | 8 | 24.6 |
| $NO_2 + NO_3$ (mg/L) | 2.0 | 3.8 | 0.9 | 0.54 | 0.72 | 6.0 | 0.01 | 1.33 |
| $F^-$ (mg/L) | 0.34 | 0.68 | 0 | 0.15 | | | | |
| $Na^+$ (mg/L) | 14 | 44 | 2 | 12.7 | | | | |
| $Ca^{+2}$ (mg/L) | 39 | 56 | 12 | 8.9 | | | | |
| $Mg^{+2}$ (mg/L) | 17 | 32 | 2.8 | 7.8 | | | | |
| $Fe^{+3}$ (mg/L) | 0.1 | 1.1 | 0 | 0.18 | 0.49 | 3.7 | 0.01 | 0.53 |
| Total $-PO_4$ (mg/L) | | | | | 2.0 | 4.0 | 0.15 | 0.68 |
| Ortho-$PO_4$ (mg/L) | 0.02 | 0.08 | 0 | 0.024 | | | | |
| Cu (mg/L) | | | | | 0.17 | 1.1 | 0.01 | 0.17 |
| $Cr^{+6}$ (mg/L) | 0 | 0 | 0 | 0 | | | | |
| $N-NH_3$ (mg/L) | 0.21 | 1.1 | 0 | 0.25 | | | | |
| F-Coliform (NPN/100 ml) | 105.5 | 180 | 70 | 19.7 | | | | |

Note: Blank fields indicate data not available for this parameter.

* Summary of bimonthly samples taken upstream of Kotri Barrage near left divide wall.

† Summary of data obtained from 5 stations; samples taken monthly from May 1985 through August 1986.

**μs/cm = $10^{-6}$ siemens per centimeter.

Source: KBN, 1986.



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Guidelines of 0.3 mg/L have been, however, observed. Phosphate and nitrate concentrations are generally much less than 1 mg/L. Concentrations of calcium and magnesium are about 40 and 20 mg/L, respectively. The pH of the Indus ranges fron 7.3 to 9, which is within the WHO drinking water guidelines.

3.1.2.2 GEOLOGY, PHYSIOGRAPHY, TOPOGRAPHY, AND SEISMICITY

The regional geology, physiography, and topography are typical of the Southern Montaine Front (Sind) division of the Calcareous Geological Zone. Topography is generally flat.

Rock units that crop out in the Sind were formed mainly from biological, chemical, and terrigenous sedimentation in the "Baluchistan Trough" (a shallow to deep marine basin) from the Late Cretaceous to the Pliocene time periods. Limestones, sandstones, and shale are the predominant lithologies with locally important deposits of evaporites, conglomerates, and coal occurring as a result of deposition along the margins and emergent areas within the basin. Minor units of volcanic rocks occur in the form of basaltic flows and ash beds.

The Lakhra anticline, an emergent area in the Sind, is the major structural feature in the region of the proposed plant sites. The general stratigraphy in the region of the Lakhra anticline is summarized in Table 3.1-6. The Lakhra anticline west and northwest of the City of Hyderabad is a north-south trending structural high, approximately 60 km (40 miles) in length along the axis or crest. The axis plunges to the north and south at approximately 0.5° to 1°, and rock units to the east and west of the crest dip at 2° to 10°. The oldest formation exposed in the region is the Lower Ranikot Formation which crops out along the crest of the anticline. Successively younger formations occur along the flanks of the anticline in the direction of dip.

Minor folds and faults occur along the flanks of the anticline and generally trend north and north-east. Faults on the eastern flank dip to

Table 3.1-6 Generalized Stratigraphy of the Lakhra Anticline Area

| Age/Period | Group | Formation | Lithology | Thickness (ft) |
|---|---|---|---|---|
| /Recent (Subrecent) | | Alluvium | Unconsolidated stream, colluvial, and eolian deposits of sandstone, siltstone, shale, and limestone fragments. Unconformity at the base. | 0-10 |
| Tertiary/Pliocene | | Manchar | Interbedded sandstone and shale: soft, crumbly sandstone predominates the upper portion; soft, clayey shale predominates the lower portion. Unconformity at the base. | 0-3000 |
| Tertiary/Early Eocene | Laki | | Mostly fine, crystalline, massive, and hard limestone with marl, calcareous shale, sandstone, and lateritic clay. Distinctive hard ferrigenous basal laterite or shale. | |
| Late Cretaceous to Tertiary/ Paleocene | Ranikot | Upper Ranikot | Fossiliferous sandstone, limestone, and shale with all gradations between each occurring. Limestone is hard, massive and cliff-forming, whereas the shale is slope forming. | 0-890 |
| | | Lower Ranikot | Unfossiliferous sandstone interbedded with shale, siltstone, and coal. The sandstone and shale display rich variegated colors and both are generally soft. | 1500-3085 |
| | | Cardita Beaumonti Beds | Sandstone and shale with minor fossiliferous limestone and prominent volcanic rocks. Sandstone is soft, friable, and calcareous. Shale is gypsiferous and earthy. At least two basaltic flows are present--one of which marks the top of the formation. Unconformity at the base. | 200 |



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Table 3.1-6 Generalized Stratigraphy of the Lakhra Anticline Area (Continued, Page 2 of 2)

| Age/Period | Group | Formation | Lithology | Thickness (ft) |
|---|---|---|---|---|
| Late Cretaceous | | Pab Sandstone | Sugary textured sandstone with minor limestone, shale, conglomerate, and basalt flows. Conformable with Hemipneutes Limestone. | 350-900 |
| Late Cretaceous | | Hemipneustes Limestone | Hard well-jointed, crystalline, reefoid limestone. | 300 |

Source: Hunting Survey Corporation, Ltd., 1960.

the east at 70° to 90°, whereas the western faults are vertical or dip slightly to the west. The throw ranges from a few feet to as much as 100 feet. Locally, these features control drainage and topography.

The Lakhra anticline and other folds and faults modify drainage systems, depending on the relative amount of uplift and the resistance of the rock units. Drainage in the region generally flows east to the Indus River. West of the Lakhra anticline, drainage flows south to the southern end of the anticline, then east to the Indus River. At the northern tip of the anticline, drainage is to the north, possibly controlled by bedding planes and faults. Within the anticline, drainage is easterly across the crest of the anticline.

The proposed sites are located in Seismic Risk Zone 1 which corresponds to minor damage and Modified Mercalli Intensities between V and VI. Recorded earthquakes in the vicinity of the proposed sites that occurred between 1819 and 1980 had intensities between 4.3 and 6 on the Richter Scale. Two major active faults are near the sites (Figure 3.1-4): the Surjam Fault and the Jhimpir Fault. Maximum intensities of earthquakes occurring along the Surjam Fault and the Jhimpir Fault are 6.1 and 5.6 on the Richter Scale, respectively.

The Surjam Fault is 10 km (6.2 miles) west of the Lakhra site and 28 km (17.4 miles) west of Khanot site. The Jhimpir Fault is 50 km (31.1 miles) southwest of the Khanot and Lakhra sites. Horizontal ground accelerations, calculated by GCII taking into account the maximum intensities of recorded local earthquakes and the sites' proximity to the active faults, are 0.14 gravitational acceleration (g) (Lakhra site) and 0.08 g (Khanot site).

GCII drilled two borings at the Lakhra site. Overburden consists of 1.5 to 3 m (5 to 10 ft) of silty sand and silty clay. Interbedded sandstone and shale occurred throughout the borings to depths of 30 m



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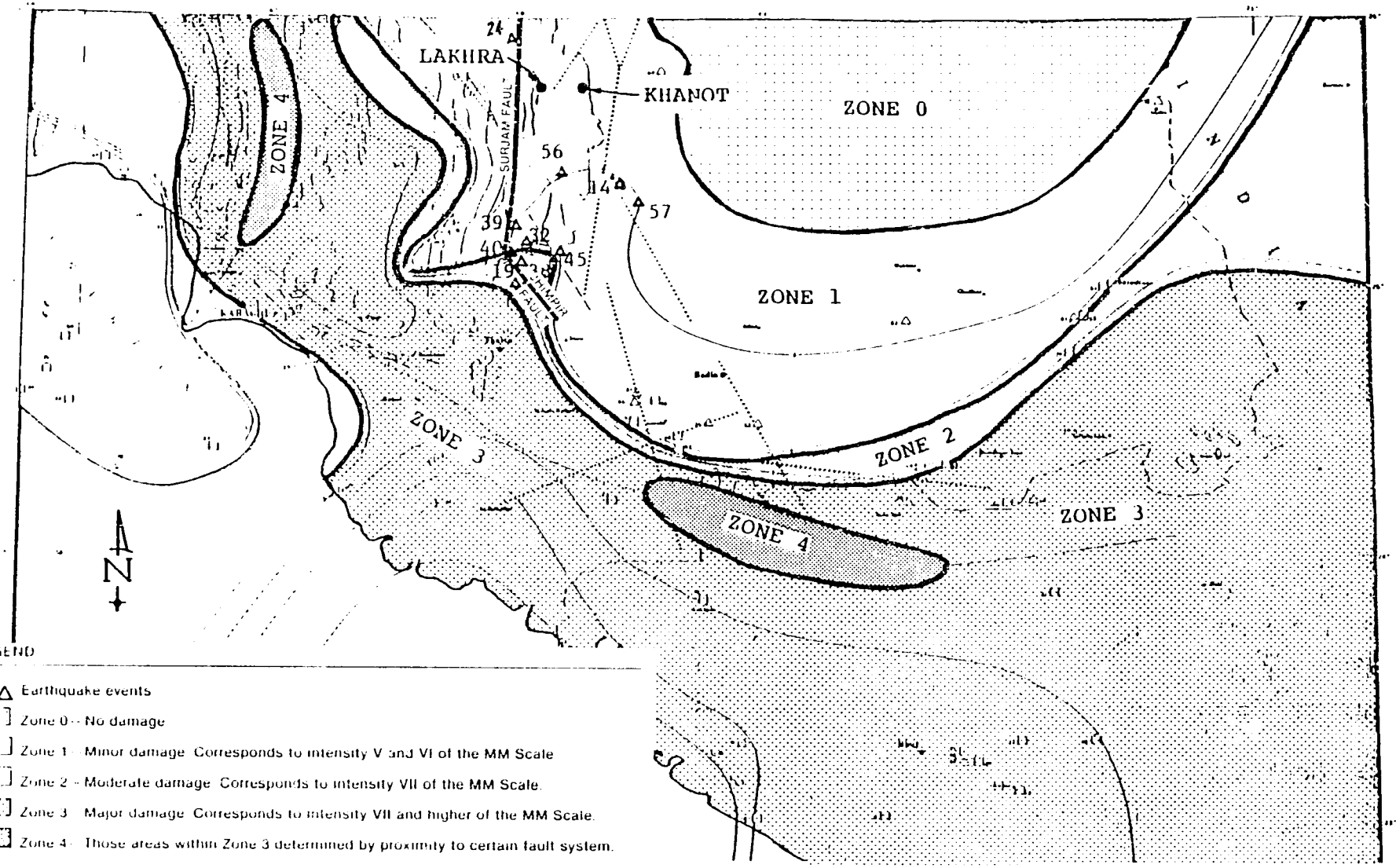


Figure 3.1-4
SEISMIC RISK MAP OF KARACHI, HYDERABAD DIVISIONS AND LASBELA DISTRICT, PAKISTAN, 1984

SOURCE: GCII, 1985

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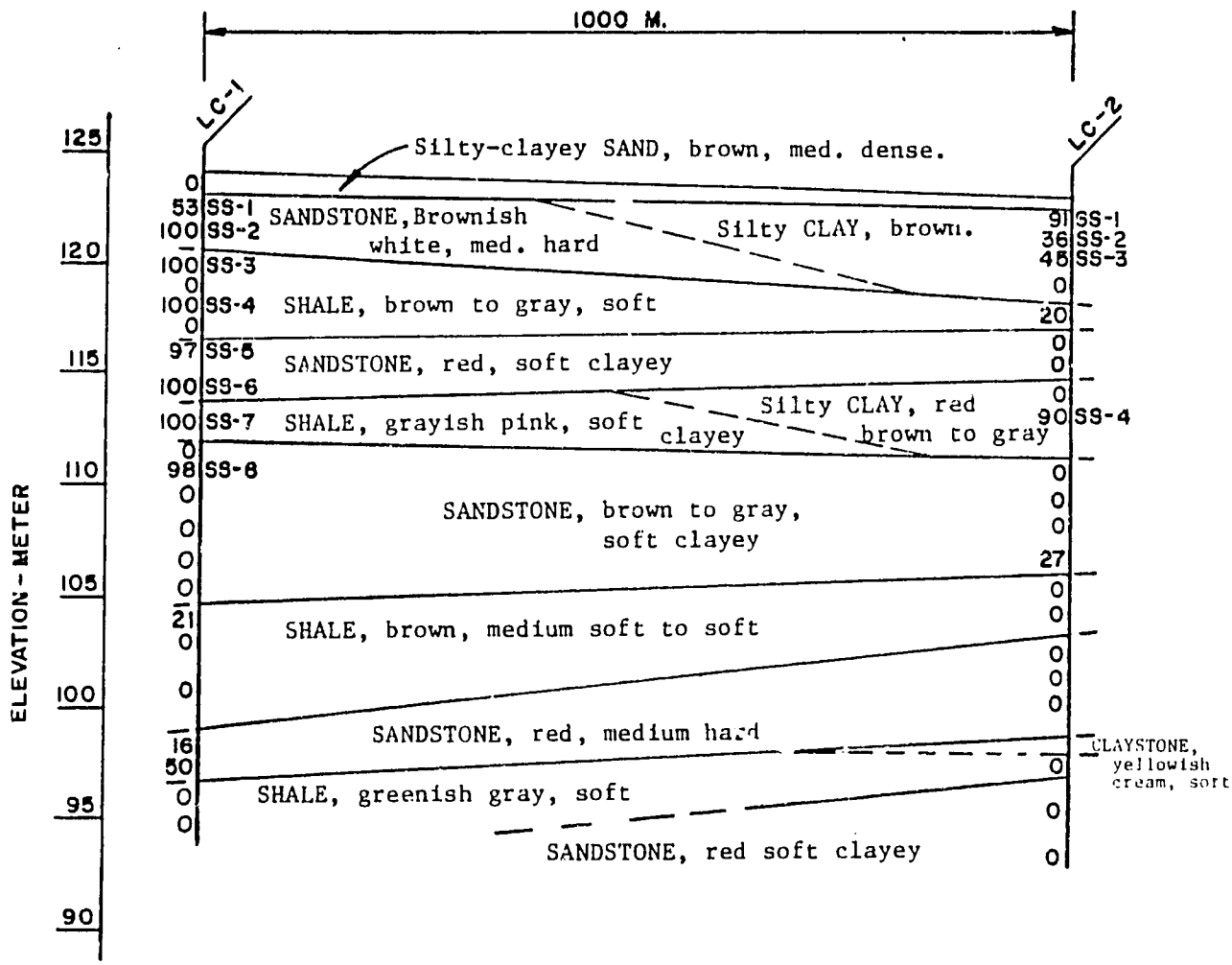
(98 ft) (Figure 3.1-5). In the Lakhra Coal Field area, the weathered zone is generally 33 m (110 ft) below the surface. Permeability is expected to be low due to the silty and clayey overburden and the shale beds. Bedding planes generally dip to the west between 2° and 5°.

3.1.2.3 GROUND WATER RESOURCES

Shallow ground water in the region occurs in small amounts in perched water table systems; however, this source of water is local, of small quantity, and usually too poor in quality for use as a drinking water supply. Soils in the region are anisotropic with large variations in physical characteristics, reflecting the properties of variable deposition of sediments from the Indus River during different time horizons. The percentage of usable quality water within about 90 m (300 ft) from the surface is extremely limited. For these reasons ground water development is difficult and uneconomical. The usable fresh ground water available throughout the entire province of Sind is not substantial enough to be considered as a water resource at present or with any future potential.

In the irrigated areas along the Indus River, the ground water is subject to effects of waterlogging and salinization. After meeting crop requirements, the irrigation water from the Indus River either evaporates or seeps into the ground. The percolation of seepage from the irrigation channels and from irrigated land has increased the ground water recharge and disturbed the equilibrium of inflow to and outflow from the ground water reservoir. Thus, the water table began rising such that in most irrigated areas the water level is at or near the surface. Tube wells have been constructed in the region to lower the water table by pumping to prevent or reduce waterlogging. Ground water from the tube wells is usually either discharged to the river or reused for irrigation, depending on the water quality.




LEGEND

29 | SS-1 SPT Value in rock cavity

0 RQD Value, %

NOTES

1. Boring location are shown on FIG. 8
2. SPT Value- Number of blows of a 63.5 kg (140 lbs) hammer falling 76 cm (30 in) required to drive a 5 cm (2 in) O.D. splitspoon sampler 30.48 cm (12 in)
3. RQD Value- Rock Quality Designation, Total length of recovered core pieces measuring 10.2 cm (4 in) or more in length expressed as a percentage of the total length of the core run.

Figure 3.1-5
SUBSURFACE PROFILE, LAKHRA SITE

SOURCE GCII, 1985

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Detailed information to determine ground water characteristics (such as location of aquifers, aquifer transmissivities, and direction and rate of ground water flows in the region) is not available. A well inventory performed by John T. Boyd Company indicated that only about five active wells exist within 16 km of the Lakhra area (see Appendix G). There are, however, seasonal wells along the Kath Buthi that are active during the rainy season (July, August, and September). Water for these wells is from drainage in the alluvium sediments. Ground water is reportedly used for domestic purposes in localized areas.

No ground water was found in the two GCII borings at the Lakhra site, which were drilled to depths of 30 m (105 ft). Ground water was encountered in only two of 65 borings drilled by John T. Boyd Company. Of four exploration holes drilled to depths of 300 to 600 m (1,000 to 2,000 ft), none experienced water inflow.

Results of investigations performed by the United States Geological Survey (USGS) and the Government of Pakistan Ministry of Industries and Natural Resources indicate that the water table level in the Lakhra area is an average of about 46 m (150 ft) below ground surface and 15 m (50 ft) below the unconsolidated sediments where weathering takes place. Complete boring data are presented in Appendix G.

A survey performed by John T. Boyd Company indicated that ground water has been encountered in some 20 of the nearby existing coal mine operations (refer to Appendix G). This number of flooded mines, however, is relatively small compared with the 50 to 70 active mines in the area (not including worked-out mines). Indeed, flooded mines are often adjacent to dry mines, and water flow between mines has not been observed. The amount of water produced in flooded mines is generally less than 36 $m^3$/day (J.T. Boyd, 1986). Samples taken from several of these mines indicate that the water is unsuitable as potable or irrigation water (see Appendix G). Permeabilities at the Lakhra site are low due to the presence of clays and shale.



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The results of available chemical analyses of the ground water at the sites are summarized in Table 3.1-7, along with WHO Guidelines for Drinking Water for those parameters which were analyzed. Ground waters at each site contain high sulfates and high dissolved solids.

In the Khanot area, ground water was encountered in 4 of the 13 bore holes (Borings KM-1, 4, 5, and 6) at approximately 4.6 to 13 m (15 to 43 ft) below the ground surface. Six water samples were collected and analyzed from Boring KM-1. Results of the hydrogeological study conducted by WAPDA indicated that the ground water quality in the Khanot area is generally alkaline and saline. A fresh ground water lense of small thickness occurs on top of saline water only along the non-perennial streams or along the Indus River. Results of the GCII water pressure tests in rock at the Khanot site indicate that the permeability of the limestone is about $1.2 \times 10^{-2}$ cm/min.

Table 3.1-7. Ground Water Quality

| Test | Sites | | Flooded Mines | WHO Drinking Water Guidelines** |
|---|---|---|---|---|
| | Khanot* | Lakhrat† | | |
| Total Dissolved Solids, mg/L | | 465-1371 | 3024-41832 | 1000 |
| Sulphate ($SO_4$), mg/L | 1197-1380 | 155-615 | 949-8233 | 400 |
| Chloride (Cl), mg/L | | 20-34 | 248-17340 | 250 |
| pH, units | 7.2-7.8 | 7.4-7.8 | 4.8-6.7 | 6.5-8.5 |
| Bicarbonate ($HCO_3$), mg/L | | 171-403 | — | — |
| Calcium (Ca), mg/L | | 104-240 | — | — |
| Magnesium (Mg), mg/L | | 4-40 | — | — |
| Total Iron, mg/L | | 0-1 | 1-90 | 0.3 |
| Manganese Dissolved, mg/L | | Nil | 0-6 | — |
| Suspended Solids, mg/L | | .02-.05 | — | — |
| Turbidity, FTU | | 6-25 | 20-2000 | 5 NTU |
| Sodium (Na), mg/L | | 10-40 | — | 200 |
| Total Dissolved Salts, mg/L | 6050-6694 | | 3024-41832 | — |
| Salinity, mg/L | 6100-6600 | | — | — |
| Conductivity, micro mhs/cm | 9531-10312 | | — | — |

* 6 samples.
† 5 samples.
** World Health Organization Guidelines, 1984.

Notes: mg/L = $10^{-3}$ g/L = ppm by volume.
FTU = Formazin Turbidity Units.
NTU = Nephelometric Turbidity Units.

Sources: GCII, 1985.
John T. Boyd Company, 1986.



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## 3.2 BIOLOGICAL ENVIRONMENT

### 3.2.1 ECOLOGICAL COMMUNITIES

No ecological surveys specific for the province of Sind or for the study area are known to exist. The ecological descriptions contained in this section are based on general ecological descriptions for Pakistan from the literature, selected references, site reconnaissance, and discussions with federal and provincial natural resource agencies, and university scientists.

The province of Sind is an arid and semi-arid land through which a great river (the Indus River) flows. The ecological resources of Sind and the study area are influenced by the Indus River and the prevailing climatic conditions. The study area (Figure 3.2-1) can be considered divided into two sub-areas: the Indus floodplain to the east and the Piedmont area to the west. The Indus Highway or Dadu Road, running north/south, is a dividing line between these two sub-areas. The Indus River has been active in shaping the topography of the Indus floodplain area. The ecological resources in this sub-area reflect the more mesic conditions provided by the river, whereas the higher Piedmont area to the west is dramatically more arid.

The study area is characterized as a tropical scrub forest community (Arid Lands Information Center, 1981). This ecological community runs north and south in the Indus Plain. Topographically, the area is a combination of sandy plains and dry stream beds. In some areas (e.g., along the road west of Khanot and in the East Pit area) rock outcroppings comprised of limestone, sandstones, and shale occur. These topographical areas differ in relief, microrelief, soil depth, moisture availability, and nutrients. These conditions are important in determining the vegetative composition in the area (Shaukat *et al.*, 1980). The vegetation is dominated by perennial xerophytic shrubs (Figure 3.2-2). The characteristic species include pilu or salvadora (*Salvadora*

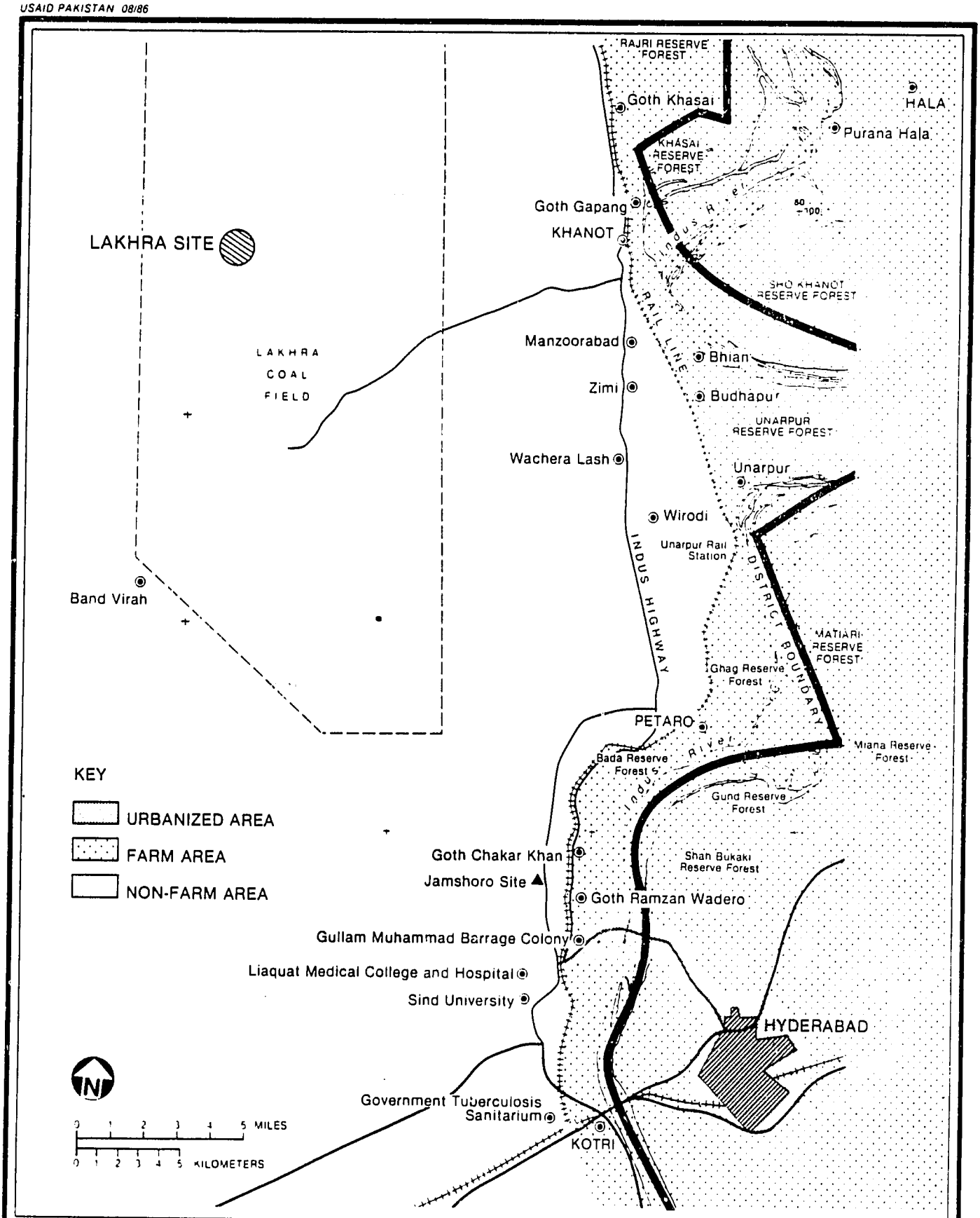


Figure 3.2-1
LAND USE IN THE STUDY AREA

SOURCES: GCII, 1985; ESE, 1986.

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Figure 3.2-2
VEGETATION PATTERN AT LAKHRA IN
FEBRUARY 1986, NEAR WEST PIT AREA

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oleoides), farash or tamarix (Tamarix aphylla and T. gallica) and mesquite (Prosopsis cineraria). In general, the vegetation is simple in its organization and the plant cover is scanty (see Figure 3.2-2). The greatest amount of plant cover is observed during the monsoon season in July and August. Observations in the study area during this time recorded 10 to 15 percent plant cover. Similar observations in February revealed 1 percent plant cover. The plant cover is patchy with the most vegetation found in non-perennial stream beds. The composition of the ecological communities varies from low-growing grasses and herbaceous vegetation (e.g., Salsola baryosoma) to shrubs and trees such as mesquite and acacia (Acacia senegal) (see Appendix H).

Vegetational succession has been described by Shaukat et al. (1981), for representative areas north of Karachi. They described five successional stages from a poorly developed vegetative community made up of primarily a herbaceous stratum and bare rocky ground to a climax stage made up of three strata: herbaceous vegetation, shrubs, and trees. As succession proceeds, soil depth increases, soil texture becomes finer, and water-holding capacity increases. With the death and decay of plants, organic matter is added to the soil and the humus content of the soil increases. $CaCO_3$ and pH of the alkaline soil decrease slightly. Longer-lived species dominate the later successional stages. There is an increase in stratification with the development of shrub layer and the appearance of trees in the later stages. The height of the community increases from less than half a meter to two meters. Microclimate, relief, and other factors influence the successional process. Uses such as grazing by goats and cattle and wood cutting also have a significant effect on vegetation development. In the Lakhra area, observations of the plants, especially shrubs and trees, showed evidence of heavy browsing. Natural growth form had been changed.

In the past the floodplain areas along the Indus River contained tracts of riverain forests dominated by acacia or babul, prosopis or jand, and

poplar or bhan. These natural areas have been severely reduced by diking and cultivation. The floodplain areas have been planted in wheat, cotton, and other crops, as well as irrigated forest plantations. The present plant composition is a mixture of natural and man-introduced vegetation.

The Khanot and Lakhra areas are west of the Indus Highway, and both are characterized as tropical scrub forests. Because of topographical differences, fewer dry stream beds, and proximity to human activity, Khanot has less vegetative structure than Lakhra. At Lakhra there are more extensive stands of acacia and prosopis, especially along dry stream beds. The Khanot area is dominated by patchy distribution of herbaceous and some shrub vegetation. At Lakhra the three strata vegetation communities are common in the dry stream beds. In the sandy tracts the single strata herbaceous community is found. Topographical maps show the presence of a forest reserve, the Jannat Khoro Reserve Forest, in the west pit area and other identified vegetational areas just north of the west pit. At Lakhra evidence of heavy browsing is observed on the vegetation. During the summer reconnaissance, grazing by cattle and goats was observed.

To the east of the Khanot site (approximately 1 km) the intersection of the Lakhra Road and the Indus Highway occurs. East of the highway, the area drops into the Indus floodplain. A mixture of irrigated cultivated land, planted forests, and remnant riverain forest occurs. Along the levees of the Indus River, poplar and tali or shisham occur. Acacia trees are common throughout this area. Acacia and shisham are grown in the planted forest plantations managed by the Department of Forestry. On the east of the river near Hala, larger and more extensive forest tracts and cultivated agricultural areas exist (see Section 3.3.1 for discussion on agriculture).

### 3.2.2 FISH AND WILDLIFE COMMUNITIES

The dominant and only permanent aquatic habitat in the study area is the Indus River. With the barrage at Kotri, the water volume above the dam is more constant than in the past. A significant fishery is supported in the study area above the dam. Numerous commercially important fish are found in the river in this area, including palla or Indian shad, rohu/dumbra or carp, dahi/calbrons, mirgal/mori or murakhi, thaila or theli, sole or snakehead, and singari or catfish. Although no specific siting records were found, the Indus dolphin is suspected to occur above the Kotri Barrage. No unique aquatic habitats supporting the fishery occur in the vicinity of the proposed cooling water intake site.

Wildlife in Pakistan has declined during the past three or four decades because of habitat destruction and overexploitation. Many of the common animals existing in the 1940s and 1950s are now facing the threat of extinction. Wildlife habitats have been classified in different ways (see Appendix H). For this study two major wildlife habitats are identified: semi-arid habitats west of the Indus Highway and the more mesic riverain or Indus plain habitats. The riverain habitat includes the irrigated and cultivated areas east of the Indus Highway. The semi-arid habitats contain a variety of reptiles, amphibians, birds, and mammals, including:

Reptiles

geckos
grass skinks
fringed-toed sand lizard
longtailed desert lacerta
desert monitor
Indian monitor
Indian sand boa
streaked Kukri snake
Indian krait
sawscaled viper

Amphibians

Indian burrowing frog
Indus toad
tiger frog

| Birds | Mammals |
|---|---|
| white throated munia | hedgehog |
| little brown dove | sand-colored rat |
| common babbler | Indian gerbil |
| collared turtle dove | Indian hare |
| desert warbler | desert cat |
| black partridge | Chinkara |
| tawny eagle | desert fox |
| | Indian fox |
| | jackal |
| | hyena |
| | wolf |

The riverain habitat, because of the proximity to water and greater vegetative diversity, has a different wildlife population. Some of the same species found in the semi-arid habitats also occur in the riverain habitat, including the geckos, skinks, turtle doves, Indian hares, jackals. Species more typical of this area and more tolerant of human habitation include turtles, Punjab snake-eyed lacerta, dhaman, Indian cobra, herons, bitterns, kites, vultures, stilts, cuckoo, owls, swallows, shrikes, crows, various species of song birds, wild pig, hog deer, and jungle cats.

Reptiles are a dominant faunal group in the semi-arid habitats. Geckos and monitor lizards were frequently seen in the Lakhra areas. Because of the generally arid conditions compared to other regions of the world, amphibians are the least represented vertebrate group in Pakistan and in the study area.

The types of wildlife found in the two areas are similar because of the similar ecological conditions. No wildlife surveys were conducted to determine the abundance and distribution of wildlife at the two sites. Reconnaissance observations suggest a greater abundance of wildlife in



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the Lakhra area because of the greater vegetative diversity and the more limited human activity. Lizards, including agama sp. and Uromastyx hardwicki, were frequently observed by John T. Boyd field team personnel and were the most common species observed during the August reconnaissance (see Figure 3.2-3a). Several tawny eagles and a desert fox were observed during the February reconnaissance. Because of the proximity of the Khanot site to the riverain areas, some riverain species may occasionally be found in the Khanot area.

### 3.2.3 ENDANGERED SPECIES

A number of reptiles, birds, and mammals considered rare, vulnerable, or endangered by the Governments of Pakistan and the United States potentially occur in the study area (Table 3.2-1). The U.S. Department of Interior, under the statutory authority of the Endangered Species Act of 1973 and its Amendments list the desert and Indian monitor lizards, the Indian softshell turtle, and the chinkara (a gazelle) as endangered. The first three species were placed on the endangered species list because of their being listed by the Committee on International Trade of Endangered Species (CITES). They are considered species that are threatened with extinction and that are or may be affected by trade (Appendix H listing). The chinkara was placed on the list in concern for overexploitation of its population because of hunting and habitat destruction. Section 7(a) of the Endangered Species Act, as amended, requires United States Federal agencies to evaluate their actions with respect to any species that is listed as endangered or threatened. Section 7(a)(2) requires Federal agencies to ensure that the activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of such a species or to destroy or adversely modify its critical habitat. An opinion of August 31, 1981, from the Office of the Solicitor, U.S. Department of Interior, indicates that Section 7 consultation, involving obtaining a biological assessment and a jeopardy opinion from the U.S. Fish and Wildlife Service, does not apply in foreign countries. Section 8(a) of the Act authorizes the provision of limited financial assistance for the development and management of



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Table 3.2-1. Endangered and Vulnerable Species Potentially Occurring in the Study Area

| Scientific Name | Common Name | Status | Potential Habitat/ Locality |
|---|---|---|---|
| BIRDS | | | |
| Anas poecilorhyncha | Spotbill Duck | Endangered-GOP | Riverain, migrant |
| Grus antigone | Sarus Crane | Endangered-GOP | Riverain |
| Chlamydotis undulata macqueenii | Houbara Bustard | Endangered-GOP | Semi arid, Lakhra area |
| Francolinus pondicerianus | Grey Partridge | Endangered-GOP | Semi arid, Lakhra area |
| MAMMALS | | | |
| Felis caracal | Caracal | Rare-GOP | Semi arid, Lakhra |
| F. viverrina | Fishing Cat | Endangered-GOP | Riverain area |
| Gazella gazella | Chinkara | Endangered-USA/GOP | Semi arid, Lakhra region |
| Axis porcinus | Hog Deer | Endangered-GOP | Riverain Forest |
| Mellivora capensis | Honey Badger | Vulnerable-GOP | Semi arid, Lakhra |
| Platanista indi | Indus Dolphin | Endangered-GOP | Indus River |
| REPTILES | | | |
| Varanus bengalensis | Indian monitor | Endangered-USA/GOP | Semi arid, Khanot |
| Varanus griseus | Desert monitor | Endangered-USA/GOP | Semi arid, Lakhra |
| Trionyx gangeticus | Indian softshell turtle | Endangered-USA | Riverain area |

Source: U.S. Department of Interior, 1985.
Zoological Survey Department, 1986.



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programs that the Secretary of Interior determines to be necessary or useful for the conservation of endangered species in foreign countries (Federal Register Vol. 50, No. 207, Friday, October 25, 1985).

Pakistan has a long history of wildlife protection laws and regulations; however, this wildlife protection has been primarily linked to the preservation of game animals to provide hunting opportunities. As mentioned earlier, wildlife of Pakistan has declined significantly during the past four decades because of habitat destruction and overexploitation. The Ministry of Food, Agriculture, and Cooperatives has overall responsibility for wildlife protection. This responsibility is delegated to the National Council for Conservation of Wildlife (NCCW). NCCW has published a list of endangered species in Pakistan. Wildlife management boards have been set up to advise local administrations. The province of Sind has a Sind Wildlife Protection Ordinance which is administered by the Sind Wildlife Management Board. Endangered species are protected under this law as "protected animals" (Sind Wildlife Protection Ordinance, 1972). In addition to the species listed as endangered by the U.S. Department of Interior, the Government of Pakistan lists nine additional species it considers endangered or vulnerable (Table 3.2-1).

The only endangered species known to occur at the proposed mine and power plant site is the desert monitor (Figure 3.2-3b). As a diurnal animal, it is frequently observed in the Lakhra area. The desert monitor prefers sandy tracts, and several were observed in such areas during the August reconnaissance. The desert monitor, which lives in burrows underground, often enlarges the holes of other animals such as gerbils. The burrows are oval-shaped and may be up to 3 m (10 ft) long, but usually are 0.9 to 1.2 m (3 to 4 ft) in length. Potential burrows were observed in the dry stream bed near the Lakhra meteorological station. Monitor lizards are strongly territorial. The monitors breed only during the monsoon season,

A. *Agama* LIZARD

B. DESERT MONITOR LIZARD
*Varanus griseus*

Figure 3.2-3
LIZARDS OBSERVED AT LAKHRA

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laying 20 to 30 eggs in the ground or in termite houses. Depending upon soil moisture, the eggs will hatch in 2 to 4 months. Monitor lizards can live up to 30 years and attain a size of several feet. They are insectivorous, feeding primarily on beetles. Their major predators besides man are jackals, pythons, and pigs (Walter Auffenburg, Florida State Museum, University of Florida, personal communication). Consultation with the US Fish and Wildlife Service (Ronald M. Nowak, Office of Endangered Species, US Fish and Wildlife Service personal communication, January 6, 1986) indicated that the reason for its endangered status is to protect it from illegal trade. It is a Convention on International Trade of Endangered Species (CITES) Appendix I species, i.e., a species threatened with extinction.

The Indian monitor, also endangered, and a Convention on International Trade of Endangered Species (CITES) Appendix I species is likely to occur around the Khanot site. Its habits are similar to the desert monitor, but it prefers less sandy conditions. Both species can occur together. Other species whose range may include the Lakhra area are the Houbara bustard, grey partridge, caracal, chinkara, and the honey badger. Although these species have the potential to occur in the area, the decline in habitat quality over the last 30 years has reduced the potential for these species to permanently reside in the Lakhra area. There is the potential that such species may occasionally pass through the area (Zoological Survey Department, 1986, personal communication). Five listed species occur in the riverain areas. The potential for their occurrence in the riverain areas east of Khanot is not known.

The fishing cat, spotbill duck, sarus crane, and Indian softshell turtle have some potential to occur in the vicinity of the proposed water intake area and associated pipeline corridor in the riverain area; however, their occurrence is considered transitory because of the existing human activity and the agricultural activity. No riverain forests occur in this area and the likelihood of the hog deer occurring in the area of the intake structure and pipeline corridor in the Indus floodplain is remote.

## 3.3 SOCIAL ENVIRONMENT

This section was developed in part from information contained in the report titled Social Soundness Assessment of the Lakhra Coal Mine and Power Generation Project (Helweg, et al., 1985). This report (without Appendices) is contained in Appendix K.

### 3.3.1 LAND USE

The study area is within the Division of Hyderabad and is divided into two districts: Hyderabad and Dadu (Figure 3.2-1). The two districts are divided north and south by the Indus River. The Hyderabad District lies east of Indus River. The Dadu District lies west of the Indus River and north of the City of Hyderabad. The two proposed plant sites and coal field are located in the Dadu District in the Kotri Taluka (subdivision). The Dadu District, containing 1,687,980 hectares (4,171,000 acres) of land, is the larger of the two districts. The Hyderabad District contains 1,286,928 hectares (3,180,000 acres) (Pakistan Population Census Organisation, 1983a, b).

The Hyderabad District is a part of the Lower Indus plain. The Indus River flows along the western boundary of the district and has a uniform land surface formed by the alluvial deposits of the Indus River. There are no mountains or hills anywhere in the district except some small hillocks south of the City of Hyderabad. The rest of the district is a fertile plain about 50 m (160 ft) above sea level. There are some good reserves of forests in the Hala Taluka along the Indus River. In contrast, the Dadu District, on the east side of the Indus River, has a hilly topography with the western areas dominated by the Kirthar Range. Lake Manchar occurs in the middle of the district.

Three major land use types are found in the study area: urbanized areas around Hyderabad and south of Jamshoro, farm areas which are east of Khanot extending across the Indus River, and non-farm areas primarily west of the Indus Highway including the Lakhra area (Figure 3.2-1).



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Based on 1979-80 reports, the Hyderabad District is the more developed of the two districts, with 34 percent (178,000 hectares) of its farmable land areas under cultivation. The Dadu District, the larger of the two districts, has only 13 percent (201,000 hectares) (Sind Bureau of Statistics, 1984). Farm areas include areas currently under cultivation or areas fallow in the year of the census but cultivated the preceding years, areas used for farm buildings, and farm areas under forests. Non-farm areas include all areas not being farmed. These are undeveloped areas and contain scattered villages.

Agriculture is the main economic enterprise in Pakistan. The agricultural year is divided into two main cropping seasons: (1) rabi or asari, and (2) kharif or saoni. Rabi crops are sown after the rainy season in October and November and harvested in the spring in April and May. These crops include wheat, barley, gram, and oil-seeds. Eighty to ninety percent of the Rabi crop is wheat. These crops require lower temperatures and lower rainfall. Kharif crops are sown between April and May and harvested in October and November. They include rice, maize, millets (jowar and bajra), cotton, and sorghum (Kureshy, 1978). Cotton is the primary crop grown along the river, comprising 75 percent of the cultivated acreage in the Khanot area. These crops were observed being grown in the study area along with fodder (e.g., Egyptian clover) east of the Indus Highway. Primary cultivation of these crops occurs on the east side of the Indus River in the Hala area. Major agricultural problems in the area are waterlogging and saline soils. Heavy use of fertilizers (e.g., ammonium sulfate) is required (Agriculture Research Institute, at Tandojam, and Agriculture Extension Service, at Hyderabad, 1986, personal communication).

Besides agriculture production, the Khanot area has extensive forestry activity. There are a number of government forest reserves along the Indus River. Two major reserves in the area are the Khasari Reserve Forest and the Khanot Reserve Forest. Acacia, tamarix, and poplars are



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the primary species planted. Acacia is the primary wood product used in the Lakhra mines for support timbers and fire wood. Poplar, which is grown only at Hala, is used for furniture in the cottage industries. Tamarix is used for fire wood and secondarily for furniture. The forest reserves in the area are considered very good for the region (T.A. Ansari, 1986, personal communication). A forest reserve, Jannat Khoro, is shown on topographical maps in the west pit area at Lakhra.

In the Lakhra area, because of the lack of water, much less extensive agricultural activity occurs. In this area seasonal subsistence agriculture conducted by the Khosa Baluch occurs. By building small earthen dams or bunds, nutrient-containing silt and runoff during the monsoon rains are trapped. These areas are sown in various grain and vegetable crops for local consumption. Topographical maps of the proposed underground and surface mine area show approximately 20 of these areas averaging approximately 12 hectares (30 acres) in size and ranging from approximately 0.8 hectares (2 acres) to 60 hectares (150 acres). Most of these agricultural plots occur in the proposed underground mining area. Several similar areas are shown just west of the west pit. It is unknown which of these areas are actively used. Grazing of goats and cattle is common during the monsoon season when vegetation is plentiful.

The only urbanized area in the study area is the City of Hyderabad. It is the headquarters for the District and Division of Hyderabad. It is the fourth largest city in Pakistan with over 750,000 people. It is an important industrial and commercial center of the Lower Indus Plain. Large-scale industries are found in the vicinity of Hyderabad including the oil-fired power plant under construction at Jamshoro, the cement factory, and associated industries located at the Hyderabad Industrial Estate east of the City Center. On the west side of the river Sind University, Meran University, and Liaquat Medical College and Hospital are found. The medical college is one of the largest medical institutions in Pakistan. These developments are approximately 6 km (4 miles) south of Jamshoro.

North of Hyderabad on both sides of the highway to the Khanot site are numerous villages (Figure 3.2-1). These are farm villages with houses constructed of solid brick or mud. There are several truck stops along the Indus Highway between Khanot and Hyderabad. At Petaro there is a government cadet school. On the east side of the Indus River is the village of Hala, which is the largest village in the area. Several other villages occur in its vicinity. This area appears more prosperous than the villages on the west side of the Indus.

The Khanot and Lakhra areas are in non-farm areas. A truck stop is 0.5 km (0.3 mile) to the east at the intersection of the Indus Highway and the main road into Lakhra. The village of Khanot, with 1,500 people, is approximately 1 km (0.6 mile) north of this intersection. Other villages are found northeast and southeast of the site along the highway and across the river.

There are 13 private mining companies operating at Lakhra. Scattered through the Lakhra area are a number of permanent villages and seasonal settlements. Topographical maps show seven named areas (Table 3.3-1) in the proposed mining area. Other than the mining camps some 5 km (3 miles) to the east and a few scattered Khosa Baluch villages, the Lakhra site is not associated with any major land use or human development. Migratory herders are found in the area, especially during and after the monsoon season.

The land within the boundary of the proposed project is owned by the Sind government and leased to the PMDC. The area is currently not classified as resettlement nor reclamation land. Several Khosa Baluch villages or settlements are in the vicinity (see Table 3.3-1).



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Table 3.3-1. Named Villages and/or Settlements in the Vicinity of the Proposed Mining Area

| Name | Location |
|---|---|
| Goth Sumro | West of the west pit area |
| Alam Khosa | West of the west pit area |
| Goth Sanjar Khan | Southwest of the west pit area |
| Goth Ghulam Ali | Southwest of the west pit area |
| Goth Khuda Bakhsh Sakrani | Southwest of the west pit area |
| Bachal | Underground mine area |
| Dhanwari | East pit area |

Source: ESE, 1986.



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### 3.3.2 SOCIOECONOMIC RESOURCES

#### 3.3.2.1 DEMOGRAPHY

Population

In 1981, Sind was the second most populous province in Pakistan with 18,966,000 people. This represents a 34 percent population increase since 1972 and a 3.5 percent per year growth rate, which is above the national average of 2.97 percent.

Sind's population and population growth are concentrated in urban areas, primarily Karachi. Forty-three percent of the population is already urban, and Sind is still Pakistan's most rapidly urbanizing province. It is difficult to accurately quantify these changes, however, because fluxes due to seasonal migration complicate population growth patterns.

The Hyderabad District has 2,080,000 people. Forty-six percent are in urban areas, with 37 percent concentrated in the City of Hyderabad. The growth rate is 2.3 percent (calculated in 1984), which is below the provincial average and population density is 361 persons/$km^2$ (Sind Bureau Statistics, 1984).

Dadu has a much smaller population (1,074,000) that is still 90 percent rural and relatively dispersed (56 $km^2$). This district is growing more rapidly, with a growth rate in 1981 of 3.4 percent, which is approximately the same as the national average of 3.5 percent.

The proposed site is in the Dadu Kotri Taluka, which has an overall population density of 55 persons/$km^2$, and an agricultural density of 1,012/$km^2$ of farmland (Helweg, 1985). This is the fastest growing area in the district, with an annual population increase of 5.8 percent (Pakistan Population Census Organisation, 1983a,b; Sind Bureau Statistics, 1984). The population of the region was projected to be 215,000 in 1984.



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The age/sex structure of the Dadu and Kotri Taluka populations are similar to the national profile, with about 45 percent of both sexes in the 0-14 age group. Thirty-five percent of the people are in the 15-39 age group. Since most of the workers fall in this category and many of them are men without local families, in the Kotri Taluka region 22.6 percent of these are males and 15.2 percent females. Twenty percent of the population falls into the 40-75 age range, which includes approximately equal numbers of men and women.

The population of Kotri Taluka is sparsely distributed in villages of 20 to 300 people scattered along the Indus Highway and the Indus River and around the coal mines. There are reported to be about 5,000 people in and around Khanot (within a 5-km radius), whereas the more geographically isolated Lakhra area has less than 2,000.

Ethnic Groups

More than 99 million people live in Pakistan of which four groups are prominent: Sindhis, Buluchis, Pathans and Punjabis. While there is commonality of the principles guiding the social behavior of these groups, and Islamization is being implemented throughout the country, there are ethnic diversities and differences among their social structures and patterns. These different ethnic groups interrelate through complex socioeconomic patterns and will likely be involved in the construction and operation of the Lakhra project.

Pakistan has 19 million Sindhis, most of whom continue to follow a traditional agrarian culture that started with the ancient Indus Valley Civilization. Their culture is historically hierarchial, with acceptable tasks and privileges strictly defined by social stratification. The attitudes of Sindhis will likely have a significant effect on the success of the project.



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There are about 6.5 million Baluchis in Pakistan; 1.4 million of them are in the Sind Province and are a strong ethnic element in the province and in the Lakhra area. They live compatibly with the local Sindhis in the Lakhra area, while adhering closely to their own traditions. The Baluchis have branched into many tribes, with the Khosas and Rinds dominating in the Lakhra area. The Rinds were the first settlers, but they were driven off their land by the more aggressive Khosas. The Rind tribe now live near the Indus riverbanks, whereas the Khosas live in the semi-desert region around the proposed coal project sites.

Pathans make up about 12 million of Pakistan's population. They reside mainly in the North-West Frontier Province (NWFP) and provide the bulk of the underground workers for the existing Lakhra field coal mines.

Pakistan's Punjabi population is the largest ethnic group with well over 50 million people. An important source of financial, upper-level management, engineering and planning expertise for the project will likely be Punjabi. Although some Punjabis will be recruited for their trade management and technical skills, WAPDA and contractors will maximize local labor employment. Indeed, WAPDA's policy is to employ all local people for positions up to Grade 16.

The groups most likely affected by the Lakhra project include settled Sindhis, Khosa Baluch, and Swati immigrants, the latter primarily consisting of two main groups: Pathans and Gujjars. The Gujjars are from the less productive, higher altitudes of the Alpuri region of the Swat district.

The Khosa Baluch are nomadic herders who garden in the summer and migrate to the Indus River area as agricultural laborers during the dry season (Helweg, 1985). From July to April, about 2,000 of these people live in



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tiny villages that consist of stick structures interspersed among the mining areas. The Khosa Baluch plant their crops in July and harvest them in November. When their water supply is depleted, usually around April, they migrate to the Indus River agricultural area and return when the rains begin.

Water is the Khosa Baluch's greatest need, and some of the mining companies regularly distribute drums of it to promote good will.

The villages in the arid areas to the north of the project area are in a state of constant flux. A Khosa Baluch village is founded by one of the nomadic leaders and persists for a generation or two before the population moves on to a new village. There is a strong emotional attachment to the land, and like many herding cultures, they prefer the spaciousness of their semi-nomadic existence.

Prior to 1965, mining labor in the Lakhra area was mainly comprised of emigrant Kashmiris. Since then the bulk of the coal cutters have come from NWFP and the Alpuri region of the tribal state of Swat. In this region, the population exceeds the available arable land resources and emigration to the Lakra coal mines is necessary.

Migration

Both genuine permanent migration and "seasonal migration" (technically termed circulation) are extremely important factors affecting the Kotri Taluka population and especially the labor force.

Since 1951, internal migration within Pakistan has been towards Karachi and away from Punjab, the NWFP, and Baluchistan. These interprovince migrations typically involve moves from rural to large urban areas and are generally economically motivated. National policy is to relocate people to limit migration.

The circulation within the Lakhra coal field area consists primarily of the Khosa Baluch (about 2,000, of which 100 work in the Lakhra mines), Swati coal cutters from the NWFP (about 8,000), Kashmiri mine workers (about 1,000) and Indus River residents who are primarily surface mine workers (about 300).

As described previously, the Khosa Baluch are a traditionally semi-nomadic people who move into this arid region with the rains in June and go back to the Indus Valley when the dry season begins in April.

The Swati coal cutters, mainly Pathans, arrive at the Lakhra mines in mid-October and return to agricultural work in their homelands during the summer monsoon when demand for coal diminishes and the brick kilns shut down. During this four to six month period, the miners live in communal camps under fairly basic conditions (Figure 3.3-1). Brick sleeping quarters are provided which are about 20 ft. by 15 ft. in area, and sleep eight to ten men. Communal kitchens, attached to the buildings, provide cooking facilities and tea stalls for relaxation are usually nearby. Each summer, from about 50 to 75 percent of the coal cutters leave the mines and return to their homelands to rest from the hard underground labor, help their families plant and/or harvest crops, and fulfill social obligations such as attending weddings and ceremonies; however a few of the mines remain open, and miners willing to stay on through these months receive extra pay analogous to a "hardship allowance."

Social Structure

Separation and hierarchy are the dominant principles governing social patterns of the ethnic groups living in and around the Lakhra coal field. Although these groups live compatibly, members of class and kin subgroups cluster generally with their own kin. For example, Pathans living in a workers colony prefer living with their own people rather than being interspersed with Baluchis. Similarly, Baluchis have their own areas within villages while Sindhis have their own. Each social group does certain types of work, and social mobility has restrictions. Birthright is a major determinant of ranking and opportunities.

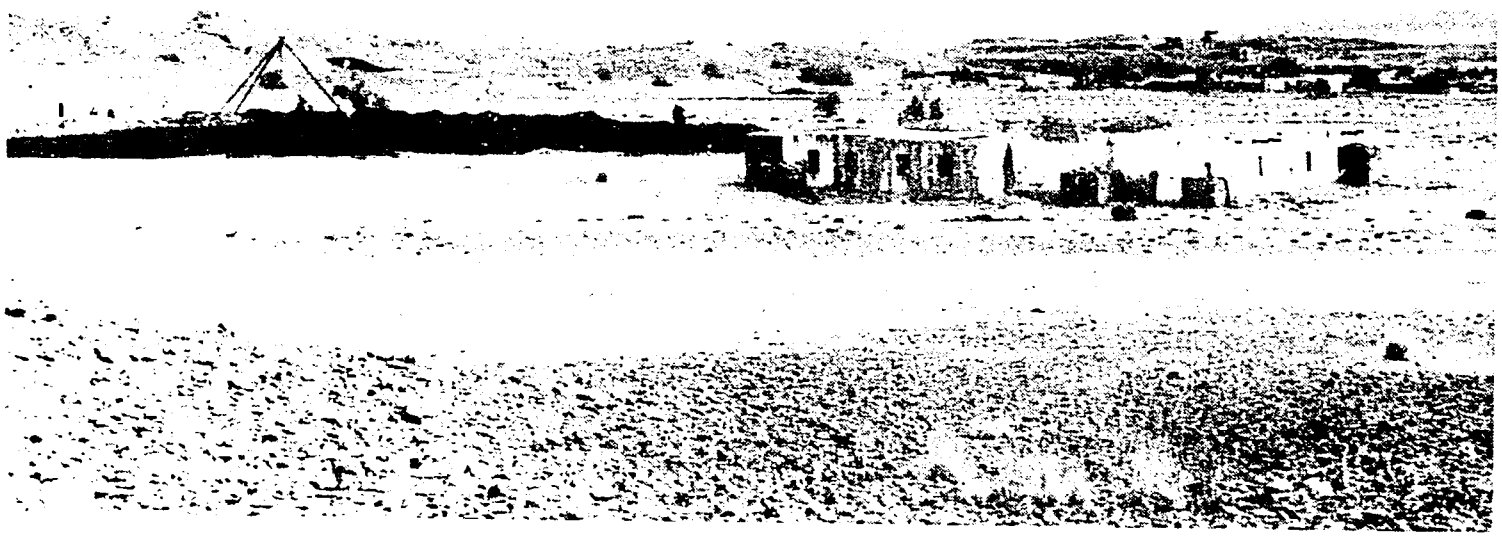

Figure 3.3-1
TYPICAL MINING CAMP IN LAKHRA COAL FIELDS

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These social values, however, are not expressed to the same degree amongst the groups potentially affected by the Lakhra project. The Khosa Baluch have little hierarchical differentiation where their villages are composed of equal kin-group members. The primary exception is the position of chief which is based on lineage. There is also little specialization of labor among the Khosa Baluch.

The Sindhis, living in villages along the river, are much more hierarchical in their social structure than the Khosa Baluch. Social rank is strict and adhered to in all interactions and residential patterns. Families with higher social status maintain control of village affairs which is commensurate with their position in that part of Sind society. Members of lower social status show deference to those of higher status and may live outside the village or in isolated sections of the community.

Social status for the Swati coal cutters is also important but appears to be less rigid than in Sind. Of the two main groups, the Pathans are considered to be of higher social status than the Gujjars. The Gujjars are considered to be among the poorer Swatis due their need to perform wage earning.

Women's opportunities vary according to region, social level, and village type. "Purdah," the practice of keeping women secluded in the home, is practiced throughout Sind, but its application varies; however, in some cases, women living in some of the more socially homogenous villages have more freedom of movement and in participating in agricultural activities.

"Purdah" does not mean that women are powerless. They generally control the domestic realm and have input into financial matters; however, major decisions, such as where to locate the home, are still made by males.

Workers' colonies for the Lakhra project will be much more homogenous than those that exist in villages in the vicinity of the Lakhra area.

### 3.3.2.2 EMPLOYMENT AND ECONOMIC PATTERNS

Employment and Organization of Labor

Coal mining is the region's primary source of employment. It is predominantly a manual labor intensive activity. Heavy equipment is scarce in both mining operations and roadway construction and maintenance.

During peak production, the size of the coal cutting labor force is estimated to be around 9,000. Eight thousand of the workers are Swatis and 1,000 are Kashmiris. The work force consists of about 30 percent local people and 70 percent migrant workers.

In Sind, landowners (or "zamindars") are the central figures around which labor is organized. These leaders are key figures in the social structure, and their influence can control workers' opportunities and activities.

The zamindar manages his enterprises through associates, and his influence may be felt throughout the region. There may be several such wealthy landowners in a community, but one usually dominates. According to the traditional system, carpenters, washermen, barbers, blacksmiths, cobblers, etc., provide services to the zamindar in return for a portion of the harvest. Wage labor is replacing this traditional system, but the zamindar still controls production, distributes goods, and mediates between his workers and police, officials, and merchants.



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Mine workers are organized as shown in Figure 3.3-2. There are three basic categories: managers, coal cutters, and mine support personnel. There are no female workers in any of these categories. The managers consist of labor contractors ("jamadars" and subsidiary) and crewleaders ("jorisars") are of varying influence. The "jamadars", as well as officer workers (clerks, accountants) and professional staff (geologists and surveyors) are responsible to the Mine Manager. Mine support work consists of activities such as shafting, timbering, and loading. The coal cutters are primarily Swati and Kashmiri immigrants. Support activities are undertaken by Swatis, Kashmiris, Baluchis, Sindhis and Punjabis.

Workers not directly involved in the underground mining activities may be salaried or piece workers. Salaried workers include professionals such as engineers, geologists, clerks, and other administrative personnel. Piece workers include unskilled laborers such as loaders who load coal onto trucks.

Lakhra miners are organized into cooperative work groups called "joris," and their collective pay is based on output measured by tons mined and delivered to the surface (and/or per meter of entry advanced) at a predetermined unit price. "Joris" comprise about 80 to 85 percent of the total labor force (J.T. Boyd, 1986).

In the "jori" system, work units linked by comradeship rooted in kin and village ties. Each jori is led by a jorisar who handles his workers' problems and represents them in dealings with a jamandar who is the primary labor contractor. Since the jorisar holds his position because his people trust his judgment and have faith in his ability to find them work, he is very careful to listen to advice and cater to the workers' needs and desires. His influence varies with the supply and demand for labor; he is relatively weak when work is plentiful and quite powerful when jobs are scarce.

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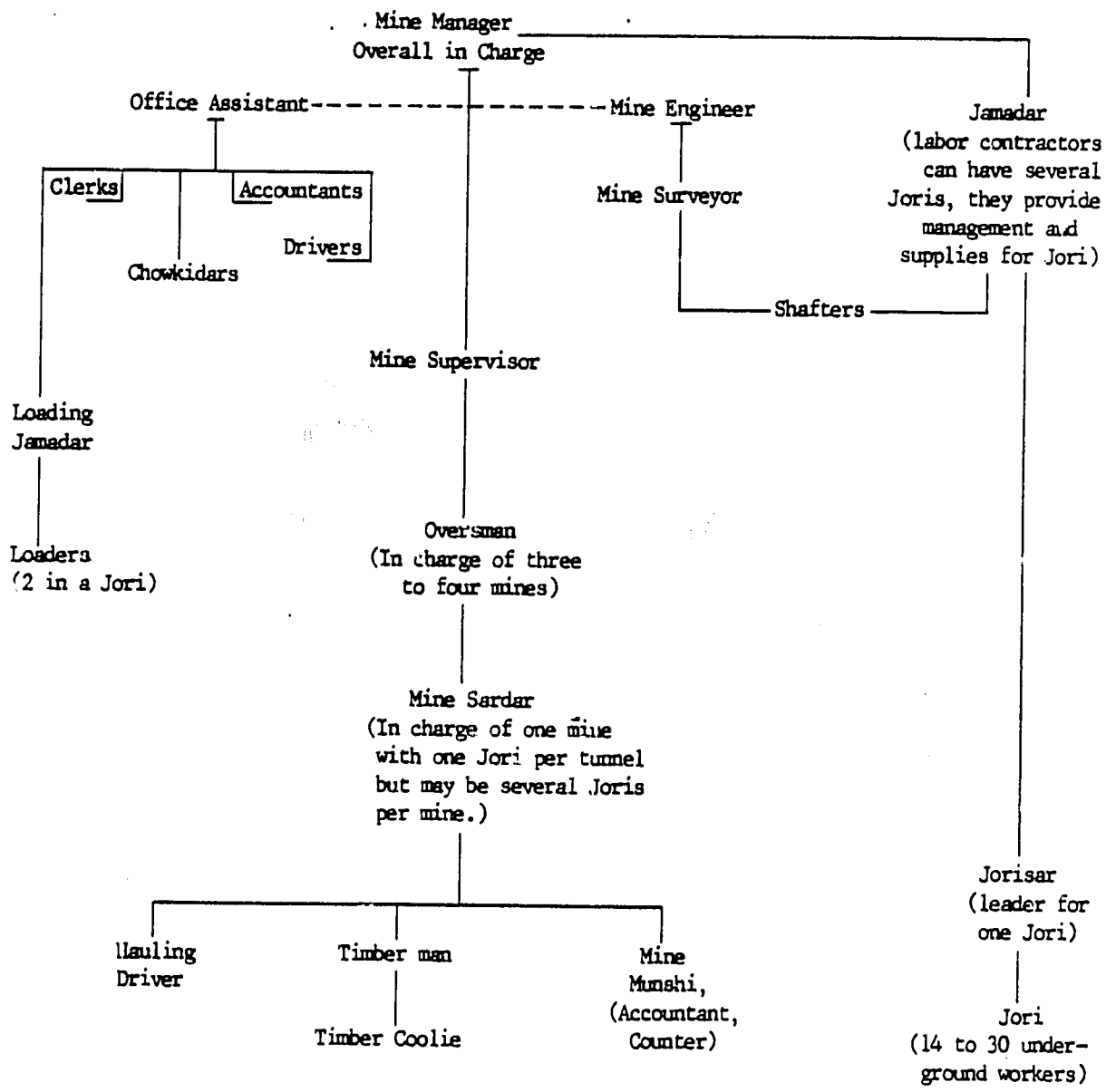


Figure 3.3-2
MINE ORGANIZATION CHART

SOURCE: HELWEG, 1985.

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For construction work, mistris act as central labor contractors equivalent to the mining industry jamadars.

Economy

Agriculture and Forestry--The economy of the study region is primarily agricultural. Sixty-seven percent of the Dadu population is involved in agriculture. Over half the people work at occupations classified as agricultural, animal husbandry, forestry, hunting, or fishing.

In the arid areas most of the rural farmers are growing maize or sorghum. Near dry riverbeds or on gradually sloped terrain, vegetables are grown behind coarse grass windbreaks.

This is a subsistence economy with little or no commercial agriculture. There are nearby urban markets for agricultural produce, such as the weekend market at Hala in the Hyderabad District, but it is presumed that the crops brought to these markets are grown nearby and not brought in from the more remote rural areas. Most of the region's cultivated land is east of the Indus River.

The major truck stops at Kotri and Jamshoro provide goods and services to the entire region. They occasionally retail fresh agricultural produce, mainly fruits and vegetables, which may be brought in by entrepreneurs operating along the Indus Highway.

Cutting acacia trees for mine timbers and other trees for use in the furniture industry is a major economic activity in this region. Practically all of the natural forest has been destroyed, and most trees are now harvested from riverine second-growth forest reserves. As discussed in Section 3.3.1, extensive forest reserves occur along the Indus River north and south of Khanot. These areas provide timber for the Lakhra mines.



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Industry--Hyderabad is an industrialized city producing textiles, oil, soap, leather goods, tiles, brick, glass, footware, bangles, and carpets. In 1980 Hyderabad had 156 registered industrial units. The Zeal Pak Cement Industries limestone quarry in Hyderabad is the largest in Pakistan.

The Dadu District has a smaller industrial base with 43 units registered in 1981 (Pakistan Population Census Organisation, 1983a,b).

Lakhra coal is a vital component of the integrated industrial economy. The one million tons of coal mined at Lakhra each year fuels brick kilns throughout Pakistan. The owners of Lakhra's largest coal companies are members of Pakistan's top 22 industrial families.

Mining--The economy of the Lakhra area is dominated by the activity associated with the existing coal mines. Figure 3.3-3 describes the economic system of these areas. The Lakhra economic system is an important part of the integrated economic system which extends north to Gilgit, east to Lahore, and south to Karachi. The 8,000 coal cutters from NWFP and 1,000 from Kashmir support approximately 45,000 people in their home regions by remitting Rs 180 million per year. To a lesser extent the mines provide important economic input to the local economies.

Commerce--The Lakhra commerce system is driven by the coal mines at Lakhra. Figure 3.3-3 depicts the flow of goods and services associated with the mine. Both local and regional economies exchange goods and services with the coal fields.

Coal from the Lakhra mines is mostly purchased by independent marketing agents. Unlike prices of other strategic products, coal is not regulated by the Pakistan government. Lakhra coals are cheaper to mine compared with coal mined in the mountainous regions of Baluchistan and Punjab but the latter is preferred by kiln operators because of its quality.



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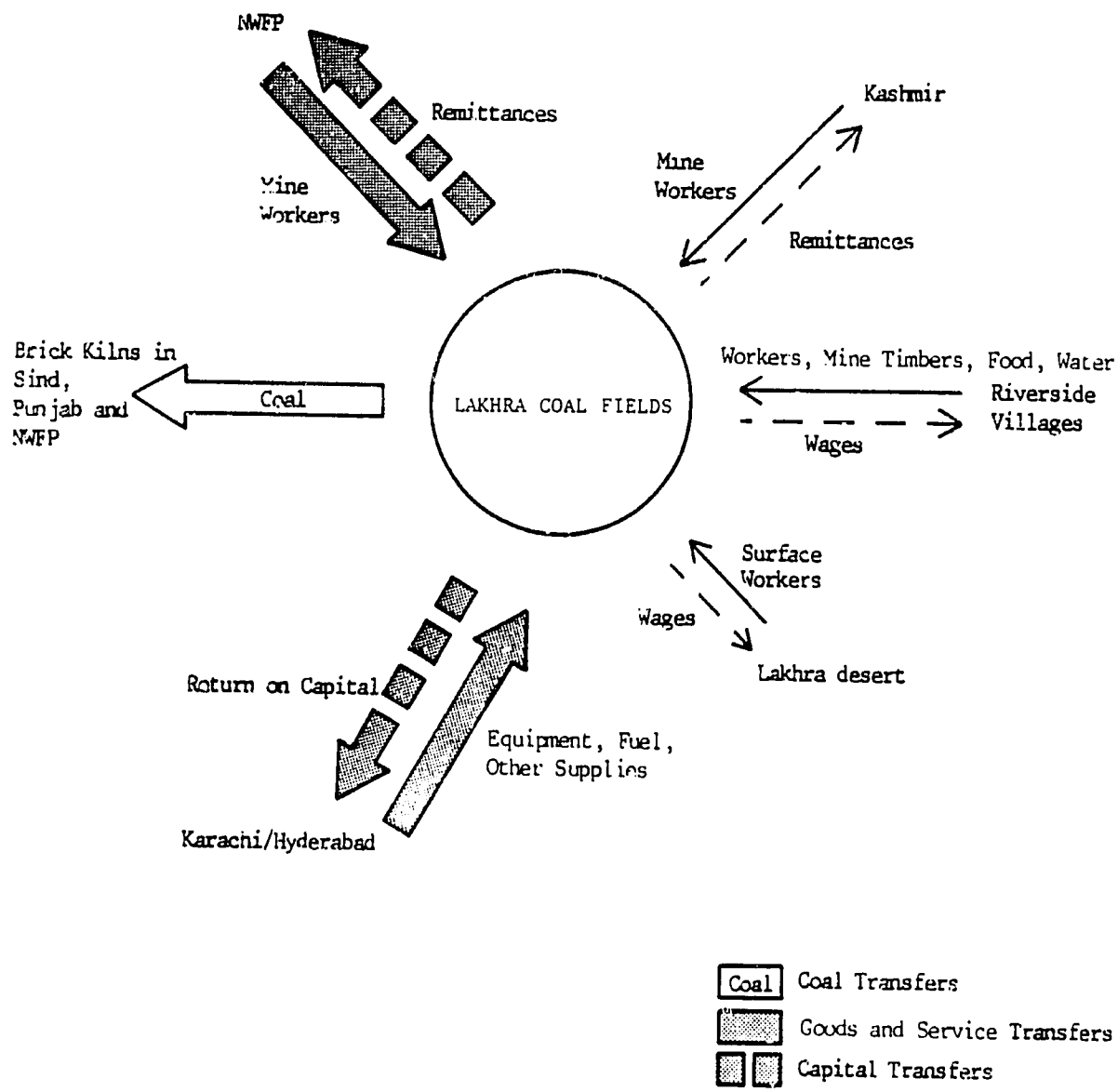


Figure 3.3-3
LAKHRA ECONOMIC AND COMMERCE SYSTEM

SOURCE: MODIFIED FROM HELWEG, 1985.

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Current coal production is estimated to be 800,000 MT/yr and could exceed 1,000,000 MT/yr (J.T. Boyd Company, 1986).

Quantitiative information is not available on the other economic activities in the area. Labor, mine timbers, food, and water flow from the riverside villages, agricultural areas, and reserve forest. Mine equipment parts, fuel, and other supplies come from Karachi and Hyderabad. Truck stops, shops, etc., along the Indus Highway and in the villages act as intermediate points for some of the commerce.

### 3.3.2.3 FACILITIES AND SERVICES

Housing

Seventy to eighty percent of the dwellings in the area are small, one-room houses. These are generally very crowded, with an average of seven people per housing unit. Eighty to ninety percent of the homes are owned by the residents.

Most homes use kerosene for lighting and wood and/or brush for fuel (Pakistan Population Census Organisation, 1983a,b). Traditional homes are frequently cooled by a curved roof ventilator that funnels air into the home.

The mining companies discourage miners from bringing their families so as to minimize building and daily overhead living costs; however, because of strong social and family responsibilities in their home district, workers from the NWFP and other northern areas do not make permanent moves to Lakhra with their families. Such responsibilities include providing for their parents and other family members, arranging for their security in old age, and meeting social obligations. Also, as discussed previously, only rudimentary housing is provided to accommodate an all-male communal living arrangement (see Figure 3.3-1). The "jori" system is well-adapted to these constraints upon mine colony living.



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Health and Nutrition

There are many serious health problems in the study area because the people generally have inadequate nutrition, overcrowded housing, debilitating work conditions, and poor access to health care.

Gastrointestinal ailments, including parasitic diseases, are the most frequent cause of severe illness (United Nations Center for Regional Development, 1981). Upper respiratory ailments are occupational hazards of subterranean mining particularly in the winter. Such problems are compounded by the dusty air in the Lakhra area, where wind speeds range from 9 to 13 meters per second (20 to 30 miles per hour).

Underground working conditions are difficult due to the high temperature and humidity, lack of mechanical ventilation, and strenuous physical demands of the work. During mine visits in February, underground temperatures of 28 to 35° centigrade (83° to 95° Fahrenheit, dry bulb) were measured at a relative humidity of 73 percent to 82 percent. Surface temperature was 30 to 35°C (86°F to 95°F), with a relative humidity of 25 percent to 34 percent. During the summer months, surface temperatures can exceed 49°C (120°F). The unfavorable underground environment results in reduced productivity, and the extreme summer temperatures contribute to the seasonal loss of miners.

Information on the nutritional status and health-related behavior of the populations of the Kotri Taluka was not available. Public health information such as unsafe water, ignorance of sanitation, overcrowding, and occupational stresses is not available.

Lakhra and Khanot do not have a comprehensive-care clinic. Two of the larger companies in the Lakhra area have onsite dispensaries each staffed with a local doctor. Other health care facilities in the area are minimal. A medical dispensary at Khanot is run by the Labor Department for miners but without a medical doctor. A basic health unit is to be

completed at Khanot in June 1987. This unit will include outpatient department services and maternal and child health care, including two maternity beds and one labor room. The unit is planned to serve the existing surrounding population (Dr. Sajjan Memon, Director of Health Services, Government of Sind, 1986, personal communication).

Water and Sanitation

The Indus River is the major supply for agricultural and domestic water uses in the region. The major drainage system is a non-perennial system, the Lakhra Nala, which flows from the northeast to the south where it enters the Indus River. During the monsoon season it occasionally is a source of water.

Fresh water is a scarce strategic commodity in the drought-prone Kotri Taluka. There are several water holes in the region, but the water is generally too brackish to be potable.

There are no wells and no piping or plumbing for water supply or wastewater disposal at either Khanot or Lakhra. Indus River water is delivered by tanker trucks, transferred into large drums/barrels and distributed by truck. Water is commonly poured into large, centrally located cement holding containers for communal use. In past years, private companies dispensed waters in these drums to placate bandits (Helweg, personal communication, 1986). Private mining companies still distribute water by drums in the arid areas to maintain good public relations and good will.

The water is untreated and potentially contaminated with water-borne pathogenic organisms. Water-related diseases are particularly likely where water is impounded for a long period and/or used frequently by many people.



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Security

The Khanot Police Department is headed by one sub-inspector known as the "Station House Officer." There is 1 assistant sub-inspector, 1 head constable desk officer, 4 head patrol constables, 1 constable desk officer, and 20 patrol constables, for a total of 28 men on the police force. One assistant sub-inspector, two head constables, and eight constables are stationed in the Lakhra coal fields.

The monitoring and control of professional banditry ("dacoity") in Pakistan has been the responsibility of the Provincial government. Dacoit activity is prevalent in the Lakhra area. The roles of the police with respect to dacoit operations ("sweeps") in the Kotri Taluka are complex and controversial.

Education

The literacy rate is estimated to be around 25 percent in Sind Province (Pakistan Population Census Organisation, 1983a,b). In Kotri Taluka, the reported literacy rate is 28 percent which consists of a literacy rate of 36 percent for males and 17 percent for females. The rural literacy rate in Kotri Taluka is reported to be 24 percent (32 percent for males and 11 percent for females).

There are 950 primary schools, 52 middle schools, and 25 high schools in Kotri Taluka with an estimated enrollment of 66,000, 3,500, and 11,700, respectively, in 1980-81. Liaquat Medical College is located in Jamshoro; and Sind University, which has an approximate enrollment of 5,000 students, is located nearby.

The two Government of Sind primary schools serving the Khanot area offer grades one through five. They have a total enrollment of 90 students.

Average education of the miners in the Lakhra area was reported at 5 years or less. The labor contractors, mine management, and technical staff average 10 years of formal education.

### 3.3.2.4 TRANSPORTATION

The study area is bisected by the Indus Highway, a paved road which is part of the main highway connecting Karachi and Peshawar (see Figure 3.2-1). North/south transport of equipment, goods and travelers, including workers, is via the Indus Highway.

Estimated travelling distances between selected points are: Khanot to Hyderabad (45 km); Khanot to Karachi (160 km); Khanot to Guddu (300 km); and Khanot to Lakhra area (15 km).

The Indus Highway is an 5.5 m (18-foot)-wide, asphalt-paved road running north-south on the west side of the Indus River valley from Kotri and Jamshoro on the south through Khanot to Dadu, Larkana, and Shikarpur to the north. At Jamshoro, the Indus Highway connects to the segment of the National Super Highway between Karachi and Hyderabad on the east side of the Indus River valley. The latter highway normally carries more traffic than the Indus Highway. However, a 6-year repair/renovation program is underway which includes both the Kotri Barrage and the National Super Highway north of Kotri and Hyderabad. Until the program is completed, heavy loads are diverted to the Indus Highway.

Improvements to the Indus Highway are also planned. The Sind Department of Highways has developed plans, specifications, and cost estimates to expand the Indus Highway to a full 7.3-m (24-ft) lane width and upgrade the load-carrying capacity to 10,000-kilogram (22,000-lb) axle loading. An application has been made to the Government of Pakistan for funding of the project. As a first step, the Indus Highway was recently proclaimed to be a part of the National Super Highway System. Improvement of the road will benefit the Lakhra Project for the movement both of materials and workers.

Traffic counts on the Indus and National Super Highways were made in early 1986, but the data are not yet available. Estimates by GCII and information from the local police offices indicate that from 2,500 to



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4,000 vehicles a day use the Indus Highway between Jamshoro and Khanot. Between Karachi and Jamshoro an estimated 10,000 to 12,000 vehicles a day use the National Super Highway. About 45 percent of these vehicles are trucks, 45 percent are automobiles, and 10 percent are buses (GCII, 1986).

The two-lane Indus Highway passes through Khanot; it is serviceable here, but wider and better graded from Jamshoro to Petaro. During peak mining periods, up to a thousand 10-ton trucks per day transport coal over these roads. The road is maintained by the Pakistani Department of Transportation. There is some heavy equipment that is used in building new sections of road or repairing old ones. However, as in the case of existing coal mining operations, much of the highway labor is done by hand.

There are two major truck stops on the Indus Highway (Khanot and Kotri) in this region. The truck stops at Kotri sell gas, diesel fuel, and provide engine repair services.

Motorized transport involves buses, vans, trucks, cars, and motorcycles. Hundreds of generally overcrowded buses can be counted daily on the Indus Highway. Non-motorized modes of transport include a variety of large domestic animals (horses, camels, oxen, donkeys, etc.) that are either ridden or pull two-wheeled carts carrying passengers and/or goods.

Although the police at Jamshoro and Khanot estimate the actual number of vehicle accidents is probably one each day, only one fatal accident is reported each year. Poor driving skills and vehicle quality, as well as the mixing of motorized and animal traffic on the same roadways, is inherently hazardous.

Rail service is provided via a single-line, broad-gauge track of the Pakistan Railways which runs parallel to the Indus Highway, passing through Khanot. A rail station exists in Khanot.

The closest airport is at Hyderabad which has scheduled service by Pakistan International Airlines. The Pakistani government does not allow non-government operated airstrips.

3.3.2.5 MINE SAFETY

Although fatal and serious injury of mining workers due to accidents in the Lakhra mines occur on a frequent basis, not all accidents are reported to the Sind Inspectorate of Mines (1985). Injuries reported to the Sind Inspectorate of Mines in 1982 and 1983 for an estimated annual production of about 0.57 and 0.64 million metric tons, respectively, are:

| | 1982 | 1983 |
|---|---|---|
| Underground Accidents | | |
| Fatalities | 4 | 7 |
| Serious Injury | 17 | 29 |
| Surface Accidents | | |
| Fatalities | 3 | 13 |
| Serious Injury | 30 | 65 |

The increase between 1982 and 1983 is believed by the Inspectorate of Mines (1985) to be a result of better reporting, not an actual increase in accidents. The causes of the underground accidents include roof failures, rock falls, suffocation (from $CO_2$, CO, and $H_2S$), and hoisting of coal. Surface accidents include accidents involving loading and hauling of coal, blasting, highwall failure, and crushing operations. The rate of fatal and serious injury for 1983 was reported to approach 200 per million metric tons of coal mined. The actual injury rate is, however, probably much higher (Inspectorate of Mines, 1985).

Use of safety equipment and protective clothing is limited to hard hats available to mine management and visitors. Because of the high temperatures and humidity, typical clothing of the workers is limited to Chardi (knee-high cotton pants) and many workers are barefoot (J.T. Boyd Company, 1986.)

Neither a standard operating procedures manual nor a skilled team of employees for firefighting exist at the mines. Safety or job-related training programs do not exist at any of the Lakhra mines.

# 4.0 ENVIRONMENTAL IMPACT OF THE PROPOSED PROJECT

## 4.1 INTRODUCTION

The Lakhra Coal Mine and Power Plant project will produce environmental impacts to the physical, biological, and social resources of the Lakhra area. These environmental impacts, however, will vary in areal extent, duration, and significance. The four sections that follow present a detailed discussion of the expected environmental impacts of the preferred mine [combination of under ground mine ($0.3 \times 10^6$ MT/yr) and surface mine ($2.4 \times 10^6$ MT/yr)] and power plant (two 250-MW units without $SO_2$ scrubbers located at Lakhra). Section 4.2 presents the impacts due to mining, and Sections 4.3 and 4.4 present the environmental impacts because of the construction and operation of the power plant complex. The final section, Section 4.5, presents an overview of the combined impacts of the project.

For many of the significant impacts presented in this section, mitigations have been recommended and are summarized in Section 6.0.



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## 4.2 MINING IMPACTS (AND WORKERS COLONY)

### 4.2.1 PHYSICAL ENVIRONMENT

#### 4.2.1.1 AIR

The objective of the air quality impact analysis was to evaluate the maximum ground-level concentrations using atmospheric dispersion modeling for comparison with the air quality levels recommended by the World Bank and to assess the significance of adverse impacts to agricultural areas. In order to perform an air modeling analysis, meteorological data representative of the plant site area were used to properly account for the transport and diffusion of the plant's emissions. Model calculations were performed on an hourly basis from which other averaging-period concentrations were developed (e.g., 3-hour concentration is based on three 1-hour concentrations). A complete discussion of the dispersion model used, the meteorological processing procedures, and modeling methodology is presented in Appendix F.

For the mine, the major air pollution impact will be caused by fugitive dust emissions. The magnitude of emissions and resulting environmental impact depends upon the type of mining (underground versus surface); the type of activities (hauling, blasting, overburden removal, lignite mining, etc.); and the amount and type of material being handled.

To provide a conservative estimate of air quality impacts, information from J.T. Boyd Company (1986) was used to develop an extensive emission inventory based on an annual coal consumption of 3,071,000 MT. The East Pit and West Pit would supply 2,000,000 MT and 745,000 MT of lignite annually, respectively. The underground mine would supply 326,000 MT/yr. An annual lignite consumption of $3.1 \times 10^6$ MT was used in the air quality analysis because of the following factors:

1. The information available from J.T. Boyd Company for this option was sufficiently detailed to make reasonable estimates of emissions,

2. Analyzing a 2.7 x $10^6$ MT/yr surface mine would be analogous to an all-surface mine for two 250-MW units, and
3. An estimate of fugitive impacts would be conservative based on any combination of surface and underground mining ultimately selected.

A complete discussion of the derivation of fugitive dust emissions from mining is presented in Appendix I. Table 4.2-1 summarizes the fugitive emissions for the mine and lignite hauling.

The results of the air quality impact analysis due to fugitive dust emissions are presented in Figures 4.2-1 and 4.2-2 for total suspended particulate matter (TSP) for the 24-hour and annual averaging times, respectively. Maximum concentrations of TSP are shown in Table 4.2-2 for the areas at the boundary of the pits. Contributions from the various source areas to the maximum 24-hour concentrations are presented in Table 4.2-3.

Calculated impacts presented in Figures 4.2-1 and 4.2-2 and Tables 4.2-2 and 4.2-3 did not include consideration of natural background particulate matter. Measurements at the air-monitoring station located within the Lakhra project boundary indicate an annual average 24-hour concentration of about 200 $\mu g/m^3$ with maximum 24-hour concentrations near 550 $\mu g/m^3$ (see Table 3.1-3). These data would suggest that a background concentration of 200 $\mu g/m^3$ may be appropriate for Lakhra, which is consistent with expected air quality levels in such an arid environment.

The results of the air quality impact analysis, coupled with estimated background concentrations, indicate that areas with predicted concentrations exceeding 300 $\mu g/m^3$ on a 24-hour basis, would exceed the criteria of 500 $\mu g/m^3$. These areas (see Figure 4.2-1) are generally confined to the south and east of the East Pit area. Predicted annual average TSP concentrations due to mining activities alone exceed the



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Table 4.2-1. Annual Fugitive Emissions of Total Suspended Particulate for Lakhra Coal Mine

| Source | Amount of Lignite Mined and Handled (MT/yr) | Amount of Overburden Moved (MT/yr) | Annual Emissions (kg/year) |
|---|---|---|---|
| East Pit | 2,000,000 | 68,200,000 | 13,126,191 |
| West Pit | 745,000 | 17,400,000 | 2,900,085 |
| ROM/UG Mine/ Power Plant | 3,071,000 | --- | 67,728 |
| Total | | | 16,094,004 |

Source: KBN, 1986.



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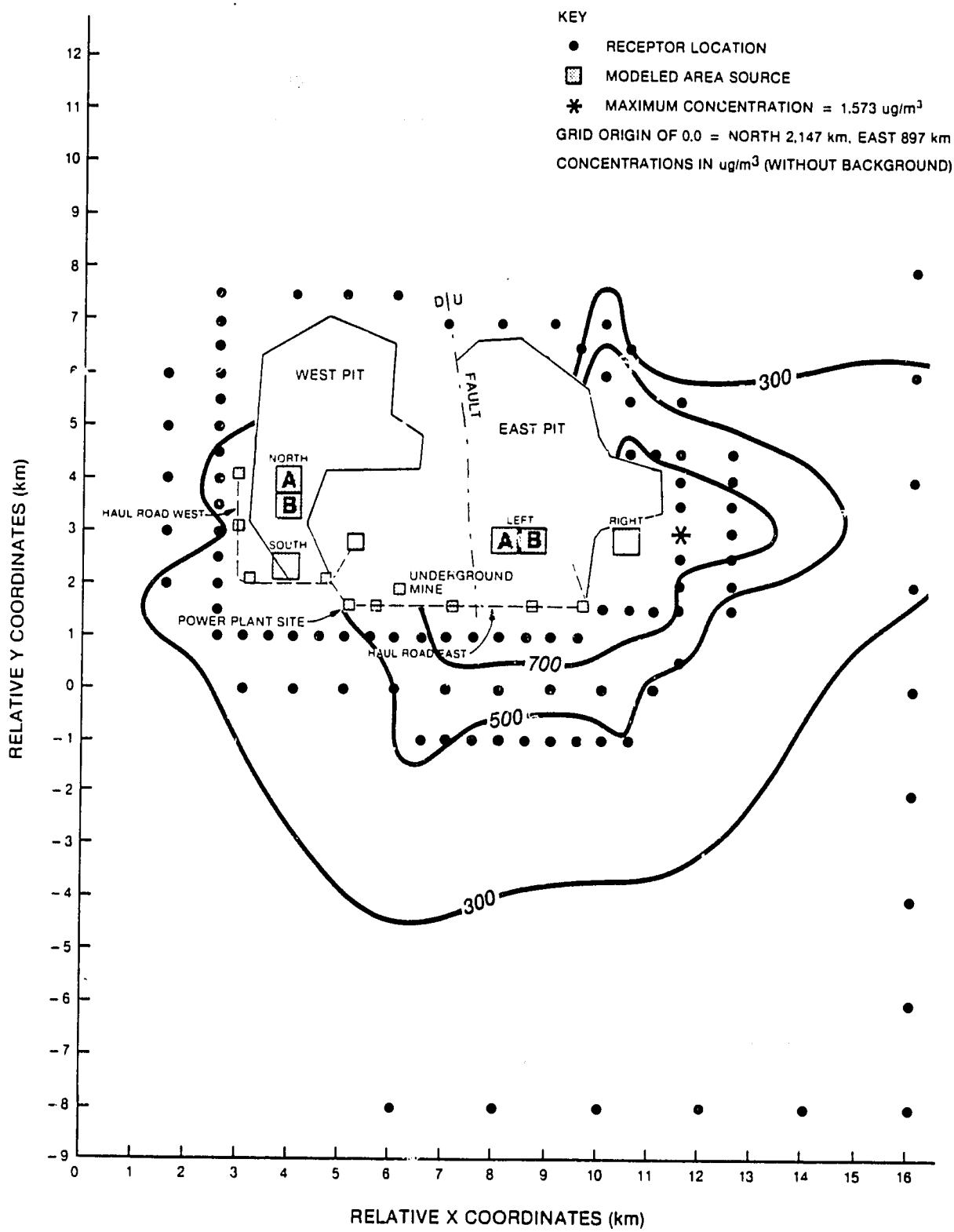


Figure 4.2-1
MAXIMUM PREDICTED 24-HOUR TSP CONCENTRATIONS, $3.1 \times 10^6$ MT/YEAR MINED

SOURCE: ESE, 1986.

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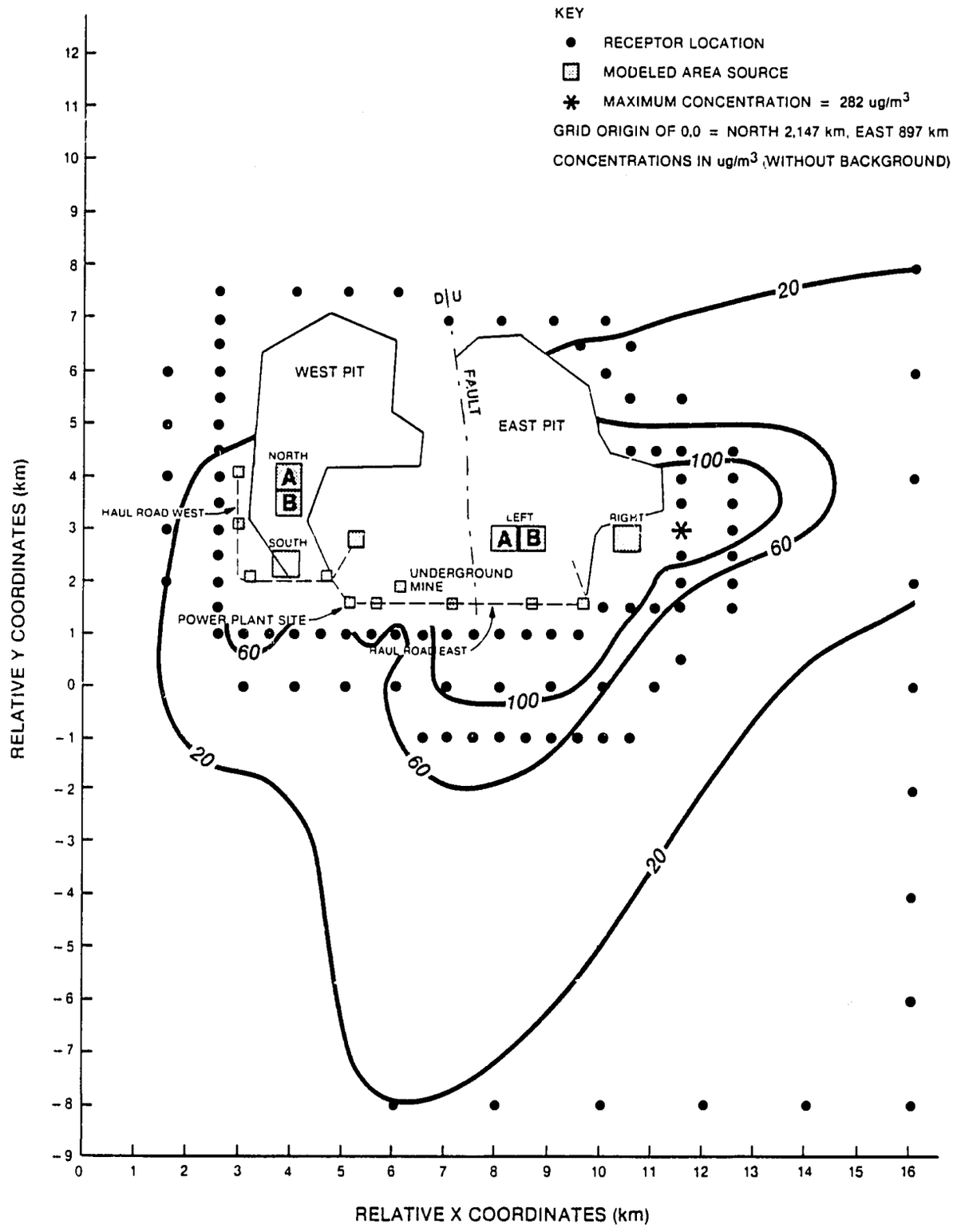


Figure 4.2-2
MAXIMUM PREDICTED ANNUAL AVERAGE TSP CONCENTRATIONS, $3.1 \times 10^6$ MT/YEAR MINED

SOURCE: ESE, 1986.

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Table 4.2-2. Maximum TSP Concentrations Due to 3.1 x $10^6$ MT/yr Mined at Various Locations Near the Proposed Mine Site

| Area | Maximum Concentrations ($\mu g/m^3$) for Averaging Periods* | |
|---|---|---|
| | 24-Hour | Annual |
| East of East Pit | 1,573 | 282 |
| South of East Pit | 1,557 | 276 |
| South of West Pit | 522 | 71 |
| West of West Pit | 451 | 49 |
| North of West Pit | 173 | 8 |
| North of East Pit | 1,098 | 84 |

*Predicted concentration without background which was estimated from monitoring data to be 200 $\mu g/m^3$.

Source: ESE, 1986.



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Table 4.2-3. Source Contribution to Maximum 24-Hour Concentrations

| Source | Concentration ($\mu g/m^3$)* South of East Pit | East of East Pit |
|---|---|---|
| East Pit-Left | 85 | 449 |
| East Pit-Right | 1,405 | 1,063 |
| West Pit-North | 7 | 4 |
| West Pit-South | <1 | 32 |
| Haul Roads-East Pit | 59 | 20 |
| Haul Roads-West Pit | <1 | 5 |
| ROM | <1 | <1 |
| Underground Mine | 0 | <1 |
| Plant Material Handling | <1 | 0 |
| Total: All Sources | 1,557 | 1,573 |

*Predicted concentration without background which was estimated from monitoring data to be about 200 $\mu g/m^3$.

Source: ESE, 1986.



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criteria of 100 $\mu g/m^3$ annual average only in some areas south and the cost of the East Pit area. However, even without the project, the currently observed TSP concentrations exceed the annual average criteria of 100 $\mu g/m^3$. The modeling results are based on the early development of mine where impacts would be closest to the existing mine colonies. As the mining activities at the surface mine progress toward the north, especially for the East Pit, TSP concentrations would decrease at the southern and eastern boundaries. The total estimated impacts (model results plus background) probably are a conservative representation of actual impacts and effects for three reasons: First, model predictions may be overestimated. Recent preliminary air quality analyses and correlations performed for the existing open pit lignite mine within the Mae Moh Power Development Project (operated by Electricity Generating Authority of Thailand) found that TSP impacts were overestimated by about a factor of 4 (ESE and KBN, 1986). These preliminary analyses and correlations performed in Thailand used onsite ambient air quality and meterological data and the same emission estimating techniques and air dispersion models used in this study. Second, the impacts presented in Figures 4.2-1 and 4.2-3 reflect total suspended particulate matter, much of which is not respirable. Adjusting for respirable particulate matter (particles $\leq$10 microns) using information published by EPA (AP-42) and a smaller surface mine (i.e., 2.4 x $10^6$ MT/yr), calculated concentrations (without background) above the criteria of 500 $\mu g/m^3$ 24-hour average and 100 $\mu g/m^3$ annual average will occur only at/or within the Pakistan Mineral Development Corporation (PMDC) boundary (see Table 4.2-4). Because of large particle (i.e., >10 micron) settling, concentrations of TSP at 5 km beyond the PMDC boundary would approach that of the background values observed previously (see Table 3.1-3). Finally, the background TSP concentration of 200 $\mu g/m^3$ also include settleable particulates and may not occur during the same meterological conditions as those predicted by modeling to cause maximum concentrations.



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Table 4.2-4. Maximum Estimated 24-Hour Average Concentrations of Respirable Particulate Matter at Various Locations Near the Proposed Mine Due to Emissions from a 2.4 x $10^6$ MT/yr Surface Mine and 0.3 x $10^6$ MT/yr Underground Mine

| Area | Maximum Estimated Concentration* ($\mu g/m^3$) |
|---|---|
| East of East Pit | 504 |
| South of East Pit | 498 |
| South of West Pit | 167 |
| West of West Pit | 144 |
| North of West Pit | 55 |
| North of East Pit | 351 |

*Predicted respirable particulate without background; the amount of respirable particulate from background is unknown.

Source: KBN, 1986.



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4.2.1.2 NOISE

Noise resulting from the mining activities will be attenuated due to hemispherical spreading, atmospheric molecular absorption, and surface features. These concepts are discussed in greater detail in Section 4.4.1.2.

For the Lakhra coal mine, J.T. Boyd Company (1986) performed a baseline noise survey and an impact analysis from mining activities consisting of a 3.8 x $10^6$ MT/yr surface mine and 0.3 x $10^6$ MT/yr underground mine. The results of this analysis indicate that the predicted time-weighted average ambient noise levels (Leq) would be substantially less than the World Bank Guidelines of 70 dBA (i.e., 55 and 59 dBA at the Lakhra Mine Colony and at the Faiz and National Mine Colonies, respectively). The predicted day-night noise levels (Ldn) were estimated to be slightly higher than the suggested guideline of 55 dBA for residential environment, i.e., 61 dBA and 65 dBA for the Lakhra Mine Colony and Faiz and National Mine Colonies, respectively. Because these impacts are for a much larger mine than currently planned, it is anticipated that noise levels will be lower. Noise impacts to non-mine colony residences will be well within the project's noise criteria since the mine will be more than 20 km (12 miles) from any villages.

4.2.1.3 LAND AND WATER RESOURCES

Any adverse impacts to surrounding land and water resources because of an underground or surface mine can be eliminated through the proper handling and disposal of wastes. Of particular concern are the following potential impacts associated with underground and surface mining activities:

1. Acid mine drainage,
2. Solid wastes,
3. Alteration in land forms and increased soil erosion and runoff/runon,
4. Change in drainage,

5. Change in surface water quality, and
6. Change in ground water quality.

The potential impacts from the Lakhra mine because of these potential impacts are discussed in the following paragraphs.

Acid Mine Drainage

The principal environmental pollutant resulting from underground coal mining operations is acid mine drainage. The amount and rate of acid formation and the quantity of water discharged depends on the amount and type of pyrite in the overburden and in the coal, time of exposure, characteristics of the overburden, and amount of available water. At Lakhra, the amount of available water is scarce (as discussed in Section 3.1.2), which therefore suggests that mine drainage will not be a major problem at Lakhra. Nevertheless, controls will be provided in the form of pumps, pipe, and auxiliary equipment that are necessary to pick up and dispose of the water that might be generated as the mine develops. Such a rapid and positive method of removing water from the face areas provides better working conditions and minimizes the overall water handling cost for the mine (J.T. Boyd Company, 1985).

Any mine drainage water that is pumped to a sump or other collecting facility will be used for roadway spray water or discharged to the evaporative pond for disposal. As a result, no adverse impacts to ground or surface waters are predicted as a result of mine drainage.

Solid wastes are generated both during underground mining and during the preparation process The solid waste from underground mines (commonly referred to as "gob") results from the digging required to reach the coal seams. In-seam parting material (clay and shale) exceeding 15 cm in thickness is selectively removed at the face. To minimize spontaneous combustion, this reject material is either hauled to the surface

(approximately once per week, when no lignite is being transported on the conveyor system) or transported to a mined-out section of the mine and sealed in the gob area.

If hauled to the surface, steps will be taken to ensure that leachate and surface runoff from the piles will not cause harm to the surrounding environment. Water collected from the piles can be treated with lime and/or discharged to evaporative ponds. In addition, piles which contain acid-producing materials can be isolated from the surface with topsoil or neutralizing materials. As these measures are implemented, no adverse effects to land and water resources are expected from the solid wastes.

Water usage in the surface mining operations is small compared to that used for coal-fired power generation. Water is used primarily for dust suppression (along haulroads, conveyor belts, and stockpiles) and for equipment cooling. Water entering disturbed areas from precipitation, ground water infiltration, and surface runoff is a hindrance to the efficiency and safety of a mining operation (unless it is beneficially reused for dust suppression or irrigation).

Wastewater handling is a primary concern in the operation of a coal mine. Unless handled properly, contaminated wastewaters can have an adverse effect on the environment. Sources of wastewater include precipitation, surface runoff, and ground water infiltration over mined areas.

Potentially negative effects are also associated with the large land areas disturbed during the mining process. The site characteristics and characteristics of the surrounding areas (e.g., land use) are factors which must be considered both during the operation of the mine and after mine closure. If proper mining techniques are employed (e.g., minimized erosion through diversion of runon), the reclamation required after operations cease can be minimal.

Alteration in Land Forms and Increased Soil Erosion and Runoff/Runon

Surface mining operations, like all other large-scale, earth-moving operations, have the potential to generate large volumes of sediment. As long as the sediment generated is contained on the mining site, it does not present a problem; however, if it washes into neighboring water-courses, it becomes a pollutant. Adverse impacts associated with sediment-laden runoff include clogged stream channels, degradation of drinking water supplies, and settlement on productive land. The absence of waterways and productive land at the Lakhra site (except during the monsoon season) reduces the potential for adverse impacts from runoff or sediment deposition. Nevertheless, measures must be taken to minimize erosion and surface water degradation to areas surrounding the mine site.

Stormwater runoff is a principal cause of soil erosion at the Lakhra site. The drainage basins in the vicinity of the Lakhra coal project indicate that surface water flows toward the south in the east pit area and toward the southwest and west in underground and west pit areas. Table 4.2-5 lists the estimated surface runoff from each basin resulting from the 30-year, 24-hour precipitation event.

Stormwater runoff control is achieved through structural practices and construction measures that control the location, volume and velocity of runoff. Use of vegetation for runoff control is not applicable to the Lakhra site, where vegetation is sparse and soils are incapable of supporting the required vegetative growth. Proper stormwater handling for erosion control will be accomplished in the following ways:

1. Reduction and retention of the runoff,
2. Interception and diversion of runoff, and
3. Proper disposal and handling of concentrated flow.

A reduction in both the amount of runoff and its speed of movement will be accomplished by staging the operations to reduce the time and area of exposure. In conjunction with the staged operations, dikes and ditches

Table 4.2-5. Surface Runoff Drainage Areas Near East and West Pits: 30-Year, 24-Hour Precipitation Event

| Watershed | Area (ha) | Peak Runoff | | Total Runoff | | |
|---|---|---|---|---|---|---|
| | | cusecs | $m^3$ | ac-ft | in | mm |
| East Pit | | | | | | |
| A | 2.552 | 1,718 | 815,600 | 661 | 1.2 | 30.5 |
| B | 97 | 90 | 31,600 | 26 | 1.2 | 30.5 |
| C | 76 | 67 | 24,500 | 20 | 1.2 | 30.5 |
| West Pit | | | | | | |
| D | 473 | 375 | 151,500 | 123 | 1.2 | 30.5 |
| E | 214 | 178 | 68,700 | 56 | 1.2 | 30.5 |
| F | 109 | 98 | 35,300 | 29 | 1.2 | 30.5 |
| G | 454 | 319 | 149,000 | 121 | 1.2 | 30.5 |
| H | 24 | 22 | 8,200 | 7 | 1.2 | 30.5 |
| I | 346 | 265 | 110,500 | 90 | 1.2 | 30.5 |
| J | 743 | 541 | 237,200 | 192 | 1.2 | 30.5 |

Source: J.T. Boyd Company, 1986.

will be used to intercept runoff before it reaches a critical area and divert it to a safe disposal area. To protect the East and West Pits from rainfall runon, these dikes/ditches will be designed to control peak runon from the 30-year precipitation event. These diversion structures may be used to direct water away from critical areas to fields used by Lakhra colony inhabitants and migratory herders. In addition, runon can be directed to impoundments and used as a water source for mine operations or irrigation. Construction of runon/runoff control devices is timed to coincide with the mining sequences planned for both surface mines (J.T. Boyd Company, 1985).

Construction of temporary diversion devices in advance of the highwall may be necessary to reduce the amount of runon entering the pit from areas downslope of the permanent diversion. Runoff from within the pit boundary will be greatest in the early years of mining and will continually decrease as mining progresses. Spoil piles will be graded to slope away from the pit to minimize runoff contributions into the pit.

The major sources of sediment in surface mining operations are areas being prestripped, roadways, spoil piles and areas of active mining, and areas being reclaimed.

Overburden removed from prestripping operations must be managed properly to avoid acid drainage or excessive sediment deposition to adjacent lands. The proposed mining plan includes a stacking sequence for overburden (i.e., limestone over acid-producing materials) which is expected to minimize potential acid drainage. The plan also includes the leveling and grading of spoil windrows as part of reclamation. These measures will reduce the likelihood of excessive sediment deposition to adjacent lands. As a result, no adverse impacts are expected from spoil piles resulting from prestripping and production mining operations.

Roadways are a major source of sediment from surface mining operations, as well as a conduit for sediment washing down from other areas of the mine into the natural drainage system. At Lakhra, excessively steep grades will be avoided to minimize the sediment concentration and flow velocity of the runoff, and also to allow the safe movement of trucks out of the mine. A surficial material, such as crushed stone, can be used to isolate the soil from the erosive action of water, wind, and traffic. The adjoining drainageways should receive regular maintenance (e.g., sediment removal) to ensure their integrity and efficiency.

Sediment-laden runoff from within the pit boundaries will be channeled to "zero discharge" structures (evaporative ponds) designed to impound runoff from the 30-year, 24-hour storm. Stormwater will either percolate into the water table or evaporate to achieve zero discharge.

Rainfall on the coal storage pile is potentially acidic due to the pyrite and moisture content of the coal. The sulfur in pyrite and moisture can combine to form sulfuric acid. Although the acidity value for stockpile runoff is high ($H_2SO_4$ concentration of 10,300 mg/L in the runoff from a 103 cm rainfall), the quantity of runoff is low and may be treated by conventional lime addition, or discharged into evaporative ponds (J. T. Boyd Company, 1985). Also, the short storage time of the coal (to minimize spontaneous combustion) and the infrequent occurrence of rainfall minimizes the necessity to treat acidic runoff from coal stockpiles.

After these runoff control measures are implemented at the Lakhra site, no adverse impacts are expected from erosion, acid-drainage, or sediment deposition. Operation of the two mines will not involve the removal of substantial vegetation. Sparse ground cover (about 15 percent coverage) exists only during the rainy season; the remainder of the year there is little or no ground cover at the site. Therefore, runoff in the area will not be increased due to loss of ground cover.

Change in Drainage

The Indus River, located 20 km (12 miles) due east of the Lakhra coal field, is the nearest perennial watercourse. Several non-perennial river beds or streams located in the region transport water during short periods of the rainy season or following heavy rainfall events. Within the immediate vicinity of the mine area, Kath Buthi Dhoro forms the main drainage system in the East Pit Area and a portion of the Central Area (J. T. Boyd Company, 1985). Kath Buthi, including its tributaries, is a rain-fed stream sloping northeast at an approximate 0.5 percent gradient which eventually joins Nak Chhinni Nali and Mua Nala to form Bharni Nali. During the rainy season, a considerable amount of runoff may flow along Kath Buthi. Two non-perennial streams, the Kachhe jo Wah and the Bairan Wari Wah, terminate along the western boundary of the West Pit Area. The Bairan Wari Wah supplies water to seasonal inhabitants of Gath Sumro. Other small, unnamed drainages convey water to seasonal inhabitants to the northeast of the West Pit Area.

Mine operations will have no effect on the inflow to the Indus River, which is located 20 km (12 miles) due east of the site.

Significant impacts will occur to the local drainages located within the pit boundary; however, the effect will be limited to the portion of the East and West Pit being actively mined. Many of the drainages which are affected supply water to seasonal torrent-watered croppers; therefore, provisions must be made to replace the water supply depleted due to excavation.

Diversion techniques will be used to divert water away from the pit areas to fields used by seasonal inhabitants. Local drainages carry primarily silts and clays, which are also the expected constituents in runoff from the reclaimed land. Runoff which contains excessive sediment can be channeled to the evaporative ponds, which also receive inflow from the pit area and underground mine. As a result, no degradation in existing

water supplies is expected to occur as a result of surface mining operations.

Change in Surface Water Quality

During the rainy season, there is surface water flow in the Kath Buthi and its tributaries. As previous stated, surface water diverted away from disturbed areas can be beneficially used in mine operation or for irrigation purposes. This runoff is expected to contain primarily silt and clays, which are normally found in runoff during heavy rainfall events. The runoff from mined areas, which is potentially acidic and high in manganese and iron concentrations, will be neutralized as necessary and directed to the evaporative ponds. Acid drainage will be reduced by stacking limestone above the acid-producing materials excavated during mining. Since surface water is present only during periods of heavy rainfall, and runoff during these periods is expected to be properly managed, no adverse impacts to surface water quality are predicted as a result of mining operations.

Changes in Ground Water Quality

A field study program by J.T. Boyd Company was conducted to determine the availability, extent, and quality of ground water in the area of the proposed Lakhra mine. The study consisted of three separate, but related, tasks (J.T. Boyd Company, 1985):

1. Analysis of ground water conditions in the immediate study area;
2. Inventory of existing flooded mines in the vicinity of the Lakhra area, with a determination of water quality and quantity, and
3. Inventory of well water sources with a determination of quality and quantity.

The results of the study indicate that the occurrence of ground water at the elevation of mineable coal seams was low. Where ground water was encountered in drilling, it was found in small quantities. The inventory



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of flooded mines supported the drill program findings. The occurrence of water among the approximately 60 active mines in the area was infrequent; in addition, the wet mines generally produced less than 36 cubic meters per day.

Analysis of the mine water revealed that it is unfit as a potential drinking water source and for irrigation purposes. In addition, only one of seven mines sampled contained water which did not exceed any of the mine effluent limitations (see Table 1-2) for suspended solids (70 mg/L), manganese (4 mg/L), total iron (6 mg/L), and pH ($6 \leq pH \leq 9$).

Wells drilled in the alluvium of non-perennial streams in the Lakhra area provide a seasonal supply of water for local inhabitants. These wells generally become dry in the winter. It is assumed that the water to these wells is supplied by the percolation of runoff during the rainy season, rather than the subsurface movement of ground water. Therefore, the impact of mining operations on the quality of well water is expected to be minimal if contaminated surface waters are contained in evaporation ponds. Seepage from the evaporative ponds may move toward these streambeds; however, the existing data on ground water in the area indicate a low potential for this occurrence. No adverse impacts are predicted as a result of these ponds.

### 4.2.2 BIOLOGICAL ENVIRONMENT

As described previously, two types of mining are planned: underground and open pit. The activities associated with mining that affect ecological resources involve road building for mine site access, excavation, overburden removal, removal of lignite, transportation of coal, and transportation of workers and materials. The potential major impacts associated with these activities include:

1. Vegetation removal and loss of wildlife habitat,
2. Loss of future biological productivity,
3. Increased fugitive dust and effects on vegetation and wildlife habitat,
4. Increased road traffic resulting in increased wildlife road kills,
5. Increased access to less accessible natural areas,
6. Increased noise and effects to wildlife, and
7. Increased silting and sedimentation of acid-bearing materials including acid mine drainage and effects to fish and wildlife.

For this analysis the impacts of underground and surface mining are treated together since the differences in impacts are in degree.

#### 4.2.2.1 VEGETATION REMOVAL AND LOSS OF WILDLIFE HABITAT

Excavation, overburden removal, and coal removal from the surface mines will occur over 30 years and will remove the existing habitats in the area. Over the life of the mine 1,360 hectares (3,360 acres) of scrub forest vegetation and tropical plain thorn forest wildlife habitat will be disturbed. These impacts are not considered significant because of the large amount of undisturbed similar habitat in the area and the lack of uniqueness of this habitat and low productivity of this habitat. Specific wildlife species most directly affected will be fossorial reptiles and mammals such as geckos, lizards, skinks, and monitors as well as mice, rats, and gerbils. Desert monitors classified as



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endangered were observed at the Lakhra site; habitat for onsite populations will be lost as a result of mining operations. The habitat loss will not affect the status of the population in Sind. The species is endangered because of trade not because of declining habitat.

With the loss of vegetation, bird habitat on the site will be destroyed. If the carrying capacity is not high in surrounding areas, birds and other mobile wildlife whose habitat is lost will be displaced into surrounding areas. There will be population adjustments, but these losses and changes are not considered significant given the size of the unaffected wildlife populations in the area. A small amount of habitat will be lost to underground mining for construction of the mine entrance and associated administration and service buildings. This loss is not considered a significant impact.

#### 4.2.2.2 LOSS OF FUTURE BIOLOGICAL PRODUCTIVITY

The development of the Lakhra mines will result in the loss of the future biological productivity of these ecological communities, but this loss is negligible because of the remaining unaffected areas and the lack of uniqueness of these communities. The corridors constructed for the pipeline will have some future biological productivity through natural recovery but any losses because of partial restoration are not considered significant.

#### 4.2.2.3 INCREASED FUGITIVE DUST AND EFFECTS ON VEGETATION AND WILDLIFE HABITAT

The mining activities and the open mine pit will result in generation of fugitive dust which will affect surrounding vegetation. No losses to surrounding vegetation are expected because of the adaptation of native vegetation to similar natural conditions (i.e., dust storms and winds of the area). No effects to wildlife are expected in the areas immediately adjacent to the mining areas.



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#### 4.2.2.4 INCREASED ROAD TRAFFIC RESULTING IN INCREASED WILDLIFE ROAD KILLS

There will be increased road traffic from hauling of overburden material, lignite, and workers. The material and coal hauling is not expected to affect wildlife because the roads will be in disturbed areas with low likelihood of wildlife occurrence. The transportation of workers will lead to an increase in road killing of wildlife. Animal groups most likely affected are small mammals (rodents) and reptiles (snakes and lizards, including monitor lizards). No significant effects are expected, given the large population densities occurring in the region.

#### 4.2.2.5 INCREASED ACCESS TO LESS ACCESSIBLE NATURAL AREAS

The coal mining activities will contribute to increased access of motorized vehicles to less accessible areas. No undisturbed wildlife habitats are in the vicinity of the proposed mine site; however, it is likely that increased hunting will occur in the vicinity because of access. It is likely that larger animals generally intolerant of human activity, such as the Houbara bustard and desert cat which were previously common in the area, occasionally pass through the area. Such occasional use will decrease as the Lakhra region is developed. This impact is not considered significant because of the low habitat quality for these species.

#### 4.2.2.6 INCREASED NOISE AND EFFECTS TO WILDLIFE

Mining activities will lead to an increase in noise (see Section 4.2.1.2). Noise from equipment and occasional blasting will occur. Such activities are likely to disturb wildlife in the vicinity of the activity. This disturbance will be short-term and in the immediate vicinity of active mining. No significant effects to wildlife are expected.

#### 4.2.2.7 INCREASED SILTING AND SEDIMENTATION INCLUDING ACID MINE DRAINAGE AND EFFECTS TO FISH AND WILDLIFE

During periods of rainfall, silting and sedimentation of acid-bearing materials could occur. The amount and rate of acid formation and the quantity of water discharged will depend on the amount and type of pyrite in the overburden and in the coal as well as other factors. No aquatic resources occur in the areas and no impacts will occur. No significant wildlife impacts due to loss of habitat from silting or sedimentation are expected to occur.

### 4.2.3 SOCIAL ENVIRONMENT

In contrast to other resources, the impacts to the social environment are not as easily separated as discrete impacts either from the mine or from the power plant activities. The land clearing activities and the influx of workers are similar for both mine and power plant and differ only in extent and duration. For this reason, the principal discussion of impacts to the social environment by both the power plant and mine will be included in this section.

The proposed project will have profound effects on not only the social environment of the immediate Lakhra-Khanot area but the Kotri Taluka as well. Potentially significant social impacts will occur when the construction of the mine and power plant begin with a large influx of construction workers and staff as well as large amounts of machinery. As operation begins, a relatively large number of power plant and mine workers will be living permanently in the Lakhra/Khanot area. Because of the remoteness of the project site, workers colonies for WAPDA and the private sector contractor will be built [see Section 2.8; also, detailed descriptions of the workers colonies can be found in the power plant and mine feasibility studies (GCII, 1986, and J.T. Boyd Company, 1986)]. These project activities are expected to have the following significant impacts (see also Appendix K):

1. Change in land use;
2. Change in employment and economic patterns;
3. Change in existing cultural patterns and values;
4. Increased demand upon for facilities and services by project personnel;
5. Induced development in the surrounding area associated with construction of the project;
6. Impacts to the existing transportation systems; and
7. Loss of cultural, historical, and archaeological resources.

4.2.3.1 CHANGE IN LAND USE

Currently three areas which are used by nomads for agricultural purposes have been identified within the East Pit boundary. The named settlement Dhanwari also occurs in the East Pit boundary. These areas are used seasonally as the monsoon rains supply the necessary water via the Kath Buthi Dhoro. The initial impact of East Pit development to these areas will occur about 15 years after production operations begin, as the portion of Kath Buthi Dhoro which traverses the East Pit is excavated. However, diversion techniques can be used to direct surface runon away from the East Pit area to fields used by seasonal inhabitants. As the East Pit development continues, efforts should be made to divert water to reclaimed areas or areas outside of the East Pit to provide alternative field locations to torrent-watered croppers. Mining of the existing areas within the East Pit boundary will occur about 20 years after production operations begin.

Within the West Pit boundary, two seasonal agricultural areas have been identified. A third area is located near the northeastern boundary of the West Pit. At the western boundary, the Bairan Wari Wah drainage retains water for seasonal inhabitants located at Gath Sumro. Most of these areas will be affected within 15 years after West Pit operations begin. To minimize adverse impacts associated with West Pit development, the diversion techniques and reclamation efforts described for the East Pit will also be used for the West Pit. Although some loss of land use will occur due to surface mining operations, the loss of land can be minimized with proper planning and water management.

Studies have been conducted on East and West Pit soils to determine the quality of materials available to support revegetation (J.T. Boyd Company, 1985). Four categories (good, fair, poor, and unsuitable) were used in the evaluation, and the results are presented in Table 4.2-6. The suitability ratings assigned in Table 4.2-6 assume that adequate irrigation water is supplied; otherwise the ratings may be further

Table 4.2-6. Soils Rating for Revegetation

| | Suitability | |
|---|---|---|
| | East Pit | West Pit |
| Depth | Good | Good |
| Reaction (pH) | Poor to Good | Poor to Fair |
| Salinity | Unsuitable to Fair | Good |
| Sodicity | Unsuitable to Good | Good |
| Stoniness | Fair to Good | Fair to Good |
| Texture | Poor | Poor to Good |
| Organic Content | Poor to Fair | Poor |
| Calcium Carbonate Equivalent | Unsuitable to Good | Fair to Good |

Good--None to slight soil limitations that affect use for plant growth medium.
Fair--Moderate soil limitations that affect use but can be overcome by good planning and management.
Poor--Severe soil limitations that make use questionable. Careful planning and very good management are required.
Unsuitable--Soil limitations considered too severe.

Sources: John T. Boyd, 1985.
ESE, 1986.



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downgraded. The results of the soils study indicate that without a water supply, the soils cannot be upgraded to agricultural use.

4.2.3.2 CHANGE IN EMPLOYMENT AND ECONOMIC PATTERNS

Development of the proposed Lakhra Project will cause a large influx of construction and operation workers to build and operate the power plant, mines, and residential colony. Additional information concerning employment and other economic effects is presented in Appendix D.7.

During construction, between 2,000 and 7,700 workers will be employed. After construction, the work force will stabilize to about 3,200 workers. The total number of people projected to live in the colony will vary during the 36-year life of the facility from about 4,500 to about 23,500. This variation will be due principally to the growth in the number of dependents and the arrival and departure of construction workers.

Several types of taxes and duties will be collected from the Lakhra Project by the Government of Pakistan, the Government of Sind, and the Dadu District Government. During the project start-up phase, annual income tax collections have been estimated to average Rs 43,196,000, based upon the projected work force. During the operation phase, annual income tax collections have been estimated to average Rs 10,838,000. Overall annual average income tax payments have been estimated to be Rs 16,231,000 for the 36-year life of the project. Coal separation tax, paid to the Government of Sind, has been estimated to average Rs 41,017,000 annually for the life of the project. Miners' welfare taxes has been estimated to average Rs 5,469,000. Duties and sales taxes would depend upon the actual amount, usually as a percentage, that would apply to the project. Total collections have been calculated to range from Rs 383,071,000 to Rs 2.95 billion .

It is probable that much employee income will initially flow to the North-West Frontier Province (NWFP) and other areas in Pakistan in the

form of remittances. Since a permanent and year-round mine work force is required, some miners will want to relocate their families to the workers colony or its vicinity, and less money will flow to the other provinces. These resources will be exchanged for goods and services in the Khanot and Hyderabad areas. The local economy will undergo a boom period for the first 7 or 8 years. After that period, the economy will decrease and level off at a point significantly higher than currently exists. These changes are considered an overall positive economic benefit to the provinces and local area but will cause short-term economic disruptions when the construction period ends. If the project ceases to exist after its planned 30 year life, economic disruption would also occur.

With the development of the mine and power plant, employment opportunities will be available to the local populations. It is assumed the basic employment patterns that exist in the present mines will be realized with the Lakhra mine. Most of the mine labor will likely come from NWFP. It is expected that some of the Khosa Baluch herders would seasonally seek unskilled jobs. They may be employed as workers in the surface mine; however, it is unlikely they would seek employment in the underground mine. The Indus River villagers have expressed willingness to work on the project. However, the availability of the local people may be limited because of the extensive agricultural activity, their lack of experience, and the likelihood of their employment in secondary infrastructure employment around the worker colony areas. As the construction phase for the project ends, local unemployment will increase and will present problems for the area. Similarly, at the end of the project, unemployment will rise because of the loss of jobs at the mine and power plant and subsequent decline in secondary infrastructure jobs (refer to Appendix K for mitigation recommendations).

#### 4.2.3.3 CHANGE IN EXISTING CULTURAL PATTERNS AND VALUES

The changes in land use, expanded economic opportunities, and influx of outsiders associated with power plant construction will disrupt the local

culture. Such impacts will be more pronounced at Lakhra than at Khanot because the Khosa Baluch live a highly traditional and independent lifestyle, whereas the peoples along the Indus River have more interchange with the outside world and have begun to adapt to and integrate into a modern lifestyle, e.g., in terms of transportation and communications. In addition, the major concentrations of construction and operational workers will be at Lakhra.

Regardless of their origins, workers stationed at the remote Lakhra site will be subject to poor morale due to separation from their families and communities. Lowered productivity could disrupt the project if these stresses are not ameliorated. For example, some disruptions arose during the development of the power plant located at Guddu (a newly constructed combined cycle power plant located in Northern Sind Province) because facilities, incentives, and leisure opportunities were initially inadequate. In addition, it will be important to be sure that workers of comparable status receive comparable services and privileges. Colony facilities for miners and construction workers should be essentially the same. As a result, adequate infrastructure from the beginning of the project is essential to ensure optimal productivity.

The greatest changes will occur at Lakhra with the Khosa Baluch but will affect the fewest number of people (< about 50). Currently, the Khosa Baluch live in a very rural setting. During the monsoon season they reside in the area and tend their herds and flocks and cultivate small agricultural plantings, and during the remainder of the year they travel to the more developed areas (Helweg, 1985). With the development of Lakhra, they will be in closer contact with urbanized society, and their life-styles at Lakhra will be more influenced by urban conditions.

Location of the workers colony at Khanot will increase the urban influences through contact with the construction and operation workers. Although the differences in life styles will not be as great as at

Lakhra, a larger number of local inhabitants will be affected. The Lakhra Social Soundness Analysis (Helweg, 1985) indicated a sensitivity of the Sindhis to the proposed energy development, especially for job opportunities and fears of inflated prices resulting from the influx of outside workers.

4.2.3.4 INCREASED DEMAND FOR FACILITIES AND SERVICES

The development of the mine along with the power plant will require additional housing, health care, education, police, and fire protection facilities and services that cannot be met by the existing infrastructure. These facilities and services will be provided for the workers directly associated with the Lakhra project by either WAPDA, Government of Sind, the mine contractor, or its constructors. The following sub-sections discuss the general nature of these facilities and services provided as part of the Lakhra project. [For more details, refer to the Power Plant and Mine Feasibility Studies (GCII, 1986, and J.T. Boyd Company, 1986)].

Housing

WAPDA and the future mine operator will each provide housing for all employees and their dependents by constructing a residential colony. The type of housing will depend on the basic pay scale of the employee. The number of housing units currently planned in the residential colony is approximately 1,750 for the mine and 1,550 for the power plant.

It is anticipated that each worker will require a single housing unit. Housing for construction workers will not be a responsibility of WAPDA but of the contractors selected for construction of the power plant. Mining company houses will be similar to WAPDA's employee houses with assignment based on a similar basic pay scale.



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Because housing will be provided for all operational employees as a part of overall project costs, no additional infrastructure costs to cover housing impacts will be provided by the project.

Health Care

At present, health care facilities do not exist in the Lakhra area and only minimal care exists at Khanot. The Lakhra project will cause significant demand in the area for health care.

All medical and dental health care services for the Lakhra Project workers and their dependents living at the Lakhra residential colony will be provided by the project. The cost of providing hospital facilities and medical staff is included in the overall cost of the Lakhra power plant.

The hospital facility constructed for the project will have a staff of 85, including 16 medical doctors, a dentist, several technicians, and nurses. In-patient and out-patient care will be provided with facilities to include medicine, surgery, gynecology, pathology, laboratory analysis, dentistry, and radiology. The hospital will provide 80 beds for in-patient care, with separate male, female, and child facilities.

Education

Educational needs of the Lakhra Project workers and their dependents living in the colony will be provided by the project. Schools will be provided for primary and secondary classes 1 through 10 and for intermediate college classes 11 and 12. The cost of these facilities and the educational staff is included in the overall costs of the Lakhra Project. Workers at the Lakhra facility will pay a minor fee to enroll their children in the WAPDA schools. The charge at the Guddu colony is 14 Rs per child for each 6 months of schooling.

Four primary schools and two secondary schools are planned for the Lakhra colony. The teaching staff will consist of 64 primary and secondary teachers and 23 college lecturers.

Police Protection

Complete police security protection will be provided for Lakhra Project employees and their dependents. A staff of 1 officer, 1 inspector, 4 sergeants, and 52 security guards will be available for colony protection and to maintain law and order. An additional security staff of 134 officers and guards will provide security for the power plant.

Communications

The proposed project will have a significant demand on existing telecommunication systems. The nearest major telephone exchange to the Lakhra site is in Hyderabad. Telephone service is not currently available in the Lakhra-Khanot area.

The Hyderabad area has two central offices, both of which are 100-percent loaded at present (GCII, 1986). The central office in the northwest area of the city would provide trunk lines to the Lakhra complex. The telephone switchgear is a Siemens 5500 line, Strowger type of 1940's vintage.

Telephone and Telegraph Authority of Pakistan (T&T) personnel realize that the existing switchgear is no longer adequate to serve the needs of the Hyderabad area and are planning to install a 20,000-line digital switch in 1987 or 1988. The new switch will be located about 5 km (3 miles) northwest of the existing central office at a location known as Qasimabad. T&T installed a major digital switch in Karachi in 1985, and the planned installation at Hyderabad will not be their first experience.

Although it is not well defined at this point, a fiber optic carrier system is planned between Karachi, Hyderabad, Islamabad, and Lahore. Current plans call for installation about 1990 or 1991. The capacity of

this fiber system will be vastly superior to the existing 960-channel microwave system and will ease traffic problems on the domestic long-distance trunks.

The new digital switching equipment which T&T plans to install in the Hyderabad area in 1987 or 1988 will have about 4 times as much capacity as the existing switching equipment. The new equipment should be able to handle all telecommunication needs of the Lakhra Project as well as the normal load growth in the Hyderabad area for many years. If this equipment is installed as planned, no project funds will be required to upgrade area telecommunications to meet the needs of the Lakhra Project.

However, if delays occur in installing the new switching equipment, serious limitations for telecommunications will affect the Lakhra Project. Providing telephone lines to Lakhra will require removing lines now used by other subscribers. The number of lines available for the Lakhra Project will be far less than that required, and reliability and quality of service will be poor.

#### 4.2.3.5 INDUCED DEVELOPMENT IN THE SURROUNDING AREA ASSOCIATED WITH THE LAKHRA PROJECT

In addition to the project workers and their dependents, other people will be attracted to the vicinity of the Lakhra Project.

The location of this secondary development will depend on the ultimate location of the residential colony. The two most apparent locations for this secondary development are at the junction of the Indus Highway and the Lakhra Road and at a location outside the principal gate to the Lakhra residential colony. If the colony is at the junction of the Indus Highway and the Lakhra Road, then the secondary development will probably be one large community, with little or no development at the power plant and mine facilities at Lakhra due to their comparative remoteness.

This community will contain various businesses catering to needs of the colony residents, including various retail shops, cafes, vehicle repair shops, small hotels, and firewood yards. Residences are combined with the shops in the same building or in the same area.

Based upon experience with the construction of the Guddu Power Plant, it is projected that up to 8,000 people will live in the secondary developments generated by the Lakhra Project. (Note: The Guddu Power Plant, located in Northern Sind Province, experienced an influx of about 5,000 people during development. From this information and the size of the WAPDA colony, a secondary development population was estimated.) Adding the secondary population growth (8,000) to the number of mine and power plant workers and their dependents (24,000) results in an estimated influx of up to 32,000 people to the Khanot-Lakhra area during the life of the Lakhra Mine/Power Plant Project. Although the infrastructure requirements of the mine and power plant workers and their dependents will be provided by the project, the infrastructure requirements of the secondary development will not be provided and must be planned for and possibly provided by the Government of Sind. The additional facilities and services will include housing, health care, education, and police protection.

Housing

Housing will not be provided for construction workers and secondary population growth resulting from the congregation of other people in the Lakhra Project area. This secondary growth will stress the area's ability to provide such housing. It is anticipated that new housing to accommodate this secondary growth would be generated by either these new residents or local builders.

Health Care

The Lakhra Project medical facility will provide limited emergency services to persons who are not WAPDA employees or their dependents if a

service fee is paid. Provisions of medical and dental services for the anticipated secondary population growth in the Khanot-Lakhra area, however, will be primarily the responsibility of the Government of Sind.

The cost to the Government of Sind to provide these services for the secondary development has been estimated by establishing a conceptual 10-bed medical care facility for a new community of 8,000 persons. The costs are estimated to be Rs 2,700,000 for capital and Rs 710,000 for operation.

Education

Educational needs will be significantly increased due to the anticipated secondary development. These needs will be partially met by the project. Schooling for children of parents who are not Lakhra Project employees or their dependents will be made available upon payment of a monthly fee. At the Guddu colony, a fee for each child of non-employee parents attending WAPDA schools is Rs 45 per month. The monthly fee was adopted at Guddu after recurrent discipline problems were encountered from children who were not residents of the WAPDA colony. The fee, which is significantly higher for non-resident children and which is expensive by local economic standards, will have the effect of eliminating most or all non-resident children from WAPDA schools. Therefore, WAPDA will provide schooling for very few non-resident children in the Khanot-Lakhra region.

Education of children of parents not desiring or able to pay the fee will be the responsibility of the Government of Sind. The cost to the Government of Sind for a Class 1 through 10 school with 500 students is estimated to be Rs 1,000,000 for capital and Rs 925,000 per year for operation.

Police Protection

The increase in population will have a significant impact on present security (police) for the area. Providing police protection and



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maintenance of law and order for secondary community development will be the responsibility of local governments. The cost estimated for a police force of 5 officers and 32 patrol constables is Rs 300,000 for capital and Rs 1,649,000 for operation.

Government Costs and Revenue Collection

Several costs to the Government of Pakistan and the Government of Sind have been estimated in the preceding subsections for secondary population growth, resulting in a new community of 8,000 people. Detailed cost information for the services required for this secondary population growth is presented in Appendix D.7. These costs have been summarized by GCII (1986) as follows:

| Service | Estimated Cost | |
|---|---|---|
| | Capital | Annual Operation |
| Health Care | Rs 2,700,000 | Rs 710,000 |
| Education | 1,400,000 | 952,000 |
| Police | 300,00 | 1,649,000 |
| Total | Rs 4,400,000 | Rs 3,311,000 |

Government revenues based on tax and duty collections are summarized as:

| Tax | Average Annual Revenue (Apportioned over 36 Years) |
|---|---|
| Income Taxes from Workers | Rs 15,922,000 |
| Coal Separation Tax | 35,948,000 |
| Miners Welfare Tax | 4,793,000 |
| Import Duties & Sales Tax at 5% | 9,113,000 |
| Total Annual Revenue | Rs 65,776,000 |

Comparison of costs to government of providing secondary population growth with health, educational, and police services indicates sufficient tax revenue is available for secondary infrastructure and that the Lakhra Project should not be tasked with funding additional infrastructure



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services other than those already planned for the residential colony, the Khanot-Lakhra road, and project utility connections.

Assuming that WAPDA is successful in obtaining waivers of the coal separation tax, the miners welfare tax, and the import duty/sales tax, income taxes from project worker salaries alone are still estimated to provide adequate revenues to fund health, education, and police services for the estimated secondary population growth.

4.2.3.6 TRANSPORTATION SYSTEM IMPACTS

Construction of the Lakhra Project will require the availability of extensive transportation facilities to provide for the movement of both materials and workers to and from the project site. Examination of road, rail, and harbor facilities in Sind Province and discussions with WAPDA, Sind Department of Highways, and a special carrier contractor indicate that materials for the project will be moved primarily by road, with imported materials arriving via the Port of Karachi.

Worker movement will involve primarily road transport. Rail movements through Khanot may provide additional material and worker transport services. Transfer from the rail line at Khanot to the Lakhra site would be by road.

Feasibility assessments have included costs for upgrading the 15-km-long Khanot-Lakhra Road to standards equivalent to those of the Pakistan National Super Highway. This upgrading is necessary for the construction and operation of the mine and power plant. The following section examines potential restrictions on the project to assume the cost of upgrading any of the remaining road, port, and rail facilities.

Shipment of construction materials, operation supplies, and the transport of workers will originate primarily in the Karachi-Hyderabad area. Road movement will be over the Indus Highway and the National Super Highway.



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The Indus Highway is a 5.4-m (18-ft)-wide, asphalt-paved road running north-south on the west side of the Indus River valley from Kotri and Jamshoro on the south, through Khanot to Dadu, Larkana, and Shikarpur to the north. At Jamshoro, the Indus Highway connects to the segment of the National Super Highway betwen Karachi and Hyderabad. The National Super Highway, which crosses the Indus River at Kotri on the Kotri Barrage, runs north from Hyderabad on the east side of the Indus River valley. The latter highway normally carries more traffic than the Indus Highway. However, a 6-year repair/renovation program is underway which includes both the Kotri Barrage and the National Super Highway north of Kotri and Hyderabad. Until the program is completed, heavy loads will be diverted to the Indus Highway.

Improvements to the Indus Highway are also planned. The Sind Highways Department has developed plans, specifications, and cost estimates to expand the Indus Highway to a full 7.3-meter (24-foot) lane width and upgrade the load-carrying capacity to 22,000-lb axle loading. An application has been made to the Government of Pakistan for funding of the project. As a first step, the Indus Highway was recently proclaimed to be a part of the National Super Highway System. Improvement of the road will benefit the Lakhra Project for the movement both of materials and workers.

Given the present situations and governmental plans, no impediments exist that will require project funding for the transportation infrastructure. The existing road and port facilities have handled similar heavy loads in the past and are considered by GCII to be adequate to handle anticipated movement of materials and workers between the Karachi-Hyderabad area and Khanot. Although traffic will increase primarily on the Indus Highway, heavy loads and traffic have been accommodated on this road. Improvements to bring the Indus Highway up to Nation Super Highway standards would greatly benefit transportation logistics for the Lakhra Project. Access to the Lakhra site, however, is not contingent on these improvements.

4.2.3.7 LOSS OF CULTURAL, HISTORICAL, AND ARCHAEOLOGICAL RESOURCES

A preliminary survey of the Lakhra area for significant archaeological sites was conducted by the Department of Archaeology (Rasool, 1986, and Bokhari, 1986). Their determination was that no important cultural, historical, and/or archaeological resources occur at the proposed site. A "chance find" procedure has been proposed as a mitigation (see Section 6.0).



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## 4.3 POWER PLANT AND WORKERS COLONY: CONSTRUCTION IMPACTS

### 4.3.1 PHYSICAL ENVIRONMENT

#### 4.3.1.1 AIR QUALITY

Any major construction activity will generate air pollutant emissions. The following subsections discuss the generation of fugitive dust emissions, exhaust emissions, and emissions from open burning. Appropriate control measures to curtail these emissions are presented.

Fugitive Dust

Local air quality will be temporarily affected by fugitive dust emissions in the vicinity of construction. Highest emission potentials will be realized during the construction of buildings and roads. Specifically, emissions are associated with land preparation, ground excavation, cut and fill operations, and individual facility construction. Fugitive emissions will also result from vehicular traffic over temporary roads located at the sites. Because the level of construction activity and the local weather conditions fluctuate, daily emissions are expected to vary.

The quantity of fugitive dust emissions are estimated to be about 1.2 tons of particulate per acre under heavy construction activity per month. One way to control fugitive dust emissions is by watering, with its effectiveness directly dependent upon the frequency of watering. For example, watering the entire construction area twice daily would reduce fugitive dust emissions by as much as 50 percent; watering every 3 hours could control emissions by as much as 70 percent. Natural fugitive dust controls (i.e., snow and rain) are not applicable for the Lakhra area. Nonetheless, most fugitive dust particles will be removed from the ambient air by gravitational settling while still within the boundaries of the proposed sites. In addition, the distance to populated areas is sufficiently large (>20 km) that fugitive dust impacts due to construction are expected to be minimal.

Vehicular traffic to, from, and around the site is another source of fugitive dust. Traffic on paved roads produces minimal dust emissions; however, unpaved roads around the site are likely to be a major source of fugitive dust emissions. Emissions from this type of source are difficult to quantify, but the amount of emissions will vary directly with the volume of traffic, average vehicle speed, vehicle type, road surface moisture, and road surface composition. Overall, vehicular traffic produces minimal emissions in comparison to site construction activities and are expected not to influence local populations.

Exhaust Emissions

Commuting and deliveries to the site from outlying areas will increase the vehicle exhaust emissions in the Lakhra and Khanot areas. In addition, general vehicular traffic associated with construction will also increase air emissions. Because the traffic is not expected to be significant, vehicular emissions impact will be minimal.

The construction equipment considered for use in this project primarily burns diesel fuel, and as such will introduce PM, CO, $NO_x$, and VOCs into the air upon combustion of that fuel. Construction equipment usage will be short-term and will not continue to any significant degree beyond completion.

Burning

During construction activities, it is anticipated that limited periods of burning will be required to eliminate waste material from the site. The main type of waste material to be burned would generally consist of trade waste and construction debris (i.e., paper, wood crating, etc.). Much of this material, however, is likely to be scavenged by local residents and, therefore, not burned.



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4.3.1.2 NOISE

Noise impacts from construction of the Lakhra plant and associated facilities will be temporary and restricted primarily to daytime hours. Most construction activities will be carried out more than 2,000 m (6,500 ft) from the nearest villages. In the early stages of the project, work performed onsite will consist entirely of surveying, soil boring, and test well drilling required to determine specific topographical and geophysical characteristics. Active construction will begin with clearing and other site preparation work, and will proceed in accordance with the project schedule. Construction activities will be continuous until completion of both units.

Typical power plant construction equipment will be used, including light and heavy earthmoving equipment, large cranes, lighter mobile cranes and hoisting equipment, heavy drilling rigs, concrete placement equipment, miscellaneous pumps and compressors, welding and metalworking equipment, and trucks and other vehicles.

Table 4.3-1 is a list of the types of equipment that will probably be used in construction of the facility. Equipment sound levels at 15 m (50 ft) and typical usage factors for a two-shift day (15 hours) are also provided in the table. The equipment usage factor is the percent of the construction day that the equipment is expected to be in use at the given noise level.

Hemispherical spreading (described in detail in Section 4.4.1.2) will cause sound levels to be reduced by 34 dBA in traveling from 15 m (50 ft) to 800 m (2,600 ft) from a source. Thus, a source with a sound level of 89 dBA at 15 m (50 ft) will produce 55 dBA at 800 m (2,600 ft). Because distances to workers colonies are generally greater than 2,000 m (6,500 ft), noise levels due to plant construction are expected to be further reduced to 45 dBA. These levels are significantly below those levels recommended by the World Bank Guidelines for a variety of situations and will protect the public health and welfare.

Table 4.3-1. General Noncontrolled Noise from Construction Equipment

| Equipment | Noise Levels (dBA)* |
|---|---|
| Earthmoving | |
| Front Loader | 79 |
| Backhoes | 85 |
| Dozers | 80 |
| Tractors | 80 |
| Scrapers | 88 |
| Graders | 85 |
| Trucks | 91 |
| Paver | 89 |
| Materials Handling | 85 |
| Concrete Mixer | 82 |
| Concrete Pump | 83 |
| Crane | 83 |
| Derrick | 88 |
| Stationary | |
| Pumps | 76 |
| Generators | 78 |
| Compressors | 81 |
| Impact | |
| Pile Drivers | 101 |
| Jack Hammers | 88 |
| Pneumatic Tools | 86 |
| Other | |
| Saws | 78 |
| Vibrator | 76 |

*All noise levels in dBA measured at a distance of 15 meters (50 feet) from the equipment.

Source: U.S. Environmental Protection Agency, 1971.

Since most construction activities will take place more than 800 m (2,600 ft) from the plant boundary and most populated areas are at a considerably greater distance, up to ten 88 dBA sources can be in continuous, simultaneous operation without exceeding the World Bank guideline of 55 dBA at residential or hospital areas. In addition, noise levels from continuous construction activities at Lakhra would not measurably increase ambient levels in any villages.

There will be some construction activities, such as pile driving and steam blowout, which will increase instantaneous and short-term ambient sound levels significantly. Pile driving will be of relatively short duration and could increase peak ambient levels 5 to 10 dBA at the property boundary. Blowout operations will occur during plant startup and will represent one of the major noncontinuous noise sources during construction. Blowout operations will be required to clean the main steam lines and hot and cold reheat pipelines prior to commencing plant operations.

Steampipe blowout procedures are variable from power plant to power plant. A typical blowout program consists of two phases. The first phase consists of 40 blowouts over a 5-day period, using steam at a gage pressure of up to 2.8 millipascals (MPa) [400 pounds per square inch (psi)]. Each blowout lasts for 3.5 to 6 minutes at intervals of 45 to 50 minutes. The second phase consists of 115 blowouts over a 7-day period, using steam at a gage pressure of up to 5.5 MPa (800 psi). These blowouts typically will occur with the same frequency and duration as the first-phase blowouts. The maximum noise levels emitted during a typical blowout operation are estimated to be 99 dBA at 1,000 m from the power block for the first phase and 107 dBA for the second phase. The maximum sound level is estimated to last for the duration of the blowout. The total blowout operation will last for a period of approximately 2 weeks per unit, and proper and sufficient community notification should minimize complaints.

Construction of the linear facilities (roads, transmission connections, etc.) will produce elevated noise levels for short periods in the immediate area of construction.

In summary, noise from continuous onsite construction activities is not expected to exceed World Bank Guidelines at the plant boundary. Intermittent activities, such as pile driving and steam blowout, will cause higher noise levels for short periods. Construction of offsite facilities will create temporarily elevated noise levels along the linear facilities.

4.3.1.3 LAND AND WATER RESOURCES

Potential construction-related impacts to land and water resources at the proposed sites include:

1. Increased stormwater runoff and erosion of soils;
2. Sanitary waste stream discharges associated with a large construction work force;
3. Accidental spills of environmentally harmful materials such as petroleum products, solvents, and detergents; and
4. Loss of land use.

As discussed in Subsection 3.1.2, the Indus River is the only perennial surface water body in the vicinity of the sites. Ground water at each of the sites is of limited availability and generally of poor quality. In general, no impacts to offsite surface or ground waters are anticipated due to construction of two 250-MW units and associated facilities.

Stormwater Runoff and Erosion Control

Rainfall at each of the sites is 156 mm (6.13 inches) per year or less. About 80 percent of the annual rainfall occurs during the rainy season between July and September. There is little or no existing vegetation present in either the Lakhra or Khanot areas; therefore, no cleaning or grubbing will be required. Surface water is present in each area in low

areas for only short periods following heavy rainfall events until the water evaporates or infiltrates into the ground. Soil compaction due to heavy equipment operations during construction will reduce soil permeabilities and may increase surface runoff in certain areas. Erosion control measures including construction of berms and slope drains will be used as required. Due to these measures and the fact that there is little or no existing ground cover at each of the sites, no significant or permanent increases in stormwater runoff or soil erosion are anticipated during construction activities.

Because of the lack of existing ground cover at the Khanot and Lakhra sites and the low annual precipitation and high evaporation rates in the region, little or no increases in stormwater runoff are anticipated during construction at either site. The Khanot site is bordered on the north by a line of ridges north of the Lakhra Road and on the south by a low drainage area which drains the area south of the proposed plant location to the Indus River. As a result, some filling and regrading of the existing drainage will be required at this site to minimize runoff. Non-perennial torrent streams from the Khanot area discharge to the Indus River during infrequent but heavy rainfall events.

The Lakhra site, on the other hand, is located about 1 km (0.6 mile) south of the proposed mine facilities in an extremely flat area. Distinct stream beds are not present near the site, and overall drainage slopes to the southwest, at a gradient of about 0.25 percent. Runoff resulting from rainfall at Lakhra occurs as sheet flow in some areas until it evaporates or infiltrates into the soil.

Sanitary Waste Stream Discharges

Development of temporary construction camp facilities and utilities, including power and water supply and sanitary facilities, will be contracted locally. The proposed GCII project schedule calls for this activity to be initiated concurrent with site preparation work and to be



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completed prior to initiating construction of the 250-MW units and associated facilities. Construction of these facilities would be contracted so that there are no discharges of untreated sanitary wastes to surrounding surface or ground waters.

Due to existing drainage patterns and remoteness of the site from populated areas and the Indus River, potential adverse impacts that may result from waste discharges during construction will be low in both the Lakhra and Khanot areas.

Accidental Spills of Environmentally Harmful Materials

All environmentally harmful or hazardous materials used during construction, such as petroleum products and solvents, should be stored, and transfer operations constructed in designated areas should be designed to contain spills and contaminated rainfall/runoff. These areas will be located away from drainageways to eliminate potential impacts.

Loss of Land Use

Both the Lakhra and Khanot areas are currently undeveloped, and loss of land use is not considered a significant impact at either site. Locating the power plant facilities at Lakhra will have less impact in relation to the loss of land than construction of the workers colony at Khanot.

### 4.3.2 BIOLOGICAL ENVIRONMENT

The activities associated with power plant construction that affect ecological resources involve clearing and excavation of the site, building of roads, and the transportation of workers and materials for construction. The potential major impacts associated with these activities include :

1. Vegetation removal and loss of wildlife habitat,
2. Loss of future biological productivity,
3. Increased fugitive dust and effects on vegetation and wildlife habitat,

4. Increased road traffic resulting in increased wildlife road kills,
5. Increased access to less accessible natural areas,
6. Increased noise and effects to wildlife, and
7. Increased silting and sedimentation and effects to aquatic life.

4.3.2.1 VEGETATION REMOVAL AND LOSS OF WILDLIFE HABITAT

Construction of the power plant site will result in the loss of several hundred acres of scrub forest vegetation and tropical plain thorn forest wildlife habitat. These impacts are not considered significant because of the large amount of undisturbed similar habitat in the area and the lack of uniqueness of this habitat. Specific wildlife species most directly affected will be fossorial reptiles and mammals such as geckos, lizards, skinks, and monitors as well as mice, rats and gerbils. Desert monitors classified as endangered were observed at the Lakhra site. Onsite populations will be lost.

With the loss of vegetation, bird habitat on the site will be destroyed. The amount of this habitat compared to the amount in the surrounding area is very small. If the carrying capacity is not high in surrounding areas, birds and other mobile wildlife whose habitat is lost will be displaced into surrounding areas. There will be population adjustments, but these losses and changes are not considered significant given the size of the unaffected wildlife populations in the area. The presence of other endangered species (Table 3.2-1) is not known at this time.

4.3.2.2 LOSS OF FUTURE BIOLOGICAL PRODUCTIVITY

The construction of the power plant site and roads will result in the loss of the future biological productivity of these ecological communities, but this loss is negligible because of the remaining unaffected areas and the lack of uniqueness of these communities. The corridors constructed for the pipeline will have some future biological productivity through natural recovery, but any losses because of partial restoration are not considered significant.



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#### 4.3.2.3 INCREASED FUGITIVE DUST AND EFFECTS ON VEGETATION AND WILDLIFE HABITAT

The construction activities will result in generation of fugitive dust which will settle on surrounding vegetation. No losses to surrounding vegetation are expected because of the adaptation of native vegetation to similar natural conditions, i.e., dust storms and winds of the area. No effects to wildlife are expected.

#### 4.3.2.4 INCREASED ROAD TRAFFIC RESULTING IN INCREASED WILDLIFE ROAD KILLS

The expected increase in road traffic will lead to an increase in road kills of wildlife. Animal groups most likely affected are small mammals (rodents) and reptiles (snakes and lizards including monitor lizards). Mortality is likely to be higher at night when such animals are attracted to metalled roads because the roads give off heat. In arid regions of the United States, large numbers of animals are often killed. Similar conditions may occur on roads built to the Lakhra site if regular use of these roads occurs. Localized effects to population numbers (i.e., lower densities) may occur. No significant effects are expected given large population densities expected to occur in the region.

Road kills will also be likely to occur along the National Highway due to increased traffic occurring with development of the power plant and workers colony. This incremental increase in traffic and resulting increase in mortality is not considered significant. Wildlife resources potentially affected and occurring along the highway are not limited in numbers, and any losses will not affect their overall population size.

#### 4.3.2.5 INCREASED ACCESS TO LESS ACCESSIBLE NATURAL AREAS

Construction of the power plant will not lead to any sizeable increase in access to less accessible natural areas. Currently, the coal mines are viewed as the primary factor contributing to increased access (see Section 4.2.2).

4.3.2.6 INCREASED NOISE AND EFFECTS TO WILDLIFE

Power plant construction activities will lead to an increase in noise (see Section 4.3.1.2). Major effects of noise to wildlife are often associated with disturbance and disruption of feeding, resting, and reproductive activities especially for species with colonial or social habitat requirements, e.g., wading birds associated with rookeries. At this time no such habitats or species with expected noise sensitive habits are known to occur in the area.

4.3.2.7 INCREASED SILTING AND SEDIMENTATION AND EFFECTS TO AQUATIC LIFE

Construction of the water intake facility will result in short-term and localized silting and sedimentation of the Indus River in the vicinity of the facility. These conditions will contribute to the short-term and localized turbidity of the Indus River. Because of high turbidity already existing in the river and the lack of any sensitive aquatic resources, no impacts to aquatic resources are expected.

4.3.3 SOCIAL ENVIRONMENT

The major construction and site development activities associated with construction of the power plant involve plant site land clearing, the influx of construction workers, and increase in traffic transporting workers and materials. These activities, which have been discussed as a part of the mining impacts on the social environment (Section 4.2.3), will result in impacts to the power plant. The major impacts are listed below and summarized in the following subsections:

1. Change in land use;
2. Change in employment and economic patterns;
3. Change in existing cultural patterns and values;
4. Increased demand for facilities and services;
5. Induced development in the surrounding area associated with construction of the power plant;
6. Impacts to existing transportation systems; and
7. Loss of cultural, historical and archeological resources.

4.3.3.1 CHANGE IN LAND USE

The power plant site will occupy several hundred acres of existing land. The present land use is considered non-farm land, however, small [less than 0.4-ha (1 acre)] tilled plots were observed during the August 1985 trip. At Khanot and Lakhra the lands are government-owned. Development will change the existing land use and ownership relationships. At the local level existing land users will lose ownership rights to this land. Baluchi nomads graze their livestock throughout the region seasonally, as well as cultivate small agricultural plots. The loss of grazing areas is not considered significant since the proposed power plant site is not located in the more heavily vegetated areas and other sufficient grazing areas exist. The loss of the tilled areas could be more significant since the nomadic groups take advantage of topographical features conducive to collecting silt and runoff. The power plant will reduce the land area available to these people and their use of the area will be lost.

Pipeline and transportation corridor construction will temporarily eliminate a few hundred acres of Khosa Baluch rangeland. Vegetation over buried lines will probably slowly recover its original usefulness, but fenced off or paved areas will not. Corridors will also result in the loss of a few acres of farmland on the east side of the Indus Highway.

The construction of the pipeline corridors will result in the loss of a few acres of farm land on the east side of the National Highway. This loss is considered negligible considering the small area affected. No long-term or larger scale impacts to agricultural activities in this area are anticipated from construction of these facilities. Pipeline and transportation corridors to the Lakhra site will result in the loss of a few hundred acres of non-farm land. This land is not suitable for agricultural purposes, and its loss is considered negligible.

4.3.3.2 CHANGE IN EMPLOYMENT AND ECONOMIC PATTERNS

Plant construction activities will cause a marked change in the existing employment and economic patterns. These have been described for the total project in Section 4.2.3. The construction of the power plant will require an average employment of 2,681 skilled and unskilled workers. Peak employment will occur with over 6,000 workers in the third year of construction. Since construction is scheduled to last for several years, these changes are considered short term with the employment and the economy rising and falling.

Construction labor appears to be available for the project since there is both underemployment and unemployment in the general area. The unemployment register of the Hyderabad area listed almost 100 unemployed engineers of various fields. In contrast, there were hardly any unemployed skilled construction tradesmen (i.e., bricklayers, carpenters, mechanics, etc) (Helweg, 1985). In the past there has been outmigration of these skills to the oil fields in the Gulf. However, recently, these workers have been returning as Gulf projects are completed and the demand for workers decreases. Unskilled laborers are in sufficient supply. In March 1985, almost 4000 unskilled men were registered as unemployed (Pakistan Population Census Organization, 1983 a,b).

Since most of the jobs associated with plant construction will be temporary, the increase in employment will have a disruptive effect, rather than consistent long-term benefits. The local economy will experience a boom period as a result of the influx of mine workers. When power plant construction ends 3 years later, and a significant decline in workers and secondary effects to the local economy will occur.

Many of the most significant social impacts will result from workers migrating into the region to meet labor needs that cannot be satisfied locally.



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Most of the construction labor would likely come from outside the Khanot and Lakhra vicinities. Skilled workers would come from Hyderabad and other urban areas. It is expected that some of the Khosa Baluch herders would seasonally seek unskilled construction jobs at Lakhra. Indus River villagers have also expressed willingness to work on power plant construction; however, the availability of local people for construction is expected to be limited because of the demand for agricultural workers in the area and the lack of developed construction skills.

Some advantages, such as increased availability of consumer goods, might be transient aspects of the boom economy, but the development of permanent workers colonies would provide a long-term contribution to the community through employment and secondary economic benefits (e.g., selling of agricultural goods to colony residents).

4.3.3.3 CHANGE IN CULTURAL PATTERNS AND VALUES

Refer to discussion in Section 4.2.3.3.

4.3.3.4 INCREASED DEMAND FOR FACILITIES AND SERVICES

The influx of workers will cause a significant increase in demand upon existing facilities and services. This increase is considered a significant impact for both the Lakhra and Khanot areas. The degree and type of demand may vary with the facility and service depending upon the site and the final plans for workers colony. It is anticipated that the contractors will provide housing for the construction workers. Housing will be needed for these workers and their families. An estimated 3 to 6 thousand workers are expected to be needed during the peak years of construction. The construction schedule calls for peak employment to occur in Year 6. Depending upon relocation of construction workers families, up to an additional 10,000 people are estimated to come into the area as result of power plant construction activity. Along with the



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housing requirements will be the need for appropriate potable water, waste treatment, health care, education, communications, recreation, and fire and safety services.

At Lakhra, no facilities or services exist to accommodate the workers. No estimates are available on what proportion of the workers will reside in the area and what proportion will maintain their residences which are within commuting distance. It is likely that workers may stay during the work week in the Lakhra area and return to their homes on weekends and holidays if the distance is not too great. Temporary housing would be required. The contractor selected for construction of the power plant should be required by WAPDA to furnish the necessary facilities and services to accommodate the expected influx of workers.

#### 4.3.3.5 INDUCED DEVELOPMENT IN THE SURROUNDING AREA ASSOCIATED WITH CONSTRUCTION OF THE POWER PLANT

It is unknown at this time if plans for further development are proposed to be associated with the power plant. It is likely that industries may be attracted to the area because of available electricity, developed infrastructure, transportation systems, and labor pool. The availability of these features and a decentralized industrial plan would suggest this eventuality. This development will likely occur on the Khanot area. At Khanot the transportation system (rail and truck) is more highly developed with direct access to the cities to the north and south, closer to a water source, and has more favorable environmental conditions for living. If development occurs on the west side of the National Highway, no significant cultural impacts are expected. There will be further urbanization of the area, and the rural nature of the Sindhi villages in the vicinity will change. If development takes place on the east side of the Highway, a loss of agricultural land could occur. Although the loss is not expected to be significant, the trend for the use of agricultural land for industrial development would be considered a negative impact.



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Cottage industries and small-scale development such as restaurants and tea houses are likely to occur. Expansion of the truck stop at intersection of the Lakhra Road and the Indus Highway is likely. No significant negative effects are associated with this type of development. The local economy will be increased and broadened.

4.3.3.6 TRANSPORTATION SYSTEMS IMPACTS

The construction activities will significantly increase the type and volume of traffic using the National Highway for both the Khanot and Lakhra site alternatives. The volume of truck and bus traffic will increase with the transportation of supplies, materials, and workers. Traffic volumes will be the greatest at the beginning and end of the work day. Heavy congestion will occur at the intersection. This potential congestion will slow traffic entering and leaving the National Highway. Because the highway is two-laned, north/south traffic will also be slowed at certain times of the day. If the power plant is built at Lakhra, the road system to and from the National Highway will need to be improved.

Discussion with the Deparment of Transportation and potential transporters indicate the Indus Highway is of sufficient condition to transport equipment and supplies to Lakhra. Equipment and supplies have been transported from Karachi to Guddu on this highway. The government of Sind has plans to upgrade the road. The transportation of large equipment will temporarily slow and cause congestion on the Indus Highway.

4.3.3.7 LOSS OF CULTURAL, HISTORICAL, AND ARCHAEOLOGICAL RESOURCES

Refer to discussion in Section 4.2.3.7.

## 4.4 POWER PLANT AND WORKERS COLONY: OPERATIONAL IMPACTS

### 4.4.1 PHYSICAL ENVIRONMENT

#### 4.4.1.1 AIR

The objective of the air quality impact analysis was to evaluate the maximum ground-level concentrations using atmospheric dispersion modeling for comparison with the air quality levels recommended by the World Bank and to assess the significance for adverse impacts to agricultural areas. In order to perform an air modeling analysis, meteorological data representative of the plant site area were used to properly account for the transport and diffusion of the plant's emissions. Model calculations are performed on an hourly basis from which other averaging-period concentrations can be developed (e.g., 3-hour concentration is based on three 1-hour concentrations). A complete discussion of the dispersion model used, the meteorological processing procedures, and modeling methodology can be found in Appendix F. The following sections describe the results of the air dispersion modeling.

Air Quality Modeling Results--$SO_2$

Operating Load and Stack Height Alternative Impact Evaluation--Table 4.4-1 presents the maximum predicted $SO_2$ impacts from two 250-MW units firing Lakhra coal at operating loads of 50, 75, and 100 percent (see Table 2-3). Worst-case meteorological conditions that represent typical combinations of wind speed and atmospheric stability were used. The results indicate that the maximum concentrations would occur under the 100 percent load conditions. It should be noted, however, that the impact for 75 percent and 50 percent load are not proportional to emissions. This effect is caused by a general decrease in plume rise brought about by lower flow rates at the lower loads.

Maximum Plant Impact Evaluation--A summary of the maximum $SO_2$ concentrations for a proposed coal-fired plant operating at 100 percent load for three stack heights using 1 year of onsite meteorological data is presented in Table 4.4-2. These results indicate that the highest



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Table 4.4-1. Maximum 1-Hour Average $SO_2$ Concentrations ($\mu g/m^3$) for Two 250-MW Units at 100 Percent Load Firing Lakhra Coal with Three Different Stacks Under Representative Worst-Case Meteorological Conditions

| Atmospheric Stability | Wind Speed (m/s) | Case | Concentrations ($\mu g/m^3$) for Stack Height of 183 m Operating Load 50% | 183 m 75% | 183 m 100% | 229 m Operating Load 50% | 229 m 75% | 229 m 100% | 305 m Operating Load 50% | 305 m 75% | 305 m 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Very Unstable | 1.5 | 1 | 2,163 | 3,244 | 4,326 | 2115 | 3,172 | 4,230 | 2,055 | 3,082 | 4,110 |
| | 2.0 | 2 | 1,636 | 2,453 | 3,271 | 1598 | 2,396 | 3,195 | 1,550 | 2,324 | 3,099 |
| | 3.0 | 3 | 1,266 | 1,898 | 2,531 | 1,212 | 1,817 | 2,423 | 1,132 | 1,698 | 2,264 |
| Moderately Unstable | 1.5 | 4 | 567 | 850 | 1,134 | 547 | 821 | 1,094 | 521 | 782 | 1,043 |
| | 2.0 | 5 | 474 | 711 | 948 | 451 | 677 | 902 | 421 | 631 | 841 |
| | 3.0 | 6 | 510 | 764 | 1,019 | 462 | 693 | 925 | 391 | 586 | 782 |
| | 5.0 | 7 | 581 | 871 | 1,161 | 496 | 743 | 991 | 391 | 587 | 782 |
| Slightly Unstable | 1.5 | 8 | 294 | 440 | 587 | 280 | 420 | 560 | 261 | 397 | 522 |
| | 2.0 | 9 | 289 | 434 | 578 | 268 | 403 | 537 | 237 | 355 | 474 |
| | 3.0 | 10 | 349 | 523 | 697 | 309 | 464 | 619 | 253 | 380 | 507 |
| | 5.0 | 11 | 409 | 613 | 818 | 341 | 511 | 681 | 256 | 384 | 512 |
| | 7.0 | 12 | 426 | 639 | 852 | 339 | 509 | 678 | 241 | 362 | 482 |
| | 10.0 | 13 | 417 | 626 | 835 | 318 | 477 | 636 | 214 | 320 | 427 |

Table 4.4-1. Maximum 1-Hour Average $SO_2$ Concentrations ($\mu g/m^3$) for Two 250-MW Units at 100 Percent Load Firing Lakhra Coal with Three Different Stacks Under Representative Worst-Case Meteorological Conditions (Continued, Page 2 of 2)

| Atmospheric Stability | Wind Speed (m/s) | Case | Concentrations ($\mu g/m^3$) for Stack Height of 183 m Operating Load 50% | 183 m 75% | 183 m 100% | 229 m Operating Load 50% | 229 m 75% | 229 m 100% | 305 m Operating Load 50% | 305 m 75% | 305 m 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Neutral | 2.0 | 14 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| | 3.0 | 15 | 18 | 27 | 36 | 12 | 18 | 24 | 5 | 8 | 10 |
| | 5.0 | 16 | 87 | 130 | 174 | 57 | 86 | 114 | 25 | 38 | 51 |
| | 7.0 | 17 | 123 | 185 | 247 | 83 | 124 | 166 | 39 | 58 | 77 |
| | 10.0 | 18 | 134 | 201 | 269 | 92 | 138 | 184 | 45 | 67 | 90 |
| | 12.5 | 19 | 133 | 200 | 266 | 89 | 133 | 178 | 44 | 67 | 89 |
| | 15.0 | 20 | 129 | 194 | 259 | 84 | 126 | 168 | 43 | 64 | 85 |
| Slightly Stable | 1.5 | 21 | 16 | 24 | 31 | 4 | 5 | 7 | 0 | 0 | 0 |
| | 2.0 | 22 | 20 | 31 | 41 | 5 | 8 | 10 | 0 | 0 | 0 |
| | 3.0 | 23 | 26 | 39 | 52 | 7 | 10 | 14 | 1 | 1 | 1 |
| | 5.0 | 24 | 30 | 45 | 60 | 8 | 13 | 17 | 1 | 1 | 1 |
| Moderately Stable | 1.5 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2.0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3.0 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Source: ESE, 1986.

Table 4.4-2. Comparison of Maximum Predicted $SO_2$ Concentrations ($\mu g/m^3$) for Two 250-MW Units at 100 Percent Load Firing Lakhra Coal for Three Stack Heights

| Averaging Period | Maximum $SO_2$ Concentrations ($\mu g/m^3$) With Stack Height of: | | |
|---|---|---|---|
| | 183 m | 229 m | 305 m |
| 1-hour | 4,765 | 4,658 | 4,526 |
| 3-hour | 1,588 | 1,553 | 1,509 |
| 8-hour | 596 | 582 | 566 |
| 24-hour | 199 | 194 | 189 |
| Annual | 12.8 | 7.8 | 3.4 |

*All concentrations occurred in the direction of 120 degrees at 1.7 km from the stack, except annual average concentration which occurred at 90 degrees and 3.0 km for heights of 183 and 229 m and 80 degrees and 3 km for height of 305.

Source: ESE, 1986.



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concentrations occur with the lowest stack height of 183 m (600 ft); however, the difference in maximum concentrations among the stack heights is less than 10 percent for the averaging periods of 24 hours or less. On an annual basis, the difference in maximum concentrations among the stack heights is larger than for the short-term averaging periods. The difference is primarily related to the frequency of meteorology conditions (i.e., combination of wind direction, wind speed, and stability) that produce maximum concentrations due to each stack height.

Impacts to Sensitive or Major Populated Areas--Table 4.4-3 presents the $SO_2$ impacts of the proposed plant with a stack height of 183 m to the Liaquat Medical College and Hyderabad City from a plant located at the Lakhra site. As shown by the table, the calculated maximum impacts at these distant sensitive receptors are substantially lower than that predicted nearby.

Agricultural Impact Evaluation--Maximum 3-hour, 24-hour, and annual $SO_2$ concentrations over a broad area of Kotri Taluka are presented in Figures 4.4-1 through 4.4-3. These figures show the spatial representation of $SO_2$ impacts with isopleths (lines of equal concentrations) for two 250-MW plants operated at 100 percent load with a stack height of 183 m (600 ft). The 3-hour and 24-hour isopleths represent the maximum concentrations that would be observed over an annual period at a particular location (receptor). The impacts for lower loads and higher stacks would be lower.

As shown by these figures, the general direction of maximum impacts will be to the northeast and south of the plant. The maximum range of $SO_2$ concentrations at agricultural lands 20 to 40 km east of the Lakhra site is presented in Table 4.4-4. These maximum concentrations are much lower than those produced near the proposed stack location (see also Section 4.4.2.1).



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Table 4.4-3. Maximum Predicted $SO_2$ Concentrations ($\mu g/m^3$) of Two 250-MW Units Located at Lakhra Site to Sensitive Receptors

| Averaging Time | Maximum $SO_2$ Concentrations ($\mu g/m^3$) | |
|---|---|---|
| | Liaquat Medical College and Hospital | Hyderabad City |
| 1-Hour | 1339 | 425 |
| 3-Hour | 446 | 156 |
| 8-Hour | 204 | 91 |
| 24-Hour | 85 | 56 |
| Annual | 5.7 | 3.8 |

Source: ESE, 1986.



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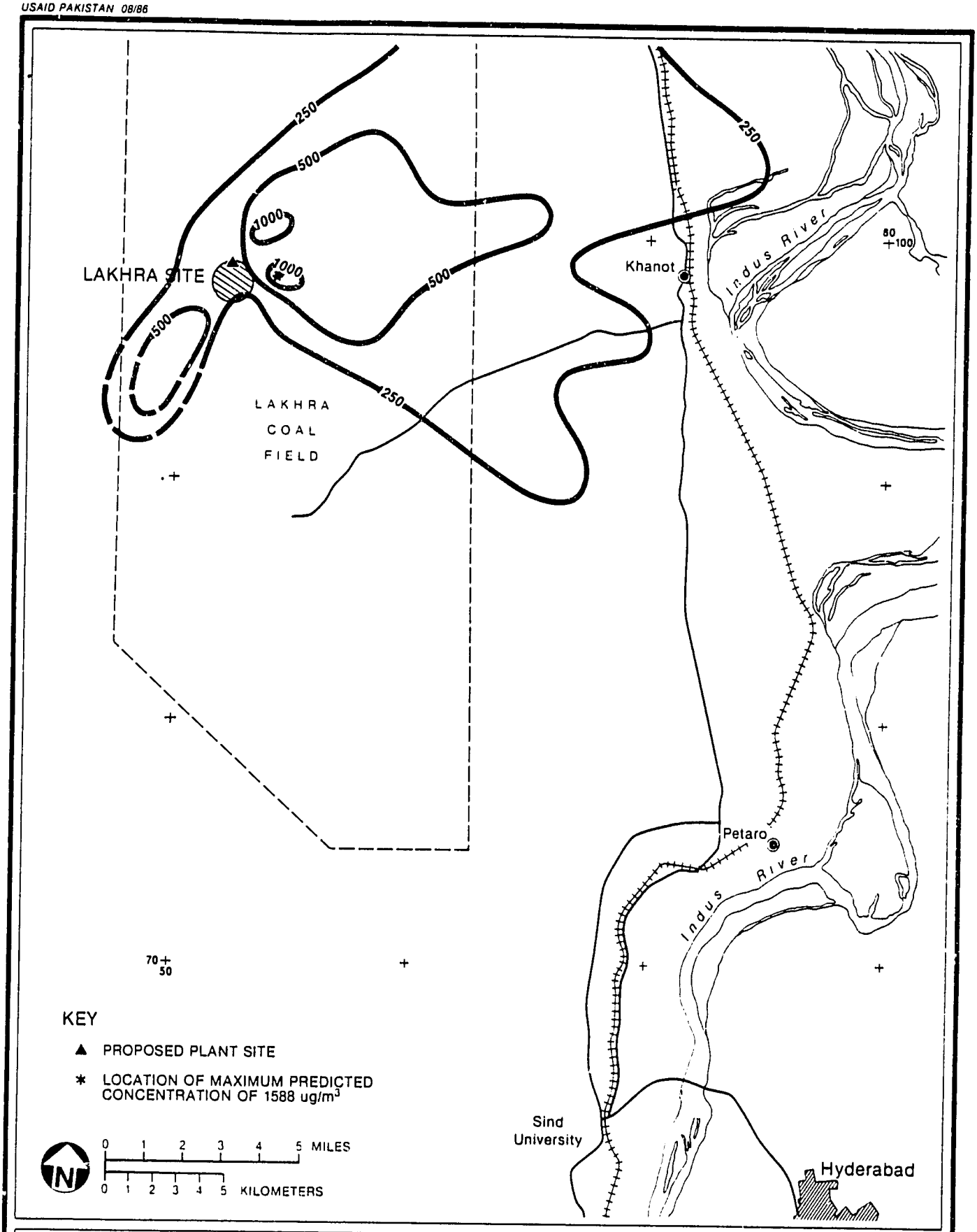


Figure 4.4-1
MAXIMUM PREDICTED 3-HOUR $SO_2$ CONCENTRATIONS (ug/m$^3$) DUE TO THE PROPOSED FACILITY

SOURCE: ESE, 1986.

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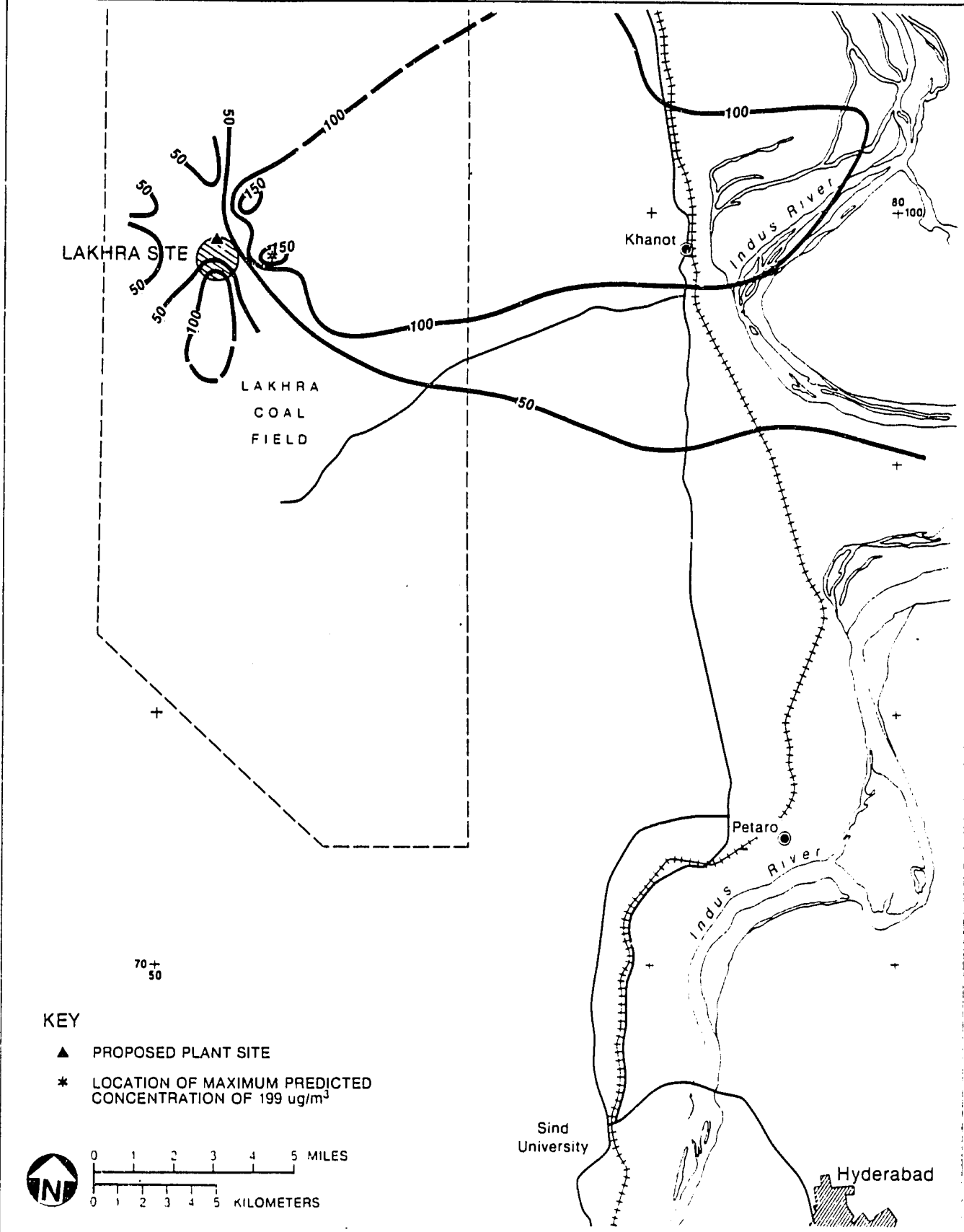


Figure 4.4-2
MAXIMUM PREDICTED 24-HOUR $SO_2$ CONCENTRATIONS (ug/m$^3$) DUE TO THE PROPOSED FACILITY

SOURCE: ESE, 1986.

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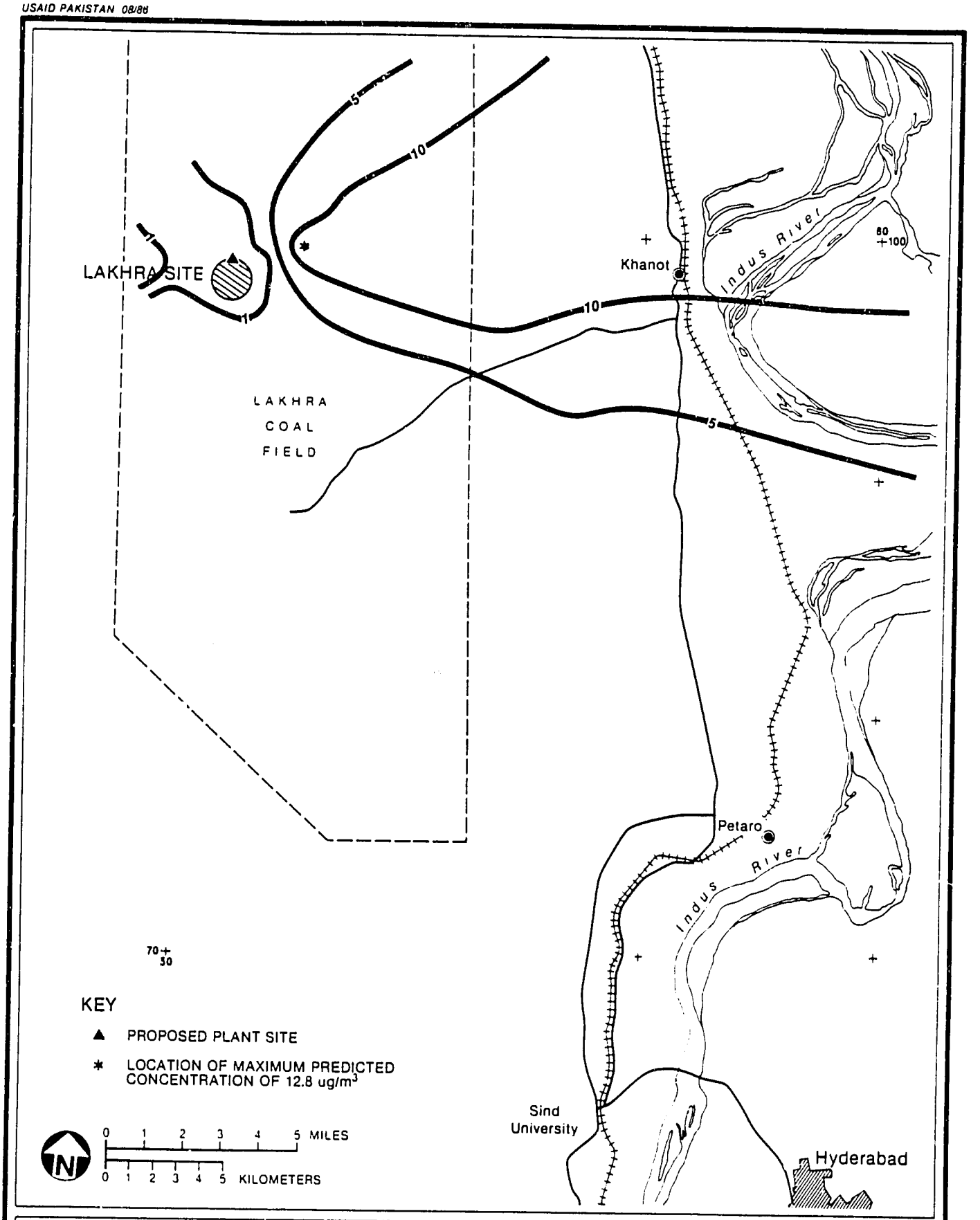


Figure 4.4-3
MAXIMUM PREDICTED ANNUAL $SO_2$ CONCENTRATIONS ($ug/m^3$) DUE TO THE PROPOSED FACILITY

SOURCE: ESE, 1986.

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Table 4.4-4. Maximum Predicted $SO_2$ Concentrations ($\mu g/m^3$) at Agricultural Lands 20 km to 40 km East of Lakhra Site

| Averaging Time | Maximum Range of $SO_2$ Concentrations | |
|---|---|---|
| | Concentration ($\mu g/m^3$) | Direction (°) |
| 1-Hour | 704 - 239 | 50 - 80 |
| 3-Hour | 303 - 116 | 80 - 120 |
| 8-Hour | 210 - 48 | 60 - 120 |
| 24-Hour | 119 - 22 | 80 - 120 |
| Annual | 17 - 1.7 | 80 - 120 |

Source: ESE, 1986.



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Interaction with the Jamshoro Oil Units--The maximum concentrations due to interaction with the Jamshoro oil-fired units (one 250-MW and three 210-MW units) are presented in Table 4.4-5. These results generally indicate that the impact of Jamshoro oil units will dominate the impacts to the areas in the vicinity of the Jamshoro plant. Maximum impacts with the addition of three 350-MW units at Jamshoro exhibit similar results. Predicted maximum $SO_2$ impacts were estimated to be 352 $\mu g/m^3$ and 46 $\mu g/m^3$ for the 24-hour and annual averaging times, respectively (Bechtel, 1987). The contribution of Lakhra to these predicted maximums was insignificant.

Air Quality Modeling Results--TSP

Maximum 24-hour and annual average TSP concentrations are presented in Figures 4.4-4 and 4.4-5 for a large area of the Kotri Taluka. These figures present TSP isopleths for two 280-MW units at 100 percent load with a stack height of 183 m (600 ft). The predicted impacts for lower loads and higher stacks would be lower.

These figures do not include a TSP background concentration which has been estimated to be about 200 $\mu g/m^3$ on an annual basis. As shown by these figures, the predicted maximum TSP impacts of the power plant are about 100 times lower than those actually observed at the Lakhra and Jamshoro monitoring stations.

Comparison with Air Quality Standards and Guidelines

A discussion of relevant standards, guidelines, criteria, and impacts of $NO_2$, TSP, and $SO_2$, are presented in the following paragraphs.

The maximum estimated nitrogen dioxide impacts and relevant air quality standards and criteria are presented in Table 4.4-6. The World Bank Guidelines to protect human health are generally based on an annual average value of 100 $\mu g/m^3$. The criterion published by WHO (1977) indicates that acute health effects were observed with annual $NO_2$ concentrations from 150 to 282 $\mu g/m^3$ accompanied by particulate

Table 4.4-5. Maximum $SO_2$ Concentrations ($\mu g/m^3$) Due to Interaction Between the Jamshoro Plant and Coal-Fired Plant Located at Lakhra

| Averaging Time | Case | Maximum Concentration ($\mu g/m^3$) |
|---|---|---|
| 1-Hour | Interaction due to: | |
| | Jamshoro | 2,303 |
| | Lakhra | 0 |
| | TOTAL | 2,303 |
| 3-Hour | Interaction due to: | |
| | Jamshoro | 1,084 |
| | Lakhra | 69 |
| | TOTAL | 1,153 |
| 8-Hour | Interaction due to: | |
| | Jamshoro | 406 |
| | Lakhra | 26 |
| | TOTAL | 432 |
| 24-Hour | Interaction due to: | |
| | Jamshoro | 135 |
| | Lakhra | 15 |
| | TOTAL | 150 |
| Annual | Interaction due to: | |
| | Jamshoro | 4.6 |
| | Lakhra | 0.3 |
| | TOTAL | 4.9 |

Source: ESE, 1986.



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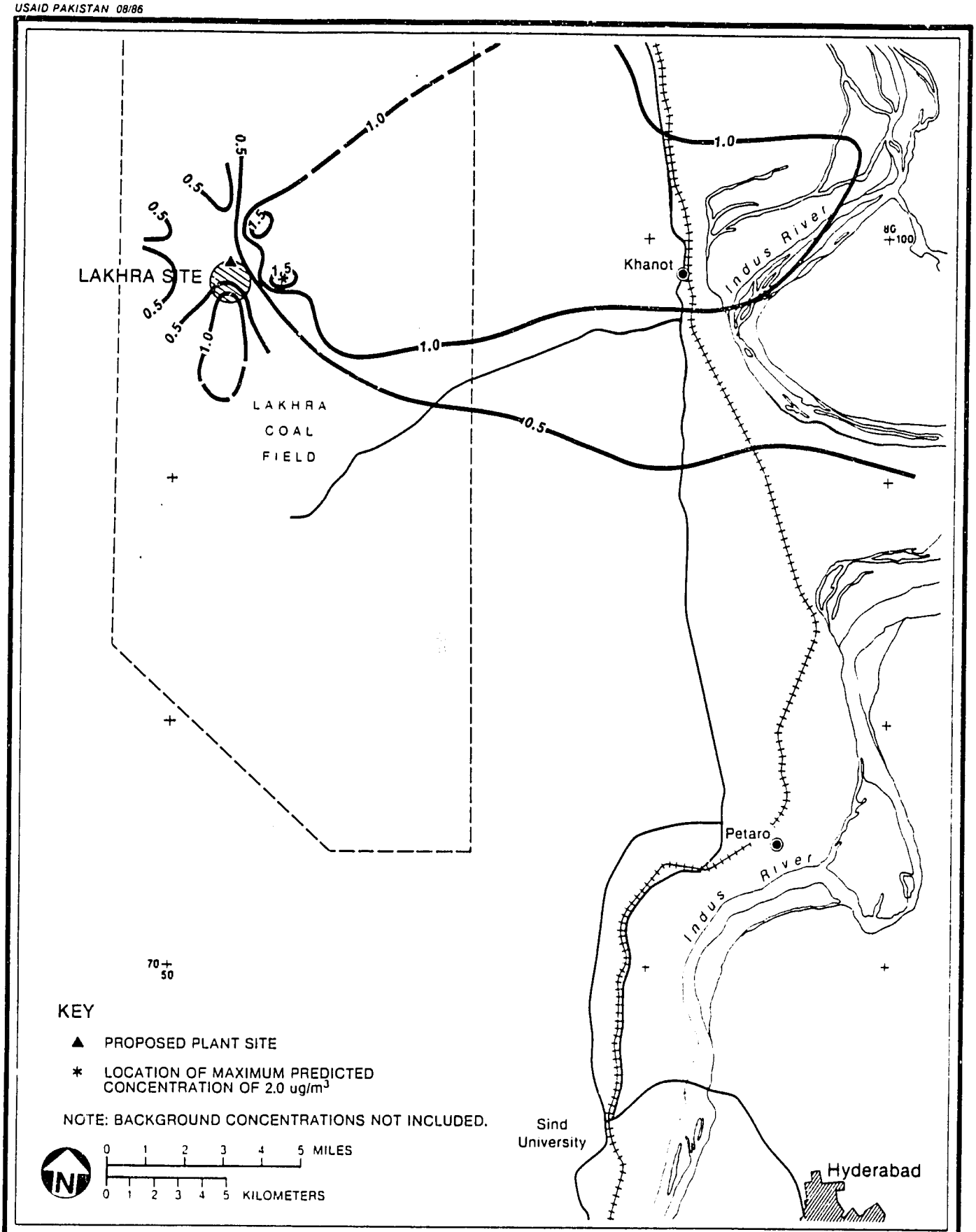


Figure 4.4-4
MAXIMUM PREDICTED 24-HOUR TSP CONCENTRATIONS (ug/m$^3$) DUE TO THE PROPOSED FACILITY

SOURCE: ESE, 1986.

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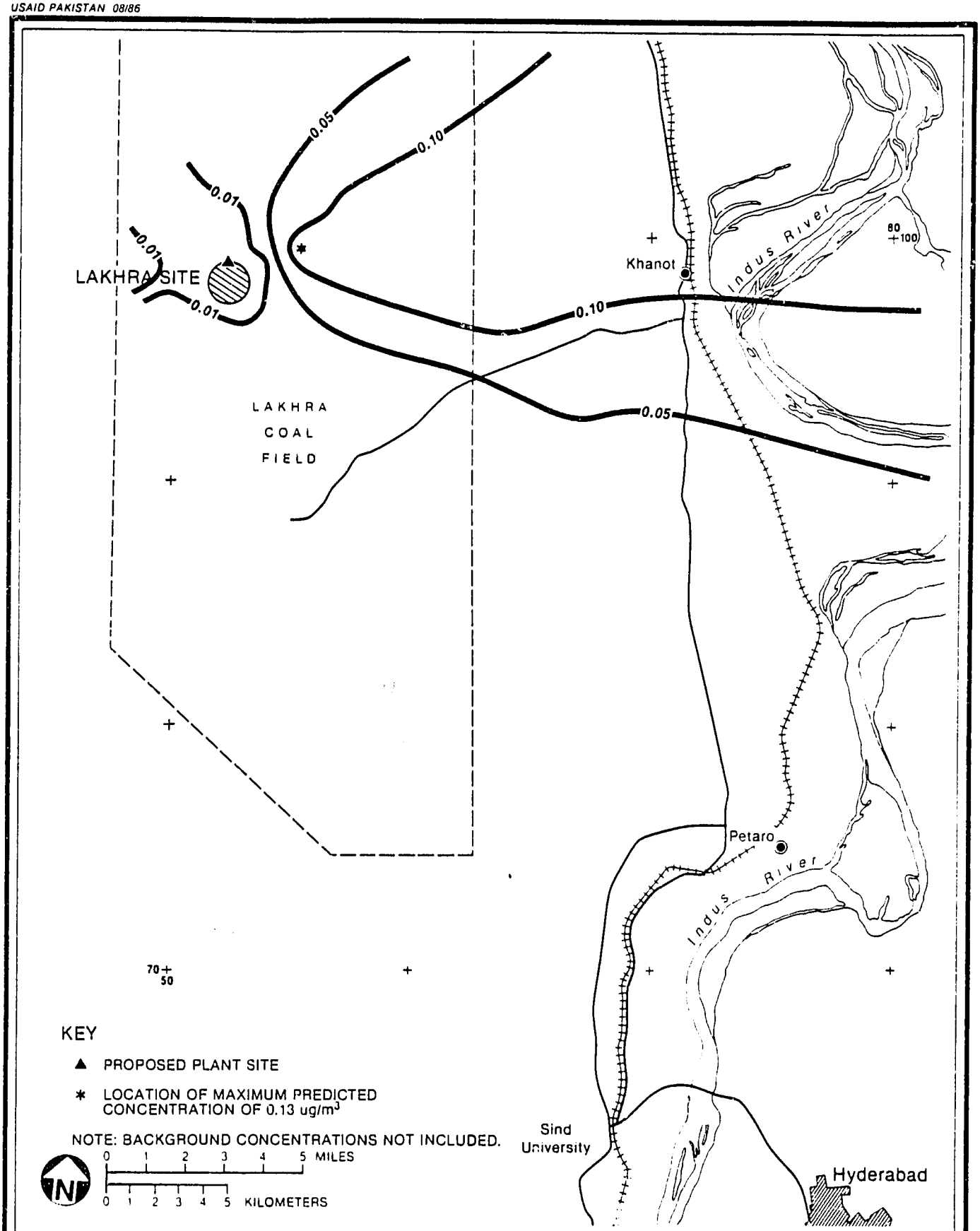


Figure 4.4-5
MAXIMUM PREDICTED ANNUAL TSP CONCENTRATIONS (ug/m$^3$) DUE TO THE PROPOSED FACILITY

SOURCE: ESE, 1986.

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Table 4.4-6. Maximum Estimated $NO_2$ Concentrations ($\mu g/m^3$) Compared to World Bank Guidelines and WHO Criteria

| | Averaging Time | |
|---|---|---|
| | Maximum 1-Hour | Annual |
| Plant Location at Lakhra | | |
| Maximum | 178 | 0.5 |
| Maximum to Populated Areas | 8.8 | 0.06 |
| Standards/Criteria | | |
| World Bank | -- | 100 |
| WHO | 940 | 100 |

Source: ESE, 1986.



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concentrations betwen 63 and 96 $\mu g/m^3$. However, no evidence of acute respiratory effects was observed at levels of 940 $\mu g/m^3$ for 1-hour averaging time and 100 $\mu g/m^3$ for the annual average (WHO, 1977). The estimated $NO_2$ impacts of the proposed plant are substantially below those levels generally considered to affect human health and welfare.

Although TSP and $SO_2$ have separate ambient air quality standards, they are generally considered together when addressing health-related effects (Table 4.4-7). WHO criteria for TSP and $SO_2$ (1979) indicate that increased symptoms of lung disease have been observed, with annual average $SO_2$ concentrations of 105 to 115 $\mu g/m^3$ and TSP levels of 160 to 185 $\mu g/m^3$ (see Table 4.4-7). For shorter averaging times, excess mortality in elderly at 500 $\mu g/m^3$ for both TSP and $SO_2$ on a 24-hour average has been observed. The World Bank guidelines, for developing countries, of 500 $\mu g/m^3$ and 100 $\mu g/m^3$ for 24-hour and annual averaging times, respectively, are generally consistent with WHO criteria; however, these criteria generally acknowledge the industrial/combustion- generated particulate matter and not that which would occur naturally. As discussed previously, the background TSP concentration of 200 $\mu g/m^3$ is relatively high but consistent with the arid nature of the area. A majority of these particulates are non-respirable particulates which would not produce synergistic effects with $SO_2$. In addition, the power plant impacts, which would be composed of fine respirable particulates, are extremely small compared to background concentrations. In contrast, the TSP air quality impacts due to mining are predicted to exceed 200 $\mu g/m^3$ several kilometers from the mine (refer to Section 4.2.1.1). Indeed, the TSP impacts from the power plant alone are considered to have an insignificant impact compared to the background levels and impacts associated with mining.

The maximum $SO_2$ impacts, which were predicted to be 199 and 12.8 $\mu g/m^3$ on a 24-hour and annual average basis, respectively, are not expected to exceed either the World Bank air quality guidelines or WHO criteria. The



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Table 4.4-7. Maximum Estimated TSP and $SO_2$ Concentrations ($\mu g/m^3$) at Lakhra Compared to World Bank Guidelines and WHO Criteria

| | Averaging Time | |
|---|---|---|
| | Maximum 24-Hour | Annual |
| I. TSP | | |
| Power Plant Impact | | |
| Maximum (Power Plant Only) | 2.0 | 0.13 |
| Maximum with Background* | 202.0 | 200.13 |
| Maximum to Populated Areas | 0.2 | 0.02 |
| Maximum with Background to Populated Areas | 202.2 | 200.02 |
| Mine Impact | | |
| Maximum | 504 | 90 |
| Maximum to Populated Areas | 38 | 7 |
| Maximum with Background to Populated Areas | 238 | 207 |
| Standards/Criteria | | |
| World Bank | 500 | 100 |
| WHO | 500 | 160-185 |
| II. $SO_2$ | | |
| Maximum (Power Plant Only) | 199 | 12.8 |
| Maximum to Populated Areas | 22 | 1.7 |
| Standards/Criteria | | |
| World Bank | 500 | 100 |
| WHO | 500 | 105-115 |

*Background concentration from monitoring data is 200 $\mu g/m^3$.

Source: ESE, 1986.



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air quality impacts of both the mine and power plant are also summarized in Table 4.4-7. It is important to note, however, that the locations of maximum impact of $SO_2$ emission from the plant and particulate matter emissions from mining will not coincide or align at any population areas due to meteorology and relative locations of the maximum predicted impacts to the populated areas. Maximum $SO_2$ impacts are predicted to occur about 1.7 km east-southeast from the stack, whereas maximum TSP impacts from mining are predicted also to occur towards the eastern boundary of the mine, which is 6 km from the power plant. No major population areas are located near these areas of maximum predicted concentrations. As a result, because of the location and magnitude of predicted TSP and $SO_2$ concentrations, significant impacts to human health are not expected to occur. Transboundary air pollution is expected to occur; however, impacts would be insignificant and perhaps immeasurable. Appendix J presents a more complete description of potential transboundary impacts.

#### 4.4.1.2 NOISE

The noise levels projected to exist in the vicinity of the power plant site during operation were developed by taking into account attenuation due to hemispherical spreading and atmospheric molecular absorption and surface feature attenuation. Sound propagates through the atmosphere in spherical waves (hemispherical spreading). Since the surface area of a sphere is proportional to its radius squared, each doubling of the radius increases the surface area by a factor of four. Likewise, as the distance from a sound source is doubled, the intensity of its radiated sound energy is decreased by a factor of four. In terms of the decibel scale, a fourfold decrease in energy (from each doubling of distance from the referenced measuring point) results in a 6-dBA decrease in sound pressure level. In addition, meteorological characteristics of the atmosphere result in additional attenuation. When no direct path exists from a source to a receptor, as is the case through any solid barrier, additional attenuation results from sound wave refraction around the



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obstacles. These refractive losses will not be realized for elevated sources for which there is a direct line of sight from source to receptor.

Noise impacts from operation of Lakhra Plant were estimated using techniques and data in the Edison Electric Institute (EEI) Environmental Noise Guide (Bolt et al., 1978), reports by Dennison (1977), and specifications of equipment noise emission levels by BRI (1983). Table 4.4-8 lists the major noise-producing equipment and estimated or specified sound pressure levels. Sound levels were estimated from the listed emission factors by the technique of decibel addition with correction for hemispherical spreading and environmental attenuation as described in this section. Decibels are added in a nonlinear manner such that two sources at 100 decibels are equivalent to a 103-decibel source.

The power plant and cooling towers will normally operate on a continuous basis, 24 hours a day. The coal handling equipment will normally operate approximately 16 hours a day. The coal delivery, unloading, and reclaim systems will produce a wide range of sound on an intermittent basis.

Noise levels at the power plant site boundary represent the greatest impacts that the human population may be subject to in the vicinity of the power plant site. Operational noise levels were projected for four distances from the power plant. Table 4.4-9 shows the predicted noise levels at each distance. Existing noise levels at these locations were assumed. From the perspective of changes in noise levels, the maximum ambient noise level is expected to increase no more than 4 dBA at the nearest property boundary due to operation of the plant. Noise levels will be attenuated to preconstruction levels shortly beyond the power plant site boundary. No measurable increase in average noise level is expected at any village or noise-sensitive receptor. Plant operation will not cause or exacerbate any noise levels above the 55 dBA $L_{dn}$ World Bank guidelines.

Table 4.4-8. Typical Plant Operation Equipment and Emitted Noise Levels

| Equipment Type | Sound Levels* (dBA) |
|---|---|
| Power Block | |
| Boiler | 105 |
| Turbine | 93 |
| Transformer | 105 |
| Condenser | 106 |
| Boiler Feed Pump | 85 |
| Induced Draft Fan | 83 |
| Forced-Draft Fan (Inlet) | 80 |
| Forced-Draft Fan (Casing) | 74 |
| Primary Air Fan | 81 |
| Coal Pulverizer | 89 |
| Air Compressor | 90 |
| Electrostatic Precipitator | 104 |
| Coal Handling | |
| Rotary Dumper | 80 (peak at 20 m) |
| Transfer Tower | 108 |
| Stacker/Reclaimer | 99 |
| Crusher Tower | 110 |
| Front-End Loader | 83 (at 15 m) |
| Haul Truck | 80 (at 15 m) |
| Cooling Towers | 50 (at 150 m) |

Note: These are nearfield equipment emission levels and do not take into account building, atmospheric, or barrier attenuation or hemispherical spreading.

*Sound level at 1 m (3 ft), unless otherwise noted.

Sources: Bolt, Beranek, and Newman, 1978.
Dennison, 1977.
ESE, 1986.
KBN, 1986.

Table 4.4-9. Predicted Lakhra Plant Operational Noise Impacts

| Distance* (m) | Existing Noise Level† (dBA) | | | Plant** Contribution (dBA) | | Total Predicted Ambient Noise Level (dBA) | | |
|---|---|---|---|---|---|---|---|---|
| | $L_d$ | $L_n$ | $L_{dn}$ | $L_d$ | $L_n$ | $L_d$ | $L_n$ | $L_{dn}$ |
| 1,000 | 46 | 42 | 49 | 43 | 43 | 48 | 46 | 53 |
| 1,250 | 46 | 42 | 49 | 37 | 37 | 47 | 43 | 50 |
| 1,800 | 46 | 42 | 49 | 36 | 36 | 46 | 43 | 50 |
| 2,500 | 46 | 42 | 49 | 19 | 19 | 46 | 42 | 49 |

*With respect to Units 1 and 2 main power block.
†Assumed based on J.T. Boyd Co. results as ambient levels over annual period.
**Maximum estimated level during plant operation, with coal-handling equipment in operation.
$L_d$ = Daytime noise levels (0700 to 2200)
$L_n$ = Nighttime noise levels (2200 to 0700)
$L_{dn}$ = Day-night noise level with 10 dBA added to nightime noise levels.

Sources: ESE, 1986.
KBN, 1986.



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#### 4.4.1.3 LAND AND WATER RESOURCES

Potential impacts to land and water resources during operation of the two 250-MW units at Lakhra and a workers' colony at Khanot include:

1. Changes in stream flows or water quality due to operational water requirements; and
2. Discharge of contaminated liquid or solid wastes to surrounding land, and surface or ground waters.

Impacts Due to Water Usage Requirements

Cooling and plant service water will be supplied by pumping from the Indus River. Water requirements under normal power plant and mining operations are estimated to be about 34 cusecs. Thus the withdrawal of cooling and service water for project operations with no return flow will reduce the available water for use downstream by 34 cusecs. Indus River discharge data (Subsection 3.1.2) indicate the minimum daily flow at the Sehwan, based on available data between 1972 and 1979, was about 895 $m^3/s$, which is far in excess of the 34 cusecs required for plant operation. Therefore, no significant impacts will result from water usage requirements.

Impacts Due to Discharge of Contaminated Wastes

Types, volumes, and methods of handling the liquid and solid wastes generated by the two proposed 250-MW power plant units are summarized in Tables 4.4-10 and 4.4-11, respectively.

Major sources of wastewater generated by the two 250-MW units include cooling water blowdown and bottom and fly ash transport water. Relatively lower volume wastestreams include boiler blowdown, water treatment filter backwash, demineralizer waste regenerates, and domestic wastewater. Infrequent waste streams include boiler chemical cleaning wastes and coal pile runoff. Domestic wastewater will be the major potential wastewater discharge for the workers colony.

Table 4.4-10. Types, Estimated Volumes, and Proposed Method of Handling of Power Plant Liquid Wastes

| Type | Frequency of Disposal | Estimated Maximum Volume* (Design) | Proposed Method of Treatment and Handling/Disposal |
|---|---|---|---|
| Sanitary Waste | Intermittent | 2,190 $m^3/d$ (579,000 gpd) | Treated in Package Activated Sludge Plant, Chlorinated. |
| Filter Backwash | Continuous | 3,330 $m^3/d$ (879,700 gpd) | Routed to FGD/FA Settling Pond-Recirculated as FGD Make-up Water or Fly Ash Transport Water |
| FGD System Sluice Water | Continuous Recirculating | 22,200 $m^3/d$ (5,865,000 gpd) | Routed to FGD/FA Settling Pond--Recirculated to FGD System |
| Fly Ash Transport Water | Continuous | 23,800 $m^3/d$ (6,284,000 gpd) | Routed to FGD/FA Settling Pond--Recirculated to FGD/FA Transport System |
| Boiler Chemical Cleaning Waste | Intermittent (once every 4 to 5 years) | | Neutralized, Routed to Miscellaneous Waste Evaporation Pond |
| Demineralizer Waste Regen-erates | Continuous | 2,050 $m^3/d$ (540,000 gpd) | Routed to Miscellaneous Waste Evaporation Pond |
| Coal Pile Runoff | Infrequent | Minimal, if any | Routed to Miscellaneous Waste Evaporation Pond |
| Cooling Water Blowdown | Continuous | 2,970 $m^3/d$ (785,000 gpd) | Routed to Bottom Ash Settling Pond--Recirculated in Bottom Ash Transport |
| Bottom Ash Sluice Water | Intermittent Recirculating | 20,600 $m^3/d$ (5,450,000 gpd) | Routed and Recirculated with Boiler Blowdown to Bottom Ash Settling Pond |

*Based on design flows from GCII.

Source: ESE, 1986.
GCII, 1986.



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Table 4.4-11. Types, Estimated Volumes, and Proposed Method of Handling Power Plant Solid Wastes

| Type | Frequency of Disposal | Estimated Volume* | Proposed Method of Treatment and Handling/Disposal |
|---|---|---|---|
| Bottom Ash | Intermittent | $650 m^3/d$ (23,000 $ft^3/d$) | Routed to Bottom Ash Pond |
| Fly Ash | Intermittent | $2,300 m^3/d$ (80,000 $ft^3/d$) | Routed to Fly Ash Silo or Directly to Fly Ash Pond |
| Water Treatment Clarifier Sludge | Continuous | $1,450 m^3/d$ (51,100 $ft^3/d$) | Routed to Miscellaneous Waste Evaporation Pond |
| Wastewater Sludge | Continuous | $30 m^3/day$ (1,040 $ft^3/d$) | Pumped to Digester, Stored Onsite, Used for Gardening and Landscaping |

*Based on design volumes from GCII.

Source: GCII, 1986.
ESE, 1986.

As shown in Table 4.4-11, the major solid wastes generated by the proposed Lakhra Power Plant and associated worker colony include: bottom ash, fly ash, solids generated from treatment of raw water and process water (including evaporation pond residue); sanitary waste treatment sludge; and miscellaneous refuse (e.g., construction debris, garbage). Bottom ash and fly ash are the most voluminous of these solid wastes. At a 70 percent plant capacity factor for the two 250-MW Lakhra units, about 224,000 metric tons/year per unit (246,000 tons/year) of bottom ash and 336,000 metric tons/year per unit (370,000 tons/year) of fly ash would be generated. The amount of FGD sludge potentially generated depends on the FGD method selected and removal efficiency requirements, but will likely approach the total volume of ash produced by the plant. Amounts of other solid wastes potentially produced by the proposed facility are comparatively small.

The power plant waste management and reuse plan, as proposed by GCII, is designed to:

1. Optimize reuse of process water,
2. Contain and evaporate excess wastewater onsite, and
3. Contain solid wastes in storage ponds and/or dispose of excess wastes in designated landfill areas.

The waste facilities are designed to result in no discharge of wastewater to surrounding surface waters or land. All liquid and solid wastes except plant oily wastes and sanitary treatment plant sludges will be directed to a series of storage, evaporation, or disposal pond areas. Plant oily wastes will be collected and sprayed on the dead coal storage site for dust control. Sanitary wastewater treatment plant sludges will be digested and landspread following stabilization.

Industrial wastes such as boiler chemical cleaning, demineralizer recharge flows, and primary water treatment plant sludge will be routed to the evaporation ponds. Chemical cleaning wastes will be collected and



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neutralized prior to disposal in the evaporation pond. Liquid effluents routed to the fly ash ponds include water treatment, filter backwash, water, and treated sanitary effluents. Sanitary wastes for the plant and workers' colony will be treated by an activated sludge package plant and chlorinated prior to routing to ponds. Sanitary effluents for the plant will be recirculated to the fly ash transport system. Make-up water will be added as required.

Cooling tower and boiler blowdown will be routed to the bottom ash disposal ponds and recycled for bottom ash transport. Any overflow from the bottom ash ponds will be routed to the evaporation ponds. All ponds will be diked to a height of 12 to 20 m (36 to 61 ft). Site runoff, other than runoff from the dead storage coal pile, will be diverted away from the pond area.

Fly ash will be routed to the fly ash storage/disposal ponds. The fly ash disposal area will consist of a system of dikes and ponds covering an area of about 96 hectares (240 acres) at total buildout. About one-third [or 48 hectares (80 acres)] will be in use at any one time. The pond and dike system is designed to allow for clarification and recirculation of ash transport water.

Bottom ash from the boiler will be routed to the bottom ash ponds which are located on the corner of the fly ash pond development. These ponds are planned for maximum 5-year storage of bottom ash. The bottom ash pond is divided into two chambers to allow for dewatering and ash removal from one chamber while the second chamber is in service.

Excess fly and bottom ash and evaporation ponds solids will be placed in the mined areas for disposal after the first 5 years of operation.

The physical and chemical composition of the solid and liquid waste material is determined by several factors including:

1. Chemical and physical properties of the coal burned,
2. Type of boilers installed,
3. Type of particulate collection,
4. Waste treatment prior to disposal, and
5. Circulation/reuse of wastes.

These processes are plant-specific and vary significantly from plant to plant. As a result, chemical constituents present in the waste materials, and hence the quality of the waste streams, are also plant specific.

Table 4.4-12 presents a list of compounds commonly found in power plant wastewater effluents by waste stream. The information in this table was compiled during an industry-wide sampling program conducted at power plants throughout the United States by the U.S. Environmental Protection Agency (USEPA). Samples were analyzed for 129 compounds designated by USEPA as Priority Pollutants (USEPA, 1982).

Since recirculating cooling systems concentrate the dissolved solids present in the make-up water, concentration increases are to be expected. Of the pollutants detected as net discharges, the net concentration increase in cooling tower blowdown exceeded 0.1 milligrams per liter (mg/L) only for cadmium, copper, cyanide, lead, and zinc. According to the USEPA study, net discharges of metals other than chromium and zinc are the result of corrosion of metal surfaces within the cooling water system. Higher levels of chromium and zinc often result from the use of corrosion control additives. The use of non-oxidizing biocides and other chemical additives listed in Table 4.4-13 may explain the presence of many other compounds detected in power plant effluents. According to the GCII Feasibility Study (1986), a minimum amount of chemical additives will be required at the Lakhra plant.



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Table 4.4-12. Priority Pollutants* Detected in USEPA Sampling Program by Waste Stream Sources

| Priority Pollutant | Waste Stream Source† | | | | |
|---|---|---|---|---|---|
| | Cooling Tower Blowdown | Bottom Ash Sluice Water | Fly Ash Sluice Water | Low Volume Waste** | Coal Pile Runoff†† |
| 1,2-Dichloroethane | 0 | 0 | 0 | X | 0 |
| 1,2-Dichlorobenzene | 0 | 0 | 0 | X | 0 |
| Phenol | X | X | X | X | 0 |
| Toluene | X | 0 | 0 | X | 0 |
| Beryllium (Total) | X | X | X | 0 | X |
| Cadmium (Total) | X | X | X | X | X |
| Chromium (Total) | X | X | X | X | X |
| Copper (Total) | X | X | X | X | X |
| Cyanide (Total) | X | 0 | 0 | X | 0 |
| Lead (Total) | X | X | X | X | X |
| Nickel (Total) | X | X | X | X | X |
| Selenium (Total) | X | X | X | X | 0 |
| Silver (Total) | X | 0 | 0 | X | 0 |
| Zinc (Total) | X | X | X | X | X |

*Only compounds for which the increases in net discharges were greater than 10 micrograms per liter (μg/L).

†X = Present in greater concentration in the effluent than in the influent at least once.
0 = Never present in greater concentration in the effluent than in the influent.

**Low volume wastes include boiler blowdown, waste streams from water treatment, and effluent from floor and yard drains.

††Since coal pile runoff has no influent stream (except rainfall), this column reflects whether or not the pollutant was ever detected in the coal pile effluent stream.

Source: USEPA, 1982.



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Table 4.4-13. Proprietary Chemicals Used by Power Plants and Containing USEPA Priority Pollutants

| Proprietary Chemical (point of application*) | Specific USEPA Priority Pollutant Contained in Product |
|---|---|
| Nalco Chemicals | |
| 25L (CT) | Copper |
| 37 (BW) | Chromium |
| 38 (CW) | Chromium |
| 75 (BW) | Phenol |
| 201 (CT) | Chlorinated Phenols |
| 344 (CT) | Acrylonitrile |
| 375 (CW) | Chromium |
| 425L(BW) | Copper |
| Calgon Chemicals | |
| CL-70 (CT) | Zinc Chloride |
| CL-35 (BW) | Sodium Dichromate |
| CL-68 (CW) | Sodium Dichromate, Zinc Chloride |
| Dearborn Chemicals | |
| 712 (CW) | Chlorinated Phenols |
| Betz Chemicals | |
| Betz 40P (CW) | Chromate and Zinc Salts |
| Betz 403 (CW) | Chromate and Zinc Salts |
| Dianodic 191 (CW) | Chromate and Zinc Salts |
| Dow Chemicals | |
| Dowicide GB (Algacide) | Chlorinated Phenols |
| Hercules Chemicals | |
| CR 403 (CT) | Zinc Dichromate, Chromic Acid |
| DuPont | |
| Karmex (CW) | Chlorinated Phenols |
| Drew Chemicals | |
| Biosperse 201 (CW) | Chlorinated Ethanes |
| Ashland Chemicals | |
| 1,1,1-Trichloroethane (FA) | Chlorinated Ethanes |
| Burris Chemicals | |
| Sodium Dichromate (CT) | Sodium Dichromate |

*Point of Application: BW - Boiler Water
CT - Cooling Tower
CW - Cooling Water
FA - Fuel Additive

Source: USEPA, 1982.



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Primary pollutants of concern present in waste ash and ash handling or transport water are trace metals. Most of the trace metals found in ash wastes originate in the coal. Chloride, sodium, sulfate, and other ions present in the coal are also found in the ash and ash transport water.

Results of chemical analyses of the Lakhra coal and ash are presented in Tables 4.4-14 and 4.4-15. As shown in these tables, the Lakhra coal has high moisture, ash, and sulfur contents. The acid-to-base ratio for the constituents present in the ash was determined to be about 0.34, which indicates that the acidic ions species present in the ash may tend to lower the pH of the ash transport water. Solubilities of heavy metals are very sensitive to changes in pH. At pH 5 or lower, metals will tend to be leached from the ash and dissolve into solution. At higher pH (greater than pH 8), heavy metals tend to precipitate from solution. The actual pH of the ash transport water will depend on the buffering capacity of the transport water and the effects of other waste streams routed to the ash handling ponds.

The water soluble content of fly ash and bottom ash can vary significantly. Principal ions contained in the leachate are calcium and sulfate, with smaller quantities of magnesium, sodium, potassium, and silicate ions present. The soluble sulfate is approximately half the total sulfate ($SO_4$) present in fly ash (Tripodi and Cheremisinoff, 1980).

Tables 4.4-16 and 4.4-17 summarize ranges of concentrations for various parameters found in ash and ash leachate at several U.S. power plants. Ash characteristics can vary significantly depending on the specific coal used, as well as individual processes employed at a plant. Thus, the values in Tables 4.4-16 and 4.4-17 represent only an indication of the ash characteristics for the Lakhra project power plants.

Table 4.4-14. Summary of Whole Coal Analyses (Plant Run)

| Proximate Analysis | Raw | Clean |
|---|---|---|
| Moist (AR/DRY/MAF) | 28.79/ - / - | 32.31/ - 1/ - |
| Ash | 23.18/32.55/ - | 13.07/19.31/ - |
| Volatile Matter | 27.82/39.07/57.92 | 28.15/41.58/51.53 |
| Fixed Carbon | 20.21/28.38/42.08 | 26.47/39.11/48.47 |
| Sulfur | 3.49/4.90/7.26 | 2.71/4.00/4.96 |
| H.H.V. | 5995/8419/12481 | 7154/10569/13098 |
| Alk. as $Na_2O$ | 0.22/0.31/0.46 | 0.25/0.37/0.46 |
| Sulfur Forms | | |
| Pyritic (AR/DRY) | 2.09/2.93 | 1.45/2.00 |
| Sulfate | 0.18/0.25 | 0.15/0.20 |
| Organic | 1.22/1.72 | 1.31/1.80 |
| Water Soluble Alkalis | | |
| $Na_2O$ (AR/DRY) | 0.167/0.234 | 0.165/0.227 |
| $K_2O$ | 0.012/0.017 | 0.008/0.011 |
| Fusion Temperatures (°F) | | |
| Initial Deform (RED/OX) | 2470/2610 | 2150/2390 |
| Softening | 2530/2670 | 2200/2460 |
| Hemi | 2570/2700† | 2250/2510 |
| Fluid | 2610/2700† | 2310/2550 |
| Ultimate Analysis (°F) | | |
| Moist (AR/DRY) | 28.79/ - | 32.31/ - |
| Carbon | 33.43/46.94 | 40.20/59.39 |
| Hydrogen | 2.56/3.59 | 2.90/4.28 |
| Nitrogen | 0.52/0.73 | 0.59/0.87 |
| Chlorine | 0.39/0.55 | 0.22/0.32 |
| Sulfur | 3.49/4.90 | 2.71/4.00 |
| Ash | 23.18/32.55 | 13.07/19.31 |
| Oxygen (diff) | 7.64/10.74 | 8.00/11.83 |
| $SiO_2$ | 41.63 | 36.28 |
| $Al_2O_3$ | 28.46 | 26.25 |
| $TiO_2$ | 2.09 | 1.86 |
| $Fe_2O_3$ | 16.79 | 18.47 |
| CaO | 3.03 | 5.14 |
| MgO | 1.76 | 2.77 |
| $K_2O$ | 0.53 | 0.51 |
| $Na_2O$ | 0.59 | 1.56 |
| $SO_3$ | 4.23 | 6.90 |

Table 4.4-14. Summary of Whole Coal Analyses (Plant Run)
(Continued, Page 2 of 2)

| Proximate Analysis | Raw | Clean |
|---|---|---|
| $P_2O_5$ | 0.09 | 0.10 |
| SrO | 0.19 | 0.09 |
| BaO | 0.07 | 0.04 |
| $Mn_3O_4$ | 0.03 | 0.03 |
| Undetermined | 0.51 | 0.00 |
| Miscellaneous | | |
| Hargrove Grind | 77* | 74† |
| Eq. Moisture | 25.69 | 27.42 |

*At 12.82 percent moisture.
†At 17.80 percent moisture.

Source: GCII, 1986.



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Table 4.4-15. Raw vs Clean Indices (Plant Run)

| | Raw | Clean |
|---|---|---|
| Slagging: | | |
| Slagging Reducing (°F) | | |
| Initial | 2470 | 2150 |
| Soft | 2530 | 2220 |
| Hemi | 2570 | 2250 |
| Fluid | 2610 | 2310 |
| Base Acid Ratio | 0.31 | 0.44 |
| Silica-Alumina Ratio | 1.46 | 1.38 |
| Silica Value | 65.86 | 57.90 |
| Iron Ratio | 3.51 | 2.34 |
| Dolomite Percentage | 21.10 | 27.80 |
| Slagging Index | 1.52 | 1.76 |
| Critical Viscosity Temp ($T_{cv}$) | 2487 | 2488 |
| $T_{250}$ (°F) | 2521 | 2363 |
| Viscosity at $T_{cv}$ (poises) | 183 | 60 |
| Fouling: | | |
| Fouling Index | | |
| B/A ($Na_2O$) | 0.18 | 0.69 |
| $Na_2O$ Ash | 0.59 | 1.56 |
| Hargrove | 77 | 74 |

Source: GCII, 1986.



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Table 4.4-16. Chemical Constituents of Bottom Ash and Fly Ash

| | Fly Ash (mg/kg) | | Bottom Ash/Slag (mg/kg) | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| Aluminum | 11,500.0 | 144,000.0 | 88,000.00 | 135,000.0 |
| Antimony | 0.8 | 1,000.0 | 0.14 | 12.0 |
| Arsenic | 2.3 | 1,700.0 | 0.98 | 40.0 |
| Barium | 96.0 | 13,900.0 | 500.00 | 4,000.0 |
| Beryllium | 1.0 | 1,000.0 | 3.00 | 10.6 |
| Boron | <10.0 | 3,000.0 | 70.00 | 300.0 |
| Cadmium | 0.1 | 250.0 | <0.50 | <250.0 |
| Calcium | 5,400.0 | 177,000.0 | 8,400.00 | 50,600.0 |
| Chlorine | 13.0 | 25,000.0 | <1,100.00 | 1,800.0 |
| Chromium | 11.0 | 7,400.0 | 15.00 | 270.0 |
| Cobalt | 6.0 | 1,500.0 | 3.60 | 380.0 |
| Copper | 30.0 | 3,020.0 | 2.80 | 720.0 |
| Fluorine | 0.4 | 624.0 | 10.60 | 100.0 |
| Iron | 7,800.0 | 289,000.0 | 27,000.00 | 203,000.0 |
| Lead | 3.1 | 1,600.0 | 5.00 | 35.0 |
| Magnesium | 4,900.0 | 60,800.0 | 4,500.00 | 32,500.0 |
| Manganese | 31.0 | 4,400.0 | 100.00 | 720.0 |
| Mercury | 0.01 | 22.0 | 0.01 | <4.0 |
| Nickel | 1.8 | 8,000.0 | 10.00 | 700.0 |
| Phosphorus | 600.0 | 2,500.0 | 300.00 | 1,600.0 |
| Potassium | 1,534.0 | 34,700.0 | 7,300.00 | 15,800.0 |
| Selenium | 1.2 | <500.0 | 0.08 | 7.7 |
| Silicon | 196,000.0 | 271,000.0 | 180,000.00 | 273,000.0 |
| Silver | 1.0 | 50.0 | 25.00 | — |
| Sodium | 1,180.0 | 20,300.0 | 1,800.00 | 13,100.0 |
| Sulfur | 0.11 | 0.25 | 0.06 | 0.09 |
| Titanium | 400.0 | 15,900.0 | 3,300.00 | 7,210.0 |
| Zinc | 14.0 | 13,000.0 | 24.00 | 950.0 |

Source: Tripodi and Cheremisinoff, 1980.



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Table 4.4-17. Laboratory Leachate Test Data*

| | Fly Ash | Bottom Ash |
|---|---|---|
| pH | 4-6 | --† |
| TDS | 4,000-6,000 | 2,500-19,000 |
| $SO_4$ | 800-1,200 | 20-5,800 |
| Arsenic | 0.01-0.20 | <0.01-0.34 |
| Barium | <0.50 | 0.2-1.0 |
| Cadmium | <0.01 | <0.01-0.11 |
| Chloride | 30-40 | 0.2-3,500 |
| Chromium | <0.05 | <0.01-0.11 |
| Copper | 2-6 | 0.02-0.98 |
| Fluoride | -- † | 0.05-3.1 |
| Iron | 80-150 | 0.04-90 |
| Lead | 0.2-0.5 | <0.01-0.25 |
| Manganese | -- | <0.01-6.5 |
| Mercury | <0.002 | -- -- |
| Nitrate | -- | -- -- |
| Selenium | <0.06 | <0.01-0.02 |
| Silver | <0.05 | <0.05 |
| Zinc | 7-9 | <0.02-3.1 |

*All results mg/L except pH.
†Not Analyzed.

Sources: Ruggiano and Poulson, 1980.
Tripodi and Cheremisinoff, 1980.



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Low volume wastes as referenced in Table 4.4-12 include boiler blowdown, waste streams from water treatment, and effluent from floor and yard drains. Floor and yard drain wastes will be routed to a separate basin and applied to the coal pile.

Boiler blowdown serves to maintain specified design limitations for dissolved and suspended solids. Primary sources of impurities in the blowdown are internal corrosion of the boiler and chemicals added to the boiler system to control scale formation, corrosion, pH, and solids deposition. Products of boiler corrosion are soluble species of iron, copper, and other metals. In addition to chemical additives listed in Table 4.4-13, the following proprietary chemicals may contribute chromium, copper, and phenol species to the boiler blowdown:

Nalco 37--contains chromium
Nalco 75--contains phenol
Nalco 425L--contains copper
Calgon CL35--contains sodium dichromate

In general, boiler blowdown is usually of high quality (see Table 4.4-18), and it is usually suitable for internal reuse in the power plant, such as cooling water makeup.

Demineralizer waste regenerants will be routed to the miscellaneous waste evaporation pond. This waste stream consists of alkaline and acidic solutions containing the chemical species removed from the intake water. The waste stream is usually characterized by wide variations in pH (<2 to >10), high dissolved solids (2,000 to 10,000 mg/L), and suspended solids concentrations ranging from <5 to about 300 mg/L. Solids concentrations are dependent on the characteristics of the influent stream.

Filter backwash water from lime softening from water treatment is characteristically high in solids, but does not contain harmful



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Table 4.4-18. Boiler Blowdown Characteristics

| Pollutants | Number of Data Points | Mean Concentration (mg/L) | Standard Deviation |
|---|---|---|---|
| Copper | 258 | 0.14 | 0.2888 |
| Iron | 273 | 0.53 | 2.0609 |
| Oil & Grease | 151 | 1.74 | 4.5311 |
| Phosphorus | 19 | 17.07 | 12.5154 |
| Suspended Solids | 230 | 66.26 | 500.3967 |

Source: USEPA, 1982.

contaminants. Since backwash water can exceed up to 10 percent of the volume of water produced, this water is often recycled to the head of the treatment plant for conservation.

Coal pile runoff will be directed to the miscellaneous waste evaporation pond. The runoff will likely be acidic, due to the high percentage of pyritic sulfur in the coal and thus will contain dissolved metals leached from the coal. Coal pile runoff will also contain oil and grease and other organics from the application of various wastes from floor and yard drains to the coal pile. The volume of runoff will be minimal due to the arid conditions at the sites (about 156 mm/year rainfall and a high evaporation rate). Volume of coal pile runoff is estimated to be less than 264 $m^3$/year ($1 \times 10^6$ gal/year).

Boiler cleaning wastes will be neutralized and routed to the evaporation pond. Major constituents of these waste streams consist of boiler metals (primarily copper, iron, nickel, and/or zinc). It is estimated that boiler cleaning will be required only once every 4 to 5 years and that the volume of waste generated will be relatively low.

Sanitary effluents from a properly operated sewage treatment system are typically characterized by about 30 mg/L $BOD_5$ and 30 mg/L suspended solids. Chlorination of the effluent will reduce total fecal coliform counts.

Potential impacts from the waste storage areas will result primarily from:

1. The discharge of any wastes from the ponds to surrounding land, surface, or ground waters; and
2. Accidental spillage of wastes or dike failures.

Impacts to Surface Water

All liquid and solid wastes generated from the power plant operations and workers' colony will be contained or evaporated onsite. No wastewaters will be discharged. According to the GCII Feasibility Study, the pond area will be developed as required to ensure no overflow of wastes from power plant or workers colony to the surrounding land. Ponds and waste storage areas will be diked or bermed and will be located above the 100-year flood elevation. Runoff, other than coal pile runoff, will be directed away from the storage/evaporation ponds.

Surface water is present at the sites for only short periods during and following infrequent rainfall events. No discharges to surface waters are anticipated, and thus no adverse impacts to surface waters were anticipated.

In the Lakhra area, which is about 20 km (12 miles) from the Indus River, overall drainage slopes to the southwest, and there are no distinct streambeds at the site. Thus, even under worst-case conditions, discharges of power plant effluents from the ponds would not impact the Indus River.

Surface runoff during and following heavy rainfall events at the Khanot colony flows eastward in non-perennial torrent streams toward the Indus River, which is about 3 km (2 miles) from the site. In the unlikely event of a design failure occurring under worst-case conditions (i.e., a dike failure occurring during or shortly following a heavy rainfall event), domestic wastewater in ponds could be discharged to these torrent streams. However, the volume will be small compared with the dilution water provided by rainfall.

Impacts to Ground Water

There are no established World Bank or USEPA standards for ground water discharges. Currently, ground water discharges in the U.S. are regulated

at the state level. USEPA is in the process of establishing federal ground water criteria, based upon whether the ground water is or is not an existing or potential source of potable water and the characteristics (quantity and quality) of the receiving ground water.

Potential impacts to ground water may result from seepage of ponded wastewater and coal pile runoff to the underlying soils. Seepage from the coal pile to the underlying soil is estimated to be minimal or none due to the low precipitation and high evaporation rates and due to the proposed lining of the coal pile area. The volume of seepage from the fly ash, bottom ash, and evaporation ponds to the underlying soils is dependent on the level of water (head) in the ponds and the characteristics of the underlying soils.

Soils at the Lakhra site consist of about 3 m of silty sand and clay overlying interbedded sandstone and shale. Due to lower permeabilities, the ponds at the Lakhra site will not be lined, unless more detailed geohydrological investigations indicate the need.

Based on characteristics of the plant wastewater, it is projected that the leachate may contain high concentrations of total dissolved solids, sulfates, trace metals, and other ions present in the coal or raw water. As discussed previously, concentrations of trace metals in the ash leachate are dependent on the pH of the waste stream. Metals that may be in solution will precipitate as sludge at pH > 8.0, but will likely remain in solution at lower pHs.

The alkaline properties of the soils at the proposed sites may tend to neutralize any acid discharges from the ponds and induce precipitation of metals and other chemical species onto the soil particles.

Ground water at the Lakhra site is of poor quality and limited quantity, occurring only in localized areas or underlying non-perennial streambeds

(refer to Section 3.1.2.3 and Table 3.1-7). It is possible, however, that leachate from the ponds may degrade localized ground waters at the site.

Seepage of ponded effluents into the underlying soils may adversely affect ground water locally.

At Lakhra, seepage is estimated to be about 475 $m^3$/day/hectare of pond area from the fly ash, bottom ash, and evaporation pond. Lakhra calculations are based on an estimated permeability of $5.5 \times 10^{-5}$ cm/sec for the topsoil material. These seepage rates are based on the permeabilities of the underlying soils or liner material. Factors that could affect seepage rates include clogging of the underlying soil pores, location of less permeable barriers in the substratum, and the pressure head of water at the bottom of the pond or liner. A reduction in infiltration rates will increase the depth of water in the ponds and could result in pond overflow if the ponds are not adequately sized. Subsurface materials at Lakhra, consist of less permeable shales and sandstones which may act as a barrier and reduce seepage flows.

The seepage water may contain low concentrations of trace metals, sulfates, and other dissolved solids. Resulting impacts to ground water, however, are not considered significant because of the low quantity and poor quality of ground water in the region. Geohydrological characteristics to accurately predict ground water flow direction and velocity are not available. Based on topographic features alone, available site information suggests that ground water at the Lakhra site would flow in a west-southwest direction.

With proper design of the evaporation ponds and the high amount of evaporation expected, contamination of ground waters is not expected to be significant.



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### 4.4.2 BIOLOGICAL ENVIRONMENT

The power plant activities associated with operation that result in ecological impacts include the discharge of emissions during the combustion of fuel and effluents from the cooling of the boilers, the leaching of toxic chemicals from the generated and stored wastes, operational noise, cooling water withdrawal, structure and traffic-related impacts. These activities can result in the following impacts:

1. Toxic effects of air emissions to natural vegetation and wildlife;
2. Toxic effects of effluents to vegetation, fish, and wildlife;
3. Disturbance to wildlife from noise;
4. Entrainment of aquatic life during cooling water withdrawal;
5. Avian hazards associated with stacks; and
6. Increased road kill mortality of wildlife.

#### 4.4.2.1 TOXIC EFFECTS OF AIR EMISSIONS TO NATURAL VEGETATION AND WILDLIFE

$SO_2$ is the only substance in stack emissions that is high enough to cause concern about effects on resources. Sulfur is an essential plant nutrient. It is usually taken up by the roots from the soil solution in the form of sulfate ions. When $SO_2$ in the atmosphere enters foliage through pores in the leaves, it reacts with water in the leaf interior to form sulfite ions. Sulfite ions are highly toxic. They interact with enzymes, compete with normal metabolites, and interfere with a variety of cellular functions (Horsman and Wellburn, 1976). Very high concentrations of $SO_2$ can cause immediate injury to sensitive plants.

At low concentrations sulfite is oxidized to sulfate ions within the leaf. The sulfate ions can then be used by the plant. If the plant is subject to long-term exposure to $SO_2$, sulfate may accumulate in the leaves because it is produced from sulfite faster than it can be metabolized by the plant. Reduced yield and other impacts on growth may result.

Environmental factors such as light intensity, time of day, temperature, humidity, soil moisture, nutrient status, disease, and presence of other substances in the air greatly influence plant response to $SO_2$. Sensitivity to $SO_2$ depends upon the rate at which it enters the leaf, which may be a function of leaf structure or stomatal behavior, the rate at which sulfite is converted to sulfate, the rate at which sulfate is used by the plant, and the sensitivity of various metabolic functions to the presence of either sulfite or sulfate.

Plant response to atmospheric pollutants is influenced by the concentration during exposure, duration of each exposure, and the frequency of exposure. The usual pattern of pollutant exposure from operation of an electrical generating facility is that of a few episodes of high concentrations for a short duration interspersed with long periods of low concentrations. Effects on most vegetation will be from the short-term higher doses (a dose is the product of the concentration of the pollutant and the duration of exposure).

For this reason the 3-hour, 8-hour, and 24-hour average $SO_2$ concentrations are more important for predicting impacts on vegetation from a point emission source than the annual average concentration.

The maximum ground-level concentrations of $SO_2$ predicted to result from stack emissions (183 m stack) are as follows:

| Averaging Period | Maximum $SO_2$ Concentrations ($\mu g/m^3$) |
|---|---|
| 1-hour | 4,765 |
| 3-hour | 1,588 |
| 8-hour | 596 |
| 24-hour | 199 |
| Annual | 12.8 |

The locations of maximum predicted short-term concentrations are 1.7 km (1 mile) east southeast from the stacks and will decrease with distance (see Figures 4.4-1 and 4.4-2).



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Native vegetation communities in the region include arid rangeland and remnants of riverain forest and tropical scrub forest. The forest communities are located in the Indus River Valley and have largely been replaced by agriculture (see Section 3.3).

Native vegetation is subject to two kinds of effects from stack emissions of $SO_2$. Acute immediate injury may result from one or a few short exposures to very high concentrations. These exposures can affect growth and health of the plants and are often accompanied by obvious foliar injury. In addition, chronic effects on growth, resistance to disease, and vigor can result from a high frequency of exposures throughout the growing season to moderately high $SO_2$ concentrations which occur episodically. Visible foliar injury does not necessarily accompany chronic effects.

Table 4.4-19 lists high short-term exposures to $SO_2$ reported to have caused injury to native plants in other regions. These exposures are well within $SO_2$ doses expected to result from stack emissions. Episodes of acute damage to native vegetation may occur. These impacts would most likely occur within several kilometers of the plant. Since part of the native vegetation will be lost because of construction and the remaining area is small compared to the available area, these impacts are not considered significant from a regional perspective.

Potential impacts on native vegetation due to chronic exposure to lower concentrations can be inferred from experimental fumigations on test species reported in the literature. There is no information available for species native to the Lakhra region. Results of $SO_2$ fumigation tests on species from arid regions of the United States show that arid climate species tend to be more tolerant of sulfur dioxide than mesic species (Table 4.4-20). This tolerance is thought to arise from the same features that give these plants high water-use efficiencies. Such features include C4 photosynthesis, lower leaf conductance, and drought-tolerant morphology.

Table 4.4-19. Peak Short-Term $SO_2$ Exposures that Cause Acute Injury to Vegetation

| Exposure ($\mu g/m^3$) | Vegetation Type | Location | Reference |
|---|---|---|---|
| 2470-1 hour<br>910-4 hours | Native trees and herbs; crops | Sudbury, Canada | Dreisinger and McGovern, 1970. |
| 780 to 2080-1 hour<br>520 to 1118-3 hour | Native vegetation, potatoes, soybeans, forage grass | Alabama, USA | McLaughlin and Lee, 1974. |
| Exposure not known. Daily coal consumption is 9120 tons, 0.5 to 2% S, 550-MW plant | Tropical deciduous forest--foliar injury up to 6 km distance | Obra, India | Pandey, 1983. |

Source: ESE, 1986.



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Table 4.4-20. $SO_2$ Doses Reported to Affect Natural Vegetation

| Number | Species | $SO_2$ Concentration ($\mu g/m^3$) | Time Period | Effect | Reference |
|---|---|---|---|---|---|
| 1 | (Oryzopsis hymenoides (desert grass in New Mexico) | 80, 170, 330, 650, 1300, 2610 | 6 weeks | Dry weight reduced above 330. | Ferenbaugh, 1976. |
| 2 | 87 species in southwest U.S. desert | From 1300 to 26,000 | 2 hrs | Most showed no foliar injury below 5200; however, growth not tested. | Hill et al., 1974. |
| 3 | 5 perennials in Mojave Desert, USA | 5200, 1742 and 572 | 16 weeks in 1977 and 32 weeks in 1978 | 5200 reduced growth of 3 species. Lower concentrations stimulated growth. | Thompson, Kats, and Lennox, 1980. |
| 4 | 5 annuals in Mojave Desert, USA | 5200, 1742, and 572 | 8 to 17 weeks | Mortality and growth reduction at 5200 and 1742. Two species showed mortality and growth reduction at 572, and three species did not. | Thompson, Kats, and Lennox, 1980. |
| 5 | $C_3$ Atriplex sp and $C_4$ Atriplex sp from arid habitat, California | 260, 520, 1300, 2340, and 3900 | 8 hrs | 1300 and higher reduced photosynthesis in both species, but affected $C_3$ species more than $C_4$ species. | Winner and Mooney, 1980. |
| 6 | Cottonwood (Populus deltoides) | 650 | 80 hrs | Reduced height growth and leaf number. | Jensen and Dochinger, 1979. |
| 7 | Green Ash (Fraxinus pennsylvanicus) | 650 | 80 hrs | Reduced height growth. | Jensen and Dochinger, 1979. |

Table 4.4-20. $SO_2$ Doses Reported to Affect Natural Vegetation (Continued, Page 2 of 2)

| Number | Species | $SO_2$ Concentration ($\mu g/m^3$) | Time Period | Effect | Reference |
|---|---|---|---|---|---|
| 8 | Sycamore (*Platanus occidentalis* | 650 | 80 hrs | Reduced height growth. | Jensen and Dochinger, 1979. |
| 9 | Riverbirch (*Betula nigra*) | 850 | 30 hrs | Reduced growth and leaf area. | Norby and Kozlowski, 1983. |
| 10 | Silver Maple (*Acer saccharinum*) | 2600 | 2 to 8 hrs | Reduced height growth. | Jensen and Dochinger, 1979. |
| 11 | Yellow Poplar (*Liriodendron tulipifera* | 2600 | 2 to 8 hrs | Reduced height growth. | Jensen and Dochinger, 1979. |
| 12 | Tree of Heaven (*Ailanthus altissima* | 260 | 1 week | Reduced biomass. | Marshall and Furnier, 1981. |
| 13 | Black Locust (*Robinia pseudoacacia*) | 1300 | 4 hrs | Reduced root mass. | Suwannapinunt and Kozlowski, 1980. |
| 14 | Red Oak (*Quercus rubra*) | 234 | 5 hrs/day for 29 days | Reduced mycorrhizal infection. | Reich *et al.*, 1985. |

Source: ESE, 1986.



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Some threshold doses of $SO_2$ reported for floodplain trees and a native woody legume in North America are shown in Table 4.4-20 and Figures 4.4-6 and 4.4-7 for comparison with expected doses from the proposed facility.

These reports show that broadleaf deciduous trees are less tolerant of $SO_2$ than arid climate species. Four of the nine tree species reported, including black locust, a legume, would be affected by predicted stack emissions. Although there is some uncertainty in using tests on trees from a temperate region to predict effects on trees in a semi-arid subtropical climate, physiological processes are sufficiently similar among plants to predict that chronic exposure to $SO_2$ from stack emissions may adversely impact some trees in the Lakhra region. Arid rangeland species are not likely to suffer significant impacts from $SO_2$.

Air pollution effects from fossil fuel energy facilities to wildlife have included mortality and injury to animals exposed to high levels of emissions to subacute physiological and behavioral changes from lower exposures (Newman 1979). Exposure can be from the inhalation, ingestion, or adsorption of pollutants.

Secondary EPA standards have been set to protect public welfare, but physiological and behavioral effects have been observed at and below these standards. The primary effects at subacute levels include:

1. Respiratory stress involving alteration in respiratory physiology,
2. Reduction in the immune response of animals, and
3. Decreased abundance of vertebrate and invertebrate animals.

Studies have established an apparent genetic variability in the sensitivity of animals to low levels of $SO_2$. Insects including pollinators have been shown to be sensitive to $SO_2$. Flight activity in bees is reduced by $SO_2$. At Colstrip, Montana, simulated field studies using low levels of $SO_2$ have demonstrated ecological effects below the

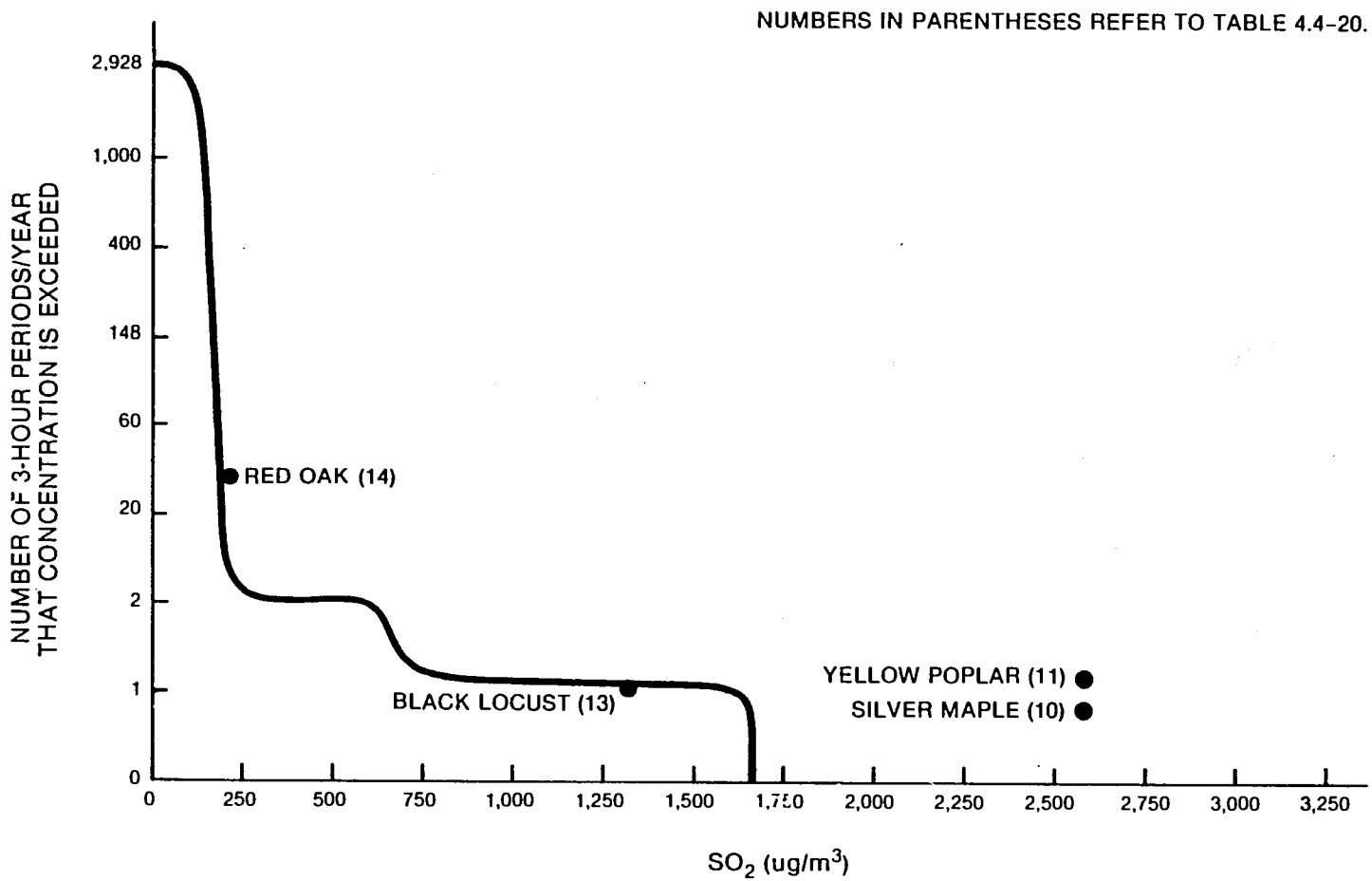


Figure 4.4-6
MAXIMUM $SO_2$ CONCENTRATIONS (3-HOUR AVERAGING PERIODS) PREDICTED FROM FACILITY OPERATION COMPARED WITH $SO_2$ DOSES KNOWN TO ADVERSELY AFFECT NATIVE PLANTS

SOURCE: ESE, 1986.

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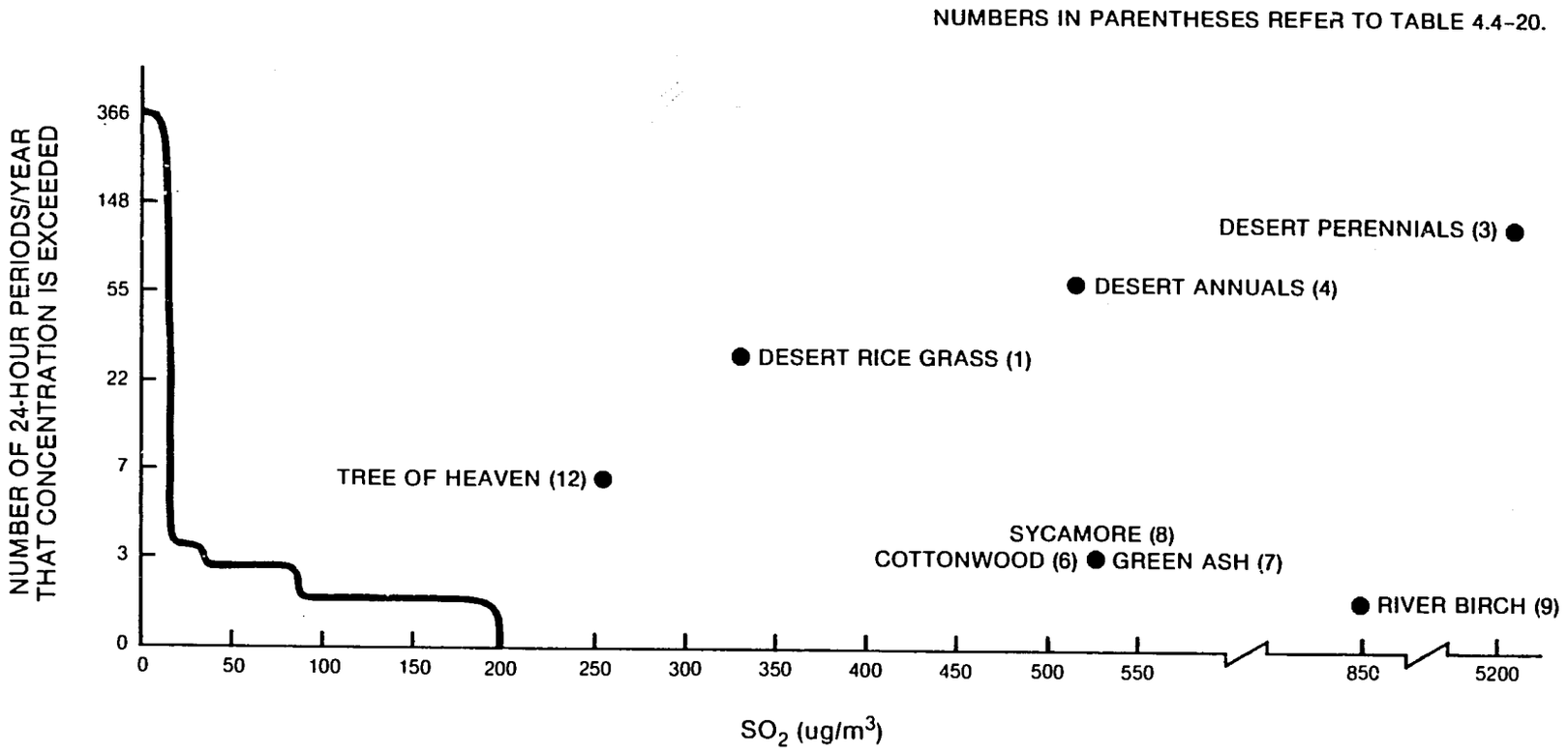


Figure 4.4-7
MAXIMUM $SO_2$ CONCENTRATIONS (24-HOUR AVERAGING PERIODS) PREDICTED FROM FACILITY OPERATION COMPARED WITH $SO_2$ DOSES KNOWN TO ADVERSELY AFFECT NATIVE PLANTS

SOURCE: ESE, 1986.

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standard, including reduced trappings and movements of small mammals and invertebrate consumers in a grassland ecosystem.

Insect pest infestation in trees is sometimes influenced by $SO_2$. Wentzel and Ohnesorge (1961, Fortstarchiv 32:177-186) report insect pest infestation of spruce forests in Germany by sawflies. This infestation was correlated with $SO_2$ and other emissions. The reported values fall within the 3-hour and 24-hour annual standards. Besides the population increase in response to $SO_2$ and other emissions (either direct or indirect effects), a significant reduction in parasitism by natural biological controlling agents was observed in the areas of high $SO_2$ emissions. Insectivorous birds are sensitive to $SO_2$ emissions and show a reduced nesting in areas with increasing $SO_2$ emissions (Newman, 1985).

The predicted ground level concentrations of $SO_2$ and particulates are within the range to cause subacute effects to small mammals and birds living within several kilometers of either plant site. These effects are not considered significant for mammals in that no widespread changes in population numbers of small mammals will occur. If acute effects occur, they would indicate a larger health problem and would be considered significant. Information on the response of reptiles to $SO_2$ and particulate emissions is not available. Even if reptiles are as sensitive as mammals, the effects are not considered significant because of the apparent large population size in the region.

4.4.2.2 TOXIC EFFECTS OF EFFLUENTS TO VEGETATION, FISH, AND WILDLIFE

No discharge of cooling water or waste waters into the Indus River or other surface water system is planned. Therefore, no toxic effects from effluents to ecological systems is expected to occur at either site.

4.4.2.3 DISTURBANCE TO WILDLIFE FROM NOISE

Operational noise levels have been described in Section 4.4.1. There are no sensitive wildlife receptors in the vicinity of either site and no effects are expected.

#### 4.4.2.4 ENTRAINMENT OF AQUATIC ORGANISMS

Significant quantities of water will be withdrawn from the Indus River for power plant systems, e.g., cooling tower makeup. During this activity if intake rates are high enough, it is possible that aquatic organisms such as small fish and larval forms of fish will be drawn into or entrained by the pumps and killed. If large numbers of organisms are entrained and if this activity occurs for a long enough period of time, significant losses to fish productivity can occur. No significant effects to fishery resources of the Indus River or the fishery resources above the Kotri Barrage are expected to occur. The location of the intake structure is not in a spawning area or a reach of the river where passage of larval forms occurs or where small fish are attracted. In addition, design recommendations call for low intake velocities (<15 cm/sec) and fish escapeways (GCII, 1986). During high flow periods in the Indus River, some migratory fish such as palla are found in the river. No effects to these fish are expected because of the small volume of water withdrawn and the ability of these fish to avoid entrainment.

#### 4.4.2.5 AVIAN HAZARDS ASSOCIATED WITH STACKS

Mortality of birds, especially small passerine birds due to collisions with tall stacks, buildings, and cooling towers, often occurs. The incidence of this mortality increases if such structures occur along a migratory route of birds. Certain weather conditions, including overcast and foggy conditions when the orientation of the migrating birds is confused, also increase the change of collisions. The lights attached to the stacks or towers for aircraft navigation and safety are thought to attract birds to the vicinity of these structures. At this time migratory routes of birds in the region are not known. Waterfowl are known to move north and south along the Indus River. It is likely that other species of small passerine birds also use this route. It is unlikely that significant migratory routes occur at Lahkra and avian hazards are considered negligible.

#### 4.4.2.6 INCREASED ROAD TRAFFIC RESULTING IN INCREASED WILDLIFE ROAD KILLS

The road traffic expected during operations will cause some road kills of wildlife (see Section 4.4.2.5 for more information).

### 4.4.3. SOCIAL ENVIRONMENT

The operational activities of the power plant will cause a number of potential direct impacts to the social environment. These activities have been included in the discussion of mining impacts (Section 4.2.3). The major impacts due to the power plant operation alone are listed below and summarized in the following subsections.

1. Change in land use,
2. Change in employment and economic patterns,
3. Change in existing cultural patterns and values,
4. Increased demand for facilities and services,
5. Induced development in the surrounding area associated with construction of the power plant,
6. Existing transportation system impacts, and
7. Air emission effects to man and agriculture.

The first six effects are similar in nature to those described for construction except they are likely to be smaller in magnitude and longer term.

#### 4.4.3.1 CHANGE IN LAND USE

The land use impacts are described in Section 4.3.3.1. The changes in land use described in this section will continue for the 30-year life of the project.

#### 4.4.3.2 CHANGE IN EMPLOYMENT AND ECONOMIC PATTERNS

The operational staff of the power plant is estimated to be about 1,550 workers who will operate the plant for 30 years. These people will be trained and skilled and will likely come from the urbanized areas. They will be housed in permanent facilities provided by WAPDA and are expected to remain at the plant as part of the permanent staff for the life of the project. By the time the plant is operational, adjustments will have occurred in the local economy, life-styles, services and



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facilities, and transportation systems so that the impact of the power plant workers should be minimal. Planning will, however, be required to avoid disruptions similar to those that arose between construction and operation workers at similar WAPDA facilities (e.g., at the Guddu Power Plant) (Helweg, 1985).

After construction ends, there will be a decline in workers and their associated impacts. There could be a sharp decline in employment and the economy causing a recession in local areas including closing of service businesses. The presence of a permanent work force will help ameliorate this decline. Unless the construction workers leave the area, unemployment will be a problem during the beginning of the operational period. These recessional impacts will occur for both sites and are considered significant. If construction workers leave, local services and other construction phase infrastructure will be underutilized. The operational staff will involve proportionally more skilled workers and fewer unskilled, so the need for relatively high quality housing and services will change less than the demand for low-income facilities. New jobs will be created and old ones phased out, however, so there will be a turnover of housing and an a fresh influx of trained urbanites, who will have a modernizing influence on the region.

To ensure smooth operation of the power plant in the initial months after commissioning, as many construction workers as possible are expected to be hired by WAPDA as operational personnel. In this way, operators will be familiar with the plant and construction workers will have a greater incentive for doing a good job. For positions that cannot be filled by construction workers, operational personnel under the supervision of competent training staff should be on the site for 1 year before plant commissioning to become fully familiar with plant equipment. In addition, to avoid conflict between the construction workers and operational staff, plans for providing adequate housing for both groups of workers should be planned. Residences of construction and operations

personnel should be separate and take into account the fact that operational personnel are more likely to be accompanied by their families whose wives will not want to live close to bachelor dwellings for reasons of safety and modesty.

4.4.3.3 CHANGE IN CULTURAL PATTERNS AND VALUES

The construction phase will cause dramatic cultural disruptions as people make major changes in their jobs and living arrangements and as infrastructure development brings in new services. The culture will slowly adapt to these changes over the long-term period of plant operation. During construction problems and conflicts will occur as people seek to function in unfamiliar roles and settings. Cultural changes will come later as provincial peoples slowly become assimilated into the more urban society.

4.4.3.4 INCREASED DEMAND UPON EXISTING FACILITIES AND SERVICES

These impacts are described in Sections 4.2.3.4 and 4.3.3.4.

4.4.3.5 INDUCED DEVELOPMENT IN THE SURROUNDING AREA

These impacts are described in Sections 4.2.3.5 and 4.3.3.5.

4.4.3.6 TRANSPORTATION SYSTEMS IMPACTS

The transportation systems developed for construction should be adequate for operational activities. Traffic should be less than during construction, and no significant impacts are expected.

4.4.3.7 AIR QUALITY EFFECTS

Air emissions from the power plant could affect both human populations and agriculture, depending on their proximity to the power plant. Figures 4.4-1 through 4.4-5 show the isopleths of $SO_2$ and TSP concentrations for the Lakhra site. The maximum predicted $SO_2$ or TSP concentrations are below the World Bank Guidelines. The major impact areas are to the northeast and south of the plant. At Lakhra there are

no major human receptors as the area is planned for mining. In addition, in the Lakhra coal field, there is very little vegetation to be affected by stack emissions.

There are two types of potential impacts on crops from stack emissions of $SO_2$. Acute immediate effects on yield or vigor can occur due to one or a few short exposures to very high concentrations. Obvious leaf injury such as bleaching or necrosis usually accompanies acute effects. In addition, chronic effects on yield can result from a high frequency of exposures to moderately high $SO_2$ concentrations which occur episodically throughout the growing season. Chronic effects may not be accompanied by visible symptoms of injury.

Peak exposures reported to have caused acute foliar injury to vegetation in other regions range from 1 to 3 hours exposure to $SO_2$ concentrations ranging from 520 to 780 $\mu g/m^3$ (Table 4.4-21). Maximum ground-level concentrations of $SO_2$ resulting from stack emissions are predicted to exceed these levels approximately twice throughout the year.

Potential impacts on yield of regional crops due to chronic exposure to lower concentrations can be inferred from experimental fumigations on test species reported in the literature. Table 4.4-21 lists the effects of various exposures on crop species that have been tested. Figures 4.4-8 and 4.4-9 show whether the threshold $SO_2$ doses that affect yield for each crop in comparison to the doses expected to result from facility operation. In some cases there is more than one threshold dose reported for a crop because different cultivars and experimental conditions were used in the fumigation tests. Crop effects listed in Table 4.4-21 can also be compared with expected maximum $SO_2$ concentrations on agricultural lands shown in Table 4.4-4.

Wheat and corn are the most resistant crops. Cotton is known to require high amounts of sulfur and is considered resistant to $SO_2$, but has not



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Table 4.4-21. Lowest Doses of $SO_2$ Reported to Affect Crops

| Number | Species | $SO_2$ Concentration ($\mu g/m^3$) | Time Period | Effect | Reference |
|---|---|---|---|---|---|
| 1 | Rice (*Oryza sativa*) | 1,300 | 1.5 hrs/day for 30 days | Leaf injury and reduction in chlorophyll. | Agrawal, Nandi, and Rao, 1982. |
| 2 | Rice (*Oryza sativa*) | 524 | 24 hrs/day for 75 days | Reduced yield (393 $\mu g/m^3$ had no effect). | Kats, *et al.*, 1985. |
| 3 | Rice (*Oryza sativa*) | 650 | 1.5 hrs/day for 40 days | Foliar protein and ascorbic acid reduced. | Nandi, *et al*, 1984. |
| 4 | Sorghum (*Sorghum bicolor*) | 117 | 3 weeks | Reduced dry weight. | Pande, 1984. |
| 5 | Corn (*Zea mays*) | 262 | 17 days | No yield effect. | Klein *et al.*, 1978. |
| 6 | Corn (*Zea mays*) | 812 | 7 days | No yield effect. | Mandl *et al.*, 1975. |
| 7 | Spring wheat (*Triticum aestivum*) | 2,600 | 2 hrs/day for 60 days | Biomass reduced. | Prasad and Rao, 1982. |
| 8 | Wheat cv. Yamhill (*Triticum* sp.) | 260 | 24 hrs/day for 30 days | Yield reduced. | Neely and Wilhoor, 1981. |
| 9 | Wheat (7 cultivars) (*Triticum* sp.) | 1,300 | 100 hrs | No yield effect. | Laurence, 1979. |
| 10 | Spring Wheat (*Triticum aestivum*) | 2,600 | 2 hrs/day for 80 days | Grain yield reduced. | Pandey, 1982. |
| 11 | Red Bean (*Phaseolus vulgaris*) | 5,240<br>966 | 1-hr peak<br>3 hrs | Shoot mass reduced 22 percent. | McLaughlin *et al.*, 1979. |
| 12 | White Bean (*Phaseolus vulgaris*) | 393 | 10 days | No yield effect. | Hofstra and Ormond, 1977. |

Table 4.4-21. Lowest Doses of $SO_2$ Reported to Affect Crops (Continued, Page 2 of 3)

| Number | Species | $SO_2$ Concentration ($\mu g/m^3$) | Time Period | Effect | Reference |
|---|---|---|---|---|---|
| 13 | Soybean (*Glycine max*) | 630 | 3 hrs | 19 exposures reduced yield in 2 cultivars. | Kohut *et al.*, 1982. |
| 14 | Pinto Bean (*Phaseolus vulgaris*) | 806<br>208 | 7 days<br>27 days | No effect on height or weight. | Mandl *et al.*, 1975. |
| 15 | Soybean (*Glycine max*) | 367 | 191 hrs over 68-day period | Stem but not pod biomass reduced. Mexican bean beetle reproduction increased. | Hughes, *et al.*, 1983. |
| 16 | Bean (*Phaseolus vulgaris*) | 540 | 7 hrs for 4 times during growth | No effect. | Bytnerowicz and Taylor, 1983. |
| 17 | Orchard Grass (*Dactylis glomerata*) | 319 to 482 | 72 to 180 days | Shoot mass reduced to 54 percent of control. | Ayazloo and Bell, 1981. |
| 18 | Rye Grass (*Lolium multiflorum*) | 43 to 894 | 26 weeks | Shoot mass reduced 33 percent. | Crittenden and Read, 1979. |
| 19 | Grama Grass (*Bouteloua gracilis*) | 114 | 31 days | No effect on shoot, root biomass. Crown biomass reduced at 114. | Lauenroth *et al.*, |
| 20 | Orchard Grass (*Dactylis glomerata*) | 37 to 62 | 72 days | Growth reduced. | Crittenden and Read, 1979. |
| 21 | Rye Grass (*Lolium perenne*) | 367 | 131 days | Growth reduced. | Ayazloo and Bell, 1981. |
| 22 | Wheat Grass (*Agropyron smithii*) (dry climate forage grass) | 25, 65, 90, 155, and 200 | Over growing season | 65 stimulated growth. 200 increased rate of senescence. | Milchumas, Lauenroth, and Dodd, 1982. |



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Table 4.4-21. Lowest Doses of $SO_2$ Reported to Affect Crops (Continued, Page 3 of 3)

| Number | Species | $SO_2$ Concentration ($\mu g/m^3$) | Time Period | Effect | Reference |
|---|---|---|---|---|---|
| 23 | Festuca arundinaceae (3 cultivars) | 260 | 6 hrs/day 1 time weekly for 12 weeks | Root weight reduced; shoot weight, no effect. | Flagler and Younger, 1982. |
| 24 | Meadow Grass (Poa pratensis) | 104 | 5 hrs/week for 20 weeks | Reduced weight 28 percent. | Ashendon, 1979. |
| 25 | Cotton (Gossypium herbacea) | | | Cotton grown near TVA power plants produced more biomass than plants grown in remote locations, but no concentrations of $SO_2$ provided. | Noggle and Jones, 1979. |

Source: ESE, 1986.



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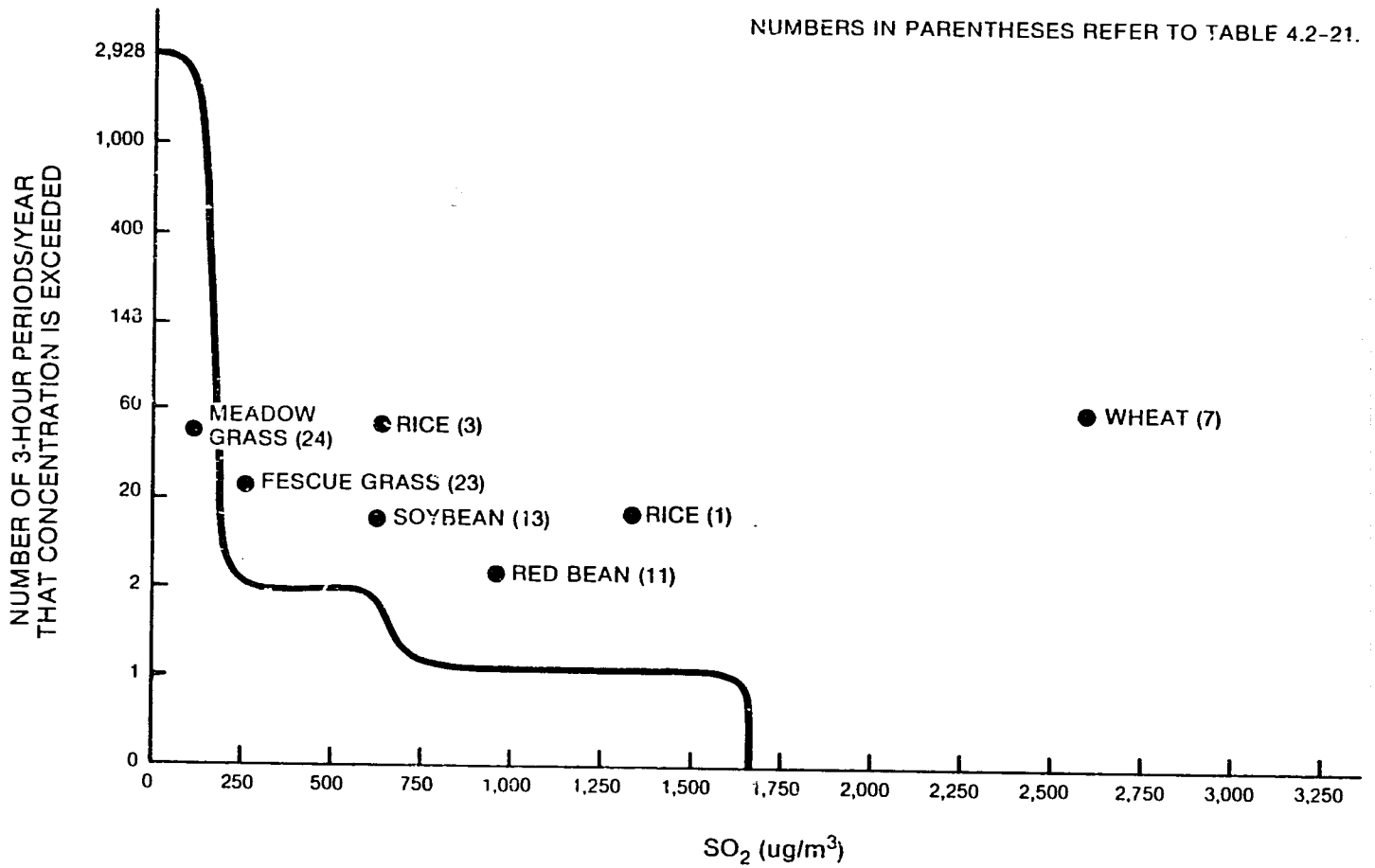


Figure 4.4-8
MAXIMUM $SO_2$ CONCENTRATIONS (3-HOUR AVERAGING PERIODS) PREDICTED FROM FACILITY OPERATION COMPARED WITH $SO_2$ DOSES KNOWN TO ADVERSELY AFFECT CROPS

SOURCE. ESE, 1986.

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PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

Lakhra Coal Mine and Power Generation Feasibility Study

USAID PAKISTAN 08/86

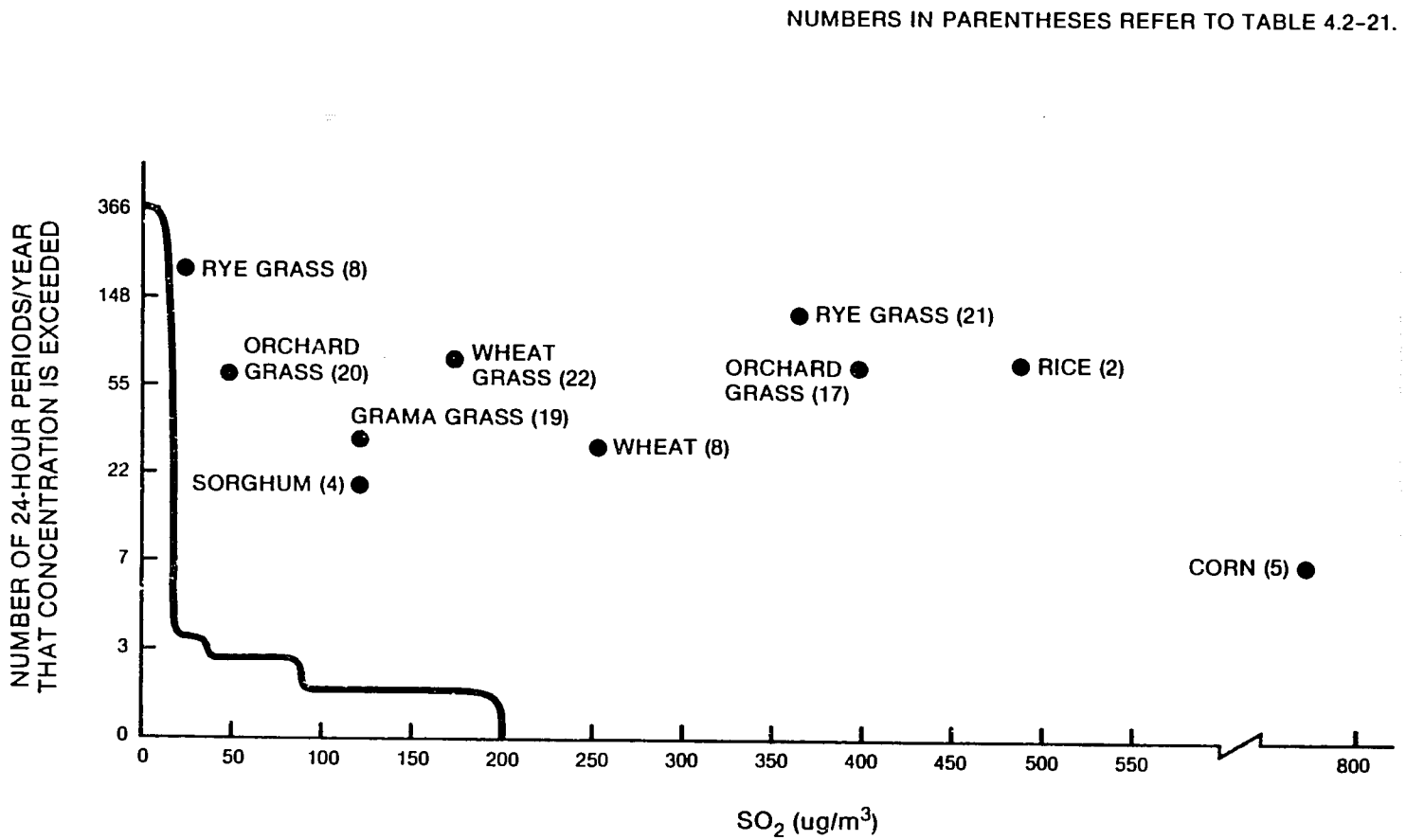


Figure 4.4-9
MAXIMUM $SO_2$ CONCENTRATIONS (24-HOUR AVERAGING PERIODS) PREDICTED FROM FACILITY OPERATION COMPARED WITH $SO_2$ DOSES KNOWN TO ADVERSELY AFFECT CROPS

SOURCE: ESE, 1986.

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PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

been tested to determine the threshold doses for injury (Noggle and Jones, 1979). Information on $SO_2$ injury is not available from the literature for millet and sugar cane. Significant reductions in yield and vigor of rice, legumes (peas and beans), sorghum, and many grasses are expected to result from exposure to $SO_2$ emitted by the facility if these crops are grown in the Lakhra area. These chronic impacts on crops would be in addition to any effects of acute exposures. Because of the distance to the agricultural areas along the Indus and the resulting lower predicted emissions, no similar impacts are likely to occur in the Khanot area.

Sulfur dioxide and particulate matter are known to cause mortality and respiratory diseases. Susceptibility to these pollutants vary in the populations. Elderly people, people with chronic cardiorespiratory diseases, and children are considered populations at risk. $SO_2$ and particulates work synergistically at lower concentrations to cause respiratory effects, whereas when acting alone, higher concentrations are necessary to cause the same effect. Reviews (Ferris, 1978) have shown that short-term (24-hour) levels above 200 $\mu g/m^3$ $SO_2$ and above 150 $\mu g/m^3$ particulates cause respiratory effects. Long-term effects have been reported at levels at low as 55 $\mu g/m^3$ $SO_2$ and 180 $\mu g/m^3$ TSP. Predicted maximum concentrations of $SO_2$ and particulate at populated areas are below the lowest reported levels causing effects. The predicted maximum concentrations of $SO_2$ and TSP at the sensitive receptors, Liaquat Medical College and Hospital and Hyderabad City (Table 4.4-22), are several times lower than the short-term and long-term levels reported to cause measurable effects and are below the standards set to protect general human health.

A discussion of the effects of acid deposition on agriculture is presented in Appendix J.

Table 4.4-22. Maximum Predicted $SO_2$ and TSP Impacts of Two 250-MW Units at Lakhra Site to Sensitive Receptors

| Averaging Time | Maximum Concentrations ($\mu g/m^3$)* | | | |
|---|---|---|---|---|
| | Liaquat Medical College and Hospital | | Hyderabad City | |
| | $SO_2$ | TSP | $SO_2$ | TSP |
| 1-Hour | 1,339 | 13 | 425 | 4.3 |
| 3-Hour | 446 | 4.5 | 156 | 1.6 |
| 8-Hour | 204 | 2.0 | 91 | 0.91 |
| 24-Hour | 85 | 0.85 | 56 | 0.56 |
| Annual | 5.7 | 0.57 | 3.8 | 0.038 |

*Predicted concentrations do not include background TSP concentration which has been estimated to be 200 $\mu g/m^3$ from monitoring data.

Source: ESE, 1986.



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## 4.5 COMBINED IMPACTS--OVERVIEW

The preferred project alternative consists of a colocated power plant (two 250-MW units) and associated surface/underground mine located at Lakhra and a power plant workers colony located at Khanot. The potential effects associated with the construction and operation of the project are summarized in Table 4.5-1. Impacts to the physical, biological, and social environments are presented in Tables 4.5-2, 4.5-3, and 4.5-4. A majority of these impacts, however, will not be significant. Potentially significant impacts are discussed in the following sections.

### 4.5.1 PHYSICAL IMPACTS

The establishment of a large surface mine and the degradation in air quality from mining and power plant emissions are potentially the most significant impacts to the physical environment.

The mining impacts will have two major components: (1) the physical disruption of mining activities, and (2) utilization of non-renewable resources (i.e., lignite). The physical disruption of the surface, which involves up to approximately 2,000 ha (5,000 acres), will change the land use, drainage, surface water, and limited ground water resources. The magnitude of these effects will primarily be confined directly to the mining area provided that appropriate management of spoil piles, highwalls, acid-producing materials, and runoff impoundments is practiced. Land within the mining area will be temporarily disrupted; however, through reclamation practices the land will be returned to conditions similar to those prior to mining. Use of the non-renewable resources will be irretrievable; however, this use is offset by the country's need to supply the required electrical power. For recovering a major portion of the lignite resources, surface mining is preferred; with a surface mine, about 80 to 90 percent of the available lignite resource is recovered, whereas for an underground mine, only about 50 percent is recovered.



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Table 4.5-1. Potential Environmental Effects Evaluated for the Construction and Operation of Lakhra Coal-Fired Plant and Coal Mine

| CONSTRUCTION |
|---|
| Change of Land Use |
| Vegetation Removal and Loss of Habitat |
| Increased Soil Erosion and Runoff |
| Change in Drainage |
| Change in Surface Water Quality |
| Spills and Chemical Usage |
| Road Traffic and Road Kills |
| Noise and Vibration |
| Air Emissions--Fugitive Dust from Construction and Overburden Removal |
| Induced Development--associated with mine power plant |
| Change in Employment and Economic Patterns |
| Increased Demand upon Existing Facilities and Services |
| Disruption of Cultural Values and Patterns |
| Loss of Cultural, Historical, and Archaeological Resources |
| **OPERATION** |
| Thermal Discharge |
| Discharge of Blowdown Chemicals |
| Change in Surface Water Flow and Quality |
| Change in Ground Water Table Quality |
| Maintenance Dredging |
| Entrainment of Aquatic Organisms |
| Fog Formation |
| Formation of Biological Barriers and Corridors |
| Loss of Future Biological Productivity |
| Chemical Spills and Nonpoint Source |
| Domestic Wastes Discharge |
| Air Emissions-includes emissions from stacks, fugitive dust from coal handling, and reclamation |
| Atmospheric Deposition |
| Noise and Vibration |
| Crop Loss |
| Avian Hazards--from stacks, transmission, etc. |
| Increased Access--i.e., opening up otherwise less accessible natural areas |
| Consumptive Water Use |

Sources: Argonne National Laboratory, 1978.
ESE, 1985.
KBN, 1986.



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Table 4.5-2. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Physical Impacts

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Construction | |
| Change of Land Use | Site specific/long-term/not significant. |
| Increased Soil Erosion and Runoff | Site specific/long-term/not significant. |
| Change in Drainage | Site specific/long-term/not significant. |
| Change in Surface Water Quality | Site specific/long-term/not significant.† |
| Spills and Chemical Usage | Site specific/short-term/easily mitigated by prevention. |
| Air Emissions | Regional/short-term/moderately significant near source, not significant after about 5 km. |
| Operation | |
| Thermal Discharge | Site specific/long-term/not significant. |
| Change in Surface Water Flow and Quality | Site specific/long-term/not significant.** |
| Change in Ground Water Quality | Site specific/long-term/minor effects; pond leachate may degrade ground water quality; acid mine waste may further degrade ground water quality; low impacts due to limited quantity and low quality of existing ground water.†† |



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Table 4.5-2. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Physical Impacts (Continued, Page 2 of 2)

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Maintenance Dredging of Ponds and Land or Mine Disposal of Solid Wastes | Site specific/long-term/not significant; will likely improve quality of leachate from settling/evaporation ponds.*** |
| Chemical Spills and Nonpoint Sources | Site specific/short-term/not significant; little or no impact due to low rainfall and high evaporation rates in region. |
| Domestic Wastes Discharges | Site specific/long-term/minor impacts. |
| Consumptive Water Use | Site specific/long term/minor impacts; downstream water availability reduced by about 25 cubic feet per second (cusecs), which is a small amount compared to available supplies from the Indus River. |
| Air Emissions | Regional/long-term/moderately significant near source, minor after 20 km. Transboundary impacts are not predicted to be significant. |

*In terms of impacts, the following definitions are used:

1. Extent refers to the areal effect of the impact, e.g., whether the impact is confined to the site only or extends some distance from the site;
2. Duration refers to the length of time the impact will last, e.g., whether the impact is short-term, lasts for several years, or for much longer periods; and
3. Significance refers to the magnitude of the impact in relation to the type of resource being impacted.

†Indus River is only perennial surface water in region.

**No perennial surface water bodies on or adjacent to the Lakhra site.

††If local wells are degraded, impacts can be mitigated by supplying treated water from power plant. Lakhra site is about 20 km in distance to the Indus River and a limited number of wells currently exist in the area.

***Mine disposal of all solid wastes (ash) at Lakhra is preferred.

Source: ESE, 1986.



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Table 4.5-3. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Biological Resources

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Construction | |
| Vegetation Removal and Loss of Habitat | Site-specific/long-term/ moderately significant; loss of some acreage of tropical scrub forest vegetation and tropical plain thorn forest habitat, including desert monitor habitat; no significant loss given the small amount lost versus amount available. |
| Spills and Chemical Usage | Site-specific/short-term/not significant: no aquatic habitat; no effects. |
| Road Traffic and Road Kills | Regional/short-term/not significant: increased probability of wildlife road kills. |
| Air Emissions--Fugitive Dust from Overburden Removal Effects on Vegetation | Regional/short-term/minor effects: vegetation will adapt to conditions. |
| Operation | |
| Entrainment | Site-specific/long-term/minor impacts: minimal larval and fish populations expected to be impacted. |
| Formation of Biological Barriers and Corridors | Site-specific/long-term/not significant. |
| Loss of Future Biological Productivity | Site-specific/long-term/not significant: small area. |
| Air Emissions--includes emissions from stacks, fugitive dust from coal handling, and reclamation | Regional/long-term/minor impacts: no major effects to natural vegetation. |



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Table 4.5-3. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Biological Resources (Continued, Page 2 of 2)

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Avian Hazards--from stacks, transmission, etc. | Site-specific/long-term/minor impacts. |
| Increased Access--i.e., opening up otherwise less accessible natural areas | Site-specific/long-term/minor impacts: no special biological resources in vicinity. |

*In terms of impacts, the following definitions are used:

1. Extent refers to the areal effect of the impact, e.g., whether the impact is confined to the site only or extends some distance from the site;
2. Duration refers to the length of time the impact will last, e.g., whether the impact is short-term, lasts only several years, or for much longer periods; and
3. Significance refers to the magnitude of the impact in relation to the type of resource being impacted.

Sources: ESE, 1986.
KBN, 1986.



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Table 4.5-4. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Social Impacts

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Construction and Operation | |
| Loss of Land Use | Site-specific/long-term/significant locally. |
| Loss of Future Agricultural Productivity | Site-specific/long-term/not significant. |
| Road Traffic | Regional/short-term/moderately significant, traffic increase.† |
| Change in Ground Water Table and Aquifer Quality | Site-specific/long-term/not significant: lower quality but not extensively used for potable supplies. |
| Air Emissions--includes emisssions from stacks, fugitive dust from coal handling, and reclamation | Regional/long-term/moderately significant to existing mining population; however, no major agricultural areas nearby. |
| Noise and Vibration | Site-specific/long-term/not significant. |
| Induced Development--associated with mine and power plant in surrounding area including facilities and services demand | Regional/long-term/significant: workers colony will require significant development of infrastructure facilities and services. |
| Change in Employment and Economic Patterns | Regional/long-term/significant. cyclic boom economy will occur probably during years 5 and 6. |
| Increased Demand upon Existing Facilities and Services | Regional/long-term/significant: facilities and services provided for needs of operation workers, construction workers, and other inhabitants. |
| Disruption of Cultural Values and Patterns | Site-specific/long-term/ significant effects to local Khosa Baluch: major changes to rural life will occur in the vicinity of the site, both positive and negative. Regional impacts are likely to be minor. |

Table 4.5-4. Environmental Impacts for Construction and Operation of Lakhra Coal Mine and Power Plant--Social Impacts (Continued, Page 2 of 2)

| Impacts | Extent/Duration/Significance* of Impacts |
|---|---|
| Loss of Cultural, Historical, and Archaeological Resources | Site-specific/long-term/not significant based on current data. |

*In terms of impacts, the following definitions are used:

1. Extent refers to the areal effect of the impact, e.g., whether the impact is confined to the site only or extends some distance from the site;
2. Duration refers to the length of time the impact will last, e.g., whether the impact is short-term, lasts only several years, or for much longer periods; and
3. Significance refers to the magnitude of the impact in relation to the type of resource being impacted.

†Road improvement of Indus Highway already planned.

Sources: ESE, 1986.
KBN, 1986.



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The impacts to air quality, resulting from the use of the high-sulfur, low-Btu Lakhra lignite at the power plant coupled with fugitive dust emissions from the mining activities, are potentially significant; however, analyses have shown that the combination of site location coupled with atmospheric dispersion will confine potentially significant air quality impacts to the immediate Lakhra area. In addition, offsite air quality impacts are projected to meet the World Bank and World Health Organization's guidelines for air quality and not significantly impact human health.

### 4.5.2 BIOLOGICAL IMPACTS

The adverse impacts associated with construction of the mine and power plant include the loss of up to approximately 2,000 ha (5,000 acres) of scrub forest vegetation and associated tropical plain forest wildlife habitat. There is the potential for the desert monitor lizard, classified as endangered, to be affected onsite by these activities; however, the status of the population in the region will not be significantly affected. In addition, in cooperation with GOP, the U.S. Fish and Wildlife Service is sponsoring specific studies on the desert monitor (see mitigation plan).

Adverse impacts of the operation of the power plant on ecological resources include potential effects on vegetation and wildlife from air emissions, including atmospheric deposition, entrainment of aquatic organisms during cooling water intake, and increased mortality of wildlife due to highway traffic. The impacts from air emissions are not likely to affect local and regional wildlife and native vegetation. These impacts would be considered significant only if acute effects from air emissions occur. The desert monitor will likely be affected by the operational activities of the mine, but no effect to the regional population is expected. Impacts to other endangered species occurring in the Lakhra area are not projected. Avian mortality due to collisions with stacks is not likely to be significant at the Lakhra site. Impacts

to agricultural crops are not considered significant because of the distance of a power plant located at Lakhra and the concomitant lower air pollutant concentrations.

### 4.5.3 SOCIAL IMPACTS

Impacts to the social environment in Kotri Taluka due to the construction and operation of the project are unavoidable. These unavoidable impacts vary in their magnitude and extent. The loss of existing land use is considered significant for local Khosa Baluch with agricultural plots in mine areas. The change in employment and economic patterns is considered a positive impact, but will be cyclic and result in a "boom" period during construction and then lesser levels of employment during operations. The disruption of cultural patterns and values and increased demand for facilities and services, however, are considered significant adverse impacts which cannot be avoided. Development of secondary infrastructure alternatives will partially mitigate these impacts. Impacts to local inhabitants will be significant on a site-specific basis; however, the number of local inhabitants (Khosa Baluch) affected is small (about 50) and their residence is seasonal. Regional impacts to the Khosa Baluch are considered minor. The disruption of transportation systems is not considered significant. Impacts to historical and archaeological resources are not expected, based on a survey performed by the Pakistan Department of Archaeology.

The major operational adverse impacts include a drop in employment and the local economy at the end of construction; potential labor productivity problems between local inhabitants and workers, between construction and operation workers, and between power plant workers and the coal miners; and disruption of existing transportation systems. Adverse effects to man and agriculture in the vicinity of the Indus Valley from air emissions are not considered significant because of the distance of human settlements and sensitive agricultural crops from the Lakhra area.

# 5.0 ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

## 5.1 MINE

### 5.1.1 PHYSICAL ENVIRONMENT

The impacts associated with air emissions and pond disturbance are the most significant adverse effects to the physical environment which cannot be avoided. The emissions of fugitive dusts and their associated impacts will, however, be confined to the immediate area of mining. Control of emissions by watering will reduce these impacts. Although the topography and land structure will be altered by mining, the proposed method of reclamation, which will restore the area to the approximate original contours, should mitigate most long-term effects to local drainage patterns. Noise impacts associated with mining cannot be avoided; however, such aspects are not considered significant because of the distances (>20 km) to either villages or population centers (i.e., Hyderabad).

### 5.1.2 BIOLOGICAL ENVIRONMENT

The adverse impacts associated with mining include the loss of approximately 1,360 hectares (3,360 areas) of scrub forest vegetation and associated wildlife habitat along with its future biological productivity and an increase in mortality of wildlife due to traffic. These impacts are not considered significant because of the low productivity of this habitat and the large amount of similar undisturbed habitat in the area. The potential exists for the local population of desert monitors, classified as endangered, to be affected by these activities. Adverse impacts to other endangered species occurring in the Lakhra area are not expected.

### 5.1.3 SOCIAL ENVIRONMENT

The adverse impacts associated with the mine include the loss of subsistence agricultural areas and temporary settlements. There will be continued change in the socio-cultural values with the increase in mine workers and their long-term residence. The large influx of different

ethnic groups and the benefits (wage and colony) received by mine workers may produce frictions with the local people. The harmony between local residents and the new mine workers may be disrupted if there is a perception that benefits are not distributed uniformly. Significant impacts to the local infrastructure and related social needs will occur as a result of the increase in permanent mine workers and secondary growth effects.

## 5.2 POWER PLANT AND WORKERS COLONY

### 5.2.1 PHYSICAL ENVIRONMENT

The emissions of air pollutants from the power plant and associated air quality impacts cannot be avoided; however, predicted impacts are well within the World Bank and WHO air quality guidelines and criteria. In addition, locating the power plant at Lakhra effectively minimizes the potential for environmental impacts to human populations and agricultural areas. Although air pollution control equipment, i.e., flue gas desulfurization (FGD) could be added to reduce $SO_2$ emissions, the economic impacts associated with FGD are significant (10 percent of total annualized cost) and not justified.

Some air quality impacts could occur at Lakhra, depending on the location of the worker colonies and if the subsistence agricultural areas are occupied. These impacts could be significant, depending upon the location of human settlements and sensitive agricultural crops.

Impacts to land areas by the plant and associated facilities (e.g., coal storage area, transmission lines, ash disposal areas, water pipeline, and workers colony) are not expected to be significant because of the type of land areas impacted and the remoteness of the Lakhra site.

Since all water discharges will be contained onsite, water quality impacts are expected to be insignificant. As the development of the underground mine occurs, subsidence and surface deformation of the previously mined areas will occur. The alteration of the land form is not considered to adversely affect surface features or major drainage in the area. Locally, drainage will be directed to these subsidence areas.

### 5.2.2 BIOLOGICAL ENVIRONMENT

The adverse impacts associated with construction of the power plant include the loss of several hundred acres of scrub forest vegetation and



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associated wildlife habitat along with its future biological productivity and an increase in wildlife mortality due to traffic. The impacts are not considered significant because of the large amount of similar undisturbed habitat in the area. There is the potential for the desert monitor, classified as endangered, to be affected by these activities. Individuals may be affected but not the population in the area or region.

Adverse operational impacts on ecological resources occurring at Lakhra include potential effects to vegetation and wildlife from air emissions, entrainment of aquatic organisms during cooling water intake, and increased mortality due to highway traffic. The desert monitor will likely be affected by the operational activities of the power plant, but no effect to the regional population is expected.

### 5.2.3 SOCIAL ENVIRONMENT

The unavoidable cultural resource impacts of construction and operation of the power plant are similar to the mining impacts. These impacts are considered additive to those of the mine. The loss of existing land use is considered a significant adverse impact to the Khosa Baluch who use the area for subsistence agricultural purposes. The change in employment and economic patterns is considered a positive impact to the area but will lead to boom economy for the first 7 years during construction of the power plant. The disruption of cultural patterns and values and the increased demand for facilities and services are significant adverse impacts which cannot be avoided.

The major operational adverse impacts include potential labor productivity problems between local inhabitants and workers, between construction and operation workers, and between power plant workers and the coal miners. In addition, a drop in employment and a concomitant effect on the local economy could occur if the power plant is taken out of service at the end of the projected 30-year operational period.

# 6.0 ENVIRONMENTAL MITIGATION PLAN

The feasibility studies performed by GCII and J.T. Boyd Company for the Lakhra Coal Mine and Power Generation Project, have, for the most part, incorporated design features that would mitigate environmental impacts (see Table 6-1). Nonetheless, unavoidable environmental impacts will occur for which a mitigation plan must be developed and properly managed. Based on the evaluations and analyses performed through the EA process, an environmental mitigation plan (EMP) has been developed by USAID in conjunction with the World Bank environmental representatives and feasibility consultants (i.e., ESE, KBN, GCII, and Boyd). When finalized, the EMP will be colloboratively adopted by GOP and the international development organizations (i.e., World Bank and ADB) prior to project implementation. The purpose of the EMP is to promulgate those activities that will be taken to avoid, reduce, or otherwise mitigate adverse environmental impacts associated with the Lakhra project. The mitigation activities proposed in the EMP are consistent with GOP, USAID, World Bank, and ADB environmental policies. A summary of the EMP is provided in Table 6-2 and includes mitigation activities that are national, regional, and site-specific in scope (refer to Draft Environmental Mitigation Plan, May 1986, USAID, for more details).

Environmental monitoring programs are a critical management tool in assessing the magnitude and extent of environmental impacts. Table 6-3 presents an outline of the suggested monitoring programs that should be considered for the project as well as the appropriate organization that should implement the programs.

The implementation of Lakhra Coal Mine and Power Generation Project will have a profound effect on the social environment of the Kotri Taluka. An analysis of the social soundness of the project that evaluated the significance of social impacts suggested various ways that would enhance the benefits of the project and minimize the social impacts of the

project. Many of these recommendations are presented in Appendix K and Table 6-2. Those recommendations most important to the success of the project include maximization of local employment, careful planning and integration of workers colonies, development and implementation of a public information program, coordination and integration of construction and operation activities to assure a smooth transition, and coordination with local governments (Dadu District and Sind Province) on secondary infrastructure development. Implementation of these recommendations would greatly ameliorate any adverse impacts to the social environment of the Kotri Taluka.

Table 6-1. Major Environmental Design Features of the Lakhra Coal Mine and Power Plant Project

| Environmental Impact | Design Features |
|---|---|
| Physical | |
| Air Quality | Electrostatic precipitators and combustion techniques; construction of Good Engineering Practice stack height; fugitive dust control (e.g., watering haul roads, storage piles) |
| Water Quality | Treatment of chemical and sewage wastes; construction of evaporation ponds |
| Biological (including agricultural) | Location of power plant at Lakhra; reduced design velocity of intake water (impingement) and evaluate the need for fine mesh screens |
| Social | Construction of workers colonies; institutional development and training |

Sources: GCII, 1986.
J.T. Boyd Company, 1986.
ESE, 1986.
KBN, 1986.



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Table 6-2. Summary of Environmental Mitigation Plan (Draft)

| Mitigation Description | Need or Impact | Proposed Mitigation Activity | Implementation Organization* |
|---|---|---|---|
| I. National Coal Development<br>A. Environmentally Sound Coal Development Strategy | GOP policy needed to evaluate/ mitigate environmental impacts of coal development in Pakistan | Develop plan and associated regulations for modern mining and utilization practices | GOP organizations: PEPA, GSP, PMDC, ENERPLAN, MH, MPD, MI and WAPDA. Assistance from international consultant |
| B. Ambient Air Quality Standards (AAQS) | Use of coal and associated air emissions from its use requires development and implementation of AAQS | Develop AAQS and institutional structure to implement standards | GOP organizations: PEPA, PCSIR, PMDC, ENERPLAN, MH, MPD, MI and WAPDA. Assistance from international consultant |
| II. Lakhra Coal Mine<br>A. Environmental, Safety, and Health Management Staff | Mine staff needed to manage potentially significant impacts | Development including training of professional staff | Coal mine operator. Oversight by PEPA and ML |
| B. Environmental Monitoring Program | Detection of potentially significant environmental impacts | Develop long-term monitoring program including monitoring of environment (air, water, etc.), reclamation program, and waste materials (see Table 6-2) | Coal mine operator with oversight by PEPA and Sind Mine Inspectorate |
| C. Mine Reclamation | Disruption of land causing air, water, safety, and social impacts | Develop and implement mitigation plan | Coal mine operator with oversight from PEPA and Sind Mine Inspectorate |
| D. Occupational Safety and Health | Potential serious injuries and fatalities from mining activities | Preparation and implementation of health and safety plan that conforms to World Bank guidelines and Boyd recommendations (see Volume 10 of J.T. Boyd Company Feasibility Report) | Coal mine operator as well as existing private sector mines if coal is received from these sources. Oversight by ML, Sind Mine Inspectorate, and donor organizations |



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Table 6-2. Summary of Environmental Mitigation Plan (Draft) (Continued, Page 2 of 3)

| Mitigation Description | Need or Impact | Proposed Mitigation Activity | Implementation Organization* |
|---|---|---|---|
| E. Emergency Prevention Planning and Management | Potential emergency situations caused by mining activities; the need to respond in a timely manner to ameliorate emergency condition | Preparation and implementation of plan | Coal mine operator with assistance from GOP and Sind organizations, as necessary. Oversight by ML, Sind Mine Inspectorate, and donor organizations |
| III. Lakhra Power Plant<br>A. Construction Safety Program | Construction accidents causing serious injuries or fatalities | Preparation and implementation of plan | Power plant contractors. Oversight by ML, WAPDA, and donor organizations |
| B. Environmental, Safety, and Health Management Staff | Potentially adverse impacts of power plant operation | Development of professional staff including training | WAPDA with oversight by PEPA and ML |
| C. Environmental Monitoring Program | Detection of potentially adverse environmental impacts | Obtain equipment and develop operation measures to implement program (see Table 16) | WAPDA with oversight from PEPA and donor organizations |
| D. Occupational Safety and Health Plan | Potential serious injuries and fatalities from power plant operation | Preparation and implementation of plan that conforms with World Bank guidelines and GCII recommendations | WAPDA with oversight from ML and donor organizations |
| E. Emergency Prevention, Planning, and Management | The need to ameliorate potentially serious injuries during emergencies | Preparation and implementation of plan | WAPDA with assistance from GOP and Sind organizations |
| IV. Solid Waste Master Plan | Potentially adverse environmental impacts from power plant and mine solid wastes | Develop and implement plan. Plan to comply with PEPA and project criteria | International consultant with input from coal mine operator and WAPDA. Oversight provided by PEPA, MH, MH and Sind Mine Inspectorate |



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Table 6-2. Summary of Environmental Mitigation Plan (Draft) (Continued, Page 3 of 3)

| Mitigation Description | Need or Impact | Proposed Mitigation Activity | Implementation Organization* |
|---|---|---|---|
| V. Waste Product Utilization | Potentially beneficial and economic uses of waste products (e.g., power plant fly ash) | Perform feasibility study and research into waste product utilization | PCSIR and universities with assistance of WAPDA and coal mine operator |
| VI. Infrastructure and Public Services | Potentially significant impacts to primary and secondary infrastructures and existing public services | Perform the following activities*:<br>A. Upgrading and improvement of Lakhra Highway<br>B. Planning and management of primary infrastructure development<br>C. Planning and management of secondary infrastructure development<br>D. Potable water stations in Khanot<br>E. Local official coordination for increasing public services<br>F. Local official coordination for development of secondary infrastructure | All potentially affected parties:<br>Coal mine operator<br>WAPDA<br>GOP<br>Sind<br>Dadu District<br>Local governments |
| VII. Grazing and Runoff Cropping | Removal of areas currently used for seasonal grazing and crops using runoff | Develop alternate areas | Coal mine operator |
| VIII. Endangered Animal Species | Loss of habitat for desert monitor (Varanus griseus) | Study of the ecology of the species in Sind/Lakhra area† | GOP Zoological Survey; Sind Ministry of Forest, Wildlife, and Forestry; US FWS |
| IX. Archeological and Historical Sites | Potential loss of significant archeological and historical sites not found in initial survey | Implementation of "Chance Find" Procedures | Coal mine operator with oversight from the GOP Department of Archeology |

*Refer to Section 4.2.3 and Appendix D.7 for more information and recommendations on infrastructure development. A public information program is also recommended.
† Study presently being conducted.
ENERPLAN = Ministry of Energy.
GSP = Geological Survey of Pakistan.
MI = Ministry of Industry.
MH = Ministry of Health.
ML = Ministry of Labor.
MPD = Ministry of Planning and Development.
PCSIR = Pakistan Council for Scientific and Industrial Research.
PEPA = Pakistan Environmental Protection Agency.
PMDC = Pakistan Mineral Development Corporation.
AAQS = Ambient Air Quality Standards.

Source: USAID, 1986.



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Table 6-3. Suggested Environmental Monitoring Programs

| Type of Monitoring | Parameters | Frequency | Number of Monitoring Stations and Location |
|---|---|---|---|
| Physical | | | |
| Air Quality | $SO_2$/Particulate | Continuous | Two stations located: (1) north-east near Indus agricultural areas (near the Rajri Reserve Forest) and (2) 1 to 2 km south of the power plant site. |
| Air Emissions | $SO_2$/Particulate/ $NO_x$ | Performance--annual | Testing of emissions at flue of each unit. Such tests should be performed annually. |
| | Meteorology | Continuous--wind speed and direction, stability (indirect methods) | One station at or near plant site. |
| Ground Water Quality | Total suspended solids, pH, temp., iron, arsenic, chromium, and selenium | Quarterly | Six to eight stations near ash/wastewater disposal areas; samples could also be obtained from existing underground |

Table 6-3. Suggested Environmental Monitoring Programs
(Continued, Page 2 of 2)

| Type of Monitoring | Parameters | Frequency | Number of Monitoring Stations and Location |
|---|---|---|---|
| Biological | Vegetation | Semi-annual | Survey of Indus agricultural areas northeast of plant for possible air pollution impacts. |
| | Monitor Lizard | Single 6-month study | Determine status of endangered species and ecology. Note: A project is currently funded by US Fish and Wildlife Service with cooperation of GOP to investigate the habitat of the monitor lizard. |
| Social | Infrastructure Development | Annually | Discussions with local/community leaders for planning and implementation of secondary infrastructure development. |

Sources: ESE, 1986.
KBN, 1986.

## 7.0 SHORT-TERM USES VERSUS LONG-TERM PRODUCTIVITY

The short-term (i.e., for the 30-year duration of the project) uses of land, water, and other resources are viewed as not having a significant effect on long-term productivity of the area. Although the existing ecological system in the Lakhra project area will be removed, this system is not a major resource for the area. The reclamation process will restore the land to approximately the same contours as the original surface, but the land will lack some of its original topographic variety. It will take a relatively long period of time (>50 years) for the ecosystem to fully recover, if at all.

Currently the land is only seasonally inhabitable, with some torrent-rain crops which probably can recover if topsoil is placed on the reclaimed land.

## 8.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The major commitment of resources is the utilization of 81 million metric tons of lignite from Lahhra Field. Steel, cement, sand, gravel, and aggregate will be used in the construction of the mine, power plant, and associated facilities.

Topsoil, removed at a rate of about 630,000 bank cubic meters per year (BCM/yr), will be irreversibly changed. Reclaimed soil placement or newly formed soil material will be dissimilar to that of the original topsoil and the surrounding undisturbed areas. The disruption and destruction of habitat caused by mining will cause some wildlife (including the monitor lizard) to be irretrievably lost. Native plant species which serve as habitat may reestablish over time; however, it is not known if the existing character of the native habitat and wildlife species (especially the monitor lizard) can completely recover.

The subsurface characteristics of the mining area will be irreversibly and irretrievably changed. The geologic and hydrologic changes in character of the area will not, however, have significant impacts to adjacent lands. Accidental destruction of archaeological or paleontological resources as a result of mining may occur. Chance find procedures, however, have been proposed for the project which might mitigate such impacts.

Although potential significant changes in the chemical and physical characteristics of the ground water may occur, the present ground water quality is relatively poor and unusable for irrigation or as potable water supplies. The removal of overburden, extraction of coal, and subsequent reclamation will result in energy consumption in the form of electrical power and fuel oil (diesel fuel for earth moving equipment). Chemicals and lubricants will be used for both mining and power plant development.

With any major construction project and large underground and surface mine, loss of human life and disabling injury may occur. Improvement in mining methods for underground miners would greatly reduce the potential hazards of serious injury or death. Under current methods, serious injury and death occur at a rate of about 180/million metric tons mined. Strict enforcement of modern methods should greatly reduce this impact.

# 9.0 LIST OF PREPARERS

Listed below are the persons who directly participated in the preparation of this Environmental Assessment for the Lakhra Coal Mine and Power Generation Project.

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## 10.0 REFERENCES

Agriculture Research Institute. 1986. Personal Communication. Sind University, Tandojam.

Agriculture Extension Service. 1986. Personal Communication. Sind University, Hyderabad.

Ahmad, M.F. and Ghalib, S.A. 1975. A Checklist of Mammals of Pakistan. Records, Zoological Survey of Pakistan, Vol. VII (1 and 2):1-34.

Ansari, T.A. Chief Conservator of Forests. 1986. Personal Communication.

Arid Lands Information Center. 1981. Draft Environmental Profile, The Islamic Republic of Pakistan. Bureau of Science and Technology, Office of Forestry, Environment and Natural Resources. USAID, Washington, D.C.

Ashenden, T.W. 1979. The Effect of Long-Term Exposures to $SO_2$ and $NO_2$ Pollution on the Growth of Dactylus glomerata L and Poa pratensis L. Environmental Pollution, 18:249-258.

Auer, A.H. 1978. Correlation of Land Use and Cover with Meteorological Anomalies, Journal of Applied Meteorology. pp. 636-643.

Beg, A.R. 1975. Wildlife Habitats of Pakistan. Biological Sciences Research Division. Pakistan Forest Institute, Peshawar. Bulletin No. 5 (Botany Branch).

Bokhari, S.H.A.S., Pakistan Department of Archaeology. 1986. Personal Communication.

Boyd (John T.) Company. 1985.
Technical Report: Field Studies Program, Lakhra Coal Project, Sind Province, Pakistan (Report No. 1800, Vols. 3A and 3B).
Technical Report: Lignite Reserve Study and Lignite Quality Study, Lakhra Coal Mine Project, Sind Province, Pakistan (Report No. 1800, Vols. 4 and 5).
Mining Feasibility and Master Mine Plan and Accompanying Exhibits, Lakhra Coal Project, Sind Province, Pakistan (Report No. 1800, Vols. 9A and 9B).
Prepared for USAID/Pakistan (Contract No. 391-0478-C-00-5006-00) and Water & Power Development Authority, Government of Pakistan.

Boyd (John T.) Company. 1986. Technical Report, Environmental Assessment Lakhra Coal Project Sind Province, Pakistan; and Interim Report, Transportation Study, Lakhra Coal Mine Study, Sind Province, Pakistan. Prepared for USAID/Pakistan (Contract No. 391-0478-C-00-5006-00) and Water & Power Development Authority, Government of Pakistan. Pittsburgh, Pennsylvania.

Briggs, G.A. 1971. Some Recent Analyses of Plume Rise Observations. In: Proceedings of the Second International Clean Air Congress. Academic Press, New York, New York.

Briggs, G.A. 1975. Plume Rise Prediction. In: Lectures on Air Pollution and Environmental Impact Analysis. American Meteorological Society, Boston, Massachusetts.

Carlson, R.W. and Bazzaz, F.A. 1982. Photosynthesis and Growth Response to Fumigation with $SO_2$ at Elevated $CO_2$ for C3 and C4 Plants. Oecologia, 54:50-54.

Cramer, H.E. Company, Inc. 1979. Industrial Source Complex (ISC) Dispersion Model User's Guide, Volumes I and II. Prepared for U.S. Environmental Protection Agency.

Dreisinger, B.R. and McGovern, P.C. 1970. Monitoring Atmospheric Sulphur Dioxide and Correlating its Effects on Forests and Crops in the Sudbury Area. In: S.N. Linzon, Ed. Proceedings of Impact of Air Pollution on Vegetation. APCA Specialty Conference, Toronto, Ontario, pp. 11-28.

Environmental Science and Engineering, Inc. 1986. Air Quality and Land and Water Data and Analyses. Gainesville, Florida.

Ferenbaugh, R.W. 1978. Effects of Prolonged Exposure of Oryzopsis hymenoides to $SO_2$. Water Air and Soil Pollution, 10:27-31.

Ferris, B.G. 1978. Health Effects of Exposure to Low Levels of Regulated Air Pollutants, A Critical Review. Journal of the Air Pollution Control Association, 28(5):482-497.

Ghalib, S.A. Rehman, H., Iffat, F., and Hasnain, S.A. 1976. A Checklist of Reptiles of Pakistan. Records, Zoological Survey Department, Vol. VIII (1 and 2):37-60.

Gifford, F.A. 1961. Use of Routinely Meteorological Observations for Estimating Atmospheric Dispersion. Nuclear Safety, 2(4):47-51.

Gilbert/Commonwealth International, Inc. (GCII). 1986. Lakhra Coal Mine and Power Generation Feasibility Study: Power Plant Feasibility. Vols. I-IX. Submitted to U.S. Agency for International Development and Pakistan Water and Power Development Authority. Jackson, Michigan.

Helweg, A.W. 1985. Social Soundness Assessment of the Lakhra Coal Mine and Power Generation Project. USAID, Islamabad.

Hill, C.A., Hill, S., Lamb, C., and Barrett, T.W. 1974. Sensitivity of Native Desert Vegetation to $SO_2$ and to $SO_2$ and $NO_2$ Combined. J. Air Pollution Control Association, 24:154-157.

Holzworth, G.C. 1972. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States. Publication No. AP-101. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Hunting Survey Corporating, Ltd. 1960. Reconnaissance Geology of Part of West Pakistan. Published for the Government of Pakistan by the Government of Canada. Toronto, Canada.

ICF, Inc. 1986. Lakhra Coal Mine and Power Generation Project--Economic Feasibility. Washington, D.C.

Japan International Cooperation Agency (JICA). 1981. Feasibility Report for Lakhra Coal Mining and Power Station Project.

Jensen, K.F. and Dochinger, L.S. 1979. Growth Responses of Woody Species to Long- and Short-Term Fumigation with Sulfur Dioxide. Forest Service Research Paper NE-442. Forest Service, USDA. Northeastern Forest Experiment Station, Broomall, Pennsylvania.

Kats, G. et al. 1985. Effects of Ozone or Sulfur Dioxide on Growth and Yield of Rice. Agriculture, Ecosystems, and Environment. 14:103-117.

KBN Engineering and Applied Services, Inc. 1986. Air Quality, Noise, Biological, and Socioeconomic Data and Analyses. Gainesville, Florida.

Khan, C.M.A. 1974. Brief Introduction to Kinds of Rangelands and Vegetation as Affected by Climate, Soil, and History for use in Pakistan. In: Pakistan Forest Institute. Proceedings of Pakistan Forestry Conference. Peshawar, Pakistan Forest Institute, pp. 94-100.

Khanum, Z., Ahmed, M., and Ahmed, M.F. 1980. A Checklist of Birds of Pakistan with Illustrated Keys to Their Identification. Records, Zoological Survey of Pakistan, Vol. IX (1 and 2):1-138.

Kohut, R.J. et al. 1982. The National Crop Loss Assessment Network: A Summary of Field Studies. Paper 82-69.5. Session 69. Presentation at the 75th Annual Meeting of the Air Pollution Control Association.

Kuresky, K.U. 1978. A Geography of Pakistan. Oxford University Press, Oxford.

Marshall, P.E. and Furnier, G.R. 1981. Growth Responses of Ailanthus altissima Seedlings to $SO_2$. Environmental Pollution 25:149-153.

McLaughlin, S.B. and Lee, N.T. 1974. Botanical Studies in the Vicinity of Widows Creek Steam Plant. Tennessee Valley Authority. Division of Environmental Planning. Muscle Shoals, Alabama.

Memon, S. 1986. Personal Communication. Director of Health Services, Government of Sind.

Minton, S.A. 1962. An Annotated Key to the Amphibians and Reptiles of Sind and Lasbela, West Pakistan. American Museum Noviales, No. 2081:1-60.

Minton, S.A. 1966. A Contribution to the Herpelotogy of West Pakistan. Bull. American Museum of Natural History, 134:27-184.

Motayed, M. ASCE. 1980. Alternative Evaluation of Power Plant Sites. Journal of Energy Division. Proceedings of the American Society of Civil Engineers, October 1980.

Newman, J.R. 1979. Effects of Industrial Air Pollution on Wildlife. Biol. Conserv., 15:181-190.

Newman, J.R. 1980. Effects of Air Emissions on Wildlife Resources. U.S. Fish and Wildlife Service, Biological Service Program, National Power Plant Team. FWS/OBS-80/401.

Newman, J.R., Novakova, E., and McClave, J.T. 1985. The Influence of Industrial Air Emissions on the Nesting Ecology of the House Martin (Delrichon urbica) in Czechoslovakia. Biological Conservation, 31:229-248.

Noggle, J.C. and Jones, H.C. 1979. Accumulation of Atmospheric Sulphur by Plants and Sulphur-Supplying Capacity of Soils. Prepared for Office of Energy, Minerals, and Industry, Office of Research and Development, U.S. Environmental Protection Agency. Office of Natural Resources, Tennessee Valley Authority, Muscle Shoals, Alabama. EPA-600/7-79-109 and TVA/DNR-79/10.

Norby, R.J. and Kozlowski, T.T. 1983. Flooding and $SO_2$ Stress Interaction in Betula papyrifera and B. nigra Seedlings. Forest Science, 29:739-750.

Pakistan Meteorological Service. 1985. Summary of Climatological Data Observed in Hyderabad, Pakistan, from 1931 to 1960.

Pakistan Population Census Organisation, Statistics Division. 1983a. 1981 District Census Report of Hyderabad. Islamabad. District Census Report No. 37.

Pakistan Population Census Organisation, Statistics Division. 1983b. 1981 District Census Report of Dadu. Islamabad.

Pandey, N.S. 1982. Ameliorating Effect of Urea Spray on Wheat Triticum aestivum Plants Exposed to Sulphur Dioxide. Environmental Pollution, 27:73-82.



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Pandey, N.S. 1983. Impact of Thermal Power Plant Emissions on Vegetation and Soil. Water Air Soil Pollution, 19:87-100.

Pasquill, F. 1961. The Estimation of the Dispersion of Windborne Material, Meteorological Magazine. 90(1066):33-49.

Rasool, N., Director of Southern Circle, Pakistan Department of Archaeology and Museums. 1986. Personal Communication.

Reich, P.B. et al. 1985. Effects of $O_3$, $SO_2$, and Acidic Rain on Mycorrhizal Infection in Northern Red Oak Seedlings. Canadian J. Botany, 63:2049-2055.

Roberts, T.J. 1977. The Mammals of Pakistan. Ernest Benn Ltd., London.

Ruggiano, L.M. and Poulson, E.S. 1980. Geotechnical Evaluation of Stabilized FGD Sludge Disposal. Presented at Second Conference on Air Quality Management in the Electric Power Industry. Austin, Texas.

Shaukat, S.S., Khairi, M.A., Khan, D., and Qureshi, J.A. 1980. Multivariate Approaches to the Analysis of Vegetation of Gadap Area, Southern Sind, Pakistan. Tropical Ecology, 21(1):81-102.

Shaukat, S.S., Khan, D., and Qadir, S.A. 1981. On the Vegetational Dynamics of Calcarious Hills Around Karachi. Pak. J. Bot., 13(1):17-37.

Sind Bureau of Statistics. 1984. Development Statistics, Sind. Bureau of Statistics, Planning and Development Department, Government of Sind, Karachi.

Sind Inspectorate of Mines. 1985. Annual Return, 1982 and 1983, on Working of Inspectorate of Mines, Sindh. Government of Pakistan, Karachi, Pakistan.

Spate, O.H.K., Learmouth, A.T.A., and Farmer, B.A. 1972. India, Pakistan, and Ceylon: The Region. Melhuen and Co., Ltd. London.

Stewart, R.R. 1982. History and Exploration of Plants in Pakistan and Adjoining Areas. In: Flora of Pakistan, E. Nasir and S.I. Ali (Eds.).

Suwannapinunt, W. and Kozlowski, T.T. 1980. Effect of $SO_2$ on Transpiration, Chlorophyll Growth, and Injury in Young Seedlings of Woody Angiosperms. Canadian Jounral of Forest Research, 10:78-81.

Thompson, C.R., Kats, G., and Lennox, R.W. 1980. Effects of $SO_2$ and/or $NO_2$ on Native Plants of the Mojave Desert and Eastern Mojave-Colorado Desert. J. Air Pollution Control Association, 30:1304-1309.

Ticehurst, C.B. 1922-1924. The Birds of Sind Ibis IV: 525-572; 604-663; Vol. V: 1-43; 235-275; 439-474; 645-666; Vol. VI; 110-146; 495-518.

Tippets-Abbett-McCarthy-Stratton (TAMS). 1985. Environmental Baseline Monitoring System and Program for the Lakhra Coal Mining and Power System Project. Prepared for USAID and WAPDA.

Tokyo Electric Power Services Co., Ltd. June 8, 1985. Correspondence from K. Takasawa, Deputy General Manager re Calculation of $SO_2$ Concentrations.

Tripodi, R.A. and Cheremisinoff, P.N. 1980. Coal Ash Disposal: Solid Waste Impacts. Technomic Publishing Co., Inc. Westport, Connecticut.

Turner, D.B. 1964. A Diffusion Model for an Urban Area. Journal of Applied Meteorology. Volume 3:83-91. February.

U.S. Environmental Protection Agency (USEPA). 1982. Development Document for Final Effluent Limitations Guidelines, New Source Performance Standards, and Pretreatment Standards for the Steam Electric Point Source Category. Effluent Guidelines Division, Office of Water and Waste Management, USEPA. Washington, D.C. EPA 440/1-82/029.

U.S. Environmental Protection Agency. 1983. UNAMAP, (Version 5) EPA/DF-81-001g. Meteorology and Assessment Division, Environmental Sciences Research Laboratory, Research Triangle Park, North Carolina.

United Nations Centre for Regional Development. 1981. Present Situation, Regional Development in Sind. A Comprehensive Planning Report. Volume 1(2).

Water and Power Development Authority (WAPDA). 1983. Surface Water Hydrological Report. Institute of Public Health Engineering and Research. Government of Pakistan.

Water and Power Development Authority (WAPDA). 1985. Reports on Total Suspended Particulate Matter Concentrations Collected at the Jamshoro and Lakhra Monitoring Stations from May 30 to August 13, 1985. Government of Pakistan.

Water and Power Development Authority (WAPDA). 1986. Air Quality, Noise, Biological, and Socioeconomic Data and Analyses. Gainesville, Florida.

Water and Power Development Authority (WAPDA). 1986. Power Development Plan for Elimination of Load-Shedding by 1990. Lahore, Pakistan.



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Winner, W.E. and Mooney, H.A. 1980. Ecology of $SO_2$ Resistance: III Metabolic Changes of C3 and C4 Atriplex Species Due to $SO_2$ Fumigation. Oecologia 46: 49-54.

Woodcock, M.W. 1984. Collins Handguide to the Birds of the Indian Subcontinent. Collins, London.

World Bank, Office of Environmental Affairs. 1984. Environmental Guidelines.

World Bank, Office of Environmental Affairs. 1986. Environmental Guidelines.

ATTACHMENT I--PRO FORMA FOR ENVIRONMENTAL IMPACT ASSESSMENT

# ATTACHMENT I

On February 7, 1985, Zia-ul-Hag, Deputy Secretary, Ministry of Housing and Works, Environment and Urban Affairs Division, requested USAID to supply a detailed Environmental Impact Assessment (EIA) for the Lakhra Coal Mine and Power Generation Project and to provide information listed in an EIA Pro Forma. This attachment provides a cross reference between the Pro Forma and the Environmental Assessment (EA) and technical support documents. The environmental information requested in the Pro Forma can, therefore, be obtained through a review of the sections, sub-sections, and tables referenced in the following pages.

# PRO FORMA FOR ENVIRONMENTAL IMPACT ASSESSMENT

| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 1. | General | |
| 1.1 | Name of the Project: | Lakhra coal mine and power generation project. |
| 1.2 | Official address at which correspondence can be made: | Address for mine to be determined. Address for power plant is WAPDA, Lahore. |
| 1.3 | Name and address of consultant appointed, if any: | Not applicable (N.A.) |
| 1.4 | Name, designation, and address of official authorised to deal with this Questionnaire/Proforma: | G.M. Ilias, Chief Engineer, Coal Power Projects, WAPDA House, Lahore. |
| 1.5 | Date on which letter of intent was issued: | N.A. |
| 2. | Process Details | |
| 2.1 | Production Schedule: | See Section 1.3 for project description. |
| 2.1.1 | List of main products proposed to be produced with designed daily production or capacity: | See Section 1.3; 8,400 MW hours/day at average capacity. |
| 2.1.2 | List of by-products produced with designed daily product capacity: | See Tables 2-3, 4.4-10, and 4.4-11. |
| 2.1.3 | Time phasing for achieving full production capacity: | Approximately 6 years. |

| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 2.2 | Raw Materials Consumption: | |
| 2.2.1 | List all raw materials with daily consumption at full production capacity: | See Tables 2-3 and 2-6. |
| 2.2.2 | List all process chemicals/materials consumed with approximate quantities: | See Table 4.4-13 |
| 2.2.3 | Is any recycled material from the waste of your project or any other project used in the process? If so, please specify quantities and source. | N.A. |
| 2.2.4 | Is any material salvaged from your waste stream re-usable economically for any other? | N.A. |
| 2.3 | Manufacturing Process: | N.A. |
| 2.3.1 | Source of process know-how: | |
| 2.3.2 | Give a brief description of the process technology utilized with a flow-chart. (Flow-chart of the process should be attached). | |
| 2.3.3 | Have you any foreign collaboration? | |
| 2.4 | Energy Consumption: | |
| 2.4.1 | Source of energy:<br>a) In-plant generation.<br>b) Public supply. | See discussions in Sections 1.3, 2.4, and 2.5. |



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| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 2.4.2 | If energy is generated in plant, type and quantity of fuel daily consumed: | See Tables 2-3, 4.4-14, and 4.4-15. |
| 3. | General Environment (Site climate settlement): | |
| 3.1 | Site: | |
| 3.1.1 | Where is the plant proposed to be sited?<br><br>Attach map showing topographical features of the area. | See discussions Sections 1.1, 1.3, and 2.4; see Figures 1-1 and 2-1. |
| 3.1.2 | Elevation above mean sea level | Approximately 120-130 m. |
| 3.1.3 | Area of land proposed to be acquired: | See Figures 1-1 and 2-1. |
| 3.1.4 | Area proposed to be built up or developed: | See Figures 1-1, 2-1 and 2-3. |
| 3.1.5 | Present use of the land: agriculture/forest/grazing/settlement/fallow | See discussions in Section 3.3. |
| 3.1.6 | Indicate the nature of topography near the site: plains/valley/hilly | See discussion in Subsection 3.1.2.2 |
| 3.1.7 | Specify site character: river basin/coastal/estuarine/land-locked | See discussion in Subsection 3.1.2.2. |
| 3.1.8 | Is the land situated within any municipal or corporation jurisdiction? | See Subsection 3.3.1. |

| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 3.1.9 | Is the land situated in an approved industrial zone or estate? If so, please specify. | See discussion in Subsection 3.3.1. |
| 3.1.10 | What, of the following features, exist within 30 km of the site? | See discussions in following Subsections: |
| | i) Human settlements: specify population. | 3.3.2.1. |
| | ii) Agricultural land: specify crops. | 3.3.1 and 3.3.2.2. |
| | iii) Grazing land: | 3.3.1. |
| | iv) Fisheries: | 3.2.2. |
| | v) Forest/sanctuary/ natural park: | 3.2.1 and 3.3.1. |
| | vi) Nullahs/streams/ rivers: | 3.1.2.1. |
| | vii) Ponds/lakes/dams: | 3.1.2.1. |
| | viii) Estuary/sea: | 3.1.2.1. |
| | ix) Hills/mountains: | 3.1.2.2. |
| | x) Archaelogical/Historic/ Cultural/Scenic sites/ Scientific Institutions/ Hospitals/Sanatoria/ Religious importance: | 3.3.2.1. |
| | ix) Industries, specify: | 2.5 and 3.3.2.2. |
| 3.1.11 | Type of flora and fauna, especially wildlife, endangered species: | See discussion in Subsections 3.2.1, 3.2.2 and 3.2.3. |
| 3.1.12 | Present employment or occupational pattern in the area: | See discussions in Sections 2.9 and and 3.3.2.2. |
| 3.1.13 | Prominent Endemic Disease (Fluorosis, Malaria, Filaria, Malnutrition, etc). | See Subsection 3.3.2.3. |
| 3.1.14 | Mortality rates: (Crude, Infant, Material): | See Subsection 3.3.2.3. |



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| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 3.1.15 | Any other observation regarding state of the environment? | |
| 3.2 | Climate: | |
| 3.2.1 | Indicate the climatic conditions at the site (e.g., arid, semi-arid, etc.). | See Table 3.1-1. |
| 3.2.2 | Rainfall yearly average. Range: | See Table 3.1-1. |
| 3.2.3 | Temperature seasonal. Ranges: | See Table 3.1-1. |
| 3.2.4 | Provide information on speed and direction of wind. | See Figure 3.1-2. |
| 3.3 | Settlement: | |
| 3.3.1 | Total number of persons proposed to be employed: | |
| | (a) During construction: | |
| | (b) After completion: | See discussion in Section 2.9. |
| 3.3.2 | Do you propose to build a township/housing quarters for your employees? | See discussion in Section 2.8. |
| 3.3.3 | Area allocated for above: | See discussion in Section 2.8. |



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| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 3.3.4 | Population to be accommodated: | See discussion in 2.9. |
| 3.3.5 | Distance from township to plant site: | Approximately 25 km from power plant workers colony. |
| 3.3.6 | Services provided in township:<br>i) Water - daily consumption:<br>ii) Sewer system:<br>iii) Sewage treatment:<br>iv) Garbage disposal:<br>v) Drainage:<br>vi) Any other: | See discussion in 2-8. |
| 4. | Water Requirements: | |
| 4.1 | What treatment is given before use, if any? | See discussion in Subsection 4.4.1.3. |
| 4.2 | Average daily quantities and characteristics of water consumed:<br>i) Process and wash:<br>ii) Cooling:<br>iii) Sanitary:<br>iv) Total: | See Tables 2-3, 4.4-10, and 4.4-12. |
| 4.3 | Are adequate quantities of water available?<br>i) At present:<br>ii) For future expansion: | See discussion in Subsection 4.4.1.3. |



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| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 5. | Wastewater Discharges: | |
| 5.1 | Total quantity of wastewater discharged from the project per day: | See Table 2-3. |
| 5.2 | Wastewater discharges per day from:<br>i) Process and wash (with break up, where possible):<br>ii) Cooling:<br>iii) Sanitary:<br>iv) Total: | See Table 4.4-10. |
| 5.3 | How do you propose to discharge the wastewater?<br>(i) Separate streams/ combined:<br>(ii) Continuous/inter-mittent: | See discussions in Subsections 4.2.1.2 and 4.4.1.3 |
| 5.4 | Type of treatment proposed to be adopted: Give details and flow chart. | See discussions in Subsections 4.2.1.2 and 4.4.1.3. |
| 5.5 | What standards for treatment effluent do you propose to adopt?<br><br>Does it conform to standards prescribed by State/Central Water Pollution Board, Local Authority, or other statutory authority? | See discussions in Section 1.5 and Tables 1-2 and 1-3. |



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| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 5.6 | Mode of final discharge: (open channel/pipeline/ covered drains) | See discussions in Subsections in 4.2.1.2 and 4.4.1.3. |
| 5.7 | Point of final discharge: fallow land/agricultural land/sewer/river/lake bay/estuary/sea. Give details of outfall design. | See discussions in Subsections in 4.2.1.2 and 4.4.1.3. |
| 5.8 | Is any portion of the wastewater proposed to be recycled? If so, give details. | See discussions in Subsections in 4.2.1.2 and 4.4.1.3. |
| 5.9 | What methods do you propose to adopt for handling and disposal of sludge from treatment plants? | See Subsections 4.2.1.2 and 4.4.1.3. |
| 5.10 | Indicate available information on wastewater characteristics before treatment as below.<br><br>a) Physical Parameters: Temperature, pH, colour, turbidity, odour, total solids, total suspended solids, and total volatile solids. | See Tables 4.4-13, 4.4-16, 4.4-17, and 4.4-18. |



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| | Types of Information | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| | b) Chemical Parameters: Acidity, total, and pH; Alkalanity, total and pH; Hardness, total, BOD; COD; Oil and Grease; total N; Phosphates, total; Chlorides; Sulphates; Sodium; Potassium; Calcium; and Magnesium. | |
| 5.11 | What other specific toxic substances are discharged?<br><br>Please specify nature and concentration: (inorganics, organics, including pesticides and organic chlorine compounds, phenols, lignin, mercaptans, heavy metals, and radioactive substances). | See Tables 4.4-13, 4.4-16, 4.4-17, 4.4-18. |
| 6. | Solid Wastes: Process and Treatment Plants | See Tables 2-3 and 4.4-11. |
| 6.1 | Total quantity of solid wastes in tonnes per day: | |
| 6.2 | Nature of Wastes: Lumps/Granules/Dust/Slurry/Sludge | See Table 4.4-11. |
| 6.3 | Type of waste (organic, inorganic, ash, glass, natal, etc.) | See Table 4.4-11. |

| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 6.4 | Method proposed for disposal, including treatment plant: | See Subsections 4.2.1.2 and 4.4.1.3. |
| | Landfill/dumping/sea/lagoon/marsh/composting/incineration/sold | |
| 6.4.1 | If landfill, possibility of leaching of toxic compounds into soil, ground water, or surface water: | See Table 4.4-17. |
| 6.4.2 | If incinerated, details of incineration plant and procedures: | N.A. |
| 6.6 | Do you anticipate any problems regarding collection, handling, and transport of solid wastes? | See discussions in Subsections 4.2.1.3 and 4.4.1.3. |
| 6.7 | Are there any problems of subsequent pollution of air, water, or soil likely at the place of disposal of solid wastes? | See discussion in Subsections 4.2.1.3 and 4.4.1.3. |
| 7. | Atmospheric Emissions | |
| 7.1 | Emission from fuel burning: | See Table 2-3. |



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| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 7.1.1 | Anticipated quantity of stack emissions: | See Table 2-3. |
| 7.1.2 | Temperature of emission: | See Appendix F. |
| 7.1.3 | Composition of emission: | See Table 2-3. |
| | (a) Particulates and smoke nature and quantity: | |
| | (b) Gases: | |
| | Sulphur dioxide | |
| | Nitrogen oxides | |
| | Hydrocarbons | |
| | Carbon monoxide | |
| | Moisture | |
| | Other, specify. | |
| 7.2 | Emissions from process: | |
| 7.2.1 | Anticipated emissions, quantity: | |
| 7.2.2 | Temperature: | |
| 7.2.3. | Composition of emissions a) Particulates, nature and quantity: | |
| | b) Gases: | |
| | i) Sulphur dioxide | |
| | ii) Nitrogen oxides | |
| | iii) Carbon monoxide | |
| | iv) Ammonia | |
| | v) Acide Mists | |
| | vi) Halogens | |
| | vii) Hydrocarbons | |
| | viii) Mercaptans | |
| | ix) Others, specify: | |

| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 7.3 | Height of stacks(s), for atmospheric emissions: | See Appendix I. |
| 7.4 | Proposed air pollution control system: | See discussions in Section 2.7 and Appendix E. |
| 7.5 | Proposed method of handling and disposal of wastes trapped by pollution arresting equipment: | See discussion in Subsection 4.4.1.3. |
| 7.6 | Are any standards of emission prescribed for or adopted by your industry? | See discussion in Section 1.8. |
| 8. | Other types of pollution: | |
| 8.1 | Is your project industry likely to cause noise pollution? | See discussions in Subsections 4.2.1.2, and 4.3.1.2, and 4.4.1.2. |
| 8.2 | Is your project industry likely to cause any odour pollution? | N.A. |
| | If yes, what measures are proposed to be taken? | |
| 8.3 | Is your project industry likely to cause any thermal pollution? | See discussions in Sections 1.3, 1.4, and 4.4.1.3. |

| | Types of Information | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| Impacts | | |
| | If yes, what measures are proposed to be taken? | |
| 8.4 | Is your project industry likely to cause radioactive pollution? | N.A. |
| | If yes, what measures are proposed to be taken? | |
| 8.5 | Describe the nature and extent of pollution nuisance caused during construction phases and measures taken to contain the same. | See discussions in Section 4.3. |
| 8.6 | Work Environment Hygiene and Housekeeping: | |
| 8.6.1 | What major health/safety hazards are likely in the working environment in your factors? | See discussions in Section 2.5 and 3.3.2. |
| 8.6.2 | Describe the industrial hygiene measures you propose to adopt. | See discussion in Section 6.0. |
| 8.6.3 | What provision have you made to confirm to health and safety requirements as per Factories Act? | See discussion in Section 6.0. |
| 9. | Management of Pollution Control: | |

| Types of Information | | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|---|
| 9.1 | Give details of the organizational set-up you propose to have for pollution control. | See discussion in Section 6.0 and Support Document. |
| 9.2 | What is the level of expertise of the person in charge of pollution control? | |
| 9.3 | Do you propose to monitor the pollution from your industry?<br><br>If yes, give details. | |
| 9.4 | What laboratory facilities do you propose to have for the above? | |
| 9.5 | Give details of operation and maintenance of facilities you propose to have for treatment plants and pollution monitoring and control equipment. | |
| 10. | Cost of Pollution Control: | |
| 10.1 | Total expenditure proposed for pollution monitoring and control: | See discussion in Section 2.7. |

| Type of expenditure | Amount (Rs) | Percentage of total capital investment/operating expenditure of the industry |
|---|---|---|
| Capital | | |
| Recurring (including monitoring) | | |



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| Types of Information | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|
| 11.1 Climate and Air Quality: | See discussion in Subsections 4.2.1.1, 4.3.1.1, and 4.4.1.1. |
| (i) Will the project modify the local wind behaviour? | |
| (ii) Will the project have an impact upon the local precipitation/humidity pattern? | |
| (iii) Will the project have an impact upon the local temperature pattern? | |
| (iv) Will the project generate and disperse atmospheric pollutants? | |
| (v) Will the project generate any intense odours? | |
| 11.2 Water: | See discussions in Subsections 4.2.1.3, 4.3.1.3, and 4.4.1.3. |
| (i) Will the project alter the hydrological balance? | |
| (ii) Will the project effect the ground water required in terms of quality/quantity, depth, and direction of flow? | |
| (iii) Will dewatering methods be necessary to undertake excavation? | |
| (iv) Will the project induce a major sediment influx into area water bodies? | |
| (v) Will the project impede the natural drainage pattern and/or induce alteration of channel form? | |
| (vi) Will the project impair existing surface waters through filling, dredging, water extraction, or other detrimental practices? | |
| (vii) Will recreation or aesthetic values be endangered? | |



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| Types of Information | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|
| 11.3 Geotechnical: | See discussions in Subsections 3.1.2.2, 4.2.1.3, 4.3.1.3, and 4.4.1.3. |
| i) Is there risk of damage or loss resulting from tectonic/seismic activity and/or volcanic activity? | |
| ii) Are there mineral resources of potential value close to the project? | |
| iii) Will there be an increase in rock deposition/degradation as a result of the project? | |
| iv) Are there potential dangers related to slow failure or falling rock? | |
| v) Is there risk of major ground subsidence associated with the project? | |
| 11.4 Soil: | See discussions in 4.2.1.3, 4.3.1.3, and 4.4.1.3. |
| i) Will there be a substantial loss of soil due to construction or operational practices? | |
| ii) Will there be a risk of losses due to instability? | |
| iii) Will project cause or be exposed to liquefaction of soils in slopes or foundations? | |
| iv) In case of settlement/heave, will there be a risk of damage of structure or services? | |
| v) Will the project modify the property of impacted soil? | |
| 11.5 Ecology: | See discussion in Subsections 4.2.2, 4.3.2 and 4.4.2. |
| i) Are there rare/endangered species which require protection? | |

| Types of Information | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|
| ii) Are there species which are particularly susceptible to human activities? | |
| iii) Would the loss of certain plants species deny food or habitat to wildlife species? | |
| iv) Are there any unusual population communities of plants that may be of scientific value? | |
| v) Will project activities impair natural productivity? | |
| 11.6 Land Use and Land Capability: | See discussions in Subsections 4.2.3.1, 4.3.3.1, and 4.4.3.1. |
| i) Will the project conflict with existing or proposed land use? | |
| ii) Will the project degrade land capability types? | |
| 11.7 Noise and Vibration: | See discussions in Subsections 4.2.1.2, 4.3.1.2 and 4.4.1.2. |
| i) Will the internal noise level present a potential risk to the hearing of workers? | |
| ii) Will the safe operation of the project be affected? | |
| iii) Will the project create noise levels which will cause annoyance or discomfort to nearby properties? | |
| iv) Will the project cause damage to structures, both natural and manmade, due to vibration? | |
| v) Will the vibration levels within the plant be such that there is a risk to employees safety? | |



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| Types of Information | Information or Sections of Environmental and Social Soundness Assessment |
|---|---|
| 11.8 <u>Visual Quality</u>:<br>i) Will the content of the scene perceived by the residents of the surrounding area be adversely affected by the project?<br>ii) Will the coherence of the surrounding area be impaired by the project? | See discussions in Subsections 4.2.1.1, 4.3.1.1 and 4.4.1.1 and 4.2.3, 4.3.3, and 4.4.3. |



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ATTACHMENT II

# RECORD OF THE SCOPING SESSION FOR THE LAKHRA COAL MINE AND POWER GENERATION PROJECT ENVIRONMENTAL AND SOCIAL SOUNDNESS ASSESSMENT AND JAMSHORO THERMAL POWER COMPLEX (PHASE II) ENVIRONMENTAL AND SOCIAL SOUNDNESS ASSESSMENT

## I. INTRODUCTION

This attachment is intended to serve as a formal record of the scoping session for the Environmental and Social Soundness Assessments of the Lakhra Coal Mine and Power Generation Project, and the Jamshoro Thermal Power Complex (Phase II). This scoping session was held by the Water and Power Development Authority of Pakistan (WAPDA) From 9:00 to 13:00 on 6 October 1986 at the Fataz Hotel in Hyderabad, Sind Province, Islamic Republic of Pakistan. The scoping session was conducted in English at the request of the Government of Pakistan.

## II. SUMMARY OF THE SCOPING SESSION

### A. Agenda

| | | | |
|---|---|---|---|
| 1. | Seating of guests | | 0900 |
| 2. | Recitation from the Holy Quran. | Qari Sahib. | 0900-0910 |
| 3. | Welcome Address | Engr. A.A. Zaidi<br>Chief Engineer Jamshoro | 0910-0915 |
| 4. | Opening Remarks | Engr. Nazim Hussain Siddiqui, C.E. (Design) Thermal, Lahore | 0915-0930 |
| 5. | Overview of Lakhra and Jamshoro Projects | Engr. A.A. Zaidi<br>Chief Engineer Jamshoro | 0930-0945 |
| 6. | Description of USAID Environmental Procedures | Dr. Stephen F. Lintner<br>Environmental Coordinator<br>USAID, Washington D.C., USA | 0945-1000 |
| 7. | USAID involvement in Lakhra and Jamshoro Projects | Mr. John Morgan<br>Mission Environmental Officer, USAID, Islamabad | 0955-1000 |
| 8. | Brief description of Lakhra Power Station Project | Engr. M. Qasim Sheikh<br>Project Engineer, Lakhra Power Station Project | 1000-1015 |
| 9. | Brief description of Lakhra Coal Mining Project | Engr. Tariq Zamir,<br>Project Engineer, Lakhra Coal Mining Project | 1015-1030 |



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| | | | |
|---|---|---|---|
| 10. | Teabreak | ---------- | 1030-1100 |
| 11. | Environmental Study & Impact of Lakhra Power Station | Kennard F. Kosky, P.E. ESE/KBN, Gainesville, Florida, USA | 1100-1130 |
| 12. | Environmental Study & Impact of Jamshoro Power Station Project | David A. Cobb, Catherine L. Damassa Bechtel National, Inc., San Francisco, California USA | 1130-1200 |
| 13. | Questions, Comments, proposals from the floor | | 1200-1300 |

B. Synopsis of the Formal Presentations

1. Lakhra Coal Mine and Power Generation Project

An overview of the draft Environmental and Social Soundness Assessment was presented by Mr. Kosky. This presentation consisted of the following topics which were supported by visual aids (figures and tables for the overhead projector):

a. Purpose of Scope of Environmental Assessment (EA)
b. Applicable Regulations
c. EA structure
d. Analysis of Alternatives including those related to management, type of technology and social-infrastructure
e. Environmental impacts, including short and long term impacts to the physical, ecological and social environments
f. Mitigation Plan - overview of proposed plan which includes provisions for environmental management and monitoring, mine reclamation, occupational safety and health, emergency prevention planning and management, solid waste management, infrastructure (primary and secondary) and archeological/historical preservation.

2. Jamshoro Thermos Power Complex (Phase II)

Mr. David A. Cobb of Bechtel National, Inc. presented an overview of information, analyses and considerations that will be part of the Environmental and Social Soundness Assessment. At the time of the presentation, the assessment was not completed. Mr. Cobb's presentation was supported by visual aids (charts) and included discussion of potential major areas of significant environmental impact on the physical and ecological environment of the Jamshoro area. Ms. Damassa presented information related to the impacts to the social environment and considerations that must be included for the projects' development.

## III. Question and Answer Session

### A. Introduction

Professor K.M. Khan, Chairman, Department of Botany, Sind University, proposed that for clarity the question and answer session be divided into two portions, one for Lakhra, one for Jamshoro. In this manner, each project could be discussed separately.

This proposal was adopted by the moderator of the meeting, Engineer Nazim Siddiqui.

### B. Lakhra Coal Mine and Power Generation Project

Professor M.R. Shabayo, Professor of Metallurgical Engineering, Mehran Engineering University, inquired about potential secondary impacts of air emissions of power plants, particularly with regard to corrosion. He asked if this had been taken into account in the Environmental Assessment. Mr. Kosky, representing ESE/KBN, replied that the power plant design incorporated an appropriate selection of materials for plant equipment to address anticipated abrasion problems. Corrosion, due to flue gases, is not anticipated to be a problem due to the low humidity and high dispersion in the area. He also noted that flue gases will be well above the dew point, reducing the amount of acid precipitation.

2. Professor K.M. Khan raised the following questions:

   (a) Why was WAPDA considering the use of high sulfur coal when in other parts of the world this is not being done? This can result in harm to the natural environment and to wildlife.

   (b) Have the potential impacts of fugitive dust from surface mining operations been considered in the Environmental Assessment? For example, will it have an impact on migratory ducks which pass through the area each year?

   (c) Have the seasonal variation in winds, and downwind impacts been considered in the Environmental Assessment?

Question (a) was answered by Engineer Siddiqui of WAPDA. He noted that WAPDA must use the coal which it has available within Pakistan to improve balance of payments. The most abundant Pakistani coal is in the Lakhra field. He observed that high sulfur coals are in use elsewhere in the world. He also assured the audience that WAPDA planned to use locally available coal in such a way as to minimize potentially adverse environmental impacts.

Question (b) was addressed as follows:

Engineer Siddiqui noted that dust emissions from surface mining had been reviewed in the design process.

Mr. Kosky made the following points:

The proposed Lakhra plant and mine site are located on a plateau, approximately 100 meters above the level of the Indus River, which will enhance dispersion of any fugitive dust. He also said that most of the fugitive dust particles which result from the mining operation are larger than 10 microns in diameter, which is above the respirable size fraction, thus posing little risk to human health. Due to their density, these materials will settle close to the point of release. He also observed that the vegetation in the vicinity of the plant and mine site is of a hardy type and should not be significantly affected by potential particle emissions. Mr. Kosky stated that from a health viewpoint the dust (fly ash) from the flue gas represented a greater health hazard and that Gilbert-Commonwealth, the power plant feasibility consultant, has included an electro-static precipitator (ESP) for flue gas particulate removal in their design.

Dr. Lintner, AID/Washington, noted that there is a significant level of experience in surface coal mining in the United States and that water suppression is the most commonly used control technique for dust. In addition, the proposed mining plan includes the reclamation of mined areas to reduce long term dust generation.

Question (c) was answered by Mr. Kosky, who noted that from the beginning of the Environmental Assessment the quantity and quality of meteorological data was a serious concern. Available data from the Pakistan Meteorological Department station at Hyderabad, because of its urban setting, did not accurately reflect the wind regime at Lakhra. Consequently, a meteorological station was set up at the proposed Lakhra site to collect the necessary data beginning in May 1985. This station has reported wind data as high as 30 knots. This on-site data was taken into account in the air pollutant analyses used in the Environmental Assessment.

3. Dr. M. Yakoob Soomro, Chairman, Department of Chemical Engineering, Mehran University, related that he was conducting research into flue gas desulfurization (FGD) processes and would be interested in any data or information relative to this technology which has been developed in the course of the Lakhra feasibility studies. He also wanted to receive some samples of coal from the Lakhra field.

Engr. Siddiqui directed Engr. Qasim Sheikh, Project Engineer, Lakhra Power Station, to provide available data and coal samples to Dr. Soomro, as well as the results of some recent WAPDA flue gas desulfurization studies.

4. Dr. Shabayo asked if WAPDA has considered gasification, and if the coal exploration data have been computerized.

Engr. Siddiqui noted that large-scale gasification technology for power generation is still in the development stage in the United States and Western Europe. He observed that once such technology was proven it would be given consideration by WAPDA.



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Mr. Morgan, USAID/Islamabad, explained that data being collected from the joint USAID/Geological Survey of Pakistan Coal Resource Assessment will be computerized for analysis. He noted that these data will not be detailed enough for development of site specific mine plans.

The audience posed no additional questions on the proposed Lakhra Coal Mine and Power Generation Project.

C. Jamshoro Thermal Power Complex (Phase II) Project

1. Dr. Hussainy, Chairman, Department of Zoology, Sind University, observed that the winter wind directions would cause direct impacts on the students and academic community from the operation of oil-fired power plants at Jamshoro, and asked if these effects had been studied.

Engr. Siddiqui responded that this is being considered in the study and that the findings and results will be shared with representatives of the university.

2. Dr. Khan stated that due to the location of university campuses immediately to the south of the proposed power complex, the Jamshoro site is not suitable for the power plant. He expressed concerns about the plans for storing fuel oil at the site. He expressed concerns that the nearby hospitals would also be affected by the air emissions of sulfur from the power plant.

He noted that since oil can be transported easily, unlike coal, it would be much better to move the plant to an alternate site.

Engr. Siddiqui stated that WAPDA would protect the environment and health of the people. He noted that the siting decision will be based on analysis of a number of factors. He promised to provide copies of reports and to have additional meetings with representatives of the university.

Engr. Siddiqui reviewed with Dr. Khan the proposed site drawings (posted behind the stage) for oil storage facilities at Jamshoro. Dr. Khan noted the acceptability of the proposed oil storage site.

3. Dr. Nazim al Din, Chairman, Department of Sociology, University of Sind, observed that the job opportunities were the most important aspects of the project. He said that from his viewpoint there were no objections to the project.

Engr. Siddiqui reiterated the policy position of WAPDA to maximize local employment at their facilities.

4. Mrs. Fouzia Jaffari, In-Charge, Mass Communications, Sind University, observed that the educated people had a great deal of questions about this project and inquired if WAPDA had any specific plans to answer the questions of the "common people" and to communicate the importance of this project to them.

Engr. Siddiqui requested that those in the audience, and particularly the mass communications faculty at Sind University, assist WAPDA in explaining the project to the "common people." He noted that this will be a long-term process and WAPDA will have press releases, statements from the Government of Pakistan, and informational articles. He noted that copies of relevant reports will be made available to the representatives of the University as they are completed.

5. Dr. Khan thanked WAPDA, USAID, and the consultants for their presentations, and observed that it was refreshing to see that someone was actually thinking about the environment.

The audience posed no further questions concerning the proposed Jamshoro Thermal Power Complex (Phase II).

Also included as part of Attachment B are the following:

1. Text of opening remarks by Engr. Nazim Hussain Siddiqui, C.E. (Design), Thermal, Water, and Power Development Authority of Pakistan (WAPDA), Lahore, Pakistan, and

2. List of persons invited and in attendance at the scoping session.

"THE ENVIRONMENTAL SCOPING SESSION"
ON
LAKHRA PROJECT
ON 06-10-1986 AT HYDERABAD

***

" OPENING REMARKS"
BY

ENGR.NAZIM HUSAIN SIDDIQUI
CHIEF ENGINEER DESIGN(THERMAL)

RECEIVED 20 OCT 1986 R.S.E.

ESE Action To: Marzan
Date:
Taken:
Initials

Distinguished guests, ladies & gentlemen,

Assalam-o-Alaikum:

Today, the importance of electrical energy in a developing country like Pakistan, needs no emphasis. All of our industrial development, agricultural growth, economical uplift and social soundness is dependent upon the electric power. In fact the per capita consumption of electrical energy in any country is an index of standard of living and prosperity.

Most of us present here are well aware, that there is a remarkable gap between the growing demand of electrical energy and its supply. The undesired phenomenon of load shedding is well known in the country for the last two-three years. Load shedding besides causing inconvenience and discomfort to the people, also has ill effect, on productivity in the country almost in all sectors. The gap between power demand and supply, therefore, has to be eliminated with all the means at our disposal.

Elimination of load shedding by 1990 is also included in the five points programme of Prime Minister. In order to bridge the gap between the power demand and supply, a number of power generation schemes have been planned. All efforts are being made to comply with the directive of the Prime Minister for eliminating the menace of the load shedding by 1990. Emphasis have been laid on the maximum utilisation of hydel potential available in the country. The capability of hydel stations, however, does not remain uniform during the year, due to which thermal support has to be provided when the output of hydel stations goes down in the lean water months.


Contd.P-2

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On the hydroelectric development, a scheme for installing four units, No.11, 12, 13 & 14 of 432 MW each at Tarbela has been prepared & work on this project has already been started. Further extension of Tarbela by adding units 15, 16 & 17 is also envisaged. Addition of unit No.9 & 10 each of 100 MW at Mangla has also been planned.

WAPDA is working untiringly for expansion of thermal generation almost day and night. Recently a 210 MW steam unit No.4 and 300 MW gas Turbine projects have rendered a remarkable relief in load shedding. Yet we have to go a long way to achieve the objective of total eradication of load shedding. A 400 MW Gas Turbine Project at Kot Addu is nearing completion. A large Power complex of about 1,700 MW based on oil firing has also been planned at Jamshoro and for this purpose preliminary works are already in hand.

Gentlemen' WAPDA is also carrying out studies for thermal power generation programme based on coal firing. Presently the Lakhra Coal Fired Power Station Project at Lakhra and Imported Coal Fired Power Station Project near Karachi are under study. We have very little experience in firing coal for thermal power generation. In the entire country, there are only two tiny units in WAPDA system each of 7.5 MW capacity at Quetta firing indigenous coal from sore-range mines in Baluchistan. Lakhra coal is comparatively poor in quality having a calorfic value of 5740 BTU/lb, with high sulfur, high ash and high moisture contents. The tentative size of the Lakhra coal fired power plant being studied will be 500 MW in its first phase. Keeping in view our little experience in coal firing technology, poor quality of Lakhra lignite and large size plant, we are carefully steping forward in connection with the Lakhra Project.

As stated eaelier, following two thermal power station projects are to be constructed in this area in the near future:-

i) Jamshoro Oil Fired Thermal Power Station with a capacity of about 1,700 MW.

ii) 500 MW Lakhra lignite fired Power Station at Lakhra

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Installation of following units is planned at Jamshoro site:-

1X250 MW
3X210 MW
3X300 MW

This Power Station will operate on furnace oil which will pumped from Keamari through a pipe line to meet the entire requirements of fuel oil.

The above two power stations besides providing thermal support to the system will have a pronounced effect on the prosperity of the area. The two Power plants and mining will provide direct employment to about 7000 people. The indirect employment figures may be as high as 40000. The majority of directly employed personnel and almost all the indirectly employed persons will be from the local area. According to laid down policy, all new technicians and non skilled staff have to be recruited from local area. A large number of people will also be provided training facilities.

The proposed thermal power expansion in this area will enable us to cope up with our rapidly rising power requirements besides bringing prosperity to the area but the environmental pollution aspects have to be analyzed very carefully. WAPDA is aware of this problem and its control technology. Considering the world as one family, the donor agencies like,the World Bank, the USAID, the Asian Development Bank etc. are also concerned about the associated problem of environmental pollution and its control.



Contd. P-4

The environmental pollution, resulting from thermal generation, particularly due to burning of sulfur, if left un-controlled, may have ill effects on the vegetation and living beings in the area. The unchecked flow of flue gases and other industrial wastes will adversely affect the human life, crops, biological life, civil structures etc. in the vicinity of these thermal units.

Being conscious of the importance of clean environment for healthy vegitation and biological life, WAPDA with the assistance of United States Agency for International Development has given a very careful consideration to the problem of environmental pollution. We have engaged consultants of International repute for both Lakhra and Jamshoro Power Plants with the assistance of USAID. M/s. ESE of United States of America have carried out the environmental studies for determining the impact of Lakhra project of this surrounding area. M/s. BECHTEL of USA have been engaged for carrying out the similar study for Jamshoro Thermal Power Station. I will request the representatives of these two Companies to explain to the participants of this scoping session about the studies, they are carrying out and the guidelines being used for control of environmental pollution. Your assistance in this regard is requested. Please advise us with your proposals, if any, which you may wish to be taken care during the studies, being carried out by our Consultants. I assure you sir that both WAPDA & our Consultants will give most careful consideration to such proposals.

In the end, ladies & gentlemen, I will thankyou all for sparing your valuable time for this scoping session despite your extremely busy programmes.

# ENVIRONMENTAL SCOPING SESSION-LAKHRA & JAMSHORO PROJECTS

Held at Hotel Faiz (Hyd-5)

| DATE | NAME | ADDRESS | TELEPHONE RES. | TELEPHONE OFF. | REMARKS/signature |
|---|---|---|---|---|---|
| 6-10-86 | Nazim Husain Siddiqui | WAPDA House LAHORE | 882770 | 56207 | |
| " | Anis Abbas Zaidi WAPDA | 38-A G.O.R. HYDERABAD | 26824 | 41590 | |
| 6-10-86 | Stephen F. Lintner Environmental Coordinator | Bureau for Asia and Near East USAID Washington, DC 20523 USA | (202) 647-8226 | | S. Lintner |
| 6-10-86 | Farrukh Mahmood, Project Manager | USAID/ISD | 841677 | 824071 | |
| 6-10-86 | Syed Anwarul Hassan, Project Manager, Lakhra | USAID/ISL | | 824071 | |
| 6.10.86 | TARIQ ZAMIR | WAPDA 38/A G.O.R Hyderabad | 25481 | 84634 | |
| 6-10.86 | A.K. MAKHDOOM | WAPDA 38/A GOR Colony Hyd. | | 25481 | |
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| 6-10-86 | Abu Adil | GTPS WAPDA KOTRI | | 51062 | |
| 6.10.86 | Dr. Javed Eida | Director (CPP) WAPDA, Lahore | | 303702 | |
| 6-10-86 | LOREN M. CHRISTIAN | BECHTEL Los Angeles, USA | 213-807-2133 | | |
| 6.10.86 | Maqsood Butt | Senior Chemist, WAPDA, Lakhra Coal Mines Project Hyd | | | |
| — | S. Habibullah Husainy | Sr. Budget & Accts. officer, WAPDA | | | |
| " | MOINUL HAQ DCM | 329-W. House Lhr. | | 302623 | |
| 6-10-86 | Major Zahir N. Shah | Dy Director Security (Lakhra) Hyderabad | | | |



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# ENVIRONMENTAL SCOPING SESSION-LAKHRA & JAMSHORO PROJECTS

| DATE | NAME | ADDRESS | TELEPHONE RES. | TELEPHONE OFF. | REMARKS |
|---|---|---|---|---|---|
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| 6.10.86 | KH. ASIEULLAH | DIRECTOR (TECHNICAL) PMDC, Islamabad | | 855364 | |
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| 6.10.1986 | Major (Retd) Naseem Ahmed Khan | Dy Director (T/S) | CAEB Hyd | | |
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| 6/X/86 | A. H. Khan | Chief Engineer GSC Hyderabad | | | |
| | Dr. K. M. Khan | Dean Faculty of Nat. Sciences S.U. | | | |
| 6-10-1986 | Abdul Khaliqua Bhatti | P.R.O Wapda | | | |
| 6-10-1986 | Mohammad Akram | Sr. XEN (Mech) | OFJ Jamshoro | | |
| 6-10-1986 | Abdul Rashid Qureshi | XEN-II | OFJ Jamshoro | | |
| 6-10-1986 | Dr. Faizullah Abbasi | Chairman Mining MUET. | | | |
| 6-10-1986 | Prof. Dr. M. L. Sabaq | Director, Industrial Liaison Jamshoro | | | |



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# ENVIRONMENTAL SCOPING SESSION - LAKHRA & JAMSHORO PROJECTS

| DATE | NAME | ADDRESS | TELEPHONE RES. | TELEPHONE OFF. | REMARKS |
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| 6-10-86 | Catherine DaMisson, Social Scientist | Bechtel, San Francisco | | | |
| 6-10-86 | Kennard Kosky | ESE, Gainesville Florida | | | |
| " | David A. Cobb, Biologist | Bechtel, San Francisco, USA | | | |
| 6-10-86 | M. GLENN RUTANEN-WHALEY | USAID / ISLAMABAD | | | |
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| 6.10.86 | Don Scott | British Council, Karachi | | | |
| 6-10-86 | John Morgan | USAID Islamabad | | | |
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| 6.10.86 | Anbar Rasool Ahmed | Sr. Engineer I.R.S | | | |
| 6.10.86 | TARIQ JAWAID MEMON. | Jr. Engineer LCMP | | | |
| 6-10-86 | MUKHTAR AHMED CHANDIO | Jr. Engineer CIVIL | | | |
| 6-10-86 | ~~MR A K MAKHDOOM~~ | ~~Sr. Engineer Civil~~ | | | |
| 6-10-86 | ZAKA FAROOQ SHEIKH | Dy. Secretary Environment & Urban affairs Division M/o Housing and works Islamabad. | | | Please supply me the relevant Papers. |



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# ENVIRONMENTAL SCOPING SESSION-LAKHRA & JAMSHORO PROJECTS

| DATE | NAME | ADDRESS | TELEPHONE RES. | TELEPHONE OFF. | REMARKS |
|---|---|---|---|---|---|
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| 6-10-86 | Ijaz Ahmed Ijaz Gulzar. Wapda. | 38/A, G.O.R colony Hyd:- | | | |
| 6. 10. 86 | Engr. Nizamat Ali L.C.M.P. WAPDA | 38/A G.O.R colony Hyd. | | | |
| 6. 10-86 | Muhammad Shafique | jr. Eng. (Environment Scientist) 38-A G.O.R colony Hyderabad. | | | |
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Few names are missing



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# Water And Power Development Authority

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6- Mr. Irshad,
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20- Mr. Bashir Ahmed Ansari, Chief Inspector Mines, Block 87/Room No.1&2, Pakistan Secretariat, Shahrae Liaquat, Saddar, KARACHI. 021/513479

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25- Mr. Ashiq Hussain Memon, Dy.Commissioner, Dadu District, D.C House, Dadu.

26- Syed Shahbuddin Shah, Member National Assembly of Pakistan, Taluka Hala, HYDERABAD.

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27- Mr. Pir [illegible] Ali Shah,
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DADU.

28- Mr. Wasi Nasir Naqvi,
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29- Malik Asad Sikandar,
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34- Syed Amir Haider Shah,
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35- Syed Amjad Ali Shah Jamot,
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37- Director (HRT), Near Airport,
Shahrae Faisal, KARACHI.

38- Mr. G.M. Taharani,
President Mines Owners Association.

39- Mr. Khan Muhammad Panhwar,
Research Officer & Advisor to
Sind University, JAMSHORO.

40- Mr. Ghulam Sarwar Shah,
Principal, Mehran University Engg.
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| | | |
|---|---|---|
| 1. | Khawaja Daood | General Manager(Thermal). |
| 2. | Mr. Nazim Siddiqui | Chief Engineer ( Design ). |
| 3. | Mr. G.M Ilias | Chief Engineer ( CPP ). |
| 4. | Mr. Yusuf Eida | Director ( Power Plant ) |
| 5. | Mr. Moin-ul-Haq | Director ( Mining ). |

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| | | |
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| 6. | Mr. Anis Abbas Zaidi | Chief Engineer Jamshoro. |
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| 8. | Mr. M. Qasim Shaikh | Project Engineer ( LPS ). |
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| 10. | Mr. A.K Makhdoom | Sr. Engineer ( Civil ) LPS. |
| 11. | Mr. Moosa Shah Hussainy | Sr. Engineer ( Env: ) LPS. |
| 12. | Mr. Mohammad Memon | Sr. Geologist LCMP. |
| 13. | Mr. A.A Chandio | Sr. Engineer ( OFJ ). |
| 14. | Mr. Zafarulla Khan | Sr. Engineer ( Civil ), OFJ. |
| 15. | Mr. Maqsood Butt | Sr. Chemist (LCMP). |
| 16. | Mr. Ghulam Rasool Akhund | Jr. Engineer ( Env:) LPS. |
| 17. | Mr. Muhammad Shafique. | Environment Scientist LPS. |
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| 19. | Mr. Ghulam Farid | Chairman Area Electricity Board, Hyd. |
| 20. | Mr. Mehmood Wahid | Chief Engineer G.S.O. |
| 21. | Mr.Abdul Hafiz Khan | Chief Engineer G.S.C |
| 22. | Mr. Rafi Farooqui | Chief Engineer 500 Kv. |
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# ENVIRONMENTAL AND SOCIAL SOUNDNESS ASSESSMENT
# LAKHRA COAL MINE AND POWER GENERATION PROJECT

PAKISTAN WATER AND POWER
DEVELOPMENT AUTHORITY
LAHORE, PAKISTAN

VOLUME III--APPENDICES

Sponsored by:

OFFICE OF ENERGY AND ENVIRONMENT
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
MISSION TO PAKISTAN
Islamabad, Pakistan

Prepared by:

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
Gainesville, Florida
and
KBN ENGINEERING AND APPLIED SCIENCES, INC.
Gainesville, Florida

86-165-1500-0120

March 1987

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# LAKHRA COAL MINE AND POWER GENERATION PROJECT

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86-165-1500-0120

March 1987

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# APPENDIX A--USAID REGULATIONS

**INTERNATIONAL DEVELOPMENT COOPERATION AGENCY**
**Agency for International Development**

**22 CFR Part 216**

**Environmental Procedures**

**§ 216.1 Introduction.**

(a) *Purpose.* In accordance with Sections 118(b) and 621 of the Foreign Assistance Act of 1961, as amended, (the FAA) the following general procedures shall be used by A.I.D. to ensure that environmental factors and values are integrated into the A.I.D. decision making process. These procedures also assign responsibility within the Agency for assessing the environmental effects of A.I.D.'s actions. These procedures are consistent with Executive Order 12114, issued January 4, 1979, entitled Environmental Effects Abroad of Major Federal Actions, and the purposes of the National Environmental Policy Act of 1970, as amended (42 U.S.C. 4371 et seq.) (NEPA). They are intended to implement the requirements of NEPA as they affect the A.I.D. program.

(b) *Environmental Policy.* In the conduct of its mandate to help upgrade the quality of life of the poor in developing countries, A.I.D. conducts a broad range of activities. These activities address such basic problems as hunger, malnutrition, overpopulation, disease, disaster, deterioration of the environment and the natural resource base, illiteracy as well as the lack of adequate housing and transportation. Pursuant to the FAA, A.I.D. provides development assistance in the form of technical advisory services, research, training, construction and commodity support. In addition, A.I.D. conducts programs under the Agricultural Trade Development and Assistance Act of 1954 (Pub. L. 480) that are designed to combat hunger, malnutrition and to facilitate economic development. Assistance programs are carried out under the foreign policy guidance of the Secretary of State and in cooperation with the governments of sovereign states. Within this framework, it is A.I.D. policy to:

(1) Ensure that the environmental consequences of A.I.D.-financed activities are identified and considered by A.I.D. and the host country prior to a final decision to proceed and that appropriate environmental safeguards are adopted;

(2) Assist developing countries to strengthen their capabilities to appreciate and effectively evaluate the potential environmental effects of proposed development strategies and projects, and to select, implement and manage effective environmental programs;

(3) Identify impacts resulting from A.I.D.'s actions upon the environment, including those aspects of the biosphere which are the common and cultural heritage of all mankind; and

(4) Define environmental limiting factors that constrain development and identify and carry out activities that assist in restoring the renewable resource base on which sustained development depends.

(c) *Definitions.*—(1) *CEQ Regulations.* Regulations promulgated by the President's Council on Environmental Quality (CEQ) (Federal Register, Volume 43, Number 230, November 29, 1978) under the authority of NEPA and Executive Order 11514, entitled Protection and Enhancement of Environmental Quality (March 5, 1970) as amended by Executive Order 11991 (May 24, 1977).

(2) *Initial Environmental Examination.* An Initial Environmental Examination is the first review of the reasonably foreseeable effects of a proposed action on the environment. Its function is to provide a brief statement of the factual basis for a Threshold Decision as to whether an Environmental Assessment or an Environmental Impact Statement will be required.

(3) *Threshold Decision.* A formal Agency decision which determines, based on an Initial Environmental Examination, whether a proposed Agency action is a major action significantly affecting the environment.

(4) *Environmental Assessment.* A detailed study of the reasonably forseeable significant effects, both beneficial and adverse, of a proposed action on the environment of a foreign country or countries.

(5) *Environmental Impact Statement.* A detailed study of the reasonably foreseeable environmental impacts, both positive and negative, of a proposed



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A.I.D. action and its reasonable alternatives on the United States, the global environment or areas outside the jurisdiction of any nation as described in § 216.7 of these procedures. It is a specific document having a definite format and content, as provided in NEPA and the CEQ Regulations. The required form and content of an Environmental Impact Statement is further described in § 216.7 infra.

(6) *Project Identification Document (PID).* An internal A.I.D. document which initially identifies and describes a proposed project.

(7) *Program Assistance Initial Proposal (PAIP).* An internal A.I.D. document used to initiate and identify proposed non-project assistance, including commodity import programs. It is analogous to the PID.

(8) *Project Paper (PP).* An internal A.I.D. document which provides a definitive description and appraisal of the project and particularly the plan or implementation.

(9) *Program Assistance Approval Document (PAAD).* An internal A.I.D. document approving non-project assistance. It is analogous to the PP.

(10) *Environment.* The term environment, as used in these procedures with respect to effects occurring outside the United States, means the natural and physical environment. With respect to effects occurring within the United States see § 216.7(b).

(11) *Significant Effect.* With respect to effects on the environment outside the United States, a proposed action has a significant effect on the environment if it does significant harm to the environment.

(12) *Minor Donor.* For purposes of these procedures, A.I.D. is a minor donor to a multidonor project when A.I.D. does not control the planning or design of the multidonor project and either (i) A.I.D.'s total contribution to the project is both less than $1,000,000 and less than 25 percent of the estimated project cost, or (ii) A.I.D.'s total contribution is more than $1,000,000 but less than 25 percent of the estimated project cost and the environmental procedures of the donor in control of the planning of design of the project are followed, but only if the A.I.D. Environmental Coordinator determines that such procedures are adequate.

**§ 216.2 Applicability of procedures.**

(a) *Scope.* Except as provided in § 216.2(b), these procedures apply to all new projects, programs or activities authorized or approved by A.I.D. and to substantive amendments or extensions of ongoing projects, programs, or activities.

(b) *Exemptions.* (1) Projects, programs or activities involving the following are exempt from these procedures:

(i) International disaster assistance;

(ii) Other emergency circumstances; and

(iii) Circumstances involving exceptional foreign policy sensitivities.

(2) A formal written determination, including a statement of the justification therefore, is required for each project, program or activity for which an exemption is made under paragraphs (b)(1) (ii) and (iii) of this section, but is not required for projects, programs or activities under paragraph (b)(1)(i) of this section. The determination shall be made either by the Assistant Administrator having responsibility for the program, project or activity, or by the Administrator, where authority to approve financing has been reserved by the Administrator. The determination shall be made after consultation with CEQ regarding the environmental consequences of the proposed program, project or activity.

(c) *Categorical Exclusions.* (1) The following criteria have been applied in determining the classes of actions included in § 216.2(c)(2) for which an Initial Environmental Examination, Environmental Assessment and Environmental Impact Statement generally are not required:

(i) The action does not have an effect on the natural or physicial environment;

(ii) A.I.D. does not have knowledge of or control over, and the objective of A.I.D. in furnishing assistance does not require, either prior to approval of financing or prior to implementation of specific activities, knowledge of or control over, the details of the specific activities that have an effect on the physicial and natural environment for which financing is provided by A.I.D.;

(iii) Research activities which may have an affect on the physicial and natural environment but will not have a significant effect as a result of limited scope, carefully controlled nature and effective monitoring.

(2) The following classes of actions are not subject to the procedures set forth in § 216.3, except to the extent provided herein:

(i) Education, technical assistance, or training programs except to the extent such programs include activities directly affecting the environment (such as construction of facilities, etc.);

(ii) Controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored;

(iii) Analyses, studies, academic or research workshops and meetings;

(iv) Projects in which A.I.D. is a minor donor to a multidonor project and there is no potential significant effects upon the environment of the United States, areas outside any nation's jurisdiction or endangered or threatened species or their critical habitat;

(v) Document and information transfers;

(vi) Contributions to international, regional or national organizations by the United States which are not for the purpose of carrying out a specifically identifiable project or projects;

(vii) Institution building grants to research and educational institutions in the United States such as those provided for under Section 122(d) and Title XII of Chapter 2 of Part I of the FAA (22 USCA §§ 2151 p. (b) 2220a. (1979));

(viii) Programs involving nutrition, health care or population and family planning services except to the extent designed to include activities directly affecting the environment (such as construction of facilities, water supply systems, waste water treatment, etc.)

(ix) Assistance provided under a Commodity Import Program when, prior to approval, A.I.D. does not have knowledge of the specific commodities to be financed and when the objective in furnishing such assistance requires neither knowledge, at the time the assistance is authorized, nor control, during implementation, of the commodities or their use in the host country.

(x) Support for intermediate credit institutions when the objective is to assist in the capitalization of the institution or part thereof and when such support does not involve reservation of the right to review and approve individual loans made by the institution;

(xi) Programs of maternal or child feeding conducted under Title II of Pub. L. 480;

(xii) Food for development programs conducted by food recipient countries under Title III of Pub. L. 480, when achieving A.I.D.'s objectives in such programs does not require knowledge of or control over the details of the specific activities conducted by the foreign country under such program;

(xiii) Matching, general support and institutional support grants provided to private voluntary organizations (PVOs) to assist in financing programs where A.I.D.'s objective in providing such financing does not require knowledge of or control over the details of the specific activities conducted by the PVO;

(xiv) Studies, projects or programs intended to develop the capability of recipient countries to engage in development planning, except to the extent designed to result in activities directly affecting the environment (such as construction of facilities, etc.); and

(xv) Activities which involve the application of design criteria or standards developed and approved by A.I.D.

(3) The originator of a project, program or activity shall determine the extent to which it is within the classes of actions described in paragraph (c)(2) of this section. This determination shall be made in writing and be submitted with the PID, PAIP or comparable document. This determination, which must include a brief statement supporting application of the exclusion shall be reviewed by the Bureau Environmental Officer in the same manner as a Threshold Decision under § 216.3(a)(2) of these procedures. Notwithstanding paragraph (c)(2) of this section, the procedures set forth in § 216.3 shall apply to any project, program or activity included in the classes of actions listed in paragraph (c)(2) of this section, or any aspect or component thereof, if at any time in the design, review or approval of the activity it is determined that the project, program or activity, or aspect or component thereof, is subject to the control of A.I.D. and may have a significant effect on the environment.

(d) *Classes of Actions Normally Having a Significant Effect on the Environment.* (1) The following classes of actions have been determined generally to have a significant effect on the environment and an Environmental Assessment or Environmental Impact Statement, as appropriate, will be required:

(i) Programs of river basin development;

(ii) Irrigation or water management projects, including dams and impoundments;

(iii) Agricultural land leveling;

(iv) Drainage projects;

(v) Large-scale agricultural mechanization;

(vi) New lands development;

(vii) Resettlement projects;

(viii) Penetration road building or road improvement projects;

(ix) Powerplants;

(x) Industrial plants;

(xi) Potable water and sewerage projects other than those that are small-scale.

(2) An Initial Environmental Examination normally will not be necessary for activities within the classes described in § 216.2(d), except when the originator of the project believes that the project will not have a significant effect on the environment. In such cases, the activity may be subjected to the procedures set forth in § 216.3.

(e) *Pesticides.* The exemptions of § 216.2(b)(1) and the categorical exclusions of § 216.2(c)(2) are not applicable to assistance for the procurement or use of pesticides.

**§ 216.3 Procedures.**

(a) *General Procedures.*—(1) *Preparation of the Initial Environmental Examination.* Except as otherwise provided, an Initial Environmental Examination is not required for activities identified in § 216.2(b)(1), (c)(2), and (d). For all other A.I.D. activities described in § 216.2(a) an Initial Environmental Examination will be prepared by the originator of an action. Except as indicated in this section, it should be prepared with the PID or PAIP. For projects including the procurement or use of pesticides, the procedures set forth in § 216.3(b) will be followed, in addition to the procedures in this paragraph. Activities which cannot be identified in sufficient detail to permit the completion of an Initial Environmental Examination with the PID or PAIP, shall be described by including with the PID or PAIP: (i) an explanation indicating why the Initial Environmental Examination cannot be completed; (ii) an estimate of the amount of time required to complete the Initial Environmental Examination; and (iii) a recommendation that a Threshold Decision be deferred until the Initial Environmental Examination is completed. The responsible Assistant Administrator will act on the request for deferral concurrently with action on the PID or PAIP and will designate a time for completion of the Initial Environmental Examination. In all instances, except as provided in § 216.3(a)(7), this completion date will be in sufficient time to allow for the completion of an Environmental Assessment or Environmental Impact Statement, if required, before a final decision is made to provide A.I.D. funding for the action.

(2) *Threshold decision.* (i) The Initial Environmental Examination will include a Threshold Decision made by the officer in the originating office who signs the PID or PAIP. If the Initial Environmental Examination is completed prior to or at the same time as the PID or PAIP, the Threshold Decision will be reviewed by the Bureau Environmental Officer concurrently with approval of the PID or PAIP. The Bureau Environmental Officer will either concur in the Threshold Decision or request reconsideration by the officer who made the Threshold Decision, stating the reasons for the request. Differences of opinion between these officers shall be submitted for resolution to the Assistant Administrator at the same time that the PID is submitted for approval.

(ii) An Initial Environmental Examination, completed subsequent to approval of the PID or PAIP, will be forwarded immediately together with the Threshold Determination to the Bureau Environmental Officer for action as described above.

(iii) A Positive Threshold Decision shall result from a finding that the proposed action will have a significant effect on the environment. An Environmental Impact Statement shall be prepared if required pursuant to

§ 216.7. If an impact statement is not required, an Environmental Assessment will be prepared in accordance with § 216.6. The cognizant Bureau or Office will record a Negative Determination if the proposed action will not have a significant effect on the environment.

(3) *Negative Declaration.* The Assistant Administrator, or the Administrator in actions for which the approval of the Administrator is required for the authorization of financing, may make a Negative Declaration, in writing, that the Agency will not develop an Environmental Assessment or an Environmental Impact Statement regarding an action found to have a significant effect on the environment when (i) a substantial number of Environmental Assessments or Environmental Impact Statements relating to similar activities have been prepared in the past, if relevant to the proposed action, (ii) the Agency has previously prepared a programmatic Statement or Assessment covering the activity in question which has been considered in the development of such activity, or (iii) the Agency has developed design criteria for such an action which, if applied in the design of the action, will avoid a significant effect on the environment.

(4) *Scope of Environmental Assessment or Impact Statement*—(i) *Procedure and Content.* After a Positive Threshold Decision has been made, or a determination is made under the presticide procedures set forth in § 216.3(b) that an Environmental Assessment or Environmental Impact Statement is required, the originator of the action shall commence the process of identifying the significant issues relating to the proposed action and of determining the scope of the issues to be addressed in the Environmental Assessment or Environmental Impact Statement. The originator of an action within the classes of actions described in § 216.2(d) shall commence this scoping process as soon as practicable. Persons having expertise relevant to the environmental aspects of the proposed action shall also participate in this scoping process. (Participants may include but are not limited to representatives of host governments, public and private institutions, the A.I.D. Mission staff and contractors.) This process shall result in a written statement which shall include the following matters:

(*a*) A determination of the scope and significance of issues to be analyzed in the Environmental Assessment or Impact Statement, including direct and indirect effects of the project on the environment.

(*b*) Identification and elimination from detailed study of the issues that are not significant or have been covered by earlier environmental review, or approved design considerations, narrowing the discussion of these issues to a brief presentation of why they will not have a significant effect on the environment.

(*c*) A description of (*1*) the timing of the preparation of environmental analyses, including phasing if appropriate, (*2*) variations required in the format of the Environmental Assessment, and (*3*) the tentative planning and decision making schedule; and

(*d*) A description of how the analysis will be conducted and the disciplines that will participate in the analysis.

(ii) These written statements shall be reviewed and approved by the Bureau Environmental Officer.

(iii) *Circulation of Scoping Statement.* To assist in the preparation of an Environmental Assessment, the Bureau Environmental Office may circulate copies of the written statement, together with a request for written comments, within thirty days, to selected federal agencies if that Officer believes comments by such federal agencies will be useful in the preparation of an Environmental Assessment. Comments received from reviewing federal agencies will be considered in the preparation of the Environmental Assessment and in the formulation of the design and implementation of the project, and will, together with the scoping statement, will be included in the project file.

(iv) *Change in Threshold Decision.* If it becomes evident that the action will not have a significant effect on the environment (i.e., will not cause significant harm to the environment), the Positive Threshold Decision may be withdrawn with the concurrence of the Bureau Environmental Officer. In the case of an action included in § 216.2(d)(2), the request for withdrawal shall be made to the Bureau Environmental Officer.

(5) *Preparation of Environmental Assessments and Environmental Impact Statement.* If the PID or PAIP is approved, and the Threshold Decision is positive, or the action is included in § 216.2(d), the originator of the action will be responsible for the preparation of an Environmental Assessment or Environmental Impact Statement as required. Draft Environmental Impact Statements will be circulated for review and comment as part of the review of Project Papers and as outlined further in § 216.7 of those procedures. Except as provided in § 216.3(a)(7), final approval of the PP or PAAD and the method of implementation will include consideration of the Environmental Assessment of final Environmental Impact Statement.

(6) *Processing and Review Within A.I.D.* (i) Initial Environmental Examinations, Environmental Assessments and final Environmental Impact Statements will be processed pursuant to standard A.I.D. procedures for project approval documents. Except as provided in § 216.3(a)(7), Environmental Assessments and final Environmental Impact Statements will be reviewed as an integral part of the Project Paper or equivalent document. In addition to these procedures, Environmental Assessments will be reviewed and cleared by the Bureau Environmental Officer. They may also be reviewed by the Agency's Environmental Coordinator who will monitor the Environmental Assessment process.

(ii) When project approval authority is delegated to field posts, Environmental Assessments shall be reviewed and cleared by the Bureau Environmental Officer prior to the approval of such actions.

(iii) Draft and final Environmental Impact Statements will be reviewed and cleared by the Environmental Coordinator and the Office of the General Counsel.

(7) *Environmental Review After Authorization of Financing.* (i) Environmental review may be performed after authorization of a project, program or activity only with respect to subprojects or significant aspects of the project, program or activity that are unidentified at the time of authorization. Environmental review shall be completed prior to authorization for all subprojects and aspects of a project, program or activity that are identified.

(ii) Environmental review should occur at the earliest time in design or implementation at which a meaningful review can be undertaken, but in no event later than when previously unidentified subprojects or aspects of projects, programs or activities are identified and planned. To the extent possible, adequate information to undertake deferred environmental review should be obtained before funds are obligated for unidentified subprojects or aspects of projects, programs or activities. (Funds may be obligated for the other aspects for which environmental review has been completed.) To avoid an irreversible commitment of resources prior to the conclusion of environmental review, the obligation of funds can be made incrementally as subprojects or aspects of projects, programs or activities are identified; or if necessary while planning continues, including environmental review, the agreement or other document obligating funds may contain appropriate convenants or conditions precedent to disbursement for unidentified subprojects or aspects of projects, programs or activities.

(iii) When environmetal review must be deferred beyond the time some of the funds are to be disbursed (e.g. long lead times for the delivery of goods or services), the project agreement or other document obligating funds shall contain a covenant or covenants requiring environmental review, including an Environmental Assessment or Environmental Impact Statement, when appropriate, to be completed and taken into account prior to implementation of those subprojects or aspects of the project, program or activity for which environmental review is deferred. Such convenants shall ensure that implementation plans will be modified in accordance with environmental review if the parties decide that modifications are necessary.

(iv) When environmental review will not be completed for an entire project, program or activity prior to authorization, the Initial Environmental Examination and Threshold Decision required under § 216.3(a)(1) and (2) shall identify those aspects of the project, program or activity for which



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environmental review will be completed prior to the time financing is authorized. It shall also include those subprojects or aspects for which environmental review will be deferred, stating the reasons for deferral and the time when environmental review will be completed. Further, it shall state how an irreversible commitment of funds will be avoided until environmental review is completed. The A.I.D. officer responsible for making environmental decisions for such projects, programs or activities shall also be identified (the same officer who has decision making authority for the other aspects of implementation). This deferral shall be reviewed and approved by the officer making the Threshold Decision and the officer who authorizes the project, program or activity. Such approval may be made only after consultation with the Office of General Counsel for the purpose of establishing the manner in which conditions precedent to disbursement or covenants in project and other agreements will avoid an irreversible commitment of resources before environmental review is completed.

(8) *Monitoring.* To the extent feasible and relevant, projects and programs for which Environmental Impact Statements or Environmental Assessments have been prepared should be designed to include measurement of any changes in environmental quality, positive or negative, during their implementation. This will require recording of baseline data at the start. To the extent that available data permit, originating offices of A.I.D. will formulate systems in collaboration with recipient nations, to monitor such impacts during the life of A.I.D.'s involvement. Monitoring implementation of projects, programs and activities shall take into account environmental impacts to the same extent as other aspects of such projects, programs and activities. If during implementation of any project, program or activity, whether or not an Environmental Assessment or Environmental Impact Statement was originally required, it appears to the Mission Director, or officer responsible for the project, program or activity, that it is having or will have a significant effect on the environment that was not previously studied in an Environmental Assessment or Environmental Impact Statement, the procedures contained in this part shall be followed including, as appropriate, a Threshold Decision, Scoping and an Environmental Assessment or Environmental Impact Statement.

(9) *Revisions.* If, after a Threshold Decision is made resulting in a Negative Determination, a project is revised or new information becomes available which indicates that a proposed action might be "major" and its effects "significant", the Negative Determination will be reviewed and revised by the cognizant Bureau and an Environmental Assessment or Environmental Impact Statement will be prepared, if appropriate. Environmental Assessments and Environmental Impact Statements will be amended and processed appropriately if there are major changes in the project or program, or if significant new information becomes available which relates to the impact of the project, program or activity on the environment that was not considered at the time the Environmental Assessment or Environmental Impact Statement was approved. When on-going programs are revised to incorporate a change in scope or nature, a determination will be made as to whether such change may have an environmental impact not previously assessed. If so, the procedures outlined in this part will be followed.

(10) *Other Approval Documents.* These procedures refer to certain A.I.D. documents such as PIDs, PAIPs, PPs and PAADs as the A.I.D. internal instruments for approval of projects, programs or activities. From time to time, certain special procedures, such as those in § 216.4, may not require the use of the aforementioned documents. In these situations, these environmental procedures shall apply to those special approval procedures, unless otherwise exempt, at approval times and levels comparable to projects, programs and activities in which the aforementioned documents are used.

(b) *Pesticide Procedures*—(1) *Project Assistance.* Except as provided in § 216.3(b)(2), all proposed projects involving assistance for the procurement or use, or both, of pesticides shall be subject to the procedures prescribed in



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§ 216.3(b)(1) (i) through (v) below. These procedures shall also apply, to the extent permitted by agreements entered into by A.I.D. before the effective date of these pesticide procedures, to such projects that have been authorized but for which pesticides have not been procured as of the effective date of these pesticide procedures.

(i) When a project includes assistance for procurement or use, or both, of pesticides registered for the same or similar uses by USEPA without restriction, the Initial Environmental Examination for the project shall include a separate section evaluating the economic, social and environmental risks and benefits of the planned pesticide use to determine whether the use may result in significant environmental impact. Factors to be considered in such an evaluation shall include, but not be limited to the following:

(a) The USEPA registration status of the requested pesticide;

(b) The basis for selection of the requested pesticide;

(c) The extent to which the proposed pesticide use is part of an integrated pest management program;

(d) The proposed method or methods of application, including availability of appropriate application and safety equipment;

(e) Any acute and long-term toxicological hazards, either human or environmental, associated with the proposed use and measures available to minimize such hazards;

(f) The effectiveness of the requested pesticide for the proposed use;

(g) Compatibility of the proposed pesticide with target and nontarget ecosystems;

(h) The conditions under which the pesticide is to be used, including climate, flora, fauna, geography, hydrology, and soils;

(i) The availability and effectiveness of other pesticides or nonchemical control methods;

(j) The requesting country's ability to regulate or control the distribution, storage, use and disposal of the requested pesticide;

(k) The provisions made for training of users and applicators; and

(l) The provisions made for monitoring the use and effectiveness of the pesticide.

In those cases where the evaluation of the proposed pesticide use in the Initial Environmental Examination indicates that the use will significantly effect the human environment, the Threshold Decision will include a recommendation for the preparation of an Environmental Assessment or Environmental Impact Statement, as appropriate. In the event a decision is made to approve the planned pesticide use, the Project Paper shall include to the extent practicable, provisions designed to mitigate potential adverse effects of the pesticide. When the pesticide evaluation section of the Initial Environmental Examination does not indicate a potentially unreasonable risk arising from the pesticide use, an Environmental Assessment or Environmental Impact Statement shall nevertheless be prepared if the environmental effects of the project otherwise require further assessment.

(ii) When a project includes assistance for the procurement or use, or both, of any pesticide registered for the same or similar uses in the United States but the proposed use is restricted by the USEPA on the basis of user hazard, the procedures set forth in § 216.3(b)(1)(i) above will be followed. In addition, the Initial Environmental Examination will include an evaluation of the user hazards associated with the proposed USEPA restricted uses to ensure that the implementation plan which is contained in the Project Paper incorporates provisions for making the recipient government aware of these risks and providing, if necessary, such technical assistance as may be required to mitigate these risks. If the proposed pesticide use is also restricted on a basis other than user hazard, the procedures in § 216.3(b)(1)(iii) shall be followed in lieu of the procedures in this section.

(iii) If the project includes assistance for the procurement or use, or both of:

(a) Any pesticide other than one registered for the same or similar uses by USEPA without restriction or for restricted use on the basis of user hazard; or

(b) Any pesticide for which a notice of rebuttable presumption against reregistration, notice of intent to cancel, or notice of intent to suspend has been issued by USEPA.

The Threshold Decision will provide for the preparation of an Environmental Assessment or Environmental Impact Statement, as appropriate (§ 216.6(a)). The EA or EIS shall include, but not be limited to, an analysis of the factors identified in § 216.3(b)(1)(i) above.

(iv) Notwithstanding the provisions of §§ 216.3(b)(1) (i) through (iii) above, if the project includes assistance for the procurement or use, or both, of a pesticide against which USEPA has initiated a regulatory action for cause, or for which it has issued a notice of rebuttable presumption against reregistration, the nature of the action or notice, including the relevant techni-

cal and scientific factors will be discussed with the requesting government and considered in the IEE and, if prepared, in the EA or EIS. If USEPA initiates any of the regulatory actions above against a pesticide subsequent to its evaluation in an IEE, EA or EIS, the nature of the action will be discussed with the recipient government and considered in an amended IEE or amended EA or EIS, as appropriate.

(v) If the project includes assistance for the procurement or use, or both of pesticides but the specific pesticides to be procured or used cannot be identified at the time the IEE is prepared, the procedures outlined in §§ 216.3(b)(i) through (iv) will be followed when the specific pesticides are identified and before procurement or use is authorized. Where identification of the pesticides to be procured or used does not occur until after Project Paper approval, neither the procurement nor the use of the pesticides shall be undertaken unless approved, in writing, by the Assistant Administrator (or in the case of projects authorized at the Mission level, the Mission Director) who approved the Project Paper.

(2) *Exceptions to Pesticide Procedures.* The procedures set forth in § 216.3(b)(1) above shall not apply to the following projects including assistance for the procurement or use, or both, of pesticides.

(i) Projects under emergency conditions.

Emergency conditions shall be deemed to exist when it is determined by the Administrator, A.I.D., in writing that:

(a) A pest outbreak has occurred or is imminent; and

(b) Significant health problems (either human or animal) or significant economic problems will occur without the prompt use of the proposed pesticide; and

(c) Insufficient time is available before the pesticide must be used to evaluate the proposed use in accordance with the provisions of this regulation.

(ii) Projects where A.I.D. is a minor donor, as defined in § 216.1(c)(12) above, to a multi-donor project.

(iii) Projects including assistance for procurement or use, or both, of pesticides for research or limited field evaluation purposes by or under the supervision of project personnel. In such instances, however, A.I.D. will ensure that the manufacturers of the pesticides provide toxicological and environmental data necessary to safeguard the health or research personnel and the quality of the local environment in which the pesticides will be used. Furthermore, treated crops will not be used for human or animal consumption unless appropriate tolerances have been established by EPA or recommended by FAO/WHO, and the rates and frequency of application, together with the prescribed preharvest intervals, do not result in residues exceeding such tolerances. This prohibition does not apply to the feeding of such crops to animals for research purposes.

(3) *Non-Project Assistance.* In a very few limited number of circumstances A.I.D. may provide non-project assistance for the procurement and use of pesticides. Assistance in such cases shall be provided if the A.I.D. Administrator determines in writing that (i) emergency conditions, as defined in § 216.3(b)(2)(i) above exists; or (ii) that compelling circumstances exist such that failure to provide the proposed assistance would seriously impede the attainment of U.S. foreign policy objectives or the objectives of the foreign assistance program. In the latter case, a decision to provide the assistance will be based to the maximum extent practicable, upon a consideration of the factors set forth in § 216.3(b)(1)(i) and, to the extent available, the history of efficacy and safety covering the past use of the pesticide the in recipient country

**§ 216.4 Private applicants.**

Programs, projects or activities for which financing from A.I.D. is sought by private applicants, such as PVOs and educational and research institutions, are subject to these procedures. Except as provided in §§ 216.2 (b), (c) or (d), preliminary proposals for financing submitted by private applicants shall be accompanied by an Initial Environmental Examination or adequate information to permit preparation of an Initial Environmental Examination. The Threshold Decision shall be made by the Mission Director for the country to which the proposal relates, if the preliminary proposal is submitted to the A.I.D. Mission, or shall be made by the officer in A.I.D. who approves the preliminary proposal. In either case, the concurrence of the Bureau Environmental Officer is required in the same manner as in § 216.3(a)(2), except for PVO projects approved in A.I.D. Missions with total life of project costs

less than $500,000. Thereafter, the same procedures set forth in § 216.3 including as appropriate scoping and Environmental Assessments or Environmental Impact Statements, shall be applicable to programs, projects or activities submitted by private applicants. The final proposal submitted for financing shall be treated, for purposes of these procedures, as a Project Paper. The Bureau Environmental Officer shall advise private applicants of studies or other information foreseeably required for action by A.I.D.

§ 216.5 Endangered species.

It is A.I.D. policy to conduct its assistance programs in a manner that is sensitive to the protection of endangered or threatened species and their critical habitats. The Initial Environmental Examination for each project, program or activity having an effect on the environment shall specifically determine whether the project, program or activity will have an effect on an endangered or threatened species, or critical habitat. If the proposed project, program or activity will have the effect of jeopardizing an endangered or threatened species or of adversely modifying its critical habitat, the Threshold Decision shall be a Positive Determination and an Environmental Assessment or Environmental Impact Statement completed as appropriate, which shall discuss alternatives or modifications to avoid or mitigate such impact on the species or its habitat.

§ 216.6 Environmental assessments.

(a) *General Purpose.* The purpose of the Environmental Assessment is to provide Agency and host country decision makers with a full discussion of significant environmental effects of a proposed action. It includes alternatives which would avoid or minimize adverse effects or enhance the quality of the environment so that the expected benefits of development objectives can be weighed against any adverse impacts upon the human environment or any irreversible or irretrievable commitment of resources.

(b) *Collaboration with Affected Nation on Preparation.* Collaboration in obtaining data, conducting analyses and considering alternatives will help build an awareness of development associated environmental problems in less developed countries as well as assist in building an indigenous institutional capability to deal nationally with such problems. Missions, Bureaus and Offices will collaborate with affected countries to the maximum extent possible, in the development of any Environmental Assessments and consideration of environmental consequences as set forth therein.

(c) *Content and Form.* The Environmental Assessment shall be based upon the scoping statement and shall address the following elements, as appropriate:

(1) *Summary.* The summary shall stress the major conclusions, areas of controversy, if any, and the issues to be resolved.

(2) *Purpose.* The Environmental Assessment shall briefly specify the underlying purpose and need to which the Agency is responding in proposing the alternatives including the proposed action.

(3) *Alternatives Including the Proposed Action.* This section should present the environmental impacts of the proposal and its alternatives in comparative form, thereby sharpening the issues and providing a clear basis for choice among options by the decision maker. This section should explore and evaluate reasonable alternatives and briefly discuss the reasons for eliminating those alternatives which were not included in the detailed study; devote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits; include the alternative of no action; identify the Agency's preferred alternative or alternatives, if one or more exists; include appropriate mitigation measures not already included in the proposed action or alternatives.

(4) *Affected Environment.* The Environmental Assessment shall succinctly describe the environment of the area(s) to be affected or created by the alternatives under consideration. The descriptions shall be no longer than is necessary to understand the effects of the alternatives. Data and analyses in the Environmental Assessment shall be commensurate with the significance of the impact with less important material

summarized, consolidated or simply referenced.

(5) *Environmental Consequences.* This section forms the analytic basis for the comparisons under paragraph (c)(3) of this section. It will include the environmental impacts of the alternatives including the proposed action; any adverse effects that cannot be avoided should the proposed action be implemented; the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity; and any irreversible or irretrievable commitments of resources which would be involved in the proposal should it be implemented. It should not duplicate discussions in paragraph (c)(3) of this section. This section of the Environmental Assessment should include discussions of direct effects and their significance; indirect effects and their significance; possible conflicts between the proposed action and land use plans, policies and controls for the areas concerned; energy requirements and conservation potential of various alternatives and mitigation measures; natural or depletable resource requirements and conservation potential of various requirements and mitigation measures; urban quality; historic and cultural resources and the design of the built environment, including the reuse and conservation potential of various alternatives and mitigation measures; and means to mitigate adverse environmental impacts.

(6) *List of Preparers.* The Environmental Assessment shall list the names and qualifications (expertise, experience, professional discipline) of the persons primarily responsible for preparing the Environmental Assessment or significant background papers.

(7) *Appendix.* An Appendix may be prepared.

(d) *Program Assessment.* Program Assessments may be appropriate in order to assess the environmental effects of a number of individual actions and their cumulative environmental impact in a given country or geographic area, or the environmental impacts that are generic or common to a class of agency actions, or other activities which are not country-specific. In these cases, a single, programmatic assessment will be prepared in A.I.D./Washington and circulated to appropriate overseas Missions, host governments, and to interested parties within the United States. To the extent practicable, the form and content of the programmatic Environmental Assessment will be the same as for project Assessments. Subsequent Environmental Assessments on major individual actions will only be necessary where such follow-on or subsequent activities may have significant environmental impacts on specific countries where such impacts have not been adequately evaluated in the programmatic Environmental Assessment. Other programmatic evaluations of classes of actions may be conducted in an effort to establish additional categorical exclusions or design standards or criteria for such classes that will eliminate or minimize adverse effects of such actions, enhance the environmental effect of such action or reduce the amount of paperwork or time involved in these procedures. Programmatic evaluations conducted for the purpose of establishing additional categorical exclusions under § 216.2(c) or design considerations that will eliminate significant effects for classes of actions shall be made available for public comment before the categorical exclusions or design standards or criteria are adopted by A.I.D. Notice of the availability of such document shall be published in the **Federal Register.** Additional categorical exclusions shall be adopted by A.I.D. upon the approval of the Administrator, and design consideration in accordance with usual agency procedures.

(e) *Consultation and Review.* (1) When Environmental Assessments are prepared on activities carried out within or focused on specific developing countries, consultation will be held between A.I.D. staff and the host government both in the early stages of preparation and on the results and significance of the completed Assessment before the project is authorized.

(2) Missions will encourage the host government to make the Environmental Assessment available to the general public of the recipient country. If Environmental Assessments are prepared on activities which are not country-specific, the Assessment will be circulated by the Environmental Coordinator to A.I.D.'s Overseas Missions and interested governments for information, guidance and comment and will be made available in the U.S. to

interested parties.

(f) *Effect in Other Countries.* In a situation where an analysis indicates that potential effects may extend beyond the national boundaries of a recipient country and adjacent foreign nations may be affected, A.I.D. will urge the recipient country to consult with such countries in advance of project approval and to negotiate mutually acceptable accommodations.

(g) *Classified Material.* Environmental Assessments will not normally include classified or administratively controlled material. However, there may be situations where environmental aspects cannot be adequately discussed without the inclusion of such material. The handling and disclosure of classified or administratively controlled material shall be governed by 22 CFR Part 9. Those portions of an Environmental Assessment which are not classified or administratively controlled will be made available to persons outside the Agency as provided for in 22 CFR Part 212.

**§ 216.7 Environmental impact statements.**

(a) *Applicability.* An Environmental Impact Statement shall be prepared when agency actions significantly affect:

(1) The global environment or areas outside the jurisdiction of any nation (e.g., the oceans);

(2) The environment of the United States; or

(3) Other aspects of the environment at the discretion of the Administrator.

(b) *Effects on the United States: Content and Form.* An Environmental Impact Statement relating to paragraph (a)(2) of this section shall comply with the CEQ Regulations. With respect to effects on the United States, the terms environment and significant effect wherever used in these procedures have the same meaning as in the CEQ Regulations rather than as defined in § 216.1(c) (12) and (13) of these procedures.

(c) *Other Effects: Content and Form.* An Environmental Impact Statement relating to paragraphs (a)(1) and (a)(3) of this section will generally follow the CEQ Regulations, but will take into account the special considerations and concerns of A.I.D. Circulation of such Environmental Impact Statements in draft form will precede approval of a Project Paper or equivalent and comments from such circulation will be considered before final project authorization as outlined in § 216.3 of these procedures. The draft Environmental Impact Statement will also be circulated by the Missions to affected foreign governments for information and comment. Draft Environmental Impact Statements generally will be made available for comment to Federal agencies with jurisdiction by law or special expertise with respect to any environmental impact involved, and to public and private organizations and individuals for not less than forty-five (45) days. Notice of availability of the draft Environmental Impact Statements will be published in the Federal Register. Cognizant Bureaus and Offices will submit these drafts for circulation through the Environmental Coordinator who will have the responsibility for coordinating all such communications with persons outside A.I.D. Any comments received by the Environmental Coordinator will be forwarded to the originating Bureau or Office for consideration in final policy decisions and the preparation of a final Environmental Impact Statement. All such comments will be attached to the final Statement, and those relevant comments not adequately discussed in the draft Environmental Impact Statement will be appropriately dealt with in the final Environmental Impact Statement. Copies of the final Environmental Impact Statement, with comments attached, will be sent by the Environmental Coordinator to CEQ and to all other Federal, state, and local agencies and private organizations that made substantive comments on the draft, including affected foreign governments. Where emergency circumstances or considerations of foreign policy make it necessary to take an action without observing the provisions of § 1506.10 of the CEQ Regulations, or when there are overriding considerations of expense to the United States or foreign governments, the originating Office will advise the Environmental Coordinator who will consult with Department of State and CEQ concerning appropriate modification of review procedures.

**§ 216.8 Public hearings.**

(a) In most instances AID will be able to gain the benefit of public par-

ticipation in the impact statement process through circulation of draft statements and notice of public availability in CEQ publications. However, in some cases the Administrator may wish to hold public hearings on draft Environmental Impact Statements. In deciding whether or not a public hearing is appropriate, Bureaus in conjunction with the Environmental Coordinator should consider:

(1) The magnitude of the proposal in terms of economic costs, the geographic area involved, and the uniqueness or size of commitment of the resources involved;

(2) The degree of interest in the proposal as evidenced by requests from the public and from Federal, state and local authorities, and private organizations and individuals, that a hearing be held;

(3) The complexity of the issue and likelihood that information will be presented at the hearing which will be of assistance to the Agency; and

(4) The extent to which public involvement already has been achieved through other means, such as earlier public hearings, meetings with citizen representatives, and/or written comments on the proposed action.

(b) If public hearings are held, draft Environmental Impact Statements to be discussed should be made available to the public at least fifteen (15) days prior to the time of the public hearings, and a notice will be placed in the FEDERAL REGISTER giving the subject, time and place of the proposed hearings.

**§ 216.9 Bilateral and multilateral studies and concise reviews of environmental issues.**

Notwithstanding anything to the contrary in these procedures, the Administrator may approve the use of either of the following documents as a substitute for an Environmental Assessment (but not a substitute for an Environmental Impact Statement) required under these procedures:

(a) Bilateral or multilateral environmental studies, relevant or related to the proposed action, prepared by the United States and one or more foreign countries or by an international body or organization in which the United States is a member or participant; or

(b) Concise reviews of the environmental issues involved including summary environmental analyses or other appropriate documents.

**§ 216.10 Records and reports.**

Each Agency Bureau will maintain a current list of activities for which Environmental Assessments and Environmental Impact Statements are being prepared and for which Negative Determinations and Declarations have been made. Copies of final Initial Environmental Examinations, scoping statements, Assessments and Impact Statements will be available to interested Federal agencies upon request. The cognizant Bureau will maintain a permanent file (which may be part of its normal project files) of Environmental Impact Statements, Environmental Assessments, final Initial Environmental Examinations, scoping statements, Determinations and Declarations which will be available to the public under the Freedom of Information Act. Interested persons can obtain information or status reports regarding Environmental Assessments and Environmental Impact Statements through the A.I.D. Environmental Coordinator.

(22 U.S.C. 2381; 42 U.S.C. 4332)

Dated October 9, 1980.

**Joseph C. Wheeler,**

*Acting Administrator.*



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# APPENDIX B

# ALTERNATIVE ANALYSIS METHODOLOGY

## B.1 APPROACH TO ALTERNATIVE ANALYSIS

### B.1.1 RATING ALTERNATIVE ANALYSIS METHODOLOGY

Alternatives (projects and sites) were evaluated using an analytical technique that rates each alternative against specific environmental criteria. To reflect the relative importance of each criterion, weights which were used as a multiplier for each criterion rating were developed. Individual weighted criterion ratings were then summed for all criteria to develop an overall rank.

Rating of each alternative with respect to the specific criteria was performed using the technique described by Mr. Asok K. Motayed (1980). The methodology differs considerably from most rating schemes, which usually involve assigning absolute numbers to each alternative to indicate its strength/weakness against subjectively weighted criteria. This technique attempts to reduce the subjectivity by simply comparing the alternatives, two at a time, with respect to the different criteria. Judgments such as poor, excellent, or how much better one area is than another are not made. The only necessary determination is which alternative is better or if the sites are equal when compared to a given criterion. Figure B-1 and Table B-1 present a detailed step-by-step description of the process.

Site coefficients were determined for each alternative to indicate the acceptability of the site with respect to each criterion. The coefficients were calculated by comparing the alternatives, two at a time, with respect to each criterion. For example, the site which is determined to be more suitable or superior with respect to the given criteria was assigned one point; the other site (i.e., the inferior site) was assigned zero. If the two sites were determined to be equal, each was assigned one-half point. This one-to-one site comparison was conducted for all combinations of the alternatives (e.g., A to B, A to C, A to D).

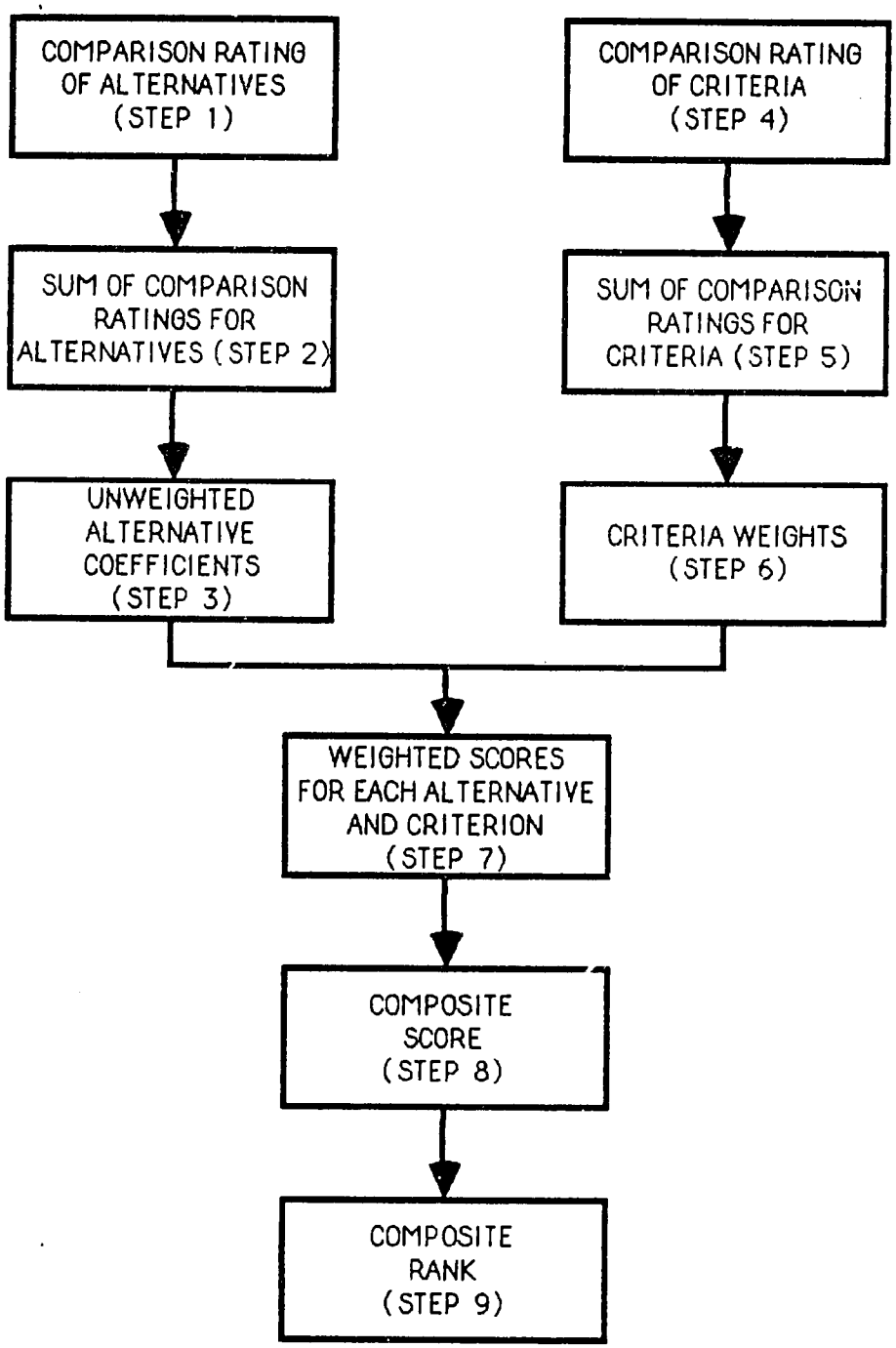


Figure B-1
ALTERNATIVE ANALYSIS PROCEDURE

SOURCE: ESE, 1986.

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**Lakhra Coal Mine and Power Generation Feasibility Study**

Table B-1. Alternative Analysis Procedures

| Step | Description |
|---|---|
| 1 | Perform one-to-one comparison of all alternatives for each criterion to determine ratings. |
| 2 | Sum comparison ratings for each alternative. |
| 3 | Obtain unweighted alternative coefficient for each criterion by dividing sum of comparison ratings for each alternative (Step 2) by the total sum over all alternatives for each criterion. |
| 4 | Perform one-to-one comparison rating of all criteria. |
| 5 | Sum comparison rating for each criterion. |
| 6 | Obtain criterion weight by dividing sum of comparison ratings for each criterion (Step 5) by total sum over all criteria. |
| 7 | For each alternative, multiply the unweighted alternative coefficient for each criterion (Step 3) by the corresponding criterion weight (Step 6) to obtain weighted scores for each alternative and criterion. |
| 8 | Sum weighted scores to obtain composite score. |
| 9 | Rank alternatives in order of increasing composite score. |

Sources: ESE, 1986.
KBN, 1986.

For each criterion, the results of the alternative comparisons (i.e., comparison ratings) were summed for each alternative. The alternative coefficients were then calculated by dividing the sums by the total number of comparisons. As a result, the alternative coefficients are scaled between zero and one (see Table B-2A).

Each criterion was compared in a similar manner to obtain the criteria weights within the engineering and environmental disciplines. So that no criterion receives a zero weight (i.e., has no influence on the ranking), a dummy variable was included which, by definition, was inferior to all other criteria (see Table B-2B).

The alternative coefficients and criteria weights were then compiled by multiplying the site coefficients for each criterion by the criterion's weight. The resultant weighted criterion scores were summed for each alternative to determine the composite scores (see Table B-2C) and an overall rank.

### B.1.2 ALTERNATIVE CRITERIA

Four environmental criteria were selected to evaluate the potential environmental differences between alternatives (projects and sites). These five criteria reflect the major environmental categories that can influence the potential suitability of alternatives. Criteria definitions are summarized in Table B-3. For the project analysis, the criteria used were much broader in scope since specific locations were not compared. Conversely, for the alternative site analysis, specific impacts were used to determine differences among sites. Criteria ratings for each environmental resource were based on decisions from experienced discipline personnel. Criteria weights were developed by concensus of the interdisciplinary team.

Table B-2. Illustrative Example of Rating and Ranking Procedure Used in Analysis of Alternatives

A. Criterion Rating for x (Steps 1 to 3)

| Alternative | Site Comparison Ratings of Alternatives | | | Sum | Unweighted Alternative Coefficient |
|---|---|---|---|---|---|
| A | 1 | 1 | | 2 | 2/3 = 0.67 |
| B | 0 | | 0.5 | 0.5 | 0.5/3 = 0.17 |
| C | | 0 | 0.5 | 0.5 | 0.5/3 = 0.17 |
| | | | | 3.0 | |

B. Weights for Criteria (Steps 4 to 6)

| Criterion | Criterion Comparison Ratings | | | | | | Sum | Criterion Coefficient |
|---|---|---|---|---|---|---|---|---|
| x | 1 | 0 | 1 | | | | 2.0 | 2/6 = 0.33 |
| y | 0 | | | 0 | 1 | | 1.0 | 1/6 = 0.17 |
| z | | 1 | | 1 | | 1 | 3.0 | 3/6 = 0.50 |
| Dummy | | | 0 | | 0 | 0 | 0.0 | 0/6 = 0.0 |
| | | | | | | | 6.0 | |



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Table B-2. Illustrative Example of Rating and Ranking Procedure Used in Analysis of Alternatives (Continued, Page 2 of 2)

C. Weighted Scores and Ranks (Steps 7 to 9)

| Alternative | Criterion x UWS | x W | x WS | y UWS | y W | y WS | z UWS | z W | z WS | Composite Score* | Composite Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0.67 | 0.33 | 0.22 | 0.33 | 0.17 | 0.06 | 0.0 | 0.5 | 0.17 | 28 | 2 |
| B | 0.17 | 0.33 | 0.06 | 0.33 | 0.17 | 0.06 | 1.0 | 0.5 | 0.50 | 62 | 1 |
| C | 0.17 | 0.33 | 0.06 | 0.33 | 0.17 | 0.06 | 0.0 | 0.5 | 0.0 | 12 | 3 |

UWS = Unweighted score.
W = Weight.
WS = Weighted score.

*Sum of WS multiplied by 100 to obtain percent.

Sources: ESE, 1986.
KBN, 1986.

Table B-3. Criteria for Alternative Environmental Analyses

| Environmental Resource | Site Analysis | Plant Analysis |
|---|---|---|
| Air | o Air Quality Impact to Population<br>o Air Quality Impact to Agriculture<br>o Air Quality Impact to Vegetation/Wildlife | o Magnitude/Level of Air Quality Impacts<br>o Regional Potential for Air Quality Degradation<br>o Relative Emission Levels |
| Land | o Habitat Loss<br>o Sedimentation/Erosion | o Magnitude of Land Change |
| Socioeconomic | o Change in social/cultural patterns<br>o Demands on Public Services Infrastructure<br>o Employment Benefits<br>o Archaeological and Historical Resources | o Regional Infrastructure Development Benefits<br>o Demands on Public Services Infrastructure<br>o Employment Benefits |
| Water | o Consumptive Use<br>o Change in Water Quality (Surface and Ground). | o Regional Changes in Water Quality<br>o Regional Impact on Consumptive Use |

Sources: ESE, 1986.
KBN, 1986.



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## B.2 RESULTS OF ENVIRONMENTAL ANALYSIS OF ALTERNATIVE PLANTS (PROJECTS)

### B.2.1 ASSUMPTIONS AND DATA

The following assumptions and data were used in the analysis:

1. Three alternative fuel types were evaluated--Lakhra coal, coal imported near Karachi, and oil imported near Karachi.
2. Power plant size was considered the same for all three alternatives.
3. Imported coal was considered to be low sulfur, 0.6 percent; imported oil, 3.2 percent; and Lakhra coal, 5 percent sulfur.
4. Because of the lack of site-specific design and environmental information for the imported fuel alternatives, the impact considerations were viewed from a regional perspective, i.e., looking at the regional impact considerations of the three alternatives.

### B.2.2 CRITERIA WEIGHTS

Table B-4 presents the results of the criteria weights. Socioeconomic and water resource impact factors were considered to have a higher weight than land and air resource impact considerations. A large amount of non-arable land exists in the areas being evaluated. The use of this land is more a function of water availability than of the land type. Changes in air quality on a regional basis would never be so great to cause significant environmental effects. Air resource impacts were not considered as great as socioeconomic and water resource impacts. Any degradation to a level resulting in acid deposition would be unlikely to cause any pronounced effects because of the lack of sensitive resources--the alkaline nature of the soils, the lack of small permanent unbuffered surface water systems, and the existence of extensive irrigation and agricultural activities. Given the developing nature of Pakistan, changes in socioeconomic conditions are considered to be more important than land and air resource impact considerations.

Table B-4. Criterion Weights for Alternative Plant Analysis

| Environmental Criterion | Criterion Comparisons | | | | | | | | | | Sum | Critical Coefficient (Weight) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Resources | 0.5 | 0.0 | 0.0 | 1.0 | | | | | | | 1.5 | 0.15 |
| Land Resources | 0.5 | | | | 0.0 | 0.0 | 1.0 | | | | 1.5 | 0.15 |
| Socioeconomic Resources | | 1.0 | | | 1.0 | | | 0.5 | 1.0 | | 3.5 | 0.35 |
| Water Resources | | | 1.0 | | | 1.0 | | 0.5 | | 1.0 | 3.5 | 0.35 |
| Dummy | | | | 0.0 | | | 0.0 | | 0.0 | 0.0 | 0.0 | — |
| | | | | | | | | | | | 10.0 | |

Sources: ESE, 1986.
KBN, 1986.

### B.2.3 DISCUSSION OF RESULTS

The results of the alternative plant comparisons are presented in Table B-5 for the four environmental criteria. The following paragraphs present the results of the comparison ratings.

Regional air resource impacts were considered to be better for the imported coal and oil alternatives than the Lakhra coal alternative due to the higher sulfur content and particulate content of the Lakhra coal and the resulting greater regional emissions associated with indigenous coal. The imported coal alternative was considered better than the oil alternative because of the lower sulfur content in the coal and lesser regional emissions.

Land resource impacts were considered better for both imported fuel alternatives because of the requirement for the surface and underground mines and subsequent changes to existing land resources at Lakhra. The imported oil alternative was considered better than the imported coal alternative because of the greater amount of wastes generated by the coal facility and the subsequent need for disposal of these wastes.

Socioeconomic impacts were considered to be more positive, from a regional perspective, for the Lakhra alternative than for the other two alternatives. There is a regional development benefit at Lakhra: greater employment, modernized infrastructure for the undeveloped area of the Dadu District of Sind. Because of the mine development, the size of socioeconomic change would be greater at Lakhra. The two imported fuel alternatives were considered equal in their socioeconomic impacts.

In relation to water resource impacts, the Lakhra site was considered equivalent to the other two alternatives. The transportation of fuel to the Karachi facility could result in spills and subsequent impacts to the marine environment. However, proper operation should not produce substantial impacts.



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Table B-5. Comparison Ratings for Alternative Plant Analysis by Criterion

| Alternative Plant | Comparison Rating | | | Sum | Unweighted Alternative Coefficient (%) |
|---|---|---|---|---|---|
| **A. Air Resources** | | | | | |
| Coal-Lakhra | 0.0 | 0.0 | | 0.0 | 0.0 |
| Coal-Imported | 1.0 | | 1.0 | 2.0 | 0.66 |
| Oil-Imported | | 1.0 | 0.0 | 1.0 | 0.33 |
| | | | | 3.0 | |
| **B. Land Resources** | | | | | |
| Coal-Lakhra | 0.0 | 0.0 | | 0.0 | 0.0 |
| Coal-Imported | 1.0 | | 0.0 | 1.0 | 0.33 |
| Oil-Imported | | 1.0 | 1.0 | 2.0 | 0.66 |
| | | | | 3.0 | |
| **C. Socioeconomic Resources** | | | | | |
| Coal-Lakhra | 1.0 | 1.0 | | 2.0 | 0.66 |
| Coal-Imported | 0.0 | | 0.5 | 0.5 | 0.17 |
| Oil-Imported | | 0.0 | 0.5 | 0.5 | 0.17 |
| | | | | 3.0 | |
| **D. Water Resources** | | | | | |
| Coal-Lakhra | 0.5 | 0.5 | | 1.0 | 0.33 |
| Coal-Imported | 0.5 | | 0.5 | 1.0 | 0.33 |
| Oil-Imported | | 0.5 | 0.5 | 1.0 | 0.33 |
| | | | | 3.0 | |

Sources: ESE, 1986.
KBN, 1986.

The weighted and composite scores and composite ranks are presented in Table B-6. These results suggest, from an environmental standpoint, that the Lakhra project is a viable alternative for new generation in Pakistan.

## B.3 RESULTS OF ALTERNATIVE POWER PLANT SITE ANALYSIS

### B.3.1 ASSUMPTIONS

The following assumptions were used in this analysis:

1. These alternative sites were evaluated--Lakhra, Khanot, and Jamshoro (site descriptions are provided in Appendix C).
2. Power plant size was considered the same for each site, i.e., 500 MW.
3. Mine development impacts were not considered as synergistic effects.
4. Linear facilities were considered in the analysis (i.e., coal transportation, water supply, and vehicular).
5. Impacts were evaluated based on site-specific impacts.

### B.3.2 CRITERIA WEIGHTS

Table B-7 presents the results for the criteria weights. Water resources was considered the most important criterion because of the importance of the Indus River to the areas surrounding the site area. This criterion was considered superior to both the air resources and land resources discipline; however, this criterion was considered equivalent to socioeconomics. The socioeconomic criterion was considered superior to the land resources criterion but equivalent to air quality. The basis for the later was the importance of the agricultural resources in the Indus valley which have the potential for being impacted by the emissions from any site. The land resources criterion was considered to be inferior to all other criterion because of the abundance of available land.

Table B-6. Weighted and Composite Scores and Composite Ranks for Alternative Plant Analysis

| Alternative Plant | Air | | | Land | | | Socioeconomic | | | Water | | | Composite Score* | Composite Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VWS | W | WS | VWS | W | WS | VWS | W | WS | VWS | W | WS | | |
| Coal-Lakhra | 0.0 | 0.15 | 0.0 | 0.0 | 0.15 | 0.0 | 0.66 | 0.35 | 0.23 | 0.33 | 0.35 | 0.12 | 35 | 1 |
| Coal-Imported | 0.66 | 0.15 | 0.1 | 0.33 | 0.15 | 0.05 | 0.167 | 0.35 | 0.06 | 0.33 | 0.35 | 0.12 | 33 | 2 |
| Oil-Imported | 0.33 | 0.15 | 0.05 | 0.66 | 0.15 | 0.10 | 0.167 | 0.35 | 0.06 | 0.33 | 0.35 | 0.12 | 33 | 2 |

*Sum of WS multiplied by 100 to obtain percent.

VWS = Unweighted score (see Table B-5).
W = Criterion weight (see Table B-4).
WS = Weighted score.

Sources: ESE, 1986.
KBN, 1986.

Table B-7. Criteria Weight for Alternative Site Analysis

| Environmental Criteria | Criterion Comparisons | | | | | | | | | | Sum | Criterion Coefficient (Weight) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Resources | 1.0 | 0.5 | 0.0 | 1.0 | | | | | | | 2.5 | 0.25 |
| Land Resources | 0.0 | | | | 0.0 | 0.0 | 1.0 | | | | 1.0 | 0.10 |
| Socioeconomic Resources | | 0.5 | | | 1.0 | | | 0.5 | 1.0 | | 3.0 | 0.30 |
| Water Resources | | | 1.0 | | | 1.0 | | 0.5 | | 1.0 | 3.5 | 0.35 |
| Dummy | | | | 0.0 | | | 0.0 | | 0.0 | 0.0 | 0.0 | |
| | | | | | | | | | | | 10.0 | |

Sources: ESE, 1986.
KBN, 1986.



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### B.3.3 DISCUSSION OF RESULTS

The results of the comparison ratings for the three sites in relation to the four major discipline areas (i.e., criteria) are presented in Table B-8 and in the following paragraphs.

In the air resource impact analysis, the Lakhra and Khanot sites were considered better than Jamshoro because of the potential human health impacts. Sind University, a medical school, and a tuberculosis hospital are directly downwind from the proposed Jamshoro site. This impact was considered a fatal flaw for the Jamshoro site. Lakhra was considered better than Khanot because of the potential effects on agricultural areas east of the Khanot site. Because of the lack of agricultural development at Lakhra, this site was considered the better of the two alternatives.

Land resource impacts at all three sites were considered to be equal, since none of the three sites has any important associated land resources. There is a potential for one or two protected animal species (monitor lizards considered endangered by GOP and USPs) to occur at the three sites. Their habitat and several individuals could be destroyed during site preparation; however, the loss of several individuals and a small amount of their habitat is not considered a threat to the status of their populations.

Socioeconomic resource impact considerations include the potential for change in social and cultural patterns, increased demand upon the existing infrastructure or demand for new infrastructures, employment and labor-related changes. The Jamshoro site was considered better than the Lakhra site because of existing infrastructural facilities and services in the Jamshoro/Hyderabad area. There would be less of an adjustment of workers in working at Jamshoro than at Lakhra. The Lakhra and Khanot sites were considered to be equal. Each site has both positive and negative factors which balance each other. At Lakhra there would be a greater need for facilities, services, and transportation as well as a



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Table B-8. Comparison Ratings for Alternative Site Analysis by Criterion

| Alternative Plant | Comparison Rating | | | Sum | Unweighted Alternative Coefficient (%) |
|---|---|---|---|---|---|
| **A. Air Resources** | | | | | |
| Lakhra | 1.0 | 1.0 | | 2.0 | 0.66 |
| Jamshoro | 0.0 | | 0.0 | 0.0 | 0.0 |
| Khanot | | 0.0 | 1.0 | 1.0 | 0.33 |
| | | | | 3.0 | |
| **B. Land Resources** | | | | | |
| Lakhra | 0.5 | 0.5 | | 1.0 | 0.33 |
| Jamshoro | 0.5 | | 0.5 | 1.0 | 0.33 |
| Khanot | | 0.5 | 0.5 | 1.0 | 0.33 |
| | | | | 3.0 | |
| **C. Socioeconomic Resources** | | | | | |
| Lakhra | 0.0 | 0.5 | | 0.5 | 0.17 |
| Jamshoro | 1.0 | | 1.0 | 2.0 | 0.66 |
| Khanot | | 0.5 | 0.0 | 0.5 | 0.17 |
| | | | | 3.0 | |
| **D. Water Resources** | | | | | |
| Lakhra | 1.0 | 1.0 | | 2.0 | 0.66 |
| Jamshoro | 0.0 | | 0.5 | 0.5 | 0.17 |
| Khanot | | 0.0 | 0.5 | 0.5 | 0.17 |
| | | | | 3.0 | |

Sources: ESE, 1986.
KBN, 1986.



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greater disruption of the social systems of the workers because of its remoteness from development areas along the Indus River. Because of the few inhabitants of the area, the magnitude of effect on social and cultural patterns is less than at Khanot. At Khanot there would be less of a disruption of the social system of the workers because of the proximity to Hyderabad. Because of the larger number of villages and the size of the villages at Khanot compared to Lakhra, there would be greater and more significant social and cultural change to the area.

Water resource impact considerations include potential effects on water quality, flow, water discharge, and discharge of pollutants into ground and surface water. Lakhra was considered the best of the three sites because of the lack of onsite and nearby surface water systems and usable ground water systems. Impacts at Khanot and Jamshoro were considered to be equal because of the equal distance of these two sites to the water resources of the Indus River. Based on the limited existing information, contamination to the ground water going to the Indus River would be long-term (1,000 years). Because of the existing agricultural activities and development near the sites, there is a potential for future use of ground water wells. The closer the wells are to the site, the greater the potential for contamination.

Table B-9 presents the weighted and composite scores and composite ranks for the alternative sites. These results suggest that Lakhra site is superior to the Khanot and Jamshoro sites from an environmental basis. The potential for air quality impacts to sensitive receptors for a power plant without substantial air pollution control equipment will make Jamshoro site unsuitable as an alternative.

## B.4 RESULTS OF ALTERNATIVE INFRASTRUCTURE EVALUATION

### B.4.1 ASSUMPTIONS

1. Two alternative sites for the workers colonies were evaluated--Lakhra and Khanot.



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Table B-9. Weighted and Composite Scores and Composite Ranks for Alternative Site Analysis

| Alternative Site | Air | | | Land | | | Socioeconomic | | | Water | | | Composite Score* | Composite Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VWS | W | WS | VWS | W | WS | VWS | W | WS | VWS | W | WS | | |
| Lakhra | 0.66 | 0.25 | 0.17 | 0.33 | 0.10 | 0.03 | 0.17 | 0.3 | 0.05 | 0.66 | 0.35 | 0.23 | 48 | 1 |
| Jamshoro | 0.0 | 0.25 | 0.0 | 0.33 | 0.10 | 0.03 | 0.66 | 0.3 | 0.20 | 0.17 | 0.35 | 0.06 | 29 | 2† |
| Khanot | 0.33 | 0.25 | 0.08 | 0.33 | 0.10 | 0.03 | 0.17 | 0.3 | 0.05 | 0.17 | 0.35 | 0.06 | 22 | 3 |

*Sum of WS multiplied by 100 to obtain percent.
†Fatal flaw due to air quality impacts.

VWS = Unweighted score (see Table B-8).
W = Criterion weight (see Table B-7).
WS = Weighted score.

Sources: ESE, 1986.
KBN, 1986.

2. Colonies were considered to have equivalent facilities at both sites.
3. Three criterion were used to evaluate each site--environmental, social acceptance (quality of life), and benefits to the secondary infrastructure.
4. The effect of transportation to job site was considered.
5. A summary category was used in the comparison ratings.
6. The plant and mine site was considered to be Lakhra.

### B.4.2 CRITERIA WEIGHTS

Table B-10 presents the results for the criteria weights. The environmental and social acceptance criteria were considered equivalent; both criteria were considered superior to secondary infrastructure benefits.

### B.4.3 DISCUSSION OF RESULTS

Table B-11 presents the results of comparison ratings. For all criterion, the Khanot site was considered superior to the Lakhra site. The potential for significant environmental impacts due to air emissions, from the mine (fugitive dusts) and power plant ($SO_2$) exists at Lakhra where as any impacts to a colony located 20 km away in Khanot would be minimal. Social acceptance would also be much more favorable at Khanot since this site is located nearer to major roads where travel to Hyderabad is reduced. Also, the general proximity of the Khanot site near the Indus River provides a much more asthetic place to live than Lakhra. Secondary infrastructure benefits would likely be experienced more directly at Khanot where some private and public facilities exist. Conversely, at Lakhra, no such facilities exist. Although a colony at Khanot would require daily transport to Lakhra, travel on an improved road should not exceed 30 to 45 mi. A staggered work shift could reduce the transportation needs. Because of the relatively small commute, this effect was not considered significant. Weighted and composite scores and ranks are presented in Table B-12 for the alternative infrastructure evaluation.

Table B-10. Criteria Weights for Alternative Infrastructure Development

| Criteria | Criteria Comparisons | | | | | Sum | Criteria Coefficient (Weight) |
|---|---|---|---|---|---|---|---|
| Environment | 0.5 | 1.0 | 1.0 | | | 2.5 | 0.42 |
| Social Acceptance | 0.5 | | | 1.0 | 1.0 | 2.5 | 0.42 |
| Secondary Infrastructure Benefits | | 0.0 | | 0.0 | 1.0 | 1.0 | 0.17 |
| Dummy | | | 0.0 | 0.0 | 0.0 | | |
| | | | | | | 6.0 | |

Sources: ESE, 1986.
KBN, 1986.



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Table B-11. Comparison Ratings for Alternative Infrastructure Development

| Alternative | Comparison Rating | | | Sum | Unweighted Alternative Coefficient (%) |
|---|---|---|---|---|---|
| **A. Environmental** | | | | | |
| Khanot | 1.0 | 1.0 | | 2.0 | 0.67 |
| Lakhra | 0.0 | | 1.0 | 1.0 | 0.33 |
| Dummy | | 0.0 | 0.0 | | |
| **B. Social Acceptance** | | | | | |
| Khanot | 1.0 | 1.0 | | 2.0 | 0.67 |
| Lakhra | 0.0 | | 1.0 | 1.0 | 0.33 |
| Dummy | | 0.0 | 0.0 | | |
| **C. Secondary Infrastructure Benefits** | | | | | |
| Khanot | 1.0 | 1.0 | | 2.0 | 0.67 |
| Lakhra | 0.0 | | 1.0 | 1.0 | 0.33 |
| Dummy | | 0.0 | 0.0 | 0.0 | |

Sources: ESE, 1986.
KBN, 1986.

Table B-12. Weighted and Composite Scores and Composite Ranks for Alternative Infrastructure Development

| Alternative | Criterion: Environment VWS | Environment W | Environment WS | Social Acceptance VWS | Social Acceptance W | Social Acceptance WS | Secondary Infrastructure Benefits VWS | Secondary Infrastructure Benefits W | Secondary Infrastructure Benefits WS | Composite Score* | Composite Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Khanot | 0.67 | 0.42 | 0.28 | 0.67 | 0.42 | 0.28 | 0.67 | 0.17 | 0.11 | 67 | 1 |
| Lakhra | 0.33 | 0.42 | 0.14 | 0.33 | 0.42 | 0.14 | 0.33 | 0.17 | 0.06 | 34 | 2 |

*Sum of WS multiplied by 100 to obtain percent.

VWS = Unweighted score.
W = Criteria weight.
WS = Weighted score.

Sources: ESE, 1986.
KBN, 1986.

# APPENDIX C
# DESCRIPTIONS OF CANDIDATE SITES

## C.1 JAMSHORO SITE

The layout of the Jamshoro site is shown on Figure C-1. This site is the most restrictive of the three in terms of layout flexibility due to the presence of the existing 500-kilovolt (kV) substation, the transmission lines leading to the substation, and the space requirements of the 250-MW oil-fired units. There is, however, adequate space to arrange the coal-fired unit with provisions for up to three additional units in line with and immediately to the south of the space reserved for the two 250-MW units. As the soils and topographic information shows, the coal-fired unit may be placed in this area with a minimum of earthwork and may be placed on a mat- or raft-type foundation with no significant excavation and compacted backfill or deep foundations required to support heavy loads from the power block. The orientation of the power block is the same as was used for the oil-fired units with the required air quality control equipment on the east side of the plant. Since the Jamshoro site may require the use of sulfur dioxide ($SO_2$) scrubbing equipment, significant space is required between the plant and the Dadu Road for absorber towers and limestone preparation equipment.

The arrangement of the coal delivery system was made based on recommendations of the J.T. Boyd Company in their initial transportation system study. Coal would be delivered to the Jamshoro site via a short-haul rail system which terminates at the plant site with a loop track placed to the north of the 500-kV substation and west of the Dadu Road. This arrangement would eliminate any crossing of the Dadu Road by coal delivery equipment. Coal would be dumped from bottom-dump hopper cars into a receiving hopper. From the hopper, coal would be forwarded to the conveying and storage portion of the system via an unloading conveyor which passes under the Dadu Road in a tunnel and discharges to a transfer

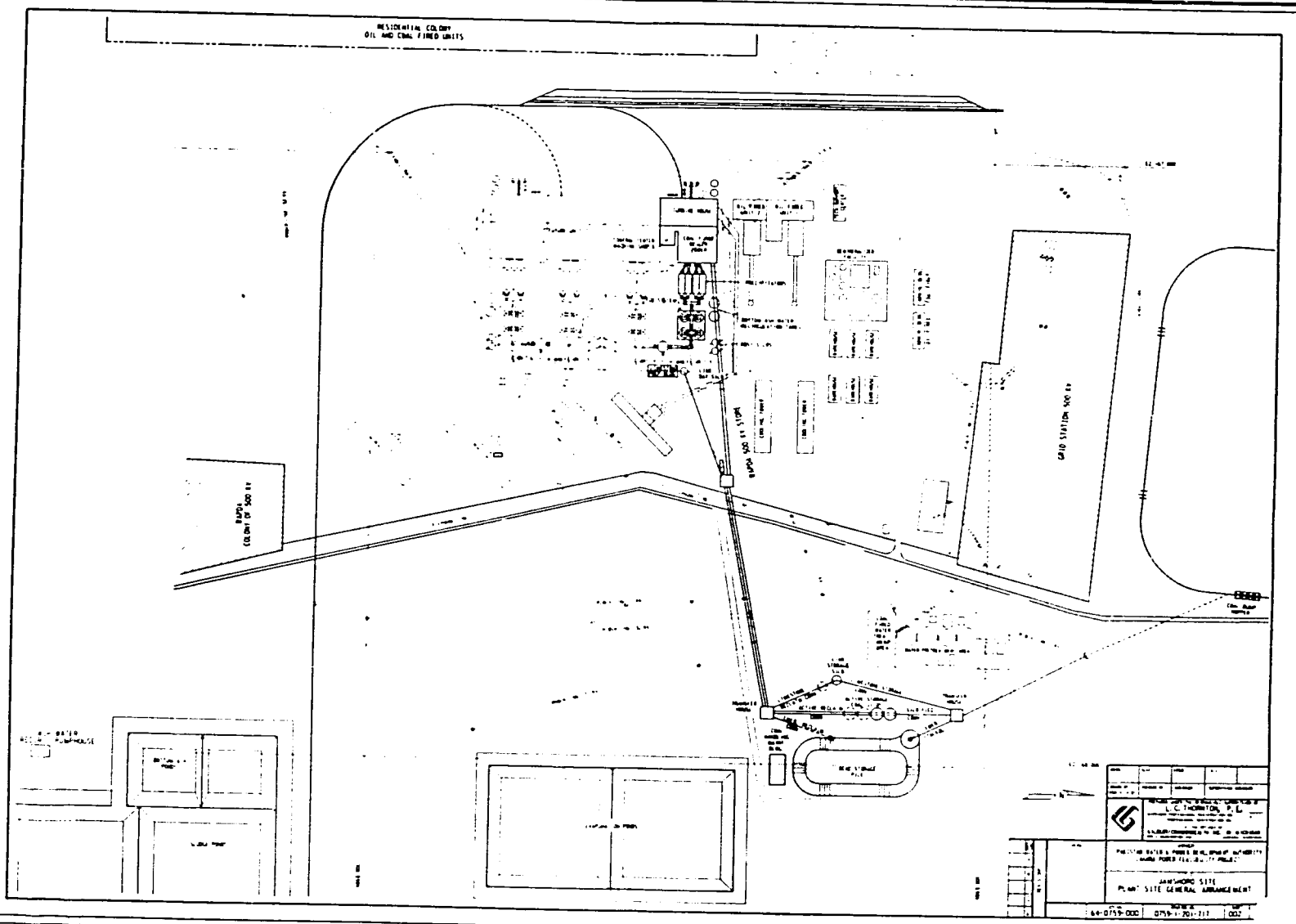


Figure C-1
JAMSHORO SITE LAYOUT

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house on the northeast corner of the plant site. Active storage silos and the dead storage pile would be located on the east side of the Dadu Road with adequate clearances to avoid interference with the 132-kV transmission lines leaving the 500-kV substation in that area. Although the same basic storage and conveying system was used for all three of the sites, the Jamshoro site requires the most conveyor length and an additional transfer house to route coal to the plant. As the layout drawings show, the coal handling system must be extended around existing equipment and structures rather than having direct access to the site.

Portions of the coal handling system at Jamshoro would also be used for the delivery and conveying of limestone used as sorbent material if an FGD system is required for this site. It is anticipated that limestone will be available from open pit mine areas at the Lakhra mine development and that the limestone can be forwarded to the Jamshoro site via the same short haul rail system used for delivery of the coal. Since limestone consumption rates are significantly lower than that of the coal, the system at Jamshoro can be kept in adequate supply by utilizing two trains per week delivery of limestone. This schedule would minimize disruption of coal deliveries. Limestone would be dumped into the same receiving hopper utilized for the delivery of coal and would be forwarded to the first transfer house using the same unloading conveyor. From transfer house #1, a separate limestone conveyor would load the limestone storage silo. Limestone would be reclaimed from the silo and forwarded to transfer house #2. From transfer house #2 to the crusher house, a separate limestone conveyor situated on the same gallery as the two plant coal supply conveyors would be used. From the crusher house to the limestone preparation area the limestone conveyor would be run on an independent gallery. The limestone preparation building is immediately east of the Unit 1 chimney and includes a small capacity limestone silo.

The circulating water system for the Jamshoro site would consist of independent cooling tower and pumping house arrangement for each of the

projected coal-fired units. The cooling towers would be located east of the plant between the air quality control area and the Dadu Road. This location parallels the arrangement used for the oil-fired units and is required due to the presence of transmission lines, the oil delivery and storage system, plus the residential colony on the west side of the plant site. This arrangement will result in the longest runs of circulating water pipe due to the remote location of the towers from the condensers in the turbine room. Cooling towers have been included for three potential future coal-fired units to ensure that adequate space is provided. The tower arrangement shown complies with U.S. cooling tower manufacturer's recommendations regarding orientation and spacing. These recommended spacings utilize a considerable amount of site area; however, they are required to minimize tower-to-tower interference and optimize performance of the tower.

The makeup water system for the plant would be located at the Indus River directly east of the plant site. It is anticipated that a direct addition may be made to the intake pump house planned for the oil-fired units. These pump houses are approximately 200 m (650 ft) offshore in the river and are connected to the river bank with a trestle system. The pumps in the makeup pump water house would feed a clarifying pond situated close to the shoreline. This pond would be used to provide settling of suspended solids in the river water and a temporary two-day storage of plant makeup water requirements. This design concept parallels that used for the oil-fired units. From the ponds, an additional set of pumps would forward makeup water to treatment facilities located east of the Dadu Road and adjacent to the water pretreatment area planned for the oil-fired units. The water pretreatment area would provide water for both the plant requirements and potable water for the power plant, administration and offices, and the residential colony.

The Jamshoro site would require the least amount of transmission lines and substation work. Takeoffs from the plant step-up transformers, and leads to cranking power transformers would be provided from the existing 500-kV substation. The lines would follow a route established for the oil-fired units which runs north from the power block area to the existing substation.

The Jamshoro site may require the most extensive system for the disposal of plant ash and if necessary FGD sludge due to the use of the $SO_2$ removal system. Approximately 89 hectares (220 acres) of land would be required for disposal of plant FGD wastes. The designated area is east of the residential colony between the Dadu Road and the existing railroad tracks. As shown on the layout, space has been provided for disposal of materials throughout the full 30-year projected plant life. The initial dike construction and storage area is planned for the first 10 years of plant operation. It is anticipated that the fully developed dike system would be built in later stages utilizing waste materials generated during the first 10 years. The areas around the Jamshoro site within a radius of approximately 5 km (3 miles) were investigated to determine if any small valleys might be available to be used for the storage of FGD sludge. This plant site is relatively flat throughout the entire area, which would require the construction of the diking system.

The ash disposal area was also laid out utilizing an asphalt liner throughout the entire pond area. Although the plant site does not show the evidence of large quantities of ground water, the highly permeable and fragmented layers of the limestone rock underlying the site indicate that an unlined pond would eventually lead to pollution of ground water in the Indus River valley area. The pond and dike system has been planned to allow for clarification and recirculation of sludge disposal service water through a recirculation pump house located immediately west of the ponds.



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The bottom ash ponds would be located on the northwest corner of the pond development. These ponds are planned for maximum 5-year storage of bottom ash. It is anticipated that bottom ash would be sold or used for future dike construction; therefore, 5 years is assumed to be adequate storage. The bottom ash pond has also been divided into two chambers to allow for dewatering and ash removal from one chamber while the second chamber is in service.

The pond area would also be used for the disposal of plant industrial waste and sewage treatment waste. Industrial waste such as boiler chemical cleaning, demineralizer recharge flows, and plant oily wastes would be collected and routed to a set of evaporation ponds on the north edge of the disposal area. Effluent from the plant and residential colony sanitary waste treatment system would be routed to the sludge disposal pond where this effluent would be included with water available for recirculation to the sludge disposal system.

Access to the Jamshoro site is very simple due to the presence of the main Dadu Road on the east border of the plant site and the existing rail line which is approximately 1 km east of the road. Plant site roads developed for the construction of the initial oil-fired units on the Jamshoro site could be extended to allow access around the coal-fired units. The rail line siding which is planned to run from the rail line to the oil unloading area would be used to provide construction and turbine room access track to the coal-fired units. The Jamshoro site requires the least development of road and rail access of any of the three sites.

## C.2 KHANOT SITE

The layout of the Khanot site is shown on Figure C-2. The Khanot site area is currently undeveloped and provides good flexibility for the efficient arrangement of equipment and structures. The only potentially

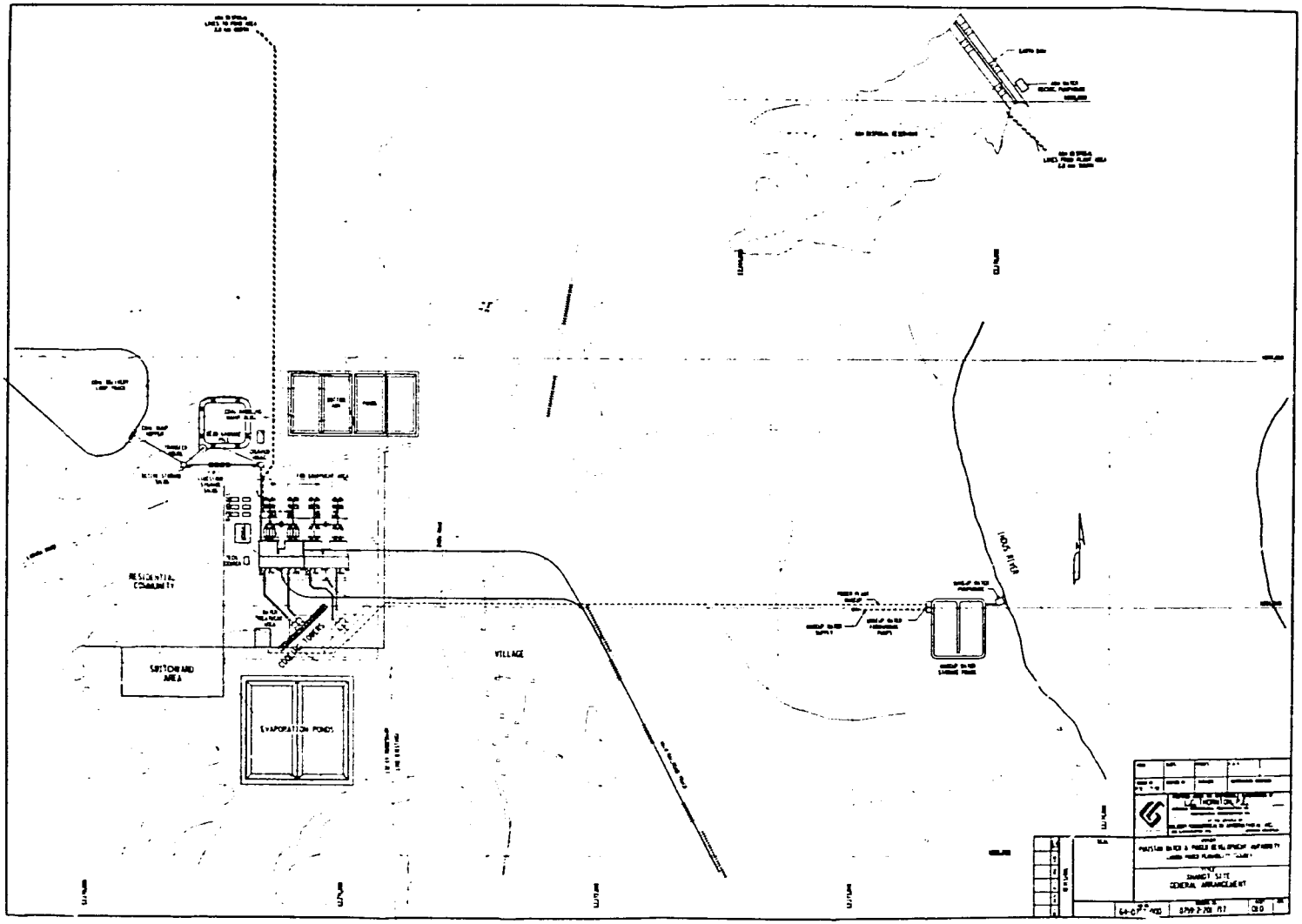


Figure C-2
KHANOT SITE: PLANT SITE GENERAL ARRANGEMENT

SOURCE GCII 1985

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

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interfering existing features of the Khanot site are the truck stop at the intersection of the Lakhra and Dadu Roads; the villages of Bhure Khan Rind, Murid Khan Rind, and Manzurabad which are southeast of the Lakhra Road adjacent to the Dadu Road; and the 132-kV transmission line which runs from south to north along the east side of the site. The Khanot site is on a relatively flat area of land which is bordered on the north by a line of ridges north of the Lakhra Road and on the south by a low drainage area which drains the area to the south and west of the plant to the Indus River. Some filling and rearrangement of existing drainage profiles would be required at this site; however, it is anticipated that this work would be minimal and, as with the Jamshoro site, power block equipment and structures could be founded on shallow, mat-type foundations. The orientation of the power block area for Khanot was determined to provide for future plant expansion in the direction of site access to avoid interferences between future expansion and operating units. This orientation also would allow good access from the coal delivery system for Khanot which would be coming from the northwest.

The delivery of coal to the plant at Khanot would also be via short-haul rail with a loop track located adjacent to the plant site. The conveying and storage area designated for this site is on a flatlands area immediately to the north of the Lakhra Road. The lack of any interfering existing structures in this area means that the layout of the storage and handling system could be optimized using minimum conveying lengths. The basic unloading and conveying equipment is the same as that described for the Jamshoro site. To avoid any interferences with road crossings, the plant supply conveyor would be routed underground to a point just south of the Lakhra Road where it would begin its climb to the in-plant bunkers for Unit 1.

The circulating water system, including the arrangement of cooling towers and pump houses, has been designed to use the minimum site space and to orient the towers to minimize the effect from fogging and plume drift.



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The towers would be located as close as feasible to the condensers to minimize circulating water pipe runs and are situated on the southeast corner of the site. In this location summertime winds from the southwest and wintertime winds from the north would carry the cooling tower plumes away from site equipment and structures such as the switchyard, residential community, and power block. The Khanot site also offers the opportunity to construct the towers in pairs, which would minimize site space requirements.

Water supply to both the Khanot and Lakhra sites would be from a makeup water pump house located on the west bank of the Indus River approximately 3 km (1.8 miles) east of the site near the Magdoom Irrigation Pump Station. The pump house is close to an existing barge-mounted irrigation pumping station. The river at this point is approximately a minimum of 4.5 m (15 ft) in depth close to the shore, which would facilitate the construction of a shoreline pump house with a small forebay and stilling area in front of the pump house. A set of clarifying ponds would be provided to remove some of the suspended solids from the river water prior to the water being forwarded to the treatment area located on-site. These ponds also would provide a short-term, 2 day supply of makeup water if an unexpected outage of the makeup water pumps or extreme low water conditions occurred. The water treatment area for Khanot would be in the southern section of the site adjacent to the cooling towers, and from this location makeup water, service water for the plant, and potable water could be provided to the residential community with a minimum of piping runs.

The transmission lines for the unit for Khanot would run from the plant southwest to an adjacent switchyard area and then directly west approximately 3 km (1.8 miles) to the existing 500-kV transmission line.

As with all of the sites, the topography within a 5-km (3-mile) radius of the plant was investigated to determine if a naturally occurring area for

ash storage is available. At the Khanot site it appears that there is an area approximately 2.8 km (1.7 miles) north-northwest of this site which could be closed off by the construction of an earth dam and used for disposal. A naturally occurring area for the disposal of ash would minimize costs of diking construction. However, this area would still require grading and sealing with an asphalt surface material. The ash water recirculation pump house would be located to the east of the disposal area. The bottom ash would be disposed immediately to the north of the plant site along the route of the ash disposal lines. This arrangement would allow minimum pipe runs and easy access to the bottom ash area for removal of saleable ash. If bottom ash in excess of that which can be sold is generated by the plant, overflows of bottom ash could be routed to the fly ash ponds.

Wastewater disposal would be divided, with sanitary waste effluents being routed to the fly ash ponds, and industrial wastes such as boiler chemical cleaning, demineralizer recharge flows, and plant oily wastes collected and routed to a set of evaporation ponds on the south edge of the plant site.

Access to the Khanot site is also relatively simple. The Dadu and Lakhra Roads are both paved, good quality roads. Access to the site is from the Lakhra Road with only road development or immediate onsite access being required. The existing rail line from Hyderabad and Dadu is approximately 1 km (0.6 mile) east of the site and, as shown on the layout drawings, two rail sidings can be run to the plant. One of the sidings would be for construction track and would enter the site along the centerline of the boilers. The second siding would be a turbine room maintenance track.

## C.3 LAKHRA SITE

The layout of the Lakhra site is shown on Figure C-3. The designated power plant areas for the Lakhra mine mouth site are on the south-central



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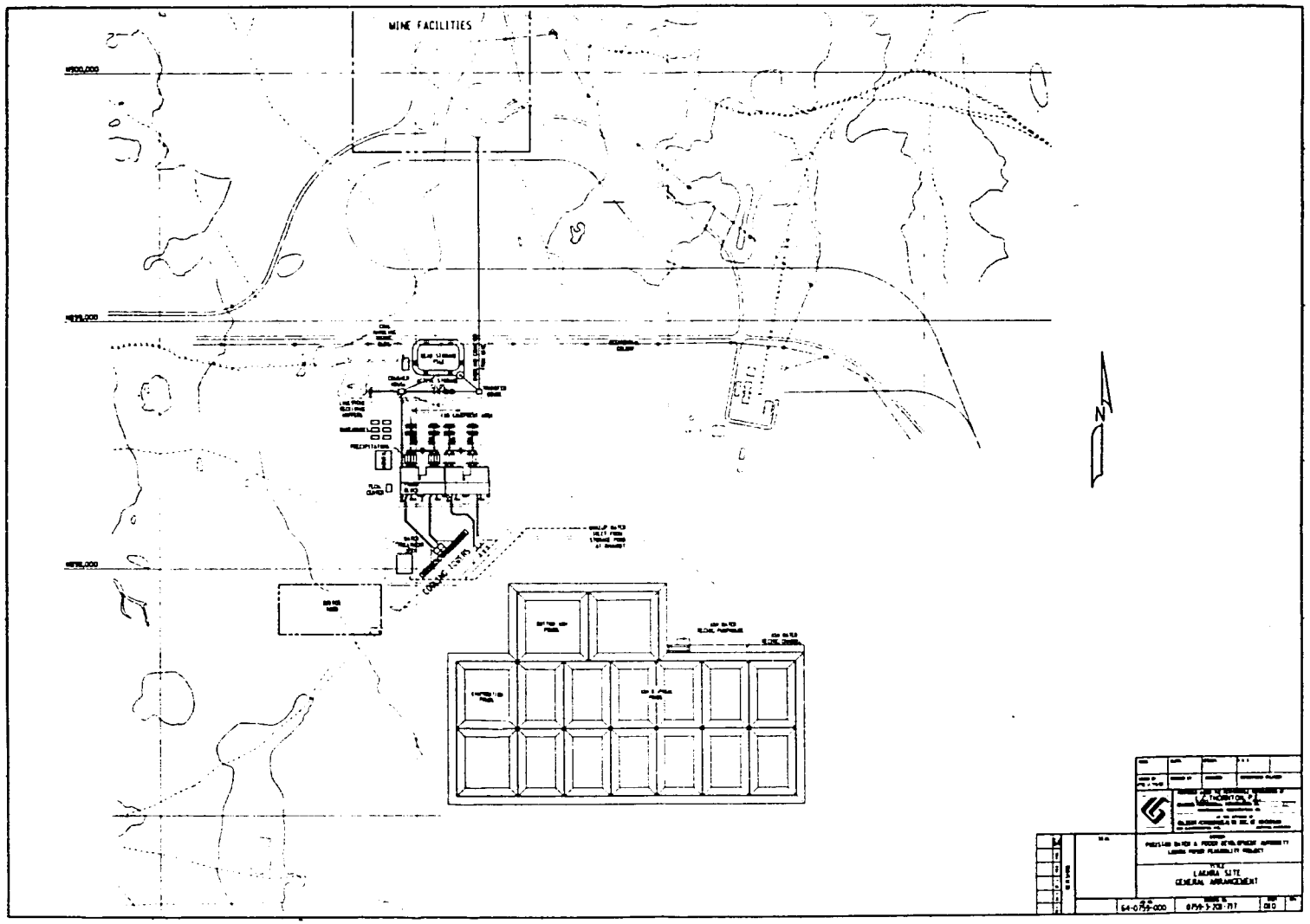


Figure C-3
LAKHRA SITE: PLANT SITE GENERAL ARRANGEMENT

SOURCE GCII, 1985

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

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section of the lease area which has been determined by the J.T. Boyd Company to be barren of mineable reserves. The area is also approximately 1 km (0.6 mile) south of the mine surface facilities planned by Boyd. The area is completely undeveloped and extremely flat in profile. As a result, layout of equipment and structures on this site is completely unrestrained. Boring No. LC-2, which was done as a part of the GCII soils investigation program, indicates that foundations for a plant in this region of the Lakhra lease area will be founded on soils conditions similar to those encountered at Khanot. Shallow, mat-type foundations are suitable for the Lakhra site. The orientation of the basic power block, air quality control and circulating water equipment at Lakhra would be essentially the same as indicated for the Khanot site.

The coal-handling system planned for the Lakhra mine mouth site would be the same as the other sites in regard to short-term active storage and conveying equipment. The major difference in the coal-handling system at this site would be that no delivery and unloading system is required. The interface between power plant coal handling and the mine will be an overland delivery conveyor which terminates in transfer house #1 onsite.

For the circulating water system at the Lakhra site, cooling towers would be located to the southeast of the main power block to minimize the effects of plume drift. The makeup water system, which supplies circulating water system makeup plus the balance of plant and residential colony requirements, would be installed in the same location along the Indus River as for the Khanot site. Supplying water to the Lakhra site would require a pumping system approximately 20 km (12 miles) in length. This piping would enter the Lakhra site from the east and terminate in the water treatment area located adjacent to the cooling towers on the south edge of the site.

The substation planned for the Lakhra site would be located southeast of the main power block development adjacent to the residential colony.



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Transmission lines from this area would be extended approximately 17 km (10 miles) east of the 500-kV transmission lines.

As at Khanot, an investigation of available topography within 5 km (3 miles) of the central power plant site was conducted to locate any available land which may be used for disposal of fly ash. Although some areas of the eastern reserve area would lend themselves to the development of ash storage facilities, these areas are currently planned for open pit mine development by J.T. Boyd. As a result, the Lakhra site has been laid out to accommodate ash storage ponds to the northwest of the primary site development. The pond development at the Lakhra site is sized to allow an initial 5-year storage of fly ash, bottom ash, and FGD sludge, if required. After 5 years of plant and mine operation, it is assumed that adequate mined-out area from strip mining operations will be available to use future ash generated from the plant as fill material for the mine reclamation program. No lining for the storage ponds at the Lakhra site has been included due to the lack of usable ground water in the area. As with the Khanot site, industrial wastes would be routed to a set of evaporation ponds on the north edge of the pond development. Sanitary wastes will be routed to the ash ponds. The required storage area for potential FGD sludge generated from an $SO_2$ scrubbing system is shown on the site plans. A 5-year storage of scrubber sludge approximately doubles the total storage area required.

The development of proper access to the Lakhra site would be the most difficult of the three sites under consideration. Paved roads would have to be extended to the Lakhra plant site area from the existing Lakhra Road. The cost of this access feature is included within the J.T. Boyd infrastructure development costs. Access by rail to the Lakhra area is required only for the power plant development and not for the mine development. As a result, approximately 22 km (14 miles) of rail line extending from the main line in the Khanot area to the Lakhra site have been included in the cost of develoment for this site. The remaining onsite access for plant area equipment and structures plus the residential colony is essentially the same as for the Khanot site.

# APPENDIX D

# DESCRIPTION OF PLANT DESIGN

## D.1 CONSTRUCTION

In the utility industry there are numerous approaches to implementing the design, construction, and operation of a power plant. These basic approaches are:

A/E and General Contractor,
A/E, Construction Management, and
A/E and Turnkey Contractor.

It is GCII's recommendation that the Lakhra power project use this third approach; that is, A/E and Turnkey Contractor. This approach utilizes an A/E to perform the preliminary engineering only and develop a tender document for a turnkey design and construction contract. This approach simplifies the contracting efforts as there is essentially a single responsible party for the design and construction of the plant.

There are several reasons for this recommendation. First, as mentioned above, maintaining single responsibility through the use of one major contractor minimizes the contractual and coordination problems often encountered with multiple contractors. The turnkey contractor would be responsible for the supply and erection of all plant components and the coordination of any subcontractors he may retain. Second, the turnkey approach has been demonstrated to be an approach which can shorten the overall project schedule on most power plant projects. The schedule for the Lakhra 250-MW units is extremely tight. Third, it gives the Owner good cost control through the use of the A/E, developing a tender document which can be competitively bid for a firm lump sum price. Finally, the turnkey contract can be designed to be flexible.



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Utilizing the A/E and Turnkey Contractor approach, the following events outline the project implementation. On selection of an A/E by the Owner, the A/E would begin the preliminary design of the plant with the awareness that the final product is a tender document for the design and construction of the plant. Other requirements of the Owner such as procurement and contracting plans, environmental and regulatory requirements, quality assurance programs, training requirement programs, etc., would also be developed for inclusion in the tender document. In addition to the prime tender document for the plant construction, it is envisioned that two additional contracts would be required. These are site preparation work and construction camp facilities. These packages would be developed for local tendering to prepare the site for the mobilization of the prime turnkey contractor. The A/E, working closely with the Owner, will issue these tender documents for bid, receive and evaluate the bids, and with the Owner's concurrence, award the contracts.

The A/E will continue on the project during the design phase as the Owner's engineer primarily responsible for design review. The detailed specifications and drawings for a particular system will be approved by the Owner's engineer prior to the contractor beginning construction of that system. During the construction phase, the engineer will continue his design review as well as mobilize the construction monitoring team at the site. This organization, supplemented with personnel from WAPDA, would monitor and report on the construction activities to assure compliance with approved design drawings and specifications. The contractor would also be responsible for system testing and commissioning of the plant. It would be required by contract that these activities be coordinated very closely with the Owner, as the Owner's operators will have received training by this time and will be included in the start-up phase of the plant as the culmination of their training program.

## D.2 RAW MATERIALS HANDLING, STORAGE, AND TRANSPORTATION

### D.2.1 COAL HANDLING

The basic function of the onsite coal-handling system is to provide means for unloading, storing, reclaiming, and forwarding coal to the in-plant coal silos. Components of the system are also supplied to accurately weigh and sample the coal being delivered to the plant. The delivery of coal to the plant is assumed to be unit train delivery directly from the Lakhra coal mine for a site located in Khanot. For a plant located at Lakhra, truck delivery is a possibility. Five trains per day of 35 cars each will supply approximately 7,500 metric tons (8,250 tons) of coal daily.

UNLOADING

Coal will be unloaded from the assumed 40-metric-ton (44-ton) capacity, bottom-dump hopper cars. Trains will be spotted such that three cars may be dumped simultaneously into a quadriplex hopper of 218 metric-ton (240-ton) capacity. Indexing for the car spotting operation will be at approximately 5-minute intervals such that a full train may be unloaded in 2 to 3 hours. Coal will be transferred for onsite storage via four 363-metric-ton (400-ton)-per-hour flat belt feeders feeding an unloading belt conveyor of 1,450-metric-ton (1,600-ton)-per-hour capacity.

ON-SITE STORAGE

Coal will be stored onsite in either one of three 13,650-metric-ton (15,000-ton) active storage silos or the compacted and sealed dead storage pile. Dead storage of 180,000 metric tons (200,000 tons) for approximately 2 weeks of fuel at full-unit load will be maintained for emergency supply only. This coal will be sealed on the surface to minimize the chance for spontaneous combustion. Stackout of coal to this pile will be via a 1,450-metric-ton (1,600-ton)-per-hour fixed stacking conveyor with telescopic chute.

Normal active coal storage for the plant fueling will be in the active storage silos. These silos will be approximately 21.3 m (70 ft) in diameter and 45.7 m (150 ft) total height and are constructed from reinforced concrete. Active storage silos are provided to maintain a controlled first-in/first-out plant inventory to avoid retaining uncompacted lignite for long periods of time. These silos will also contain the coal within an area which will minimize the potential for coal fires and fugitive dust problems. Coal will be distributed to the active storage silos via a 1,450-metric-ton (1,600-ton)-per-hour tripper belt conveyor.

RECLAIM

Coal from the active storage silos will be reclaimed and forwarded to the plant via one of two 725-metric-ton (800-ton)-per-hour conveyors. These conveyors are supplied by flat belt feeders at the base of the silos. There will be four feeders per silo, and each feeder can feed either of the reclaim belts.

Reclaim from the dead storage pile will be by bulldozers pushing material to an underground reclaim hopper. A single 725-metric-ton (800-ton)-per-hour emergency reclaim feeder and 725-metric-ton (800-ton)-per-hour emergency reclaim belt will supply material to the crusher house surge hopper.

Coal from either active or dead storage is sent to the crusher house where it is reduced to 38 mm (1.5 in) maximum size in one of two 363-metric-ton (400-ton)-per-hour, ring-type crushers before being forwarded to the plant silos. Transfer of material to the plant silos is via one of two 725-metric-ton (800-ton)-per-hour plant supply belts. Final transfer to the in-plant bunkers is via a 725-metric-ton (800-ton)-per-hour tripper conveyor. The tripper conveyor has five unloading points, one for each of the in-plant silos. An in-plant surge hopper is provided which is sized and detailed to allow the addition of future

conveyors which will be installed to forward coal from the initial unit to future units.

SAMPLING

Two sampling systems are provided for the onsite coal handling system. The first is a two-stage "as-received system" which will sample coal delivered to the plant prior to stack-out. This system is located in the transfer house. An "as-fired" sampling system is located in the boiler house to sample coal prior to delivery to the in-plant coal silos.

MAGNETIC SEPARATORS

Electric magnetic separators are provided at the head end of the unloading conveyor and emergency reclaim conveyor to remove tramp magnetic material from coal before it is loaded into the system.

WEIGHT SCALES

Electronic belt weight scales are provided on the unloading conveyor to weigh and record the material received at the plant. Weight scales are also provided on the two plant supply conveyors to record the weight of coal delivered to the in-plant silos.

D.2.2 LIMESTONE

If flue gas desulfurization (FGD) is installed (see Section 2.3.6 for discussion of alternatives), wet limestone is the preferred alternative. This alternative will require a limestone handling system. The limestone delivery and storage system will receive limestone forwarded to the site by truck. The unloading hopper and conveyor used for the coal handling system will also be used for limestone. The unloading rate of 1,450 metric tons/hour (1,600 tph) will be maintained by reducing dumper hopper feeder rates when limestone is being delivered. A limestone storage conveyor rated at 1,450 metric tons/hour (1,600 tph) will be used to stack limestone in an active storage silo with 118,000-metric-ton (13,000-ton) capacity. This capacity depends on sulfur content of the

coal and daily capacity factor and is adequate for 10 days to 2 weeks storage of limestone for the preparation system. Limestone will be reclaimed from the active storage silo and forwarded to a 910-metric-ton-per-day (1,000-ton-per-day) silo adjacent to the preparation area by a series of 30-cm (12-inch) belt conveyors rated at 145-metric-tons/hour (160 tph) capacity. Limestone will be supplied to the preparation system in four 2-hour loading cycles per day. This loading operation parallels that of the coal handling reclaim system.

## D.3 COOLING AND PROCESS WATER SYSTEMS

### D.3.1 WATER SOURCES

From the results of field investigations performed by J.T. Boyd Company and other information gathered from existing mine operators, it can be concluded that very little usable ground water is present at any of the three sites. Ground water in isolated or perched areas has been observed at the Lakhra mine site; however, this water is of limited quantity and generally poor quality. At Khanot, ground water was observed in four of the bore holes at a depth of 4.6 to 13 m (15 ft to 43 ft). Work done by WAPDA for soils resistivity in the area indicates that fresh water supplies are minimal at Khanot and overlie a generally saline ground water table. As a result the water needs of the power plant and mines will be obtained from the Indus River. For both sites water will be taken in the Kotri pool near the Magdoom Irrigation Pump Station.

Surface water flow in the Indus River has been investigated by GCII to ensure that quantities are adequate for supply of the plant. The best data available regarding river flows also were taken from the monitoring station at Sehwan, which is approximately 85 km (53 miles) northwest of Khanot. These data indicate that a minimum monthly average discharge of approximately 60 $m^3$/sec is present during the period of late February and early March. This flow is far in excess of plant requirements.

Water quality of the Indus River may be characterized as being high in suspended solids content, especially during high flow periods of the year. A set of clarifying ponds will be constructed onsite to remove some of the suspended solids as well as to provide a 2-day supply of makeup water because of unexpected power outages or extreme low flow conditions.

Surface water is alkaline with a pH in the range of 7.3 to 9. Due to the high suspended solids concentration, slightly high sulfate content, and alkaline nature of the river water, it is recommended that a filter be installed in the system and that water be treated to minimize any scaling effect inside any plant components.

### D.3.2 WATER TREATMENT

A number of major waste streams are generated by power plant operations including:

1. Cooling tower blowdown,
2. Fly ash transport water,
3. Bottom ash transport water,
4. Chemical metal cleaning wastes,
5. Nonchemical metal cleaning wastes,
6. Scrubber discharge (if any),
7. Low volume wastes:
    a. Boiler blowdown,
    b. Ion exchange water treatment wastes (rinse and regenerants),
    c. Laboratory and sampling drains,
    d. Yard and floor drains,
    e. Water treatment clarification wastes,
8. Coal pile runoff and leachate, and
9. Sanitary waste.

These wastes have a number of pollutants associated with them (Table D-1). If discharged into the environment, these wastes can cause human and environmental health effects.

Table D-1. Major Pollutants Associated with Power Plant Waste Streams

| Stream | Pollutants | | |
|---|---|---|---|
| Cooling Tower Blowdown | TDS*<br>Copper<br>Nickel<br>Chromium | Total Resid. Chlorine<br>Phosphorus<br>Beryllium | Chlorinated Organics<br>Zinc<br>Cadmium |
| Fly Ash Pond Overflow (and Leachate) | Arsenic<br>Boron<br>Chromium<br>Nickel | Silver<br>Zinc<br>Selenium<br>Copper | Cadmium<br>Mercury<br>Barium |
| Bottom Ash Pond Overflow (and Leachate) | Arsenic<br>Barium | Silver | Cadmium |
| Chemical Cleaning Wastes | Ammonia<br>Phosphorus<br>Beryllium<br>Copper<br>Nickel | Iron<br>Phenol<br>Cadmium<br>Lead<br>Silver | Manganese<br>Arsenic<br>Chromium<br>Zinc |
| Waterside Boiler Cleaning Wastes | Ammonia<br>Manganese<br>Turbidity<br>Arsenic<br>Chromium<br>Mercury<br>Silver | Chloride<br>Nitrate<br>Phosphorus<br>Zinc<br>Copper<br>Nickel | Iron<br>TDS<br>Phenol<br>Cadmium<br>Lead<br>Selenium |
| Fireside Boiler Cleaning Wastes | Iron<br>Chromium | Sulfate<br>Zinc | TDS |
| Air Preheater Cleaning Wastes | Ammonia<br>TDS<br>Chromium | Iron<br>Turbidity<br>Nickel | Sulfate<br>Phosphorus<br>Zinc<br>Copper |
| Boiler Blowdown | Phosphrous<br>Chromium | Copper<br>Iron | Oil & Grease |
| Boiler Feedwater Clarification Wastes | TSS†<br>Turbidity | Iron<br>Phosphorus | TDS<br>Chromium |
| Boiler Feedwater Ion Exchange Wastes | Ammonia<br>Sulfate<br>Phosphorus<br>Mercury | Chloride<br>TDS<br>Chromium<br>Nickel | Nitrate<br>Turbidity<br>Copper |

Table D-1. Major Pollutants Associated with Power Plant Waste Streams (Continued, Page 2 of 2)

| Stream | Pollutants | | |
|---|---|---|---|
| Water Treatment Wastes | Arsenic | | |
| Coal Pile Drainage (and Leachate) | Ammonia<br>TDS & TSS<br>Chromium<br>Selenium<br>Zinc | Iron<br>Arsenic<br>Copper<br>Aluminum | Sulfate<br>Cadmium<br>Mercury<br>Nickel |
| Sanitary Waste | BOD**<br>Phosphates | COD††<br>Fecal Coliform | Nitrates<br>TSS |

*TDS is total dissolved solids
†TSS is total suspended solids
**BOD is biological oxygen demand.
††COD is chemical oxygen demand.

Source: GCII, 1986.

Sufficient pollution control technology is employed within the constraints imposed by guidelines, site conditions, and water conservation to minimize these impacts. In general, reuse of water is contemplated wherever feasible. Technology used has been kept simple.

A listing of major wastewater streams and treatment options along with recommended methods is given below:

A. Cooling Tower Blowdown: Cooling tower blowdown is estimated to be approximately 2,900 $m^3$/day at eight cycles of concentration. Under these operating conditions the recirculating water system is expected to be slightly scale forming. The recirculating water would require acidification with a small quantity of an organic dispersant. Cooling water is not expected to require appreciable use of corrosion inhibitors.

   Options for disposition of cooling tower blowdown are: (1) evaporation, or (2) reuse. The reuse option was selected in order to conserve treated water and to save evaporation pond land area.

B. Water Treatment Wastes

   1. Clarifier Underflow: This stream consists of sludge from coagulation cold lime softening process. Waste is high in suspended solids. This waste stream will be directed to the miscellaneous waste evaporation pond.

   2. Filter Backwash: This waste stream results from the backwashing of pressure filters. The waste stream is 40-200 mg/L of suspended solids and can be reused in ash disposal or FGD systems. Reuse of this stream is the preferred method of disposal.

3. Demineralizer Backwash: This stream consists of acid and caustic wastes, rinses from the makeup demineralizers. These wastes will be collected in a tank, and they tend to self-neutralize. Wastes are high in total dissolved solids. This waste stream will be directed to the miscellaneous waste evaporation pond or to the ash disposal pond as dictated by plant operations requirements.

C. Oily Wastes: These waste streams originate from floor drains, equipment drains, turbine area sump and yard drains. Wastewaters contain suspended solids and oil. Oil separation and suspended solids settling were considered; however, in keeping with the general philosophy of conserving water and minimizing mechanical equipment, it was decided to collect these wastes and reuse them to spray over the coal pile for dust suppression.

D. Coal Pile Runoff: Coal pile runoff is expected to be minimal due to low rainfall at all three Lakhra sites. Runoff, if any, will be directed to the miscellaneous waste evaporation pond.

E. Chemical Cleaning Wastes: Chemical cleaning of the boiler is performed after installation and prior to the first service use. Thereafter, the frequency is every 4 to 5 years or more often depending upon in-service conditions.

Chemical wastes contain heavy metals, acid, amines, and passivating agents. Chemical wastes will be collected in a tank, neutralized, and pumped to the miscellaneous waste evaporation pond. This neutralized water could block the interstices of sand due to precipitation of heavy metals. It can also infiltrate heavy metals into the ground water. This waste is classified as hazardous. The miscellaneous waste

evaporation pond will be sealed using a synthetic material lining to mitigate the possibility of leakage of hazardous materials.

F. Boiler Blowdown: Boiler blowdown will be used in the bottom ash sluice system in order to reuse the water. Boiler washes, air heater washes, and overflows will also be used in the bottom ash sluice system.

G. FGD/Fly Ash Water: FGD system and fly ash sluice system water will be ponded and reused. The system is not expected to have any overflows due to evaporation exceeding precipitation for this area of Pakistan.

H. Bottom Ash Water: Bottom ash will be wet sluiced, ponded, and reused. The system is not expected to have any overflow.

I. Sanitary Waste: Sanitary waste will originate from human occupancy at the power plant complex and the workers' colony at the site. It is expected that 7500 persons will live and work at the colony and the plant.

Design Criteria

| | |
|---|---|
| Population Equivalent (P.E.) | 7500 |
| Flow @ gpd | 1845 $m^3$/day (487,500 gpd) |
| $BOD_5$ P.E. x 0.17 | 578 kg/day (1,275 lbs/day) |
| TSS, P.E. x 0.2 | 680 kg/day (1,500 lbs/day) |

Sanitary wastewater will be treated in a separate plant. Major options available for sanitary waste treatment are as follows:

1. Septic tank and seepage field,
2. Primary settling and land disposal,



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3. Secondary treatment and land disposal, and
4. Secondary treatment and reuse.

Depending upon the wastewater volume, a septic tank and seepage field is the most inexpensive solution, provided the percolation rate is adequate and the land is available for a seepage field.

Primary treatment using a stabilization pond and land disposal could also be used fairly inexpensively depending on the geology, hydrology, and other site conditions. A surface stabilization pond could cause some odors under certain conditions.

An activated sludge plant would require more operation and maintenance compared to the previous two methods. However, the plant will produce a stable effluent treated to a $BOD_5$ of 30 mg/L and suspended solids of 30 mg/L. Chlorination of the effluent would reduce the total and fecal coliform counts to within World Bank guidelines. Effluent can be disposed of on land, discharged to a waterway, or reused in the FGD or ash disposal systems. The land disposal option can be exercised in quite a few ways:

1. Spray irrigation,
2. Rapid infiltration and evaporation,
3. Slow rate infiltration by ridge and furrow distribution, and
4. Subsurface disposal.

For the purposes of this study, a secondary biological package system was considered because it is the most versatile and it is not site-specific. It should be recognized that an economic and site-specific evaluation should be performed to select and design the system during the design phase. In addition, the effluent will be reused in the FGD or ash disposal systems.

Sludge will be digested and recycled as humus to the local colony's landscaping and gardening needs.



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### D.3.3 COOLING SYSTEMS

The closed-cycle cooling water system is designed to circulate cooled condensate through a closed-loop system to all major equipment coolers in the main turbine generator area and the boiler area.

There are two 100-percent-capacity, closed-cycle cooling water pumps. One pump circulates the water through the system during normal plant operation.

A closed-cycle cooling water head tank, vented to atmosphere, is included and located at the highest point in the system. The head tank is provided to maintain a reserve volume of treated condensate and to maintain positive pressure on the pump suction piping. A level control valve with a manual bypass admits condensate makeup to replace system leakage.

A chemical treatment tank is connected across the cooling water pumps to introduce chemicals into the suction header when required.

The water passes through the shell side of the two station service heat exchangers for cooling during normal plant operating conditions. The cooling water through the tubes of these heat exchangers is supplied from the plant circulating water system. A closed condensate bypass around these heat exchangers is controlled automatically to limit the minimum cooling water temperature.

The major components of this system are the closed-cycle cooling water pumps, station service water heat exchangers, all station auxiliary coolers, closed-cycle cooling water head tank, chemical fill tank, piping, instruments, and controls.

### D.3.4 STATION CONSUMPTIVE USES

The makeup and service water system is designed to supply makeup water to the cooling tower and thus to replace losses due to evaporation, drift,

and blowdown. Additionally, makeup water is supplied for the ash handling system and, if used, the FGD system. The system also supplies water for air heater wash, pump seals, demineralizer, fire protection, and potable water.

The major components of this system are:

1. Makeup water pumps,
2. Trash racks,
3. Traveling screens,
4. Screen wash water pumps,
5. Makeup control valve,
6. Holding ponds,
7. Storage tanks, and
8. Makeup water piping from the Indus River to the plant.

Water is supplied to the system by one of two 100-percent-capacity, vertical wet-pit type makeup pumps, through trash racks and traveling waterscreens from the Indus. There are two 100-percent-capacity, vertical wet-pit type screen wash water pumps, with suctions downstream of the traveling screens. Either pump will operate to wash one or both screens, automatically or by manual control.

Water is pumped to onsite storage ponds which settle out some suspended solids and provide an emergency storage for the makeup water system. The water supply is pumped from the storage ponds through reactor clarifiers and filters to remove suspended solids and some hardness. Makeup to cooling towers can be unfiltered or filtered, depending upon raw water suspended solids concentration. Water for other plant services is treated and stored in a tank until used.

One 100-percent-capacity, cooling-tower makeup pump runs continuously at all loads and during shutdown when cooling load is required. A second

100-percent-capacity pump is provided as standby. The system is designed for operation at all loads including shutdown requirements.

The water pretreatment plant will treat the incoming Indus River water (see Makeup and Treatment Water System Description). Treatment will remove suspended solids and some hardness. Three 50 percent flow rate reactor clarifiers will be used to treat the water. Alum, lime, and a polymer (if required during high flow conditions) will be added. Clarified water will be filtered through pressure filters filled with graded anthracite. Service water and water for inplant use will be stored in a filtered water storage tank. Makeup water for the circulating water system can be either clarified water or filtered water. Makeup water for the boiler feed system will be treated further in demineralizer trains, as described in the Makeup Demineralizer Description.

Potable water for plant personnel use and the associated worker's colony will be the filtered water from the water treatment plant which will be stored in an elevated tank. The elevated tank will be used for both fire protection water and potable water. A standpipe will be used in the storage tank to supply water for potable use to the distribution system in the worker's colony and within the plant.

### D.3.5 INDUSTRIAL WASTE DISPOSAL SYSTEM

The wastewater disposal system is designed to treat the various wastes to minimize adverse environmental impact and to minimize the waste discharges. Water reuse is employed wherever practical. Only one stream, chemical cleaning waste, will be treated. The remaining streams are reused, recycled, or ponded for evaporation without any treatment. A description of the various streams and their disposition is described below:

1. Cooling Tower Blowdown: Blowdown from the cooling tower is used in the ash handling system. Blowdown is directed to the bottom ash pond.

2. Boiler washes, air heater washes, seal and cooling water, and ash pit overflows are collected in a sump near the boiler. These wastes are pumped to the bottom ash pond and reused.
3. Demineralizer Regenerant Wastes: Acid and caustic wastes and rinses from the makeup demineralizers are collected in a tank where they combine and tend to self-neutralize. The wastes are pumped to the miscellaneous waste evaporation pond.
4. Oily Wastes: Floor drains, equipment drains, turbine area sump, and yard drains are collected in a pond. Wastes contain oil and suspended solids. These wastes are collected in a sump or tank and are sprayed on the coal pile for fire suppression.
5. Makeup Water Pretreatment: Sludge from the water treatment plant is disposed of in the miscellaneous waste evaporation pond.
6. Filter Backwash: Water filtration plant backwash is directed to the bottom ash sluice system for reuse.
7. Coal Pile Runoff: Coal pile runoff is expected to be minimal, if any. Any coal pile runoff will be directed to the miscellaneous waste evaporation pond.
8. Chemical Cleaning Wastes: Chemical cleaning wastes which occur prior to plant startup and infrequently thereafter are directed to a holding tank. The wastes are neutralized and pumped to the miscellaneous waste evaporation pond.

The only waste steam requiring treatment is the chemical cleaning wastes, and treatment is required infrequently. The treatment consists of equalization and neutralization. The waste tank is equipped with an agitator and a recycle pump. The tank is equipped with level switches. A pH controller is provided to pace the acid and caustic pumps which are fed in the pump recirculating line. Acid and caustic clay tanks and metering pumps are provided (to feed the chemical) and are paced by the pH controller signal. The tank will be lined with corrosion-resistant linings to accommodate pH swings of 1-12. Piping, pumps, and valves are of corrosion-resistant materials.

# D.4 SOLID WASTE: SOURCES, TREATMENT, HANDLING, TRANSPORTATION AND DISPOSAL

## D.4.1 FLY ASH HANDLING

The purpose of the fly ash handling system is to automatically unload and convey dry, free-flowing fly ash from the precipitator, economizer, and air heater hoppers. The fly ash is either transported dry to a storage silo where it is unloaded into trucks for transport offsite, or wet to a storage pond onsite.

The system will be a dry-vacuum type. The dry fly ash will be fed from the various hoppers into an ash transport piping network. The vacuum will be induced by a hydraulic exhauster. The vacuum system will convey the fly ash from the dust-collector hoppers to the ash-storage silo. The fly ash will be separated at the silo by a cyclone separator and a bag filter. The ash will be discharged into the silo, and the remaining air will flow to the suction side of the hydraulic exhauster where it will be mixed with motive water supplied by one of two full-capacity ash water supply pumps. In a secondary operating mode, the separator and/or bag filter will be bypassed, and ash will be conveyed to the hydraulic exhauster. At the exhauster, the high pressure motive water will be mixed with the fly ash conveying air stream and conveyed to an air separator tank. The air will be removed from the slurry at the air separator and vented to the atmosphere from the air separator, and the slurry will flow by gravity to the ash pond. The ash water supply pumps will recirculate water from the ash pond.

The fly ash vacuum piping will be arranged with one branch per precipitator field or row of economizer or air heater hoppers. Each branch will have a spring-loaded air intake valve to admit air for transport of the fly ash. Each branch will have a pneumatically operated conveyor line branch segregating valve.

Each hopper will be provided with a solenoid-controlled, penumatically operated fly ash intake valve and a manually operated emergency slide gate valve. The control system will provide for automatic sequencing of the hopper intake valves.

### D.4.2 BOTTOM ASH HANDLING

The purpose of the bottom ash handling system is to remove ash from the boiler ash hopper and convey it to the onsite bottom ash pond.

The bottom ash from the boiler furnace will be collected in the furnace bottom ash hopper which includes a furnace seal and discharge gate. A clinker-grinder on the discharge of the bottom ash hopper will grind ash to an appropriate size for conveying.

Hydraulic ejectors will be used to provide motive force for fly ash conveying to the ash pond. The motive water will be supplied from one of two bottom ash water booster pumps which will recirculate water from the bottom ash pond.

## D.5 FIRE PROTECTION

The fire protection system provides early detection of fires and warning for plant personnel and provides manual and automatic means of fighting fires.

The major components of the plant and yard fire protection systems are:

1. Deluge valves, associated trim piping, fire detectors, control panels and manual stations, and spray nozzles;
2. Alarm check valves for wet systems, fusible sprinkler heads;
3. Standpipe and hose stations and associated manual actuation stations;
4. Halon storage cylinders, associated automatic valves, smoke detectors, discharge nozzles, manual actuation station, and control panels;

5. Yard fire hydrants and associated hose houses;
6. One electric motor-driven fire pump;
7. One diesel engine-driven fire pump; and
8. One jockey pump.

The in-plant and yard fire protection system will provide fire detection, alarm, and automatic and manual suppression for the various hazards in the plant and yard areas. Deluge systems may be applied to the following hazards:

1. Hydrogen Seal Oil Unit,
2. Turbine Oil Reservoir,
3. ID and FD Fan Lube Oil Reservoir,
4. Oil-Filled Main, Start-up and Station Power Transformers, and
5. Coal Handling Areas.

The deluge systems are automatically activated by heat detectors or by manual-pull stations. The system is equipped with open sprinklers and upon heat detection or by manual activation, the deluge valve opens and water flows to the piping system and discharges from all sprinklers. Local and remote alarms activate to provide warning of the condition.

Wet sprinkler systems may be applied to the following areas:

1. Diesel Generator Area,
2. Cable Spreading Room,
3. General Office Areas,
4. Assembly/Meeting Rooms, and
5. Main Fire Pump Room and Diesel Fire Pump Day Tank Area.

A wet sprinkler system is equipped with closed sprinklers and piping filled with water. An alarm check valve monitors flow in the system. If a sprinkler fuses due to fire, water flows and discharges from the open sprinkler head. A local and remote alarm activates upon water flow to annunciate the condition and cause the fire pumps to turn on.

The pre-action sprinkler system may be applied to the following areas:

1. Turbine generator bearings,
2. Boiler feed pump, and
3. Turbine generator governor housing.

Pre-action sprinkler systems are equipped with closed sprinkler heads and piping normally filled with air that may or may not be under pressure. A supplemental fire detection system is installed in the same area as the sprinklers. When activated as from a fire, the fire detection system opens the normally closed pre-action valve and permits water to flow into the sprinkler piping system and be discharged from any sprinkler which may be open. Local and remote alarms activate to annunciate the condition.

The main control room and the computer room will be equipped with halon extinguishing systems. Halon is a colorless, odorless, electrically non-conductive gas, ideal for fire suppression in clean areas. Halon can be automatically released to the space by signal from smoke detectors located in the room. The halon gas is stored in pressurized cylinders with extra cylinders to store an additional 100-percent-discharge capacity.

Standpipe and hose stations will be located throughout the plant for manual fire fighting use. Yard fire hydrants will be located throughout the yard for manual fire fighting use.

Water to various extinguishing systems will supplied by a 126 L/s (2,000 gal/min) electric fire pump, which has a 100-percent-capacity, diesel fire pump backup. The pump will draw water from a 950-$m^3$ (250,000-gallon) overhead water tank located 30 m (100 ft) above grade.

Pump starting will be controlled by automatic or manual means. The electric fire pump would be arranged to start upon decrease of system

pressure below a pre-set level beyond that which the jockey pump cannot maintain. The electric fire pump can be manually started if required. The diesel fire pump would be arranged to be the primary pump upon loss of power to the electric fire pump. The method for automatic or manual starting would be similar.

## D.6 TRANSMISSION SYSTEM

### D.6.1 INTRODUCTION

Transmission system alternatives have been developed for the Lakhra and Khanot power plant sites. The Jamshoro site is located nearby the Jamshoro 220/500 kV substation and therefore does not require substantial transmission facilities.

The WAPDA electric grid currently uses voltages of 66 kV, 132 kV, 220 kV, and 500 kV. Since these voltages have been adopted as standard in Pakistan and since these voltage levels are sufficient for transmission of large blocks of power, it is proper to limit the scope of the transmission analysis to consider only these existing voltage levels.

A large proportion of the generating capacity in Pakistan is provided by hydro-electric units. The hydro-electric power is at its peak capability during the high water months and at minimum during low water months. The hydro-electric generation is located in the northern sections of Pakistan. During high water periods, with peak hydro-electric generation, the power flow on the 500-kV transmission grid will be from the north to the south. During low water months, thermal generation is brought on-line to supplement the reduced hydro-capability. As a result, the flow on the transmission system can be substantially different depending on hydrological conditions. The transmission for the Lakhra power plant is evaluated for both high water and low water periods.



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An extensive 500-kV and 220-kV bulk transmission system is being developed in a general north-south orientation paralleling the Indus River in Pakistan. The bulk of the hydro-electric generation is located in the north. The Lakhra coal project is located in the south near Hyderabad. The proposed 500-kV grid begins at the hydro-electric generation in the north and extends south, terminating at a 500/220/132 kV substation at Jamshoro near Hyderabad. From Jamshoro, 220 kV extends south to the city of Karachi and a short distance easterly across the Indus River.

The first 500-kV circuit into Jamshoro is currently in service but operating at 220 kV. This circuit will be energized at 500-kV, and a 450-MVA, 500/220-kV transformer placed in service at Jamshoro in mid-1987. A second 500-kV circuit and second 450-MVA, 500/220-kV transformer are planned for service in 1989.

Two oil-fired steam generating units are planned for construction and connection to the transmission grid at 220-kV at Jamshoro. The first unit is 250 MW and is to be in service by late 1988. The second unit is 210 MW and is to be in service by early 1990.

The Lakhra coal units are planned to come in service after the oil-fired units. Lakhra Unit 1 is tentatively scheduled for early 1992 and Unit 2 for late 1992.

### D.6.2 TRANSMISSION ALTERNATIVES

There are three transmission voltages in the general vicinity of the power plant sites: 132, 220 and 500 kV (Figure D-1). A single 132-kV transmission line runs north from Jamshoro near the Khanot site to supply settlements along the west side of the Indus River. This circuit is not capable of transmitting the power of even a single 275-MW unit and need not be considered further for bulk transmission purposes.



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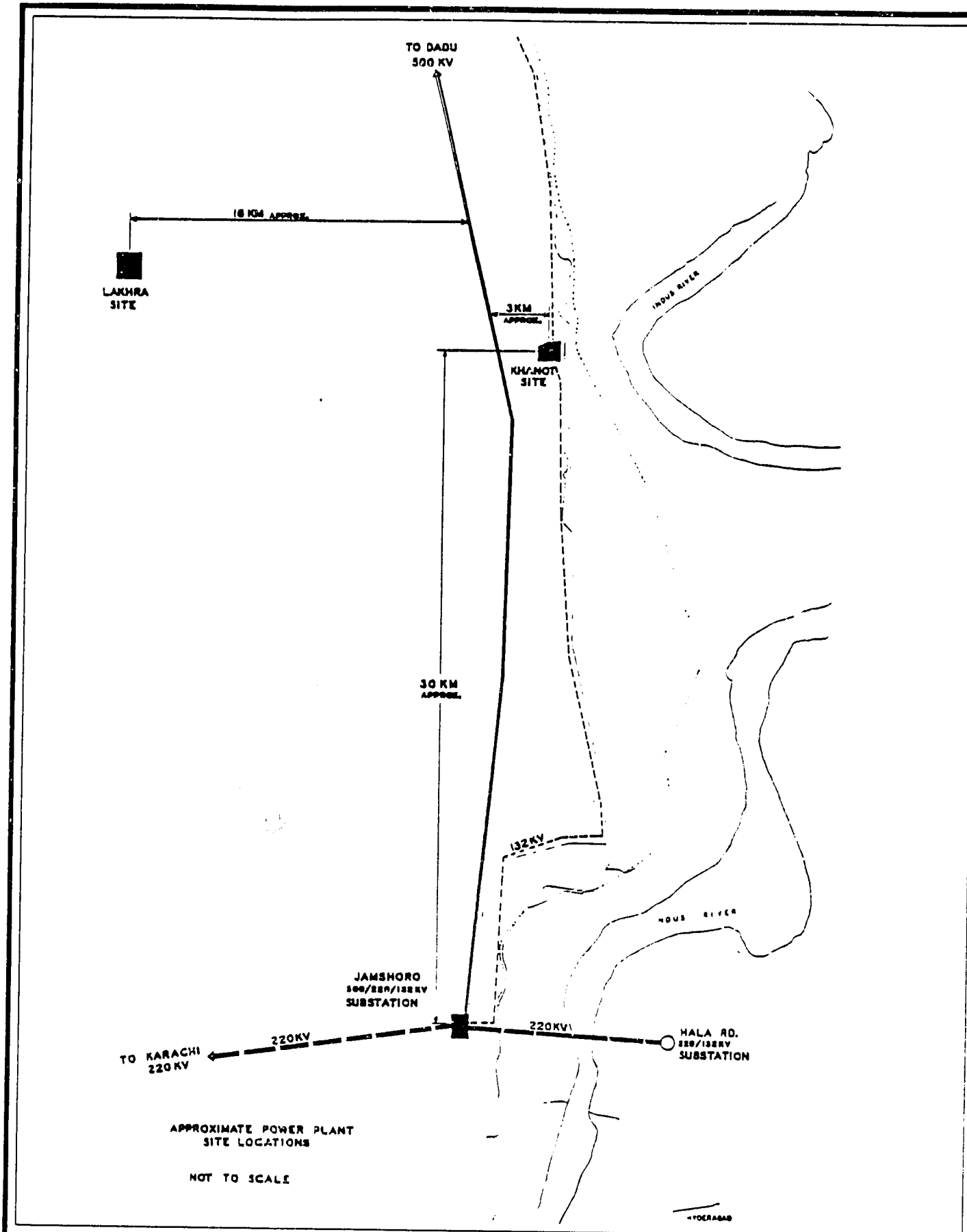


Figure D-1
POWER PLANT SITES AND TRANSMISSION LINES

SOURCE: GCII, 1985.

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

Both the 500-kV and 220-kV voltage levels are reasonable candidates for connecting two 275-MW power plants to the system. The Khanot power plant site is within 3 km of the existing 500-kV line. The nearest 220-kV line to the Khanot and Lakhra sites is at Jamshoro.

A 500-kV and a 220-kV alternative transmission plan was developed for both of the power plant sites. This results in four alternative transmission plans which are shown on Figure D-2.

If the power plant is located at the Khanot site, it can be connected into the 500-kV system by building two sections of single-circuit, 500-kV lines each 3 km long. The 220-kV alternative for the Khanot site would require building approximately 33 km of 220-kV line from Khanot to Jamshoro. Two 220-kV circuits would be required with the first unit, and one additional circuit would be needed for Unit 2.

If the power plant is located at the Lakhra site, two 16-km sections of 500-kV line would be required to connect the power plant to the 500-kV system. The 220-kV alternate requires approximately 46 km of 220-kV circuit from Lakhra to Jamshoro. Two 220-kV circuits would be required with the first unit, and one additional 220-kV circuits would be needed for Unit 2.



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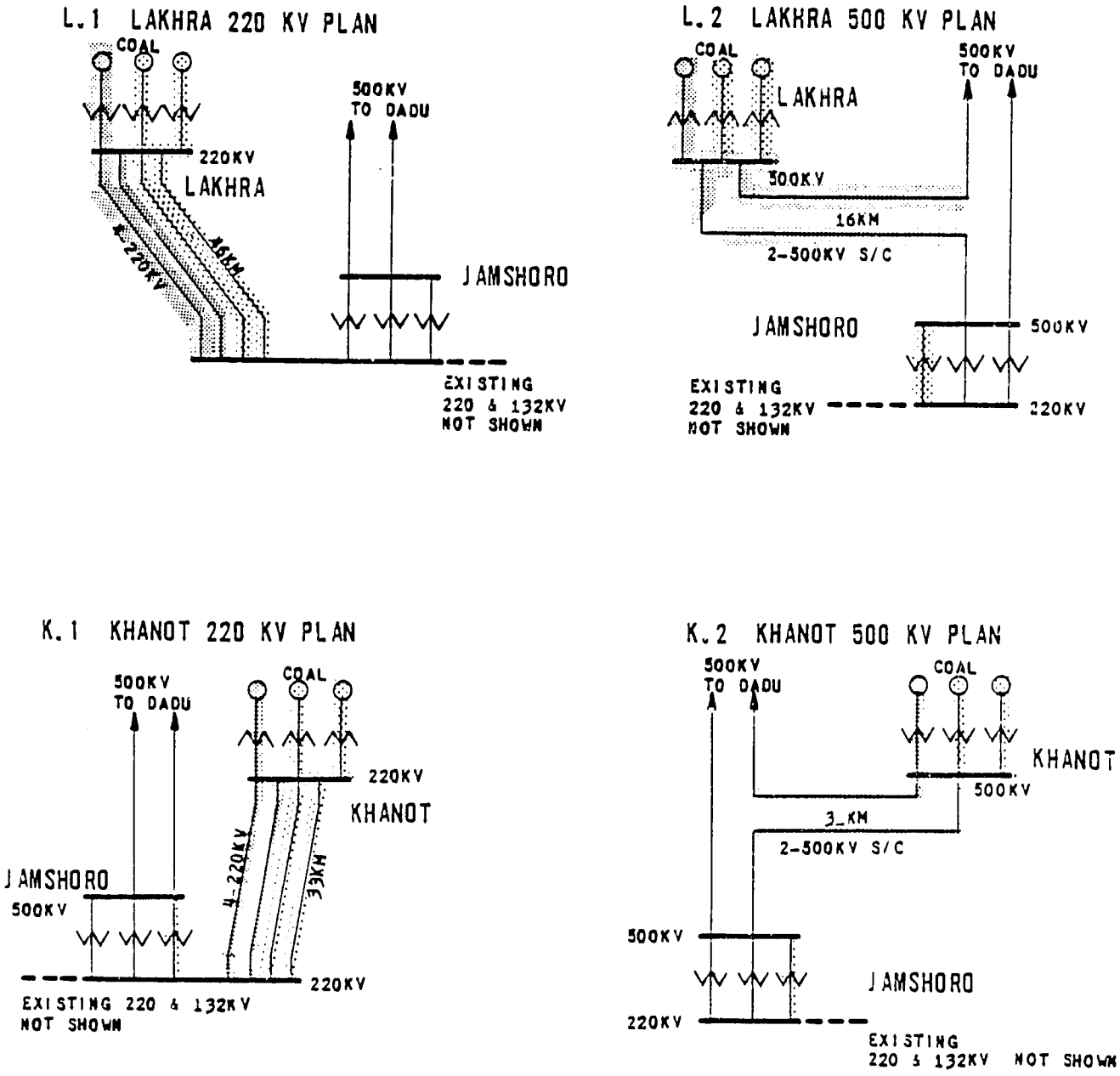


Figure D-2
220- AND 500-kV ALTERNATIVE TRANSMISSION PLANS FOR LAKHRA AND KHANOT SITES

SOURCE: GCII, 1985.

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

## D.7 EMPLOYMENT, TAXES, AND INFRASTRUCTURE

### D.7.1 CHANGE IN EMPLOYMENT AND ECONOMIC PATTERNS

Development of the proposed Lakhra Project will cause a large influx of construction and operation workers to build and operate the power plant, mines, and residential colony. Figure D-3 shows this change over the life of the project. Table D-2 lists by year the estimated numbers of people who will work for the project or live at the colony. As shown in the table, during Construction Years D-6 to D-1, between 2,000 and 7,700 workers will be employed annually in the construction and start-up of the project. Most of these workers will be involved with the construction of the mine, especially during Years D-6 to D-3, and the power plant during Years D-4 to D+1.

During the operation period between Years D+1 and D+30, workers will be employed mining coal, operating the power plant, and maintaining the colony. As shown in Table D-2, a majority of these workers will be employed in mining operations. The number of workers will decrease during the first 2 years of operation as the remaining construction workers depart. During Years D+3 to D+20, the work force will stabilize at about 3,200 workers, with a slight decrease as the positions of expatriates are taken over by Pakistanis in the coal mining operation.

Most of the people living in the workers' colony will be family members of construction and operation workers. During the early years of construction and operation of the large oil-fired Guddu Generating Station, significant numbers of single workers were employed. Over time many married, had children, and had other members of their family join them. During 1986, 18 years after the start of construction of the Guddu facility, the ratio of workers to dependents was 7 dependents for every worker. Following the patterns at Guddu, the process used to estimate the number of dependents at Lakhra, shown in Table D-2, assumes that in the first year (D-6), the average ratio of workers to dependents will be



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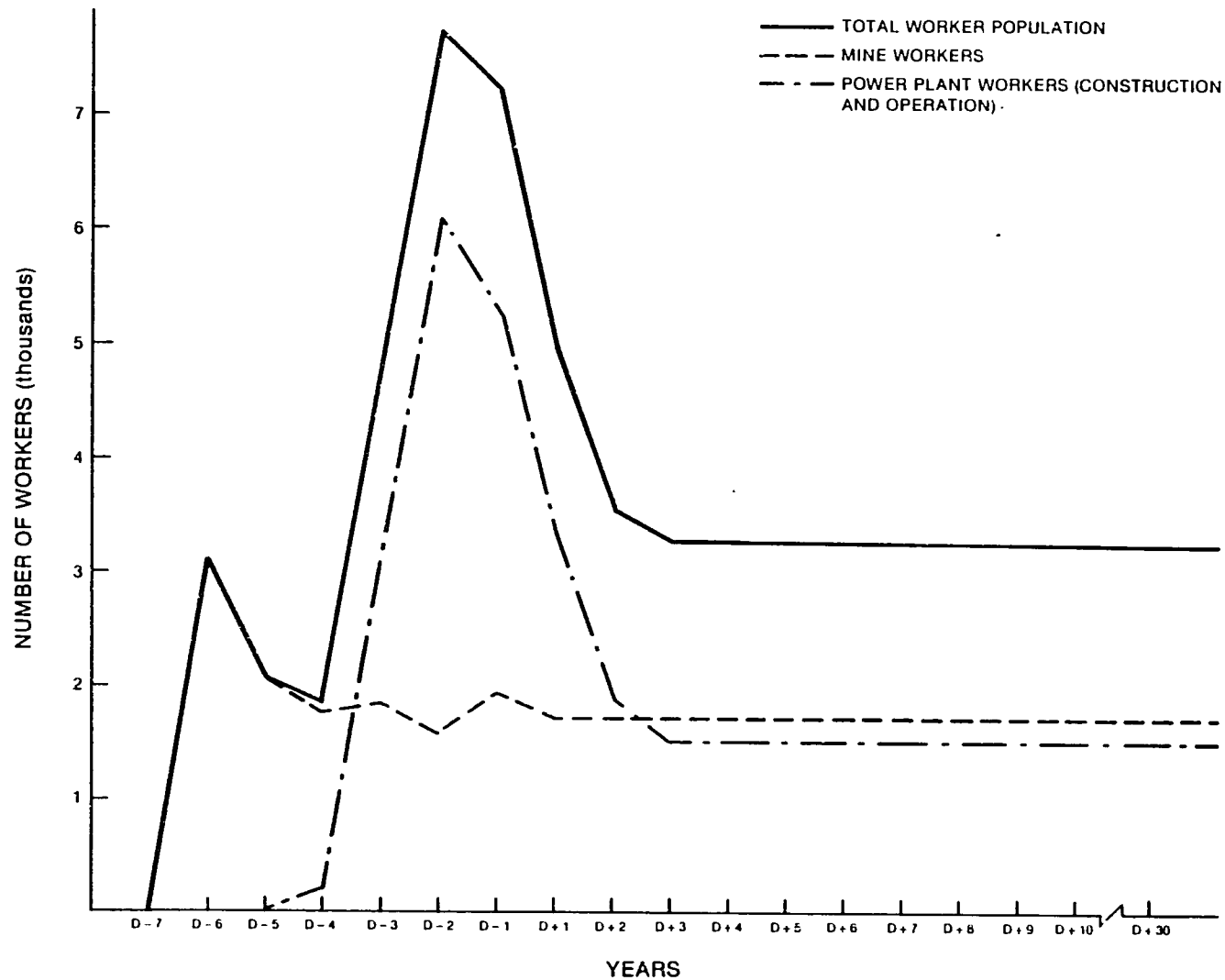


Figure D-3
COMPARISON OF THE CHANGE IN NUMBER OF WORKERS (TOTAL WORK FORCE, MINE AND POWER PLANT) DURING THE LIFE OF THE PROJECT

SOURCE: ADAPTED FROM GCII, 1986.

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

USAID PAKISTAN 08/86

Table D-2. Projected Number of Workers, Dependents, and Total Population Associated with Lakhra Project

| Years | Start-Up Phase | | | | | | Operation Phase | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D-6 | D-5 | D-4 | D-3 | D-2 | D-1 | D+1 | D+2 | D+3 | D+4 | D+5 | Avg. D+6 to D+10 | Avg. D+11 to D+15 | Avg. D+16 to D+20 | Avg. D+21 to D+25 | Avg. D+26 to D+30 |
| Surface Mine East Pit | 0 | 67 | 117 | 164 | 242 | 347 | 512 | 512 | 512 | 510 | 506 | 501 | 501 | 500 | 500 | 500 |
| Surace Mine West Pit | 0 | 0 | 139 | 228 | 292 | 327 | 323 | 323 | 323 | 321 | 317 | 313 | 284 | 284 | 284 | 284 |
| First Underground Mine* | 0 | 0 | 3 | 95 | 210 | 511 | 516 | 516 | 516 | 516 | 516 | 516 | 497 | 229 | 0 | 0 |
| Second Underground Mine* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 287 | 516 | 516 |
| Common Mine Facilities | 14 | 55 | 89 | 106 | 115 | 171 | 181 | 181 | 180 | 180 | 180 | 179 | 179 | 179 | 179 | 179 |
| Mine Infrastructure† | 2 | 8 | 44 | 71 | 148 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 | 215 |
| Mine Construction** | 3,140 | 1,965 | 1,395 | 1,167 | 589 | 365 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Power Plant | 0 | 0 | 0 | 6 | 21 | 872 | 1,543 | 1,543 | 1,543 | 1,543 | 1,543 | 1,543 | 1,543 | 1,543 | 1,543 | 1,543 |
| Power Plant Construction** | 0 | 0 | 200 | 3,198 | 6,115 | 4,445 | 1,762 | 366 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Workers | 3,156 | 2,095 | 1,986 | 5,035 | 7,732 | 7,253 | 5,052 | 3,656 | 3,289 | 3,285 | 3,277 | 3,267 | 3,238 | 3,237 | 3,237 | 3,237 |
| Dependents†† | 3,156 | 2,367 | 2,542 | 7,200 | 12,294 | 13,838 | 9,851 | 7,860 | 7,762 | 8,508 | 9,274 | 11,828 | 15,847 | 18,930 | 20,205 | 20,264 |
| Total Population | 6,312 | 4,462 | 4,528 | 12,235 | 20,026 | 20,091 | 14,903 | 11,516 | 11,051 | 11,793 | 12,551 | 15,095 | 19,085 | 22,167 | 23,442 | 23,501 |

*First underground mine will operate during years D+1 to D+18. Second underground mine will start as production tapers off from first mine.
†Power plant infrastructure workers are included in overall power plant tabulations.
**Workers employed solely for construction who are not intended to become part of the operational staff.
††Number of dependents assumes an average ratio of 2 colony residents per worker during year D-6 and an annual growth rate in the ratio of residents to workers of 6.7 percent annually through year D+6, and then a decline in the growth rate of 0.392 percent annually. Using this assumption, ratio of 7 colony residents per worker will be reached in year D+19. A stable ratio of 7.26 residents per worker will be reached in year D+23.

Source: GCII, 1986.

2 dependents to every worker and that this ratio will grow at an annual rate of 6.7 percent during the period D-6 and D+6. After Year D+6 the growth rate in the ratio is assumed to decline at a rate of 0.392 percent a year until a ratio of approximately 7 dependents for each worker is reached about Year D+23.

The total number of people projected to live in the colony, as shown in Table D-2, will vary during the 36-year life of the facility from about 4,500 to about 23,500. This variation will be due principally to the growth in the number of dependents and the arrival and departure of construction workers during Years D-6 to D+2.

D.7.2 TAXES

Several types of taxes and duties will be collected from the Lakhra Project by the Government of Pakistan, the Government of Sind, and the Dadu District Government. Because it is a Government of Pakistan agency, WAPDA has requested that several of these taxes and duties be waived, as noted below.

Income taxes on Lakhra Project workers' salaries will be collected by the Government of Pakistan. Table D-3 summarizes anticipated annual salary disbursements for the 6-year start-up phase and 30-year operational phase of the project. All salaries for WAPDA power plant employees include a 50 percent generation allowance (to a maximum of Rs 1,500 per month) in addition to the normal WAPDA basic pay scale. This generation allowance is intended to compensate WAPDA employees for the remote living conditions encountered at the Khanot/Lakhra site. Total project payroll will be the greatest during the start-up period due to mine and power plant construction activities. During the start-up years of D-6 to D-1, total project annual payroll will average Rs 222,426,000, with 82 percent coming from construction-related activities. During the operation years of D+1 to D+30, annual project payroll will average Rs 93,113,000. The average worker salary will be Rs 49,566 during the start-up phase and

Table D-3. Estimated Payroll and Income Tax (Thousands of Rupees and Thousands of Dollars) for the Lakhra Project

| Years | Start-Up Phase | | | | | | Operation Phase | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D-6 | D-5 | D-4 | D-3 | D-2 | D-1 | D+1 | D+2 | D+3 | D+4 | D+5 | Avg. D+6 to D+10 | Avg. D+11 to D+15 | Avg. D+16 to D+20 | Avg. D+21 to D+25 | Avg. D+26 to D+30 |
| Total Payroll (Rs) | 112,514 | 89,269 | 149,401 | 194,670 | 409,582 | 379,120 | 164,671 | 122,858 | 111,182 | 106,597 | 100,145 | 89,808 | 87,593 | 86,729 | 86,729 | 86,729 |
| Total Payroll ($) | 7,032 | 5,579 | 9,338 | 12,167 | 25,599 | 23,695 | 10,292 | 7,679 | 6,949 | 6,662 | 6,255 | 5,613 | 5,475 | 5,421 | 5,421 | 5,421 |
| Total Income Tax (Rs) | 8,253 | 11,429 | 39,993 | 25,505 | 86,860 | 87,134 | 21,515 | 19,487 | 18,729 | 16,848 | 14,258 | 10,107 | 9,451 | 9,101 | 9,101 | 9,101 |
| Total Income Tax ($) | 516 | 714 | 2,500 | 1,594 | 5,429 | 5,446 | 1,345 | 1,218 | 1,171 | 1,053 | 891 | 632 | 591 | 569 | 569 | 569 |

Source: Adapted from GCII, 1986.

Rs 27,920 during the operational phase. The infusion of these millions of rupees into the Hyderabad-Khanot-Lakhra area will be a major stimulus to the local economic system.

Table D-3 presents estimated annual income tax collections from project workers' salaries by the Government of Pakistan. During the project start-up phase, annual income tax collections will average Rs 43,196,000. During the operation phase, annual income tax collections will average Rs 10,838,000. Overall annual average tax payments will be Rs 16,231,000 for the 36-year life of the project. Each worker will pay an annual average income tax of Rs 9,420 during the start-up phase of the project and Rs 3,233 during the operational phase of the project.

Coal separation (royalty) taxes will be paid to the Government of Sind at the rate of Rs 15 per ton of coal mined. Tax payments will average Rs 41,017,000 annually for 33 years of coal production. WAPDA has requested that this tax be waived.

A miners welfare tax of 2 rupees per ton is paid to assist in meeting medical and retirement costs. Annual collections will average an estimated Rs 5,469,000 for the 33-year production life of the mines. Because the Lakhra Project will provide the miners with various services, WAPDA has proposed that this tax be waived.

Duties and sales taxes are normally paid on the value of equipment imported into Pakistan. Imported equipment will consist primarily of large or specialized single units or assemblages not readily available from Pakistani sources. WAPDA has requested that all duty and sales tax on imported equipment be waived.

Duties and sales taxes would be collected during years D-5 to D+3 and were estimated at the 45 percent, 22.5 percent, and 5 percent levels. At the 45 percent level, total collections would be about Rs 2.95 billion,

with annual collections averaging Rs 369,080,000 for 8 years. At the 22.5 percent level, total collections would be Rs 1.48 billion with an annual collection averaging Rs 184,540,000 for 8 years. At the 5 percent level, total collections would be Rs 328,071,000 with annual collections averaging Rs 41,009,000 for 8 years.

Other taxes which could be paid by the Lakhra Project include taxes on the profits of expatriate companies working on the project, octroi charges, and road tolls. The amount of these taxes cannot be estimated at the present time.

### D.7.3 INCREASED DEMAND UPON EXISTING FACILITIES AND SERVICES

The development of the mine along with the power plant will require additional housing, health care, education, police, fire protection, and transportation facilities and services. For the workers directly associated with the Lakhra project these will be provided. The following sections discuss the general nature of these facilities and services.

#### D.7.3.1 HOUSING

WAPDA and the future mine operator will provide housing for all employees and their dependents by constructing a residential colony. The type of housing will depend on the basic pay scale of the employee. The numbers of housing units planned in the residential colony are presented in Table D-4.

#### D.7.3.2 HEALTH CARE

The cost to the Government of Sind to provide these services has been estimated by establishing a conceptual 10-bed medical care facility for a new community of 8,000 persons. The generalized costs are presented in Table D-5.

#### D.7.3.3 EDUCATION

Educational needs will be significantly increased because of the project. These needs will be partially met by the project.



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Table D-4. Mine and Power Plant Housing Units

| WAPDA Housing Class | WAPDA Square Footage | Number of WAPDA Units | Number of Equivalent Mining Company Units | Total Units in Colony |
|---|---|---|---|---|
| I | 3,000 | 5 | 8 | 13 |
| II | 2,500 | 26 | 61 | 87 |
| III | 1,500 | 78 | 76 | 154 |
| IV | 1,000 | 103 | 857 | 960 |
| V | 606 | 256 | 224 | 480 |
| VI | 520 | 813 | 223 | 1,036 |
| Single Officer | | 31 | 35 | 66 |
| Single Worker | | 231 | 263 | 494 |
| Total Units | | 1,543 | 1,747 | 3,290 |

Source: GCII, 1986.

Table D-5. Estimated Capital and Operation Costs for 10-Bed Medical Facility

| | |
|---|---|
| Start-Up Costs: | |
| Building Construction | Rs 1,000,000 |
| Equipment | 1,500,000 |
| Administration | 200,000 |
| Total | 2,700,000 |
| Annual Costs | |
| Medical Staff | Rs 252,000 |
| Support Staff | 158,000 |
| Facility Maintenance | 100,000 |
| Supplies | 200,000 |
| Total | 710,000 |

Source: GCII, 1986.

Educational needs of the Lakhra Project workers and their dependents living in the colony will be provided by the project. Schools will be provided for primary and secondary classes 1 through 10 and for intermediate college classes 11 and 12. The cost of these facilities and the educational staff is included in the overall costs of the Lakhra Project. Workers at the Lakhra facility will pay a minor fee to enroll their children in the WAPDA schools. The charge at the Guddu colony is 14 Rs per child for each 6 months of schooling.

Schooling for children of parents who are not Lakhra Project employees or their dependents will be made available upon payment of a monthly fee, which will be significantly higher for non-resident children and which is expensive by local economic standards.

Education of children of parents not desiring or able to pay the fee will be the responsibility of the Government of Sind. The cost to the Government of Sind for a Class 1 through 10 school with 500 students is presented in Table D-6.

D.7.3.4 POLICE PROTECTION

Providing police protection and maintenance of law and order for secondary community development will be the responsibility of local governments. The cost estimates presented in Table D-7 are based on a force of 5 officers and 32 patrol constables.

D.7.3.5 GOVERNMENT COSTS AND REVENUE COLLECTION

Several costs to the Government of Pakistan and the Government of Sind have been estimated in the preceding sections for secondary population growth resulting in a new community of 8,000 people. These costs are summarized in Table D-8.

Comparison of costs to government of providing secondary population growth with health, educational, and police services indicates that the



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Table D-6. Estimated Capital and Operating Costs for School with Classes 1-10 and 500 Students

| | |
|---|---|
| Start-up Costs: | |
| Building Construction | Rs 1,000,000 |
| Equipment | 200,000 |
| Administration | 200,000 |
| Total | 1,400,000 |
| Annual Costs: | |
| Professional Staff | 538,000 |
| Other Staff | 114,000 |
| Facility Maintenance | 200,000 |
| Supplies | 100,000 |
| Total | 952,000 |

Source: GCII, 1986.



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Table D-7. Estimated Costs for Police Force of 6 Officers and 32 Patrol Officers

| | |
|---|---|
| Start-up Costs: | |
| Building Construction | Rs 100,000 |
| Equipment | 150,000 |
| Administration | 50,000 |
| Total | 300,000 |
| Annual Costs | |
| Officer Staff | Rs 245,000 |
| Constable Staff | 1,210,000 |
| Other Staff | 44,000 |
| Facility Maintenance | 50,000 |
| Supplies | 100,000 |
| Total | 1,649,000 |

Source: GCII, 1986.

Table D-8. Estimated Costs of Services and Government Resources Associated with the Lakhra Project

| Service | Estimated Cost | |
|---|---|---|
| | Start-up | Annual |
| Health Care | Rs 2,700,000 | Rs 710,000 |
| Education | 1,400,000 | 952,000 |
| Police | 300,00 | 1,649,000 |
| Total | Rs 4,400,000 | Rs 3,311,000 |

| Tax | Average Annual Revenue (Apportioned over 36 Years) |
|---|---|
| Income Taxes from Workers | Rs 15,922,000 |
| Coal Separation Tax | 35,948,000 |
| Miners Welfare Tax | 4,793,000 |
| Import Duties & Sales Tax at 5% | 9,113,000 |
| Total Annual Revenue | Rs 65,776,000 |

Source: GCII, 1986.



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Lakhra Project should not be tasked with funding additional infrastructure services other than those already planned for the residential colony, the Khanot-Lakhra road, and project utility connections.

Assuming that WAPDA is successful in obtaing waivers of the coal separation tax, the miners welfare tax, and the import duty/sales tax, income taxes from project worker salaries are still estimated to provide adequate revenues to fund health, education, and police services for secondary population growth.

D.7.3.6 TRANSPORTATION SYSTEM

Traffic counts on the Indus and National Super Highways were made in early 1986, but the data are not yet available. Estimates by GCII and information from local police offices indicate that from 2,500 to 4,000 vehicles a day use the Indus Highway between Jamshoro and Khanot. Between Karachi and Jamshoro an estimated 10,000 to 12,000 vehicles a day use the National Super Highway. About 45 percent of these vehicles are trucks, 45 percent are automobiles, and 10 percent are buses.

The increased amount of highway traffic attributable to the Lakhra Project cannot be estimated accurately. Many thousands of trips of various lengths will be made over the 4-year construction period of the power plant and the 30-year life of the project. The construction materials and operational supplies will be transported by trucks, the vast majority of which will be similar to those using the highway at present. Transportation of workers will be primarily by bus due to the relatively high personal cost of automobile travel. Most workers will live in the residential colony and are anticipated to make only occasional trips beyond the Khanot-Lakhra area.

Examination of these two highways by GCII and discussions with officials of the Sind Department of Highways indicate that the highways can handle

the increased traffic generated by the Lakhra Project; therefore, planned improvements to the highway will be beneficial but not mandatory for the project. It is, therefore, assumed that no costs to the project will be necessary to upgrade the Indus Highway or the National Super Highway to handle increased traffic volumes resulting from the Lakhra Project.

Traffic congestion is expected to occur at the intersection of the Indus Highway and the road to the Lakhra coal fields. This congestion will occur at shift change times and when oversize loads are being transported.

Shipments of heavy imported equiment for Units 1 and 2 of WAPDA's Guddu Generating Station were originally made by rail. A special rail spur 12 km long was built for heavy equipment movement between the main line at Kashmor and the Guddu Station. However, recent improvements to roads, continuing railroad clearance restrictions, continuing problems with the railroad responding slowly to unforeseen needs, and complications involving final erection on the site have made highway transport of heavy loads far more attractive. Road transport was used entirely for delivery of heavy loads for Guddu Units 3 and 4. Road transport is planned for delivery of heavy materials for the Lakhra Project.

Estimated weights and dimensions for heavy equipment required for the Lakhra Project are as follows:

| Component | Weight (MT) | Size Feet (Meters) |
|---|---|---|
| Generator Stator | 255 | 30 ft long x 15 ft wide x 12 feet high (9 m x 4.5 m x 3.6 m ) |
| Generator Rotor | 50 | 36 ft long x 8.5 ft diameter (11 m x 2.6 m) |
| Low Pressure Turbine Rotor | 60 | 24.7 ft long x 11.4 ft diameter (7.5 m x 3.5 m) |
| Low Pressure Turbine Cover | 52 | 25.5 ft long x 22.5 ft wide x 20.5 ft high (7.8 m x 6.8 m x 3.2 m) |
| Step-up Transformer | 118 | 16 ft long x 14 ft wide x 16 ft high (4.9 m x 4.3 m x 4.9 m) |
| Boiler Steam Drum | 180 | 60 ft long x 6 ft diameter (18.3 m x 1.8 m) |
| Dragline Electrical Set | 84 | 40 ft long x 10 ft wide x 7 ft high (12.2 m x 3.0 m x 2.1 m) |

Two heavy-duty equipment haulers in Karachi have the ability to handle equipment in the load and size ranges listed above. One of these haulers, Speedways Ltd., was contacted, and a review of the equipment movements required between Karachi and Lakhra was made. Speedways described their extensive experience in hauling equipment to the Guddu Generating Station, which uses the same transportation route between Karachi and Khanot as that required to serve Lakhra. Speedways owns two Golhoffer incremental multi-axle transporters which can be coupled in both length and width dimensions to arrive at the necessary load-carrying capability. Each axle supports a pair of hydraulic packs which raise, lower, and level the cargo bed for stabilizing the cargo under varying road conditions. The axles are also steerable for negotiating sharp radius turns.

The transporter is towed by large tractors. The two used by Speedways are a Caterpillar 480-horsepower diesel and a Mercedes-Benz with a 525-horsepower diesel. Using this arrangement, loads in the range of

230 MT have been hauled to Guddu. Currently, plans are underway for the movement, by Speedways, of a 255-MT, 7.5-meter-diameter hydroturbine rotator from Karachi to Tarbella Dam.

Discussions with the Sind Department of Highways indicate that the axle loadings of the transporters slightly overload the Indus Highway. However, due to the weight restrictions on the Kotri Barrage, transport permits on the Indus Highway have been allowed. In common practice, road repair crews travel with the equipment transporters to immediately repair any road surface that is damaged and prepare any road or culvert diversions that are required. In addition to road load-carrying capacities, clearances were reviewed between the Port of Karachi and the Lakhra area. Loads up to 5 m (16 ft.) wide and 6 m (20 ft.) high have been hauled over the road. When high clearance loads must be transported, movement through Karachi is done at night with utility crews present to de-energize and lift interfering lines.

# APPENDIX E

# AIR EMISSIONS AND ALTERNATIVE CONTROL SYSTEMS

## E.1 INTRODUCTION AND EMISSION GUIDELINES

The combustion of fossil fuels will cause air pollutants to be emitted into the atmosphere. Primarily, the emissions will be in the form of particulate matter (PM) and three gases: sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and carbon monoxide (CO). When emitted, these air pollutants can affect the air quality in the proximity of the source, potentially causing impacts to human health and welfare.

With an average as-fired heat content of 2.4 MJ/kg (5100 Btu/lb) coupled with the high ash and sulfur content (24.5 percent and 5 percent as fired, respectively), a significant quantity of PM and $SO_2$ emissions will result from combusting Lakhra coal. In addition, within the combustion process, significant quantities of $NO_x$ and, to a lesser extent, CO can be formed and thereby emitted from each unit.

Recognizing the need to consider environmental factors such as air pollution emissions in their projects, the World Bank, Office of Environmental Affairs, published Environmental Guidelines (1984) which cover various industries and air pollutants. These guidelines are used to evaluate the adequacy and effectiveness of pollution control measures of projects funded by the World Bank. For Lakhra coal firing, the applicable emission guidelines are:

$SO_2$ - 500 metric tons/day/source - annual average,
$NO_x$ - 260 mg/J heat input, and
PM - 100 mg/$m^3$ of flue gas.

Discussions with the World Bank specifically related to the Lakhra plant clarified the $SO_2$ emission limiting standard to be:

$SO_2$ - 500 metric tons/day/unit @ 85 percent capacity factor

The five subsections that follow present a discussion of alternative control systems available for $SO_2$, PM, $NO_x$, and CO.

## E.2 FLUE GAS DESULFURIZATION (FGD) SYSTEMS

FGD processes have been under investigation for more than 40 years, and hundreds of schemes have been devised. Commercial application of FGD systems in the utility industry became important in the early 1970's.

By the early 1980's, there were 222 FGD system units (102,781 MW) in various stages of operation, construction, and planning for the electric utility industry. There were 94 units (32,683 MW) in operation, 40 units (16,666 MW) under construction, 17 units (9,819 MW) with contracts awarded, 20 units (13,215 MW) in the bidding and evaluation phase, and 51 units (30,398 MW) for which FGD systems were being considered. Of the 94 operational FGD systems, 51 were designed for medium- and high-sulfur coals with a removal efficiency of 90 percent or greater. In addition, 15 FGD units with this design criterion were either under construction or had contracts awarded.

Although many FGD systems exist, only a few systems have been used extensively, and many processes have never been proven effective on a large scale. Only six processes have been demonstrated on larger coal-fired boilers (i.e., 200 MW or larger). All of these processes are capable of 90-percent removal efficiency.

The six demonstrated processes are listed below, with 1982 operational capacities shown in parentheses:

1. Limestone slurry and limestone/alkaline fly ash (15,578 MW);
2. Lime slurry and lime/alkaline fly ash (12,609 MW);
3. Dual alkali, i.e., sodium absorption with lime regeneration (1,181 MW);

4. Sodium carbonate (1,255 MW);
5. Sodium carbonate/spray drying (440 MW); and
6. Wellman-Lord® (1,540 MW).

These six processes all remove sulfur from the flue gas in an aqueous-phase reaction. They can be divided into two types according to the method of disposal of the removed sulfur. The first five processes represent "throwaway" or "nonregenerative" processes, which use large quantities of relatively inexpensive reagents that react with $SO_2$. These reagents are used once, creating a wet, solid waste which must be disposed.

Throwaway FGD processes can be further characterized by the type of scrubber (wet or dry) used to contact flue gases. With wet scrubbers, the absorbing reagent is dissolved in water and injected into the gas stream, which results in humidification of the flue gas and a decrease in temperature [usually to 322°K to 327°K (120°F to 130°F)]. The resulting water material has a high moisture content. In dry scrubbing, the aqueous scrubbing solution is sprayed into the pollutant gas stream, which acts as a drying agent, and the resulting waste material is dry (typically less than 2-percent moisture). Based on total FGD operating capacity, most FGD systems employ wet scrubbers rather than dry scrubbers (36,690 MW versus 550 MW, respectively).

The sixth process is an example of a "recovery" or "regenerative" process. This process is characterized by smaller quantities of waste material and reagents, and generation of a material that has commercial value in certain circumstances. FGD systems which amount to approximately 5 percent of the total operating FGD capacity use regenerative systems (Wellman-Lord®). In the Wellman-Lord® process, the byproduct can be either sulfuric acid or sulfur.

Limestone FGD With/Without Alkaline Fly Ash--The process of limestone scrubbing consists of close contact between boiler exhaust flue gases and a slurried mixture of limestone and water. The $SO_2$ in the gas stream combines with the calcium carbonate in the limestone slurry and precipitates as calcium sulfate/sulfite salts. A ball mill is used to grind and slurry the limestone. Both single- and double-loop systems have been developed. Many variations to the basic limestone slurry process have been developed by manufacturers.

Many of the early problems associated with limestone systems have been minimized or eliminated by advances in absorber design and process chemistry. $SO_2$ removal efficiencies of 90 percent and greater are achievable. Most scrubbers are of the open, counter-current flow, spray-tower type. Packed-bed and moving-bed towers have also been developed. Liquid-to-gas (L/G) ratios range from 6.7 to 13.4 $L/m^3$ (50 to 100 $gal/1,000\ ft^3$) of gas treated.

A major advantage of the system is that the reagent (limestone) is inexpensive and generally available. $SO_2$ removal efficiency is generally controlled through the pH of the scrubbing liquor. Manufacturers have recently designed limestone-scrubbing systems that operate in a double-loop mode. The first loop, known as the quenching or prescrubbing loop, operates at a lower pH (4 to 5). The second loop, known as the scrubbing loop, operates at a higher pH (6 to 7). The advantages of the double-loop scrubber are lower operating costs (better utilization of limestone), lower maintenance costs (lower probability of scaling and plugging), and a higher ratio of calcium sulfate to calcium sulfite, which produces a sludge that settles and dewaters more easily. Disadvantages of the double-loop scrubber are higher capital costs and higher power requirements. As of this date, limited operational data are available for double-loop scrubbing systems on utility boilers.

Disadvantages of the limestone system include higher maintenance requirements (e.g., limestone handling, grinding, and slurrying) due to the solid waste material. However, forced oxidation can be used to convert the sludge from sulfite to sulfate, resulting in a material that is easily dewatered and handled.

Fly ash can be used as a reagent instead of limestone if the fly ash is highly alkaline. Wet scrubbers are generally used for particulate removal in this application, and the resulting slurry is used as the $SO_2$ scrubbing solution. Reagent cost savings depend directly on the alkalinity (calcium content) of the fly ash, which is low for high-sulfur eastern coal. In addition, the fly ash cannot be sold (e.g., to a cement company) or used for stabilization/fixation of FGD waste materials. Fly ash for the Lakhra plant is not expected to be alkaline because of the use of the fuel analyses and combustion tests, and is expected to be abrasive. As a result, an alkaline fly ash FGD system would have low reliability and high maintenance requirements and would not realize signficiant cost savings. Therefore, an alkaline fly ash FGD system would not be applicable for the Lakhra plant.

Recently, limestone FGD technology has been improved through the use of chemical additives. Additives that have been developed and tested include magnesium, adipic acid, and dibasic acid. These additives have improved overall performance of limestone/lime FGD systems by increasing $SO_2$ removal, increasing limestone utilization, and/or reducing the L/G ratio. Thiosorbic lime (Dravo Corporation's magnesium containing lime) is currently being used on 7,000 MW of coal-fired electric generating capacity and has demonstrated $SO_2$ removal efficiencies of greater than 90 percent, as well as an excellent operational record.

The electric utility industry has considerable experience in the operation of limestone FGD systems. As a result, these systems have a

higher degree of reliability than other available systems. Of the total 72,189 MW of operational, under-construction, or planned electric utility FGD systems in the United States, 37,842 MW (52 percent) is dedicated to the use of limestone slurry systems. The limestone system represents the most commonly employed type of FGD system, totaling 15,578 MW in operation, 8,179 MW under construction, and 14,085 MW planned. No other FGD system type, other than lime systems, exceed 4,000 MW in total dedicated capacity (i.e., total of operational, under-construction, and planned capacities).

Lime FGD With/Without Alkaline Fly Ash--The process of lime scrubbing consists of close contact between boiler exhaust flue gases and a slurried mixture of finely ground slaked lime and water. A slaker is required to hydrate the lime prior to use in the scrubber. The $SO_2$ present in the flue gas combines with the calcium hydroxide in the lime, producing a wet scrubber sludge which must be disposed.

The scrubbers used in lime FGD systems are generally open, counter-current flow, spray-type systems. Packed- and moving-bed towers are also used. $SO_2$ removal efficiencies of 90 percent or greater are achievable. Liquid/gas (L/G) ratios can range from 4.0 to 10.7 L/m$^3$ (30 to 80 gal/1,000 ft$^3$) of gas, depending on design. Many of the earlier operational problems associated with this system have been minimized or eliminated by advances in absorber design and process chemistry.

Lime scrubbing is similar to limestone scrubbing. Although lime is significantly more chemically reactive than limestone, it is also significantly more expensive (about ten times) and energy intensive. In general, less lime than limestone is required to achieve a given result, which compensates to some degree for its greater cost. The quantity of waste material from a lime system is usually less than from a limestone system, but frequently the difference is not significant. A major drawback of the lime system is that the waste contains a significant



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amount of calcium sulfite, which does not readily dewater, and forced oxidation to decrease the sulfite content is difficult.

Major lime scrubbing installations have been put into operation utilizing a scrubbing agent called thiosorbic lime, developed by Dravo Corporation (13 units representing a total capacity of 7,000 MW). This material, which contains 4- to 8-percent magnesium oxide, utilizes the greater solubility of the magnesium compounds in the scrubber liquor to improve scrubbing efficiency while alleviating scaling problems. Operational records for these systems indicate better than 90 percent availability, and $SO_2$ removal efficiencies of up to 95 percent have been reported with the use of this reagent.

A recent development in lime scrubbing is the advent of the spray drying system. In this system, the aqueous alkaline solution (i.e., lime and water) is introduced into a spray dryer vessel where $SO_2$ absorption and evaporation of the water takes place. The resulting dry waste product and the boiler fly ash are collected in a baghouse or ESP. As of 1981, only two systems of this type were in operation, both on industrial boilers; however, 11 installations have been ordered for utility boilers totaling 3,200 MW. The spray dryer system potentially offers substantial savings in equipment and waste disposal costs.

A total of 72,189 MW of FGD-controlled generating capacity was either operational, under construction, or planned by 1982. Of this capacity, 25,176 MW (35 percent of the total) was dedicated to lime slurry systems, including alkaline fly ash/lime and spray drying systems. Operational lime systems totaled 12,609 MW; 6,608 MW were under construction; and 5,959 MW were planned to be constructed. The use of lime FGD system by the electric utility industry in the United States is exceeded only by limestone systems, which total 37,842 MW (operational, under construction, and planned).

Dual-Alkali Scrubbing Systems--The dual-alkali scrubbing process consists of $SO_2$ scrubbing with a soluble alkali, such as sodium carbonate or aluminum sulfate, and recovery of the alkali with an insoluble alkali, such as lime or limestone. The scrubbing is performed with a "clear" solution, rather than a slurry, and has the advantages of reduced system erosion, plugging, and scaling. Normally, scrubbing is accomplished with the counter-current flow, spray-type tower.

Alkali recovery is performed outside the scrubber loop in a separate operation. Therefore, the process requires two high-cost reagents. The advantages of the system are low energy, capital, and maintenance costs compared to other FGD technologies. $SO_2$ removal efficiencies of 95 percent and greater have been achieved with L/G ratios of up to 5.4 $L/m^3$ (40 gal/1,000 $ft^3$) of gas treated. However, problems still remain with system reliability and peripheral equipment. The primary waste product of the process is calcium sulfate, which can be disposed in ponds or landfills or converted to gypsum for use in wallboard.

There are only three dual-alkali scrubber systems currently in operation on electric utility boilers in the United States. Each of these systems has been modified extensively to improve operability and reliability. Only 1,181 MW of dual-alkali FGD capacity was operational in the United States, and only another 842 MW of capacity was under construction or planned by 1982. As a result, utility experience with the system is limited.

Sodium Carbonate Process/Spray Drying--The sodium carbonate process is similar to the limestone/lime scrubbing process, except that sodium carbonate is used as the reagent. The system has the same operational advantages as the dual-alkali system (i.e., scrubbing with a clear solution, high $SO_2$ removal efficiencies, etc.). However, the reagent is nor recovered in the sodium carbonate process, and disposal of the waste liquid is required, normally to a pond. Since the process relies on

natural evaporation in the pond to dry the waste product, the evaporation rate must exceed the precipitation rate.

Sodium carbonate/spray drying has the advantage of evaporating the scrubbing solution in the spray dryer vessel, resulting in a dry waste product which may be landfilled. By the use of atomizers, the absorbing slurry is atomized into fine droplets which are brought into contact with the flue gas stream. The solution reacts with $SO_2$ and the water is evaporated at the same time, leaving a dry product. L/G ratios for this application are less than 0.13 $L/m^3$ (1 gal/1,000 $ft^3$). The system eliminates the requirements associated with ponding.

Only 5 percent (1,695 MW) of the total electric utility operating capacity was using the sodium carbonate process as of January 1982. Of this total, 440 MW of capacity employed the spray drying technique. These figures indicate that the operating experience for these systems is low, and sufficient data do not exist to judge the reliability, adequacy, and economics of the system.

Wellman-Lord® Process--In the Wellman-Lord® process, an aqueous solution of sodium sulfite is used to scrub the $SO_2$-laden flue gases. The liquid waste stream is converted to a liquid $SO_2$ stream and a regenerated sodium sulfite stream through thermal decomposition. The concentrated $SO_2$ can then be converted to liquid $SO_2$, sulfuric acid, or elemental sulfur, which in effect requires a chemical processing plant. The conversion to elemental sulfur also requires natural gas. Solid waste disposal is not entirely eliminated by the system; calcium sulfate sludge is produced as a result of pre-scrubber equipment blowdown.

The process has demonstrated high $SO_2$ removal efficiencies (greater than 90 percent), but reagent and waste disposal costs are high. In January 1982, a total of 1,181 MW of electric utility capacity utilized the Wellman-Lord® process, with 534 MW under construction and no additional units planned.

## E.3 COAL CLEANING

The process of physically cleaning coal has been practiced for many years to reduce ash-forming impurities and, more recently, to reduce the sulfur content of coals. Sulfur occurs in coal in two forms: organic sulfur, in which the sulfur is chemically bound to the coal and cannot be removed by mechanical means, and inorganic sulfur (pyritic sulfur), which is not chemically bound and may be removed from the coal in varying degrees. Processes are available for chemically removing organic sulfur (solvent-refined coal), but these processes have not been demonstrated commercially.

Coal washability tests performed under the direction of GCII and J.T. Boyd Company indicated that $SO_2$ and PM emissions could be reduced by about 40 and 50 percent, respectively. In addition, the Btu content would be improved by approximately 20 percent; however, there is a concomitant loss of about 22 percent in net energy by coal washing which would result in a significant increase in coal costs. Therefore, this alternative was rejected from further consideration as an air pollution control system alternative.

## E.4 PM EMISSION CONTROL TECHNOLOGIES

Three control technology types are currently used for the removal of fly ash from the flue gases of electric utility steam generating units: (1) high-energy wet scrubbers, (2) electrostatic precipitators (ESP), and (3) fabric filters (FF). The selected control technology must be able to achieve an emission limit of 100 $mg/m^3$ or about 99.5 percent efficiency.

Wet scrubbers have not been demonstrated to achieve over 99 percent control. Additional disadvantages of using wet scrubbers as the selected BACT include increased wear and corrosion associated with the use of wet or semi-wet induced-draft fans, and the handling of fly ash in a wet



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state, preventing it from being recovered and sold as a byproduct or used as a fixative in the FGD effluent processing system. Therefore, only ESP and FF will be considered further as potential alternative control systems.

ESPs are the traditional method of controlling particulate matter emissions from electric utility steam generating units, but FF have recently experienced widespread use. Both are capable of meeting the applicable NSPS for particulate matter when employed on utility boilers firing a wide range of bituminous coals.

ESPs use the principle of attraction between electrostatically charged objects and an uncharged ground or an oppositely charged object. In 1970, Cottrell developed the first successful application of ESP. The first ESP used for collecting fly ash from electric power boilers was installed in 1923, and since then thousands have been installed.

Operation of a modern ESP includes the following sequence:

1. Generation of a high-voltage corona discharge;
2. Bombardment and charging of particles in the gas stream;
3. Migration of charged particles to a collection plate; and
4. Transfer of collected particles from the ESP for disposal.

The generation of a high-voltage corona discharge is accomplished with transformer-rectifiers which energize discharge and grounded electrodes. The flue gas is passed between the electrodes, and the particulate matter in the gas stream becomes charged. The charged particles then migrate to the collecting electrodes, where they are periodically displaced and removed to collecting hoppers, and subsequently removed by the fly ash handling system.

ESP design depends on the electrical properties of the particulate being collected, flue gas volume and properties, and the desired collection



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efficiency. ESP efficiency is affected by the alignment of ESP electrodes, the specific collection area (SCA), the flow pattern of gas through the ESP, the rapping method, and the electrical characteristics of the corona discharge system. ESPs can be either the hot- or cold-side type. A hot-side ESP is located before the boiler air heaters, where temperatures range from 590°K to 755°K (600°F to 900°F). These have been used on low-sulfur coal applications where the fly ash is of low resistivity and, therefore, hard to collect. The higher collection temperature improves the resistivity, making the particulate easier to collect. The hot-side ESP has not been used on high-sulfur coal applications primarily based on operating characteristics and economics. Although a hot-side ESP theoretically requires a lower SCA than the cold-side ESP to achieve the same collection efficiency, this advantage is offset by the larger volume of air handled by the hot-side ESP (due to the higher flue gas temperature), the decrease in the heat rate of the unit, and operational problems caused by the high temperatures. Based on these factors, a hot-side ESP is not to be considered as an alternative for the Lakhra plant.

A cold-side ESP is located downstream of the boiler air preheater and operates at temperatures generally in the range of 395°K to 450°K (250°F to 350°F). The cold-side ESP is by far the most common method of controlling particulate matter emissions from new electric utility steam generating units. Of 46 planned utility plants, 27 specified cold-side ESP; only one installation was dedicated to a hot-side ESP, none were dedicated to FFs, six were not specified, and three used other control methods. Although the lower operating temperatures experienced by the cold-side ESP make fly ash collection more difficult, the high-sulfur fuels expected to be used by the Lakhra are not expected to have a high resistivity, and proper SCA specification will ensure adequate particulate removal efficiency.



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Although FFs have been used for many years, they have not been applied to utility boilers until recently. For example, only one 350-MW unit fired with low-sulfur coal was tested in the mid 1970's. The next largest unit, for which test data was available, was a 44-MW unit. As of May 1979, at least 26 utility boilers were equipped with FFs. As of October 1985, there were 107 fabric filters in operation on utility boilers representing 16,650 MW. These boilers are principally for low-sulfur coal applications.

FFs rely on filter bags as a removal medium. The particulate-laden flue gas stream is passed through the filter bags, on which a thin filter cake is formed. This filter cake aids in the removal process by increasing the removal efficiency. Inertial impaction, interception, and molecular diffusion are the mechanisms of collection. The collected particulate can be removed by shaking the bags, pulsed air flow, or reversed air pulsing. The particulate falls into hoppers located below the bags, where it is removed by the fly ash handling system.

Design and efficiency of FF depend primarily on the volumetric air flow and the air-to-cloth (A/C) ratio. Fiberglass bags which can withstand temperatures up to approximately 560°K (550°F) are used for utility applications. These generally require reverse air cleaning to minimize bag failure. FFs normally follow the air preheaters (i.e., cold-side) and, therefore, typically experience operating temperatures of 395°K to 450°K (250°F to 350°F). A/C ratios of 2:1 are typical for FF utility applications.

## 5.5 $NO_x$ EMISSION CONTROL TECHNOLOGIES

Historically, control of $NO_x$ emissions from electric utility boilers has been accomplished solely through combustion modification techniques. $NO_x$ emissions from large utility boilers are a function of fuel burned, furnace size, method of firming, burner design, excess air, and flame temperature. Combustion modification techniques include staged combustion, low excess air, and reduced heat-release rate. In 1979,

USEPA concluded that boiler manufacturers could design boilers that burn high-sulfur bituminous coal and guarantee the NSPS limit of 260 ng/J (0.60/lb/$10^6$ Btu), 30-day rolling average, without adverse effects on boiler operation.

$NO_x$ is produced in coal-fired boilers either by thermal fixation of atmospheric nitrogen in the combustion air (thermal $NO_x$) or by conversion of fuel-bound nitrogen (fuel $NO_x$). Up to 80 percent of the total $NO_x$ is from fuel $NO_x$. Thermal $NO_x$ is formed at high temperatures in an excess of air when the normally stable oxygen molecule disassociates to oxygen atoms and combines with the normally stable nitrogen molecule. The rate of $NO_x$ formation depends on temperature, oxygen level, and length of exposure; therefore, controlling these parameters can theoretically reduce $NO_x$ formation. Methods tested to date to control the oxygen level in coal-fired boilers include low excess air firing, off-stoichiometric combustion, and staged combustion. Peak flame temperatures have been reduced by using flue gas recirculation and reduced air preheat. Combined control methods have centered on burner design, which affects air/fuel mixing, thereby altering temperatures and species concentrations which control the rate of $NO_x$ formation.

Fuel $NO_x$ is theorized to form when coal is introduced into the burner area and rapidly heated, and a portion of the volatile species containing some nitrogen is vaporized and burned. Only a portion of the fuel-bound nitrogen is converted to $NO_x$, and data indicate that the percentage converted to $NO_x$ decreases as the nitrogen content of the fuel increases. Although fuel $NO_x$ typically predominates over thermal $NO_y$ in coal-firing, fuel-dentrification techniques to reduce fuel $NO_x$ have not proven feasible.

Control methods which theoretically should reduce fuel $NO_x$ include low excess air firing, burner design, staged combustion, and high air preheat; however, high air preheat tends to favor thermal $NO_x$ formation.



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A recent USEPA study concluded that the most effective combustion modification technique to reduce $NO_x$ emissions from coal-fired boilers, without reducing boiler performance, consists of a combination of low excess air firing and staged combustion. Boiler testing indicated that boiler efficiency, particulate mass loading and particule size distribution, and boiler tube waste were not adversely affected by these control methods. However, slagging in the boiler was identified as a potential problem, with the possibility of using additives in the boiler to reduce slagging potential.

Flue gas treatment is another method of controlling $NO_x$ emissions from coal-fired boilers. As the name implies, this method involves cleaning of the flue gases exiting the boiler. Little research in the United States has been devoted to $NO_x$ flue gas treatment from utility boilers, primarily because combustion modification techniques, which are much less costly, are able to meet existing emission regulations. However, research in Japan has led to the development of both wet and dry flue gas removal processes. The dry process involves the use of a selective catalyst (typically using ammonia) to reduce the $NO_x$. The dry process has been applied to oil-fired power plants but has not been proven on coal-fired boilers with particulate- and $SO_2$-laden flue gases. The wet flue gas removal process involves the use of a strong oxidant (typically ozone or chlorine dioxide) to convert NO to $NO_2$ or $N_2O$ for subsequent removal. In general, the wet processes need further research to prove their operating and economic feasibility. Waste disposal problems must also be overcome.

Of the 46 planned utility boilers, 35 utilized some form of boiler design or combustion modification to achieve the NSPS emission limitation (nine were unspecified). Combustion modifications selected included staged combustion, low excess air, and low $NO_x$ burners. Based on the proven,

widespread use of boiler design and combustion modification techniques and the generally unproven, relatively high cost $NO_x$ flue gas cleaning technologies available for coal-fired steam boilers, only a combination of boiler design and combustion modification techniques will be considered further as a candidate for BACT for control of $NO_x$ emissions from Taylor Plant.

## E.6 CARBON MONOXIDE CONTROL SYSTEMS

CO, as well as volatile organic compounds (VOC), are relatively minor byproducts of coal burning and have received little control technology research. Combustion efficiency is related to CO emissions; more complete combustion results in lower emissions. Good air/fuel mixing, high temperature, and longer combustion times all allow complete combustion to take place. Unfortunately, combustion practices that tend to reduce CO (and VOC) emissions also tend to increase $NO_x$ emissions.

No feasible, cost-effective flue gas cleaning methods have been developed to control CO emissions from large coal-fired boilers. As a result, proper boiler design and operation are the only feasible control methods available for these pollutants. In practice, the boilers will be operated to minimize $NO_x$ and CO emissions without sacrificing boiler efficiency or operation.

# APPENDIX F

# DISPERSION METEOROLOGY, METEOROLOGICAL PROCESSING, AND MODELING METHODOLOGY

## F.1 DISPERSION METEOROLOGY

### F.1.1 GENERAL

When pollutants, either small particles or gases, are released into the atmosphere, a plume which contains both ambient air and the released pollutants is formed. Due to the dynamic action of the atmosphere, this plume tends to expand in size with increasing distance from the source. Because of this expansion, the concentration of air pollutants is decreased due to the larger volume of ambient air relative to the same concentration of pollutants. This natural process is referred to as air dispersion, i.e., the atmospheric phenomena of high concentration diffusion to lower concentrations.

Atmospheric diffusion is a function of the type of source and specific meteorological conditions which can influence the ground-level pollution concentrations experienced by human populations as well as agriculture and the native ecology. Its importance must be considered when evaluating the magnitude of air pollutant impacts for major pollutant sources such as power plants. However, a direct measure of the air quality impact of a source of air pollutants can be obtained only by using ambient air quality monitoring equipment. For major developments, such as the Lakhra Power Project, which require several years to complete, it is generally not practical to measure air quality after project completion and implement control measures that would reduce air quality impacts below safe levels once the project is constructed. Consequently, a method is required that can use principles of dispersion meteorology to forecast the future air quality impact. The method used to forecast future air quality impacts is referred to as atmospheric dispersion modeling.

An atmospheric dispersion model is a mathematical algorithm which simulates the dispersion of air pollutants. The models commonly used take hour-by-hour meteorological data, stack parameters, and emission rates and calculate hourly ground-level concentrations of pollutants emitted by the stack(s).

Meteorological data input to the model include hourly wind speed, wind direction, temperature, atmospheric stability, and mixing height. The model uses these parameters to determine the direction the pollutants will travel (wind direction), the dilution of the plume (wind speed), the horizontal ($\sigma z$) and vertical ($\sigma y$) spread (dispersion) of the pollutants, and the height to which further dispersion of the pollutants is limited (mixing height). (Note: The word "plume" is used to denote the volume of air containing the pollutants emitted from the stack.) The wind direction determines the locations (receptors) in the vicinity of the stacks where the plume will pass during the hour. The concentration of pollutants within the plume is inversely proportional to the wind speed, due to dilution of the pollutants within the plume (i.e., twice as great a wind speed yields half as great pollutant concentration). The spreading or dispersion of the plume is dependent upon atmospheric stability. The less stable the atmosphere is, the greater is the plume's spread in both the horizontal and vertical directions. The mixing depth forms a lid above the ground through which pollutants cannot penetrate. The model portrays the mixing depth as a "mirror" which reflects pollutants back down toward the ground.

Pollutants emitted from a stack will rise due to the velocity of the stack gases (momentum rise) and the temperature difference between the stack gases and the ambient temperature (buoyancy effect--hot air always tends to rise). The hourly meteorological data are used in conjunction with the stack parameters to calculate the rise of the pollutants above the stack. Empirical equations are used to determine plume rise, which is dependent primarily upon wind speed (higher wind speeds tend to reduce

the plume rise), the volumetric flow rate of the stack gases, and temperature difference between the stack gases and the ambient air (larger flow rate or hotter stack gases increase plume rise). Holding all other model inputs constant, greater plume rise will result in lower ground-level concentrations, because the pollutants are diluted through a greater volume of air before reaching the ground.

Stack parameters required by the model include stack height, stack diameter, volumetric flow rate, exit gas velocity, exit gas temperature, and pollutant emission rate. In a typical use of a dispersion model, these parameters would be considered to remain constant for all hours of meteorology evaluated. Generally, the maximum pollutant emission rate is used along with the stack parameters associated with this rate. Thus, if there are actual changes, the assumption of maximum emissions would produce higher-than-expected impacts. These concepts are presented in Figure F-1.

When the plume is released into the atmosphere, the vertical depth to which the plume can disperse is also important. This "mixing depth" is defined as the height above the surface through which vertical dispersion occurs (Holzworth, 1972). The concepts of mixing depth are based upon the theoretical principles of the dry adiabatic lapse rate (-1.0°C/100 m) and can account for inversions which can trap pollutants within a confining layer.

The majority of atmospheric dispersion models in use today and those accepted and suggested for use by the scientific community are Gaussian-type plume models. The model which was applied to the Lakhra Project area are Gaussian-based models. In a Gaussian model, pollutants emitted into the atmosphere spread out in the horizontal and vertical directions according to the Gaussian (i.e., "normal") distribution. This spreading, which is a function of atmospheric stability, can be expressed in terms of the horizontal and vertical standard deviations of pollutant concentration, $\sigma y$ and $\sigma z$.

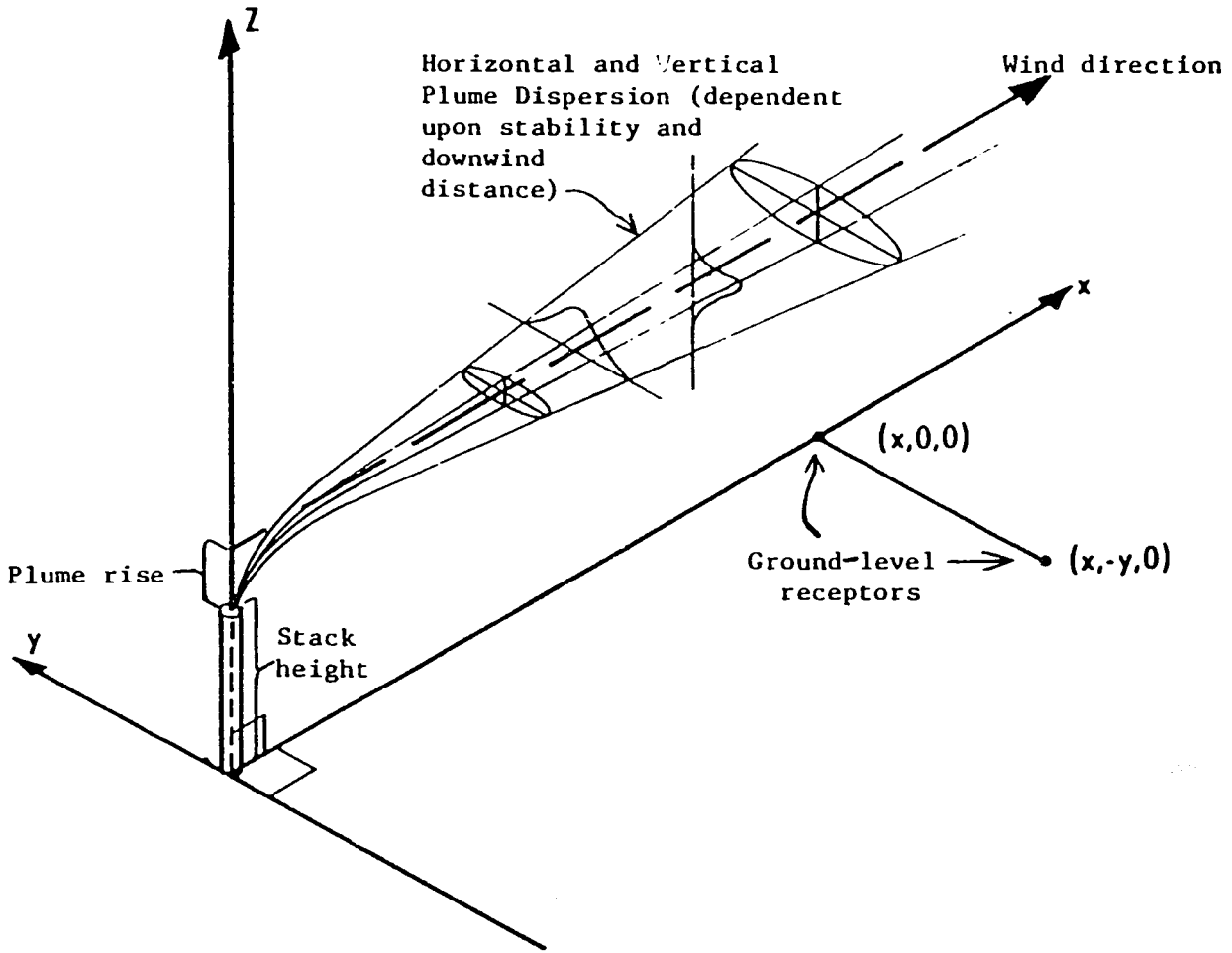


Figure F-1
PRINCIPLES OF PLUME DISPERSION

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Pasquill (1961) presented information on the lateral and vertical spreading of diffusing plumes as a function of downwind distance and atmospheric stability. The original Pasquill (1961) stability criteria (see Table F-1) were presented in terms of wind speed, cloud cover, and solar insolation. Gifford (1981) took Pasquill's information and converted the plume spreading data into families of curves of $\sigma y$ and $\sigma x$ versus downwind distance. These have been termed the Pasquill-Gifford (P-G) curves (see Figure F-2). These curves of plume spreading have been adopted by U.S. EPA for use in approved Gaussian plume models.

Atmospheric stability cannot be obtained directly from any meteorological system. Therefore, an important aspect of processing meteorological data is determining the most applicable method for atmospheric stability classification. Because P-G dispersion parameters are used in the dispersion models, the chosen stability classification scheme must relate to the P-G stability categories.

Numerous P-G atmospheric stability typing schemes have been developed over the years, primarily due to the widespread use of the Gaussian plume dispersion model and the need to estimate P-G stabilities from various meteorological network designs and equipment. To standardize or at least uniformly apply stability typing schemes for use in dispersion modeling analysis, several schemes have been recommended in the publication Regional Workshops on Air Quality Modeling: A Summary Report (U.S. EPA, 1983). The United States Nuclear Regulatory Commission (U.S. NRC) also has recommended certain stability typing schemes as part of required environmental impact studies concerning radioactive releases from nuclear power plants. These schemes are named as follows:

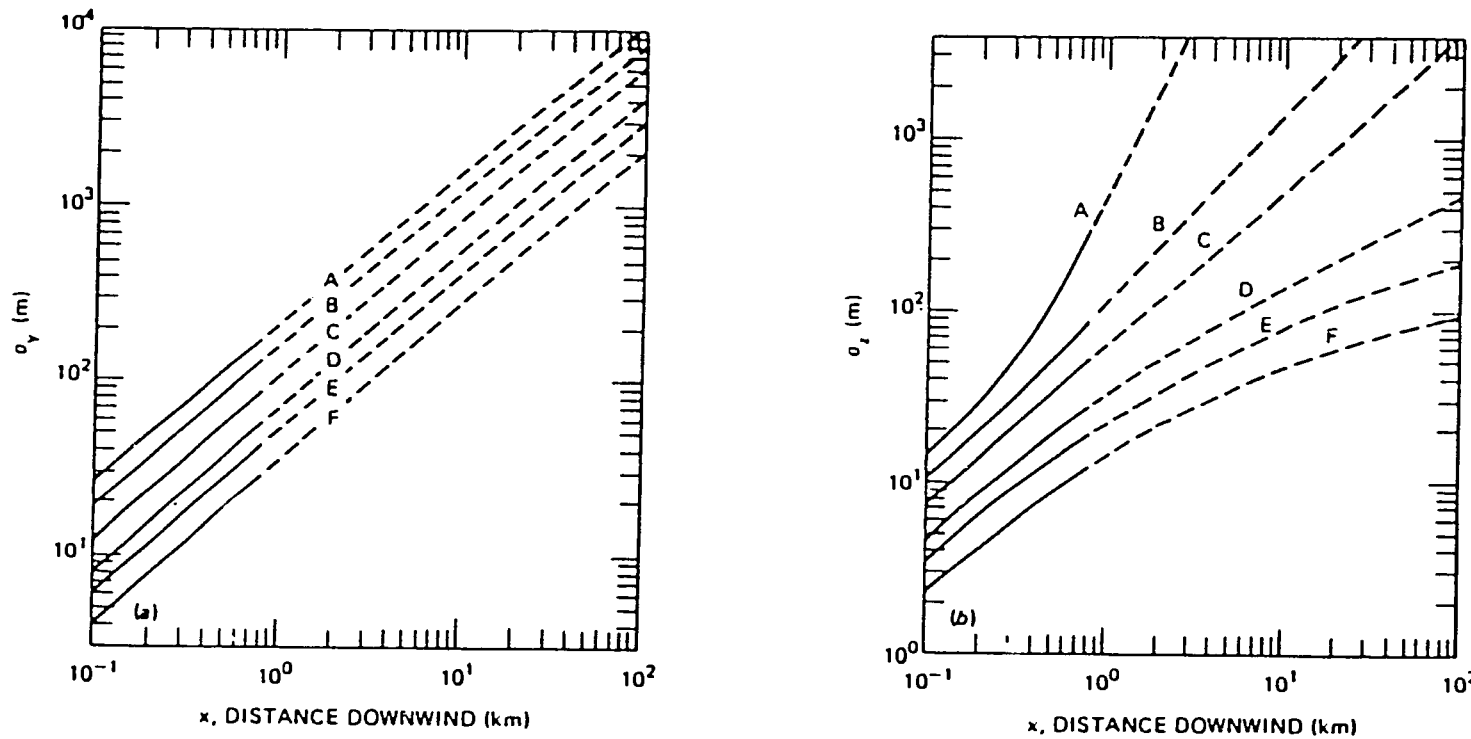
1. Pasquill-Turner Method,
2. Sigma Theta Method,
3. Modified Sigma Theta Method,
4. Sigma Phi Method, and
5. Delta T Method.

Table F-1. Meteorological Conditions Defining Pasquill Turbulence Types*

| Surface Wind Speed (m/sec) | Daytime Insolation | | | Nighttime Conditions | |
|---|---|---|---|---|---|
| | Strong | Moderate | Slight | Thin Overcast or ≥4/8 Cloudiness† | ≤3/8 Cloudiness |
| <2 | A | A-B | B | E | F |
| 2 | A-B | B | C | E | F |
| 4 | B | B-C | C | D | E |
| 6 | C | C-D | D | D | D |
| >6 | C | D | D | D | D |

*The Pasquill Turbulence Types are:
A = Extremely unstable conditions.
B = Moderately unstable conditions.
C = Slightly unstable conditions.
D = Neutral conditions (applicable to heavy overcast day or night).
E = Slightly stable conditions.
F = Moderately stable conditions.
†The degree of cloudiness is defined as that fraction of the sky above the local apparent horizon that is covered by clouds.

Source: Pasquill, 1961.




STABILITY KEY:

| | |
|---|---|
| A -Very Unstable | D -Neutral |
| B -Moderately Unstable | E -Slightly Stable |
| C -Slightly Unstable | F -Moderately Stable |

Figure F-2
CURVES OF $\sigma_y$ AND $\sigma_z$ FOR PASQUILL'S TURBULENCE TYPES

SOURCE: GIFFORD, 1976.

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Turner (1964) developed a scheme in which the solar insolation was expressed as a function of solar elevation angle, cloud cover, and cloud ceiling height. The intent of the scheme was to express Pasquill's criteria in terms of routinely measured meteorological parameters. These parameters can be calculated or are measured routinely at weather stations throughout the United States. As a result, the Turner method has gained widespread use throughout the United States.

F.1.2 METEOROLOGICAL PREPROCESSING METHODS

A description of the dispersion meteorology and the data need to perform dispersion modeling is defined by the following five meteorological parameters:

1. Wind Direction--determines the transport directions toward which the plume will travel and potentially affect receptors downwind of the plant;
2. Wind Speed--determines the amount of dilution of plume concentration and height to which the plume will rise;
3. Temperature--affects the height to which the plume will rise and also is used in estimating afternoon mixing heights;
4. Atmospheric Stability--determines the extent of plume spread or dispersion in the vertical and horizontal directions;
5. Mixing Height--determines the maximum vertical extent or volume of air in which the plume can disperse.

These parameters can be measured directly or inferred from other measured parameters. In general, surface observations collected at meteorological stations include wind direction, wind speed, temperature, cloud cover, and cloud ceiling. The wind speed, cloud cover, and cloud ceiling values are used in the preprocessor program to determine atmospheric stability using the Turner stability scheme (1964). Based on the maximum afternoon surface temperature, morning and afternoon mixing heights can be calculated with radiosonde data (generally calculated twice daily at 7:00 a.m. and 7:00 p.m.) using the Holzworth approach (1972). Hourly



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mixing heights can be derived from the morning and afternoon mixing heights using the interpolation method developed by USEPA (Holzworth, 1972). The hourly surface data and mixing heights are used to develop a sequential series of hourly meteorological data (i.e., wind direction, wind speed, temperature, stability, and mixing heights). If the observed hourly wind directions are classified into sectors (such as 10 or 22.5 degrees), the wind directions can be randomized within each sector using an USEPA preprocessing program to account for the expected variability in air flow.

### F.1.3 METEOROLOGICAL DATA SELECTED FOR ANALYSIS

Meteorological data taken from the U.S. AID-sponsored meteorological stations located at the Jamshoro and Lakhra sites were used to describe the dispersion meteorology. These stations were installed in May 1985 and provide an annual data base for analysis.

Meteorological data from the Lakhra site are expected to be representative of the proposed plant's location because it is the closest meteorological station to the proposed site, and the necessary parameters to describe the dispersion meteorology were collected. However, because a full year of meteorological data was not available due to the inoperation of equipment, data from the Jamshoro site were used to supplement the Lakhra data base to make a complete set of hourly data. The Lakhra data from May 1985 through February 7, 1986, and the Jamshoro data from February 8, 1986, through April 30, 1986, were used.

A comparison of the air dispersion model and meteorological preprocessor input requirements to the parameters available from the stations in Lakhra and Jamshoro is presented in Table F-2. Because the meteorological program was based on processing data from NWS stations in the United States in specific formats, the preprocessor program was modified to convert parameters into proper units, calculate stability and mixing heights by assuming values of cloud cover and ceilings, and

Table F-2. Comparison of Air Dispersion Model and Meteorological Preprocessor Input Requirements to Parameters Available from Meteorological Stations at Lakhra and Jamshoro

| Parameter | Lakhra and Jamshoro Meteorological Stations | Model and Preprocessor Requirements |
|---|---|---|
| Wind Direction | | |
| Frequency | Every hour | Every hour |
| Reported Units | Nearest 10 degrees; up to 36 directions | Nearest degree but can be randomized over sector width for reported direction |
| Wind Speed | | |
| Frequency | Every hour | Every hour |
| Reported Units | mph | Units converted to m/s |
| Minimum Value | 3 mph | Assumes valid speed is 3 knots or 1.0 m/s |
| Temperature | | |
| Frequency | Every hour | Every hour |
| Reported Units | °C | Units converted to K |
| Stability* | | |
| Based on: | | |
| Cloud Cover | | |
| Frequency | Not available | Every hour |
| Reported Units | | Units coded from 0-10, which, when multiplied by 10, indicate amount of cloud cover in percent |
| Cloud Height | | |
| Frequency | Not available | Every hour |
| Reported Units | | Actual height in ft |
| Wind Speed | See above | See above |

Table F-2. Comparison of Air Dispersion Model and Meteorological Preprocessor Input Requirements to Parameters Available from Meteorological Stations at Lakhra and Jamshoro (Continued, Page 2 of 2)

| Parameter | Lakhra and Jamshoro Meteorological Stations | Model and Preprocessor Requirements |
|---|---|---|
| Mixing Height† | | |
| Based on: | | |
| Radiosonde Data | | |
| Frequency | Not available in format for model | Twice daily |
| Reported Values, Units | | Sufficient height to compute mixing height |
| Temperature | See above | See above |
| Stability | See above | See above |

*Not measured directly but inferred using Turner method (USEPA, 1964) and specified parameters.
†Not measured directly but inferred using Holzworth method (USEPA, 1982) and specified parameters.

Source: ESE, 1986.

assigning an indicator for hours of missing data. Prior to processing the data through the preprocessor, however, the Lakhra and Jamshoro data were reviewed to compare and determine consistency of reported values between the sites (i.e., wind direction, wind speed, temperature) and ensure that the reported values were reasonable and generally typical for the time of year, time of day, and location. Based on the results of that review, the Lakhra data were adjusted in the following manner:

1. Wind speed--Based on a comparison with the Jamshoro data, the wind speeds at Lakhra were reduced by 25 percent to account for values that were unrealistically high on hourly and monthly average bases (e.g.--winds were in excess of 32 kph 50% of the time). This adjustment resulted in wind speeds that appeared more typical throughout the day and seasons than those observed for Jamshoro.
2. Temperature--Based on comparisons with the Jamshoro data and historical observations made in the region, the temperatures for Lakhra were adjusted using the same temperature scale used at the Jamshoro site.

The annual frequencies of wind directions and wind speeds for the combined data set using the Lakhra and Jamshoro data are shown in Figure F-3. This figure is based on using the actual observations from both sites. The data indicate the influence of the monsoon seasons which produce a predominant west-southwest wind direction occurring approximately 21 percent, primarily during the summer months (i.e., June to September) and secondary prevailing north-northeast wind direction occurring approximately 15 percent, primarily during the winter months.

A summary of the frequency of prevailing wind directions and atmospheric stability for the combined Lakhra and Jamshoro data is presented in Table F-3 based on the processed meteorological data. Using actual observations, no calm conditions occurred throughout the period of observation. The most frequent atmospheric stability is neutral stability (i.e., Class D) which occurred approximately 65 percent and during day or nighttime hours. By comparison, unstable stability (i.e.,

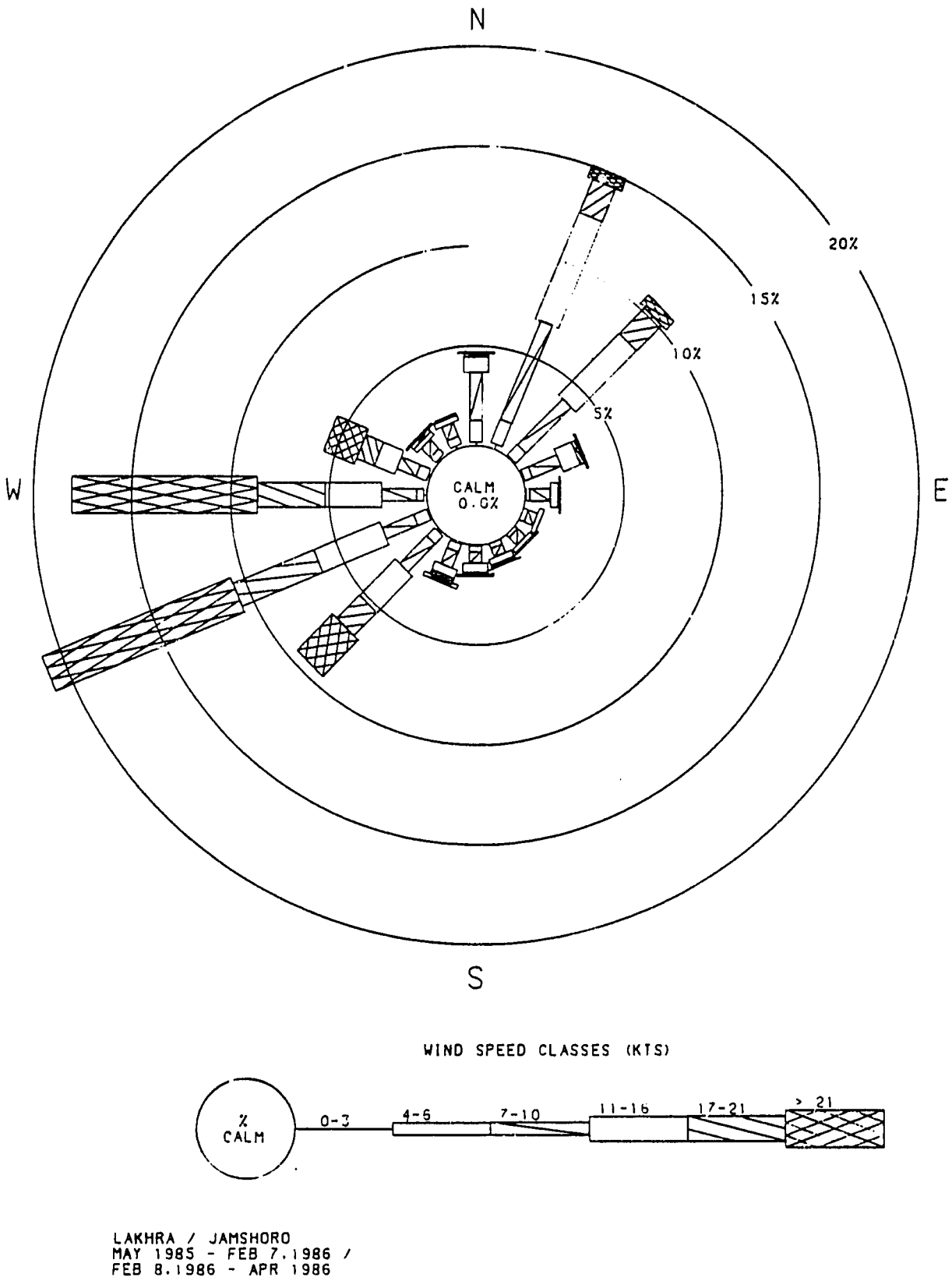


Figure F-3
WIND ROSE FOR LAKHRA/JAMSHORO

SOURCE: ESE, 1986.

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Table F-3. Frequencies of Prevailing Wind Directions and Atmospheric Stability for the Combined Lakhra and Jamshoro Data

| Case | Number of Values | Atmospheric Stability Occurrence (Percent)* | | | | | | Wind Statistics (Percent) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Most Frequent Wind Directions | | | |
| | | A (Very Unstable) | B (Moderately Unstable) | C (Slightly Unstable) | D (Neutral) | E (Slightly Stable) | F (Moderately Stable) | West-Southwest | West | North-Northeast | North-East |
| Processed Data for Model Input* | 6,522 | 0.2 | 3.3 | 13.5 | 65.3 | 14.8 | 2.9 | 21.0 | 18.0 | 15.0 | 10.7 |

*Based on temporal interpolation scheme and not allowing stability to vary by more than one class per hour.

Source: ESE, 1986.

Classes A, B, and C), which is daytime stability, occurred approximately 17 percent. Stable stability (i.e., Classes E and F), which occurred during the night, had a frequency of approximately 18 percent. The low frequency for very and moderately unstable stability is related to the observed high wind speeds. Higher wind speeds during the day and night increase the occurrence of neutral conditions and decrease the potential for other stabilities to occur.

## F.2 AIR MODELING METHODOLOGY

### F.2.1 AIR DISPERSION MODEL DESCRIPTION

The Industrial Source Complex (ISC) dispersion model (Cramer, 1979) was used to evaluate the proposed plant's emissions. This model is contained in USEPA's User's Network for Applied Modeling of Air Pollution (UNAMAP),Version 5 (USEPA, 1983). The ISC model was selected primarily for the following reasons:

1. USEPA has approved the general use of the model for air quality dispersion analyses throughout the United States because the model's methods and assumptions have undergone extensive review. The review has ensured that the methods and assumptions are based upon and are consistent with scientific studies, either by field experiments, wind tunnel studies, or theoretical findings.
2. The ISC model is capable of predicting the impacts from stacks (such as the proposed plant's stacks) that are located in flat or gently rolling terrain.
3. The results from the ISC model are processed into formats that are appropriate for ambient air quality guidelines recommended by the World Bank.

Concentrations are calculated by the ISC model using the steady-state Gaussian plume equation for a continuous source. The basic assumption of the Gaussian model is that concentrations along a cross section of the plume are described by a normal distribution curve. The peak of the curve corresponds to the plume centerline, and the shape of the curve depends on the stability category of the atmosphere. The area source equation in the ISC model is based on the equation for a continuous and finite crosswind line source.

The ISC uses the generalized Briggs (1971, 1975) plume rise equations, including the momentum terms, to calculate plume rise as a function of downwind distance. A wind profile exponent law is used to adjust the

observed mean wind speed, from the measurement height to the emission height, for the plume rise and concentration calculations. The Pasquill-Gifford (Turner, 1970) dispersion curves are used to calculate the horizontal standard deviation ($\sigma_y$) and vertical standard deviation ($\sigma_z$) of the plume spread.

The ISC model has rural and urban options which affect the plume rise formulas, wind speed profile exponent law, dispersion curves, and mixing height formulations used in calculating ground-level concentrations. One criterion used to determine when the rural or urban mode is appropriate is based on land use near the proposed plant (Auer, 1978). If the land use is classified as heavy industrial, light-moderate industrial, commercial, or compact residential for more than 50 percent of the area within a 3-km radius circle centered on the proposed source, the urban mode should be selected. Otherwise, the rural option is more appropriate. Based on a review of the land use around the proposed facility, the rural mode was selected because of the general lack of or minimal industrial and commercial development.

The ISC model consists of two model codes. The first model code, the ISC short-term (ISCST) model, is an extended version of the single-source (CRSTER) model (USEPA, 1977). The ISCST model is designed to calculate hourly concentrations based on hourly meteorological parameters (i.e., wind direction, wind speed, atmospheric stability, ambient temperature, and mixing heights). The hourly concentrations are processed into non-overlapping, short-term averaging periods. For example, a 24-hour average concentration is based on twenty-four 1-hour averages calculated from midnight to midnight of each day. For each short-term averaging period selected, the highest and second-highest average concentrations are calculated for each receptor. As an option, a table of the 50 highest concentrations over the entire field of receptors can be produced. For the annual averaging period, the 1-hour concentrations are summed for all hours in the year for each receptor.

The second model code is the ISC long-term (ISCLT) model, which is an extension of the Air Quality Display Model (AQDM) and the Climatological Dispersion Model (CDM). The ISCLT model uses joint frequencies of wind direction, wind speed, and atmospheric stability to calculate seasonal and/or annual average ground-level concentrations. This model code was not used because the annual average concentrations were obtained from the ISCST model. A description of the mathematical formulas used in the ISC model follows this section.

An integral part of the modeling evaluation was the analysis of missing meteorological data that occurred approximately 26 percent of the time in the 1-year meteorological database. Since the model will not operate with missing data, a procedure was used to identify hours with missing data. Because calm conditions did not occur throughout the reported period, the calm indicator was substituted for identifying missing periods. During calm conditions, neither a wind direction nor wind speed is recorded. For such hours, the ISCST model uses the last recorded wind direction and a wind speed of 1 meter per second (m/s) to calculate concentrations and continues these conditions until the next noncalm condition is recorded. The persistence in wind direction caused by calm conditions can cause artificially and unrealistically high concentrations to be predicted by the ISC model.

As part of the analysis to review occurrences of calm meteorological conditions (in this instance, missing data), the post-processing computer program Calms Processor (CALMPRO) was used to identify the wind direction and wind speed assigned for each hour and to adjust the short-term average concentrations if an hourly average concentration was produced during calm conditions. The CALMPRO program was developed by USEPA (1984), and the method used for evaluating the effects of calm conditions reflects current USEPA modeling policy (USEPA, 1983). The following criteria were used to calculate valid average concentrations:

1. Valid hourly average concentrations for each receptor were based on any concentration predicted during noncalm conditions.

2. Hours of calm conditions were considered invalid, and concentrations were set to zero for all receptors for that hour.
3. Valid 3-hour average concentrations were calculated by summing concentrations and dividing by 3.
4. Valid 8-hour average concentrations were calculated by summing concentrations produced during noncalm hours and dividing by the maximum of 6 hours or the number of noncalm hours during the 8-hour period.
5. Valid 24-hour average concentrations were calculated by summing concentrations produced during noncalm hours and dividing by the maximum of 18 hours or the number of noncalm hours during the 24-hour period.
6. Annual average concentrations were calculated by dividing the sum of all hourly contributions by the number of non-calm hours during the year.

### F.2.2 MODEL IMPLEMENTATION

In the modeling analysis, two scenarios of impacts were investigated. The first scenario involved addressing impacts of pollutants due to stack emissions. Concentrations were calculated for one pollutant, and, based on multiplying these concentrations by the ratio of emissions for other pollutants to that modeled, the concentrations for the other pollutants were estimated.

The second scenario dealt with addressing impacts of PM emissions due to fugitive and miscellaneous low-level PM sources resulting from the mine operation. Because these sources are released near the surface, the highest impacts from these sources occur close to the associated activity areas and under different meteorological conditions than those for the stack emissions.

In the first scenario, a series of receptors were selected that would account for air quality impacts from plant design alternatives and to

sensitive receptors. In addition, receptors were placed to evaluate the potential for air quality interaction with the Jamshoro oil-fired units. These special receptor grids were:

1. Operating Load and Stack Height Alternative Impact Evaluation--40 receptors along one radial spaced to 20 km at 0.3-to 0.5-km intervals. Operating loads of 50-, 75-, and 100-percent capacity were evaluated for three stack heights.
2. Maximum Plant Impact Evaluation--288 receptor locations in a radial grid around the proposed stack location. The radial grid consisted of 36 radials located 10 degrees apart with 8 receptors located along each radial. The downwind distances of the receptors from the proposed source were 0.5, 0.8, 1.1, 1.4, 1.7, 2.0, 2.5, and 3.0. km along each radial.
3. Agricultural Impact Evaluation--56 receptors along 10° radials spaced from 15 to 50 km at 5-km intervals.
4. Interaction with the Jamshoro Oil Units: Lakhra Site--24 receptors placed at 10° radials from 313° to 333° spaced at distances of 0.5, 0.8, 1.1, 1.4, 1.7, 2.0, 2.5, and 3.0 km from the center of the proposed stack; Jamshoro--24 receptors placed at 10° radials from 133° to 153°, similarly spaced distances as the Lakhra site, from the center of the Jamshoro oil unit stack.
5. Sensitive or Major Populated Areas--Discrete receptors for the Liaquat Medical College and Hospital and Hyderabad City.

For Receptor Grid 1, concentrations were calculated using representative "worst-case" meteorological conditions (see Table F-4) in order to identify which operating load produced maximum concentrations. Based on these results, concentrations for Receptor Grids 2 through 5 were calculated for the one load under which maximum concentrations were predicted using the one year of Lakhra and Jamshoro meteorological data. Three stack heights were evaluated for Receptor Grids 1 and 2.

Table F-4. Summary of Representative "Worst-Case" Meteorological Conditions*

| Atmospheric Stability | Wind Speed (m/s) |
|---|---|
| Very Unstable | 1.5 |
| | 2.0 |
| | 3.0 |
| Moderately Unstable | 1.5 |
| | 2.0 |
| | 3.0 |
| | 5.0 |
| Slightly Unstable | 1.5 |
| | 2.0 |
| | 3.0 |
| | 5.0 |
| | 7.0 |
| | 10.0 |
| Neutral | 2.0 |
| | 3.0 |
| | 5.0 |
| | 7.0 |
| | 10.0 |
| | 12.5 |
| | 15.0 |
| Slightly Stable | 1.5 |
| | 2.0 |
| | 3.0 |
| | 5.0 |
| Moderately Stable | 1.5 |
| | 2.0 |
| | 3.0 |

*Wind direction is aligned to receptor location; ambient temperature and mixing height assumed to be 300 k and 1,500 m, respectively.

Source: ESE, 1986.

In the second modeling scenario, a series of receptors were selected that would account for air quality impacts due to the mine operation. Since maximum impacts are expected to occur near the mining activity areas, 84 receptors were spaced around the surface and underground mining areas at intervals of approximately 500 m. An additional 14 receptors were located between 5 to 9 km to the east and south of the mining areas because higher concentrations were predicted in those areas (see Figure F-4).

The emissions from the Lakhra Plant are presented in Table F-5. $SO_2$ emissions were based on assuming 10 percent removal in bottom and fly ash. Stack parameters are presented in Table F-6. The basis for 10 percent retainage of sulfur in bottom and fly ash is contained in the GCII feasibility study. In Volume IX of the study, various supporting data are presented to justify that there will be at least 10 percent mill rejection of sulfur and retention of sulfur in ash (see Page 4-5 of Volume I for a discussion of sulfur retention in the ash and rejects from the pulverizers). In Volume IX, see the following:

1. Baseline Coal Report, Table 3-18, Page 3-53: 8.4- to 9.6-percent retention of sulfur in ash.
2. BT-11 Coals Report, Table 3-20, Page 3-49: 15.1- to 15.8-percent retention of sulfur in ash, Seam 2. 13.6- to 13.9-percent retention of sulfur in ash, Seam 1.
3. Page 3-10 of baseline coal report: 2.1-percent reject rate of the weight of coal feed is equivalent to 4.8 percent of the sulfur in the coal.
4. Page 3-12 of BT-11 coal report: 0.7- and 0.2-percent reject rate of the weight of Seams 1 and 2 coals fed is equivalent to 1.8 and 0.5 percent of the sulfur in the coals, respectively.

It is concluded that 10 percent was a conservative representation of the mean expected retention. Baseline coal could be 13.2 to 14.4 percent retention of sulfur, if the mill reject rate remained at 4.8 percent of the sulfur in the coal. Seams 1 and 2 BT-11 coals could be 16.9 to

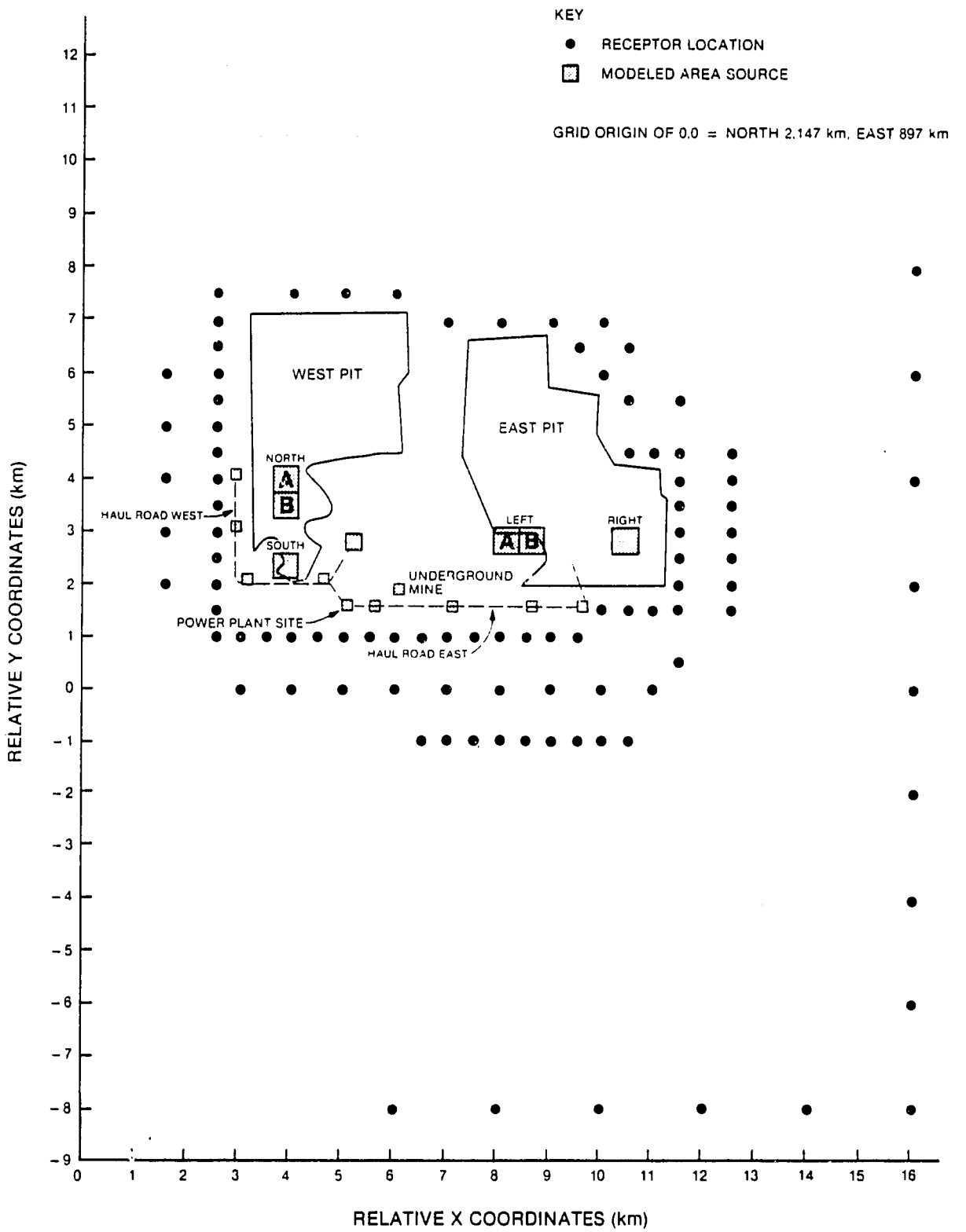


Figure F-4
FUGITIVE DUST RECEPTOR LOCATIONS

SOURCE: ESE, 1986.

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Table F-5. Emissions from Two 250-MW Units Firing Lakhra Coal

| Pollutant | Emissions | | |
|---|---|---|---|
| | Maximum at 100 Percent Load (g/s) | Metric Tons | |
| | | Per Day | Annual* |
| $SO_2$ - uncontrolled | 11,167 | 967.0 | 247,000 |
| PM | 113 | 9.8 | 2,500 |
| $NO_x$ | 417 | 36.0 | 9,200 |

*Assumes 70 percent capacity factor.

Source: ESE, 1986.



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Table F-6. Stack Parameters for Two 250-MW Units Firing Lakhra Coal (with Common Stack, Dual Flue)

| Parameter | Value |
|---|---|
| Stack Height (m) | 183,229,305 |
| Stack Diameter (m) | 7.93 |
| Stack Temperature (k) | 423 |
| Stack Velocity (m/s) | 22.9 |

Source: GCII, 1986.

17.6 percent and 14.1 to 14.4 percent, respectively. These data are based on laboratory test burn results and while they are greater than 10 percent, the USEPA factor of 12.5 percent for low sodium lignite could be used. It was decided for the purposes of the modeling analysis, however, to use 10 percent as it was not known what the central and east lease area coals would show if they were test burned under laboratory conditions. Furthermore, if they demonstrated a retention rate similar to baseline coal and the mill reject sulfur was similar to BT-11 coals, the mean rate would be near 10 percent.

For the fugitive PM emission analysis, the emissions and source characteristics assumed for the mining activities are presented in Table F-9. The methods and assumptions used in deriving the emissions and emission factors are presented in Appendix I. The spatial distribution of the modeled fugitive dust source locations within and around the mining areas is presented in Figure F-4.

The emissions and stack parameters for Jamshoro oil units that were used in the modeling are presented in Table F-7. Other emission sources were not included in the analysis because of the distance and magnitude of emissions from these sources (see Table F-8). The emissions and stack parameters for this comparison were performed under 100-percent load conditions.

Table F-7. Model Input Parameters of Fugitive PM Emissions Due to Mining Operations

| Source No. | Description Name | Assumed Area of Activity (m x m) | Emissions kg/yr | Emissions g/s | Emissions $g/m^2$-s | Relative X, Y Location (m)-* Southwest Corner of Area |
|---|---|---|---|---|---|---|
| 1. | East Pit-Left-A | 500 x 500 | 3,157,895 | 100.1 | 0.00040 | 7900, 2600 |
| 2. | East Pit-Left-B | 500 x 500 | 3,157,895 | 100.1 | 0.00040 | 8400, 2600 |
| 3. | East Pit-Right | 500 x 500 | 5,520,741 | 175.1 | 0.00070 | 10200, 2600 |
| 4. | West Pit-North-A | 500 x 500 | 817,186 | 25.9 | 0.00010 | 3600, 3800 |
| 5. | West Pit-North-B | 500 x 500 | 817,186 | 25.9 | 0.00010 | 3600, 3300 |
| 6. | West Pit-South | 500 x 500 | 943,246 | 29.9 | 0.00012 | 3600, 2100 |
| 7. | Haul Road East-Area 1 | 200 x 200 | 318,688 | 10.1 | 0.00025 | 9500, 1500 |
| 8. | Haul Road East-Area 2 | 200 x 200 | 318,688 | 10.1 | 0.00025 | 8500, 1500 |
| 9. | Haul Road East-Area 3 | 200 x 200 | 318,688 | 10.1 | 0.00025 | 7000, 1500 |
| 10. | Haul Road East-Area 4 | 200 x 200 | 318,688 | 10.1 | 0.00025 | 5500, 1500 |
| 11. | Haul Road West-Area 1 | 200 x 200 | 80,617 | 2.56 | 0.000064 | 4500, 2000 |

Table F-7. Model Input Parameters of Fugitive PM Emissions Due to Mining Operations (Continued, Page 2 of 2)

| Source Description No. | Name | Assumed Area of Activity (m x m) | Emissions kg/yr | g/s | $g/m^2$-s | Relative X, Y Location (m)-* Southwest Corner of Area |
|---|---|---|---|---|---|---|
| 12. | Haul Road West-Area 2 | 200 x 200 | 80,617 | 2.56 | 0.000064 | 3000, 2000 |
| 13. | Haul Road West-Area 3 | 200 x 200 | 80,617 | 2.56 | 0.000064 | 2800, 3000 |
| 14. | Haul Road West-Area 4 | 200 x 200 | 80,617 | 2.56 | 0.000064 | 2800, 4000 |
| 15. | ROM | 250 x 250 | 26,925 | 0.854 | 0.000014 | 5000, 2750 |
| 16. | Underground Mine | 167 x 167 | 10,249 | 0.325 | 0.000012 | 6000, 1833 |
| 17. | Plant | 100 x 100 | 30,554 | 0.969 | 0.000097 | 5000, 1500 |

*Relative location based on 0, 0 equal to 897 km East, 2,147 km North

Source: ESE, 1986.

Table F-8. Emissions and Stack Parameters for the Jamshoro Oil-Fired Thermal Power Station

| Parameter | Value (Per Unit) |
|---|---|
| Rating (KW) | 250,000 |
| Heat Rate | 2,050 Kcal/kwh |
| Heat Input | 566.5 x $10^6$ Kcal/hr |
| Fuel Rate | 55,000 kg/hr |
| Stack Height | 150 m |
| Stack Diameter | 4.5 m |
| Stack Velocity | 20 m/s |
| Stack Temperature | 408 K |
| Emissions | |
| Sulfur Dioxide | 1,069 g/s |
| | 26,970 metric tons/year* |
| Particulate | 76.9 g/s |
| | 1,940 metric tons/year* |
| Nitrogen Oxides | 129 g/s |
| | 3,255 metric tons/year* |
| Carbon Monoxide | 9.7 g/s |
| | 245 metric tons/year* |

*At 80-percent capacity factor.

Source: Tokyo Electric Power Services Co., LTD., 1985.
ESE, 1986.

Table F-9. Estimated Emissions from Existing Sources

| Source | Emissions (Metric Tons/year) | | | |
|---|---|---|---|---|
| | Sulfur Dioxide | Particulate Matter | Nitrogen Oxide | Carbon Monoxide |
| Kotri Gas Turbine Power Station | 56 | 128 | 3,265 | 892 |
| Hyderabad Thermal Power Station-43.7 MW | 448 | 90 | 879 | 64 |
| Zeal Pak Cement | 7,450 | 164,145 | 1,537 | --- |

Source: ESE, 1986.

APPENDIX G--SURFACE WATER FLOW AND QUALITY DATA AND GROUND WATER TABLE DATA

Table G-1. Maximum and Minimum Discharges ($m^3$/sec) of the Indus River, 1981-1983, Sample Station Kotri Barrage

| YEAR/LOCATION | JANUARY | | FEBUARY | | MARCH | | APRIL | | MAY | | JUNE | | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | | YEAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN |
| 1981 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UPSTREAM OF BARRAGE | 32,473 | 3,657 | 30,831 | 11,954 | 11,640 | 2,830 | 44,261 | 8,075 | 171,510 | 13,410 | 169,224 | 12,742 | 188,401 | 26,650 | 316,246 | 152,110 | 145,369 | 21,501 | 20,100 | 8,455 | 9,910 | 3,412 | 6,952 | 2,138 | 316,246 | 0 |
| DOWNSTREAM OF BARRAGE | 12,107 | 3,657 | 12,021 | 4,431 | 4,398 | 0 | 39,382 | 1,575 | 147,863 | 7,200 | 137,757 | 0 | 165,575 | 0 | 302,172 | 136,134 | 127,301 | 6,432 | 8,100 | 0 | 0 | 0 | 6,952 | 0 | 302,172 | 0 |
| WITHDRAWAL FROM BARRAGE | 20,366 | 0 | 18,810 | 7,523 | 7,242 | 2,830 | 4,879 | 6,500 | 23,647 | 6,210 | 31,467 | 20,742 | 22,826 | 26,650 | 14,074 | 15,976 | 10,068 | 15,069 | 12,000 | 8,455 | 9,910 | 3,412 | 0 | 2,138 | 31,467 | 0 |
| 1982 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UPSTREAM OF BARRAGE | 17,548 | 3,000 | 16,890 | 1,247 | 9,153 | 1,273 | 24,043 | 2,711 | 76,516 | 12,819 | 45,115 | 14,660 | 47,218 | 35,069 | 250,054 | 33,191 | 162,245 | 5,904 | 30,709 | 13,695 | 15,191 | 1,332 | 25,782 | 1,013 | 250,054 | 0 |
| DOWNSTREAM OF BARRAGE | 0 | 3,000 | 1,105 | 0 | 0 | 0 | 20,000 | 0 | 58,385 | 6,150 | 12,300 | 0 | 10,400 | 1,496 | 219,661 | 2,751 | 131,499 | 70 | 2,600 | 2,903 | 2,899 | 0 | 1,981 | 0 | 219,661 | 0 |
| WITHDRAWAL FROM BARRAGE | 13,586 | 0 | 15,785 | 1,247 | 9,153 | 1,273 | 4,043 | 2,711 | 16,131 | 7,969 | 32,815 | 17,960 | 28,818 | 34,286 | 30,393 | 28,440 | 30,746 | 6,804 | 23,109 | 10,792 | 12,292 | 1,532 | 17,801 | 1,313 | 34,286 | 0 |
| 1983 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UPSTREAM OF BARRAGE | 22,571 | 1,651 | 9,496 | 1,646 | 5,347 | 799 | 126,138 | 931 | 114,868 | 30,582 | 123,693 | 51,544 | 174,620 | 62,819 | 364,798 | 111,680 | 493,163 | 46,924 | 38,084 | 11,278 | 12,594 | 8,959 | 717,032 | 4,835 | 717,032 | 0 |
| DOWNSTREAM OF BARRAGE | 3,279 | 0 | 0 | 0 | 0 | 0 | 114,526 | 0 | 90,726 | 9,052 | 88,932 | 20,252 | 149,300 | 32,305 | 358,179 | 85,488 | 474,311 | 33,500 | 23,000 | 2,231 | 2,213 | 482 | 17,032 | 432 | 474,311 | 0 |
| WITHDRAWAL FROM BARRAGE | 19,292 | 1,651 | 9,496 | 1,646 | 5,347 | 1,099 | 11,612 | 931 | 24,142 | 21,530 | 34,761 | 31,292 | 25,320 | 30,514 | 6,619 | 26,192 | 18,852 | 13,424 | 15,084 | 9,047 | 10,381 | 9,627 | 0 | 9,303 | 34,761 | 0 |

SOURCES: Institute of Public Health Engineering and Research, 1983.

ESE, 1985.

Table G-2. Discharge Characteristics of Indus River at Sehwan for the Years 1972-75 and 1979*

| Year | MONTHLY AVERAGE DISCHARGE (CUSECS) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1972 | 6,010 | 2,350 | 1,520 | 5,370 | 20,000 | 82,400 | 224,000 | 136,000 | 62,000 | 7,640 | 2,740 | 2,490 |
| 1973 | 13,400 | 2,170 | 1,160 | 21,000 | 57,600 | 159,000 | 396,000 | 497,000 | 305,000 | 51,900 | 11,800 | 7,120 |
| 1974 | 18,200 | 6,440 | 2,330 | 73,200 | 9,230 | 34,200 | 70,300 | 93,400 | 12,000 | 7,230 | 2,760 | 1,820 |
| 1975 | 9,220 | 1,950 | 1,250 | 2,060 | 12,600 | 54,600 | 135,000 | 249,000 | 312,000 | 31,800 | 4,990 | 3,870 |
| 1979 | 13,000 | 11,200 | 63,500 | 68,600 | 77,500 | 50,400 | 170,000 | 229,000 | 51,900 | 30,100 | 13,000 | —† |
| AVG | 11,966 | 4,822 | 13,952 | 34,046 | 35,386 | 76,120 | 199,060 | 240,880 | 148,580 | 25,734 | 7,058 | 3,825 |

*Minimum daily discharge for period of record as follows:

Extreme Daily Minimum: 895 cusecs (for 7 consecutive days in April 1975).
Average of Extreme Daily Minimums for Period: 1,363 cusecs.

† Data not available.

Source: WAPDA Surface Water Hydrological Report, 1960-1979.

Table G-3. Mean Monthly Water Quality Data, 1980-1984, Sample Station Upstream of the Kotri Barrage near the Left Divide Wall

| | O-PHOSPHATE mg/l | F-COLI FORM MPN/ 100 ml | CHROMIUM IRON TOTAL mg/l | SODIUM mg/l | SULFATE mg/l | CALCIUM mg/l | MAGNESIUM mg/l | FLOURIDE mg/l | C.O.D. mg/l | IRON TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| JANUARY | 0.01 | 118 | 0 | 13.6 | 103 | 39 | 18.4 | 0.3 | 76.7 | 0.2 |
| FEBUARY | 0.01 | 112 | 0 | 15.4 | 104 | 41 | 16.6 | 0.3 | 18.2 | 0.2 |
| MARCH | 0.02 | 109 | 0 | 13.2 | 105 | 43 | 19.1 | 0.4 | 16.3 | 0.1 |
| APRIL | 0.02 | 107 | 0 | 12.9 | 96 | 41 | 17.0 | 0.4 | 15.4 | 0.1 |
| MAY | 0.02 | 112 | 0 | 14.2 | 101 | 40 | 16.1 | 0.4 | 12.8 | 0.1 |
| JUNE | 0.02 | 104 | 0 | 13.4 | 100 | 36 | 13.3 | 0.4 | 10.1 | 0.1 |
| JULY | 0.00 | 92 | 0 | 13.9 | 102 | 31 | 14.3 | 0.3 | 8.9 | 0.1 |
| AUGUST | 0.00 | 92 | 0 | 13.8 | 90 | 37 | 15.4 | 0.3 | 10.8 | 0.1 |
| SEPTEMBER | 0.00 | 95 | 0 | 14.6 | 91 | 39 | 16.2 | 0.3 | 14.1 | 0.1 |
| OCTOBER | 0.00 | 100 | 0 | 14.7 | 96 | 40 | 17.3 | 0.3 | 13.3 | 0.1 |
| NOVEMBER | 0.00 | 108 | 0 | 14.8 | 97 | 41 | 19.3 | 0.3 | 14.9 | 0.1 |
| DECEMBER | 0.01 | 115 | 0 | 13.1 | 97 | 39 | 19.4 | 0.3 | 17.7 | 0.1 |

| | TEMP IN DEGREES C | pH | COND mohs/cm | D.O. mg/l | CHLORIDE mg/l | ALTH LINITY TOTAL mg/l | SUSPENDED SOLIDS mg/l | N-NH3 mg/l | NO2 +NO3 | B.O.D. mg/l |
|---|---|---|---|---|---|---|---|---|---|---|
| JANUARY | 18 | 7.4 | 318 | 10.8 | 50 | 106 | 110 | 0.30 | 2.2 | 7.0 |
| FEBUARY | 19 | 7.4 | 346 | 10.6 | 55 | 109 | 60 | 0.30 | 2.2 | 6.9 |
| MARCH | 24 | 7.4 | 395 | 11.2 | 63 | 109 | 46 | 0.22 | 2.3 | 6.5 |
| APRIL | 30 | 7.5 | 367 | 10.6 | 57 | 100 | 38 | 0.16 | 1.9 | 6.1 |
| MAY | 32 | 7.5 | 360 | 9.1 | 56 | 100 | 160 | 0.27 | 1.9 | 5.7 |
| JUNE | 34 | 7.5 | 332 | 8.2 | 51 | 100 | 483 | 0.20 | 1.8 | 4.8 |
| JULY | 31 | 7.5 | 309 | 7.2 | 46 | 90 | 1213 | 0.16 | 1.8 | 4.7 |
| AUGUST | 30 | 7.5 | 303 | 7.8 | 43 | 93 | 2075 | 0.16 | 1.9 | 5.9 |
| SEPTEMBER | 29 | 7.5 | 322 | 8.8 | 46 | 98 | 1440 | 0.16 | 1.9 | 6.8 |
| OCTOBER | 28 | 7.5 | 327 | 8.9 | 49 | 102 | 270 | 0.16 | 2.0 | 6.3 |
| NOVEMBER | 23 | 7.4 | 333 | 10.8 | 54 | 96 | 58 | 0.18 | 2.0 | 7.8 |
| DECEMBER | 21 | 7.4 | 320 | 12.3 | 49 | 109 | 50 | 0.24 | 2.3 | 7.5 |

SOURCE: Public Health Engineering Research Laboratory, Hyderabad; ESE, 1985

Table G-4. Summary of Indus River Water Quality Monitoring Data, 1980-1984, Maximum, Minimum, Mean, and Standard Deviation, Sample Station Upstream of the Kotri Barrage near the Left Divide Wall

| | Temp. in Degrees (°C) | pH | COND mohs/cm | D.O. mg/l | Chloride mg/l | Alkalinity Total mg/l | Suspended Solids mg/l | N-$NH_3$ mg/l | $NO_2$ + $NO_3$ | DOD mg/l |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | | | | | | | | | | |
| Maximum | 40 | 7.8 | 510 | 24 | 100 | 140 | 2200 | 1.1 | 3.8 | 12.8 |
| Minimum | 14 | 7.2 | 230 | 4 | 30 | 40 | 10 | 0 | 0.9 | 1 |
| Mean | 26.35 | 7.45 | 335.44 | 9.74 | 51.62 | 101.98 | 487.15 | 0.21 | 2.03 | 6.34 |
| Standard Deviation | 6.295 | 0.089 | 48.493 | 4.152 | 12.515 | 24.490 | 810.677 | 0.246 | 0.539 | 2.844 |

Table G-4. Summary of Indus River Water Quality Monitoring Data, 1980-1984, Maximum, Minimum, Mean, and Standard Deviation, Sample Station Upstream of the Kotri Barrage near the Left Divide Wall (Continued, Page 2 of 2)

| | O-Phosphate mg/l | F-Coliform NPN/100 ml | Chromium Iron Total mg/l | Sodium mg/l | Sulfate mg/l | Calcium mg/l | Magnesium mg/l | Fluoride mg/l | C.O.D. m/gl | Iron Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | | | | | | | | | | |
| Maximum | 0.08 | 180 | 0 | 44 | 149 | 56 | 32 | 0.68 | 720 | 1.1 |
| Minimum | 0 | 70 | 0 | 2 | 64 | 12 | 2.8 | 0 | 2 | 0 |
| Mean | 0.02 | 105.47 | 0.00 | 13.98 | 98.45 | 38.90 | 17.04 | 0.34 | 19.99 | 0.10 |
| Standard Deviation | 0.024 | 19.706 | 0.000 | 12.721 | 11.838 | 8.940 | 7.805 | 0.154 | 63.803 | 0.183 |

Sources: Public Health Engineering Research Laboratory, Hyderabad.
ESE, 1985.

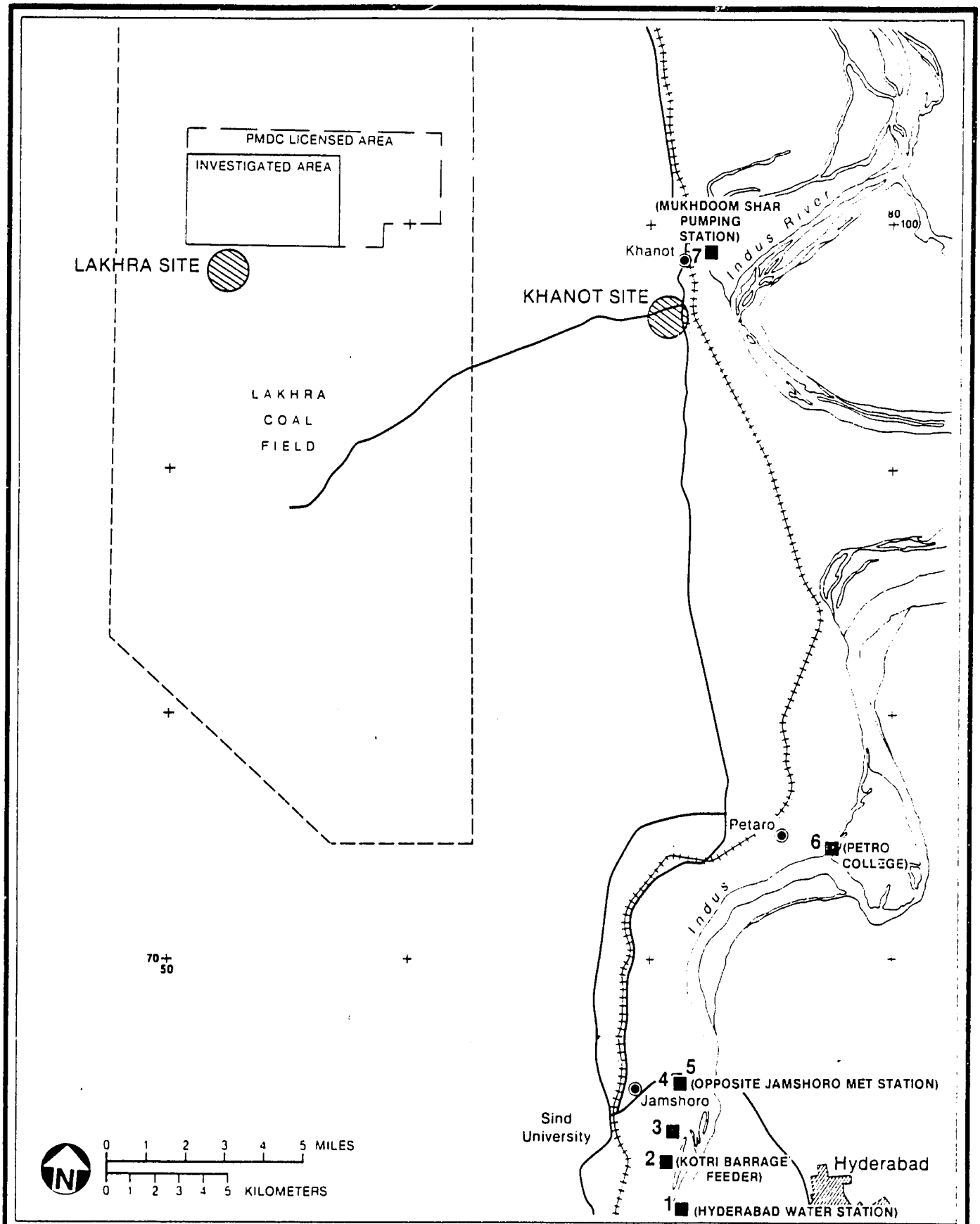


Figure G-1
WATER QUALITY MONITORING STATIONS
LOCATIONS, 1985

SOURCE: GCII, 1985.

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Table G-5. Summary of Indus River Water Quality

TEMPERATUE (DEG C)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | | 30.4 | | | | | 30.40 | 30.40 | 30.40 | 0.00 | 30.40 | 30.40 | 30.40 | 0.00 |
| JUNE | 27.9 | 28.6 | 29.0 | 28.0 | 30.0 | 30.0 | 28.92 | 30.00 | 27.90 | 0.85 | 29.12 | 30.00 | 28.00 | 0.79 |
| JULY | 26.0 | 25.6 | 25.5 | 26.1 | 25.8 | 26.0 | 25.83 | 26.10 | 25.50 | 0.22 | 25.80 | 26.10 | 25.50 | 0.23 |
| AUGUST | 30.6 | 30.0 | 30.0 | 28.0 | 30.0 | | 29.72 | 30.60 | 28.00 | 0.89 | 29.58 | 30.00 | 28.00 | 0.87 |
| SEPTEMBER | 29.7 | 32.6 | 29.6 | 30.3 | 30.0 | 30.3 | 30.45 | 32.60 | 29.70 | 0.99 | 30.60 | 32.60 | 29.60 | 1.02 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.00 | 24.00 | 24.00 | 0.00 | 24.00 | 24.00 | 24.00 | 0.00 |
| DECEMBER | 21.3 | 19.2 | 19.2 | 19.2 | 19.2 | 19.2 | 19.55 | 21.30 | 19.20 | 0.78 | 19.26 | 19.20 | 19.20 | 0.00 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 16.1 | | | 18.0 | 18.0 | 18.0 | 14.02 | 18.00 | 0.00 | 7.05 | 13.50 | 18.00 | 0.00 | 7.79 |
| FEBRUARY | 22.0 | 22.0 | 21.6 | 22.0 | 21.5 | 21.6 | 21.78 | 22.00 | 21.50 | 0.22 | 21.74 | 22.00 | 21.50 | 0.22 |
| MARCH | 22.0 | 21.0 | 21.0 | 21.0 | 21.5 | 21.7 | 21.43 | 22.00 | 21.00 | 0.26 | 21.20 | 21.70 | 21.00 | 0.28 |
| APRIL | 21.0 | 20.0 | 21.0 | 19.0 | 22.0 | 22.0 | 20.83 | 22.00 | 19.00 | 1.07 | 20.50 | 22.00 | 19.00 | 1.17 |
| MAY | 25.0 | 24.0 | 25.0 | 24.0 | 24.0 | 25.0 | 24.50 | 25.00 | 24.00 | 0.50 | 24.40 | 25.00 | 24.00 | 0.49 |
| JUNE | 30.0 | 32.8 | 32.4 | 32.4 | 32.0 | 32.5 | 32.07 | 32.80 | 30.00 | 0.94 | 32.48 | 32.80 | 32.30 | 0.17 |
| JULY | 32.2 | 32.3 | 32.2 | | 32.2 | 32.2 | 32.22 | 32.30 | 32.20 | 0.04 | 32.23 | 32.30 | 32.20 | 0.04 |
| AUGUST | 26.8 | 25.0 | 30.5 | 23.3 | 23.3 | 23.3 | 25.37 | 30.50 | 23.30 | 2.63 | 25.08 | 30.50 | 23.30 | 2.79 |
| MEAN | 25.73 | 26.25 | 24.37 | 24.28 | 25.27 | 25.06 | | | | | | | | |
| MAXIMUM | 32.20 | 32.80 | 32.40 | 32.40 | 32.30 | 32.50 | | | | | | | | |
| MINIMUM | 16.10 | 19.20 | 0.00 | 18.00 | 18.00 | 19.00 | | | | | | | | |
| STD. DEV. | 4.39 | 4.65 | 8.01 | 4.31 | 4.24 | 4.24 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 2 of 12)

PH (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | 8.34 | 7.20 | | | | | 7.77 | 8.34 | 7.20 | 0.57 | 7.20 | 7.20 | 7.20 | 0.00 |
| JUNE | 8.33 | 8.48 | 8.41 | 8.50 | 8.40 | 8.30 | 8.40 | 8.50 | 8.30 | 0.07 | 8.42 | 8.50 | 8.30 | 0.07 |
| JULY | 7.90 | 8.00 | 8.40 | 8.00 | 8.10 | 7.80 | 8.03 | 8.40 | 7.80 | 0.19 | 8.06 | 8.40 | 7.80 | 0.20 |
| AUGUST | 7.40 | 7.45 | 7.40 | 7.40 | 7.50 | | 7.43 | 7.50 | 7.40 | 0.04 | 7.44 | 7.50 | 7.40 | 0.04 |
| SEPTEMBER | 7.80 | 8.00 | 7.60 | 8.10 | 7.50 | 7.70 | 7.82 | 8.10 | 7.50 | 0.20 | 7.92 | 8.10 | 7.50 | 0.21 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 8.05 | 8.05 | 8.10 | 8.19 | 8.06 | 8.27 | 8.13 | 8.27 | 8.05 | 0.08 | 8.13 | 8.27 | 8.05 | 0.08 |
| DECEMBER | 7.90 | 8.07 | 8.00 | 8.05 | 8.04 | 7.90 | 7.99 | 8.07 | 7.90 | 0.07 | 8.01 | 8.07 | 7.90 | 0.06 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 7.90 | | 8.00 | 7.60 | 7.30 | 7.70 | 7.70 | 8.00 | 7.30 | 0.24 | 7.65 | 8.00 | 7.30 | 0.25 |
| FEBRUARY | 7.70 | 7.60 | 7.70 | 7.70 | 7.50 | 7.50 | 7.65 | 7.80 | 7.50 | 0.11 | 7.64 | 7.80 | 7.50 | 0.12 |
| MARCH | 7.76 | 7.66 | 7.90 | 7.70 | 7.70 | 7.65 | 7.71 | 7.80 | 7.65 | 0.05 | 7.70 | 7.80 | 7.65 | 0.05 |
| APRIL | 8.30 | 8.40 | 8.40 | 8.10 | 8.20 | 8.30 | 8.28 | 8.40 | 8.10 | 0.11 | 8.28 | 8.40 | 8.10 | 0.12 |
| MAY | 8.20 | 8.10 | 8.00 | 7.90 | 7.90 | 8.00 | 8.02 | 8.20 | 7.90 | 0.11 | 7.98 | 8.10 | 7.90 | 0.07 |
| JUNE | 8.70 | 7.60 | 7.60 | 7.60 | 7.60 | 7.60 | 7.78 | 8.70 | 7.60 | 0.41 | 7.60 | 7.60 | 7.60 | 0.00 |
| JULY | 7.40 | 7.24 | 7.60 | | 7.40 | 7.30 | 7.39 | 7.60 | 7.24 | 0.12 | 7.39 | 7.60 | 7.24 | 0.14 |
| AUGUST | 7.30 | 7.20 | 7.20 | 7.10 | 7.50 | 7.10 | 7.23 | 7.50 | 7.10 | 0.14 | 7.22 | 7.50 | 7.10 | 0.15 |
| MEAN | 7.93 | 7.80 | 7.89 | 7.84 | 7.76 | 7.75 | | | | | | | | |
| MAXIMUM | 8.70 | 8.48 | 8.41 | 8.50 | 8.40 | 8.30 | | | | | | | | |
| MINIMUM | 7.30 | 7.20 | 7.20 | 7.10 | 7.30 | 7.10 | | | | | | | | |
| STD. DEV. | 0.39 | 0.41 | 0.36 | 0.36 | 0.33 | 0.36 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 3 of 12)

ALKALINITY (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | 118 | 74 | | | | | 32.00 | 118.00 | 0.00 | 47.00 | 14.80 | 74.00 | 0.00 | 29.60 |
| JUNE | 139 | 99 | 94 | 89 | 73 | 77 | 95.17 | 139.00 | 77.00 | 21.59 | 86.40 | 99.00 | 73.00 | 9.91 |
| JULY | 89 | 77 | 94 | 95 | 99 | 85 | 89.83 | 99.00 | 77.00 | 7.27 | 90.00 | 99.00 | 77.00 | 7.95 |
| AUGUST | 92 | 126 | 114 | 112 | 130 | | 114.80 | 130.00 | 92.00 | 17.30 | 120.50 | 130.00 | 112.00 | 7.66 |
| SEPTEMBER | 93 | 79 | 83 | 105 | 70 | 93 | 88.00 | 105.00 | 70.00 | 11.86 | 87.00 | 105.00 | 70.00 | 12.76 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 99 | 100 | 111 | 103 | 92 | 95 | 100.83 | 111.00 | 92.00 | 6.72 | 101.20 | 111.00 | 92.00 | 7.30 |
| DECEMBER | 109 | 124 | 115 | 126 | 112 | 126 | 118.67 | 126.00 | 109.00 | 6.92 | 120.60 | 126.00 | 112.00 | 5.92 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 144 | 100 | 143 | 155 | 146 | 126 | 135.67 | 155.00 | 100.00 | 18.12 | 134.00 | 155.00 | 100.00 | 19.42 |
| FEBRUARY | 110 | 125 | 120 | 110 | 111 | 120 | 116.00 | 125.00 | 110.00 | 5.92 | 117.20 | 125.00 | 110.00 | 5.78 |
| MARCH | 168 | 112 | 95 | 115 | 117 | 122 | 121.67 | 168.00 | 95.00 | 22.43 | 112.40 | 123.00 | 95.00 | 9.41 |
| APRIL | 160 | 114 | 101 | 109 | 109 | 97 | 115.00 | 160.00 | 97.00 | 20.89 | 106.00 | 114.00 | 97.00 | 6.13 |
| MAY | 129 | 97 | 99 | 109 | 227 | 206 | 144.33 | 227.00 | 97.00 | 52.36 | 147.60 | 227.00 | 97.00 | 56.79 |
| JUNE | 90 | 86 | 93 | 103 | 207 | 215 | 132.33 | 215.00 | 86.00 | 55.91 | 140.80 | 215.00 | 86.00 | 57.63 |
| JULY | | | | | | | | | | | | | | |
| AUGUST | 127 | 132 | 127 | 150 | 122 | 127 | 130.83 | 150.00 | 122.00 | 9.04 | 131.60 | 150.00 | 122.00 | 9.73 |
| MEAN | 119.00 | 103.21 | 99.21 | 106.14 | 115.36 | 115.00 | | | | | | | | |
| MAXIMUM | 168.00 | 132.00 | 143.00 | 155.00 | 227.00 | 215.00 | | | | | | | | |
| MINIMUM | 89.00 | 74.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | | |
| STD. DEV. | 25.33 | 18.80 | 31.56 | 34.38 | 53.52 | 52.14 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 4 of 12)

CONDUCTIVITY (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | | | | | | | | | | | | | | |
| JUNE | 1700 | 200 | 100 | 1100 | 1100 | 1100 | 883.33 | 1700.00 | 100.00 | 561.00 | 720.00 | 1100.00 | 100.00 | 466.48 |
| JULY | 1100 | 220 | 260 | 700 | 700 | 400 | 563.33 | 1100.00 | 220.00 | 306.03 | 456.00 | 700.00 | 220.00 | 208.00 |
| AUGUST | 236 | 230 | 226 | 227 | 229 | | 229.60 | 236.00 | 226.00 | 3.50 | 228.00 | 230.00 | 226.00 | 1.58 |
| SEPTEMBER | 222 | 225 | 223 | 220 | 222 | 220 | 222.00 | 225.00 | 220.00 | 1.73 | 222.00 | 225.00 | 220.00 | 1.90 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | | | 260 | | | | 260.00 | 260.00 | 260.00 | 0.00 | 260.00 | 260.00 | 260.00 | 0.00 |
| DECEMBER | 300 | 300 | 300 | 300 | 300 | 300 | 300.00 | 300.00 | 300.00 | 0.00 | 300.00 | 300.00 | 300.00 | 0.00 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 400 | | 400 | 399 | 421 | 397 | 403.40 | 421.00 | 397.00 | 8.87 | 404.25 | 421.00 | 397.00 | 9.73 |
| FEBRUARY | 525 | 270 | 365 | 358 | 357 | 356 | 371.83 | 525.00 | 270.00 | 75.87 | 341.20 | 365.00 | 270.00 | 35.74 |
| MARCH | 950 | 320 | 380 | 300 | 300 | 310 | 426.67 | 950.00 | 300.00 | 235.63 | 322.00 | 380.00 | 300.00 | 29.93 |
| APRIL | 1550 | 370 | 310 | 300 | 320 | 410 | 543.33 | 1550.00 | 300.00 | 451.80 | 342.00 | 410.00 | 300.00 | 41.67 |
| MAY | 800 | 250 | 230 | 220 | 230 | 215 | 324.17 | 800.00 | 215.00 | 213.08 | 229.00 | 250.00 | 215.00 | 12.00 |
| JUNE | 180 | 170 | 160 | 175 | 175 | 190 | 175.00 | 190.00 | 160.00 | 9.13 | 174.00 | 190.00 | 160.00 | 9.70 |
| JULY | 280 | 300 | 270 | | 260 | 270 | | | | | 275.00 | 300.00 | 260.00 | 15.00 |
| AUGUST | 290 | 290 | 180 | 220 | 250 | 190 | 236.67 | 290.00 | 180.00 | 43.84 | 226.00 | 290.00 | 180.00 | 40.30 |
| MEAN | 656.38 | 262.08 | 261.71 | 376.58 | 374.15 | 363.17 | | | | | | | | |
| MAXIMUM | 1700.00 | 370.00 | 400.00 | 1100.00 | 1100.00 | 1100.00 | | | | | | | | |
| MINIMUM | 180.00 | 170.00 | 100.00 | 175.00 | 175.00 | 190.00 | | | | | | | | |
| STD. DEV. | 561.50 | 54.29 | 82.21 | 255.43 | 245.35 | 235.51 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 5 of 12)

SS (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | 500 | 1 | | | | | 250.50 | 500.00 | 1.00 | 249.50 | 1.00 | 1.00 | 1.00 | 0.00 |
| JUNE | 60 | 52 | 80 | 100 | 150 | 75 | 91.17 | 180.00 | 52.00 | 42.55 | 97.40 | 180.00 | 52.00 | 44.03 |
| JULY | 130 | 220 | 225 | 230 | 310 | 200 | 219.17 | 310.00 | 130.00 | 52.79 | 237.00 | 310.00 | 200.00 | 37.89 |
| AUGUST | 930 | 950 | 800 | 800 | 850 | | 860.00 | 950.00 | 800.00 | 58.31 | 850.00 | 950.00 | 800.00 | 61.24 |
| SEPTEMBER | 600 | 300 | 260 | 140 | 155 | 130 | 264.17 | 600.00 | 130.00 | 163.00 | 197.00 | 300.00 | 130.00 | 69.40 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 70 | 350 | 90 | 95 | 100 | 80 | 170.83 | 350.00 | 70.00 | 93.51 | 143.00 | 350.00 | 80.00 | 103.71 |
| DECEMBER | 135 | 190 | 120 | 300 | 220 | 100 | 177.50 | 300.00 | 100.00 | 68.42 | 186.00 | 300.00 | 100.00 | 72.00 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 465 | | 740 | 230 | 250 | 125 | 362.00 | 740.00 | 125.00 | 218.92 | 336.25 | 740.00 | 125.00 | 237.89 |
| FEBRUARY | 600 | 120 | 280 | 290 | 580 | 160 | 341.67 | 600.00 | 120.00 | 184.97 | 290.00 | 580.00 | 120.00 | 158.24 |
| MARCH | 60 | 50 | 190 | 90 | 60 | 90 | 90.00 | 190.00 | 50.00 | 47.26 | 96.00 | 190.00 | 50.00 | 49.64 |
| APRIL | 920 | 280 | 350 | 600 | 1400 | 380 | 651.67 | 1400.00 | 280.00 | 398.51 | 598.00 | 1400.00 | 280.00 | 416.29 |
| MAY | 230 | 80 | 120 | 700 | 450 | 170 | 291.67 | 700.00 | 80.00 | 217.82 | 304.00 | 700.00 | 80.00 | 236.69 |
| JUNE | 120 | 450 | 840 | 1400 | 1800 | 900 | 918.33 | 1800.00 | 120.00 | 558.64 | 1078.00 | 1800.00 | 450.00 | 470.68 |
| JULY | 180 | 350 | 350 | | 700 | 300 | 376.00 | 700.00 | 180.00 | 173.31 | 425.00 | 700.00 | 300.00 | 160.08 |
| AUGUST | 1800 | 1000 | 1200 | 900 | 1100 | 1200 | 1200.00 | 1800.00 | 900.00 | 288.68 | 1080.00 | 1200.00 | 900.00 | 116.62 |
| MEAN | 451.33 | 312.36 | 403.21 | 451.92 | 582.50 | 302.31 | | | | | | | | |
| MAXIMUM | 1800.00 | 1000.00 | 1200.00 | 1400.00 | 1800.00 | 1200.00 | | | | | | | | |
| MINIMUM | 60.00 | 1.00 | 80.00 | 90.00 | 60.00 | 75.00 | | | | | | | | |
| STD. DEV. | 460.00 | 299.07 | 335.74 | 385.46 | 513.26 | 335.16 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 6 of 12)

D.O. (mg/l)

| | STATION NUMBER | | | | | | ALL STATIONS | | | | STATIONS 2 - 7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 5 | 6 | 7 | MEAN | MAXIMUM | MINIMUM | STD. DEV. | MEAN | MAXIMUM | MINIMUM | STD. DEV. |
| **1985** | | | | | | | | | | | | | | |
| MAY | 6.9 | 6.8 | | | | | 6.85 | 6.90 | 6.80 | 0.05 | 6.80 | 6.80 | 6.80 | 0.05 |
| JUNE | 6.9 | 7.6 | 7.7 | 7.7 | 6.6 | 6.6 | 7.16 | 7.70 | 6.60 | 0.49 | 7.24 | 7.70 | 6.60 | 0.49 |
| JULY | | 7.9 | | 7.4 | | | 7.65 | 7.90 | 7.40 | 0.25 | 7.65 | 7.90 | 7.40 | 0.25 |
| AUGUST | | | 7.0 | 7.2 | 7.1 | | 7.10 | 7.20 | 7.00 | 0.08 | 7.10 | 7.20 | 7.00 | 0.08 |
| SEPTEMBER | 7.0 | 6.8 | 7.1 | 7.0 | 7.0 | 6.8 | 6.95 | 7.10 | 6.80 | 0.11 | 6.94 | 7.10 | 6.80 | 0.11 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | | | | | 12.0 | | 12.00 | 12.00 | 12.00 | 0.00 | 12.00 | 12.00 | 12.00 | 0.00 |
| DECEMBER | 7.9 | 9.2 | 9.1 | 9.0 | 8.4 | 7.5 | 8.50 | 9.20 | 7.50 | 0.66 | 8.64 | 9.20 | 7.50 | 0.66 |
| **1986** | | | | | | | | | | | | | | |
| JANUARY | 8.7 | | 8.2 | 10.1 | 9.3 | 9.3 | 9.12 | 10.10 | 8.20 | 0.64 | 9.23 | 10.10 | 8.20 | 0.64 |
| FEBRUARY | 9.7 | 9.6 | 8.5 | 9.6 | 9.4 | 7.7 | 9.08 | 9.70 | 7.70 | 0.74 | 8.96 | 9.60 | 7.70 | 0.74 |
| MARCH | 8.7 | 9.1 | 9.1 | 7.7 | 7.6 | 7.8 | 8.33 | 9.10 | 7.60 | 0.65 | 8.26 | 9.10 | 7.60 | 0.65 |
| APRIL | 7.5 | 8.7 | 8.2 | 7.5 | 6.5 | 6.5 | 7.82 | 8.70 | 6.50 | 0.74 | 7.88 | 8.70 | 6.50 | 0.74 |
| MAY | 8.8 | 8.7 | 8.7 | 9.1 | 8.7 | 9.0 | 8.83 | 9.10 | 8.70 | 0.16 | 8.84 | 9.10 | 8.70 | 0.16 |
| JUNE | 6.5 | 6.0 | 6.9 | 16.5 | 6.8 | 7.2 | 8.37 | 16.50 | 6.00 | 3.66 | 8.68 | 16.50 | 6.00 | 3.66 |
| JULY | 6.5 | 6.7 | 7.0 | | 7.0 | 6.4 | 6.64 | 7.00 | 6.30 | 0.30 | 6.68 | 7.00 | 6.30 | 0.30 |
| AUGUST | 6.4 | 6.6 | 6.6 | 9.7 | 6.7 | 5.9 | 6.98 | 9.70 | 5.90 | 1.24 | 7.10 | 9.70 | 5.90 | 1.24 |
| MEAN | 7.64 | 7.77 | 7.84 | 9.04 | 8.08 | 7.34 | | | | | | | | |
| MAXIMUM | 9.70 | 9.60 | 9.10 | 16.50 | 12.00 | 9.30 | | | | | | | | |
| MINIMUM | 6.40 | 6.00 | 6.60 | 7.00 | 6.60 | 5.90 | | | | | | | | |
| STD. DEV. | 1.04 | 1.21 | 0.87 | 2.48 | 1.48 | 1.02 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 7 of 12)

Cl- (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | 110 | 40 | | | | | 75.00 | 110.00 | 40.00 | 35.00 | 40.00 | 40.00 | 40.00 | 0.00 |
| JUNE | 182 | 23 | 27 | 21 | 24 | 17 | 49.00 | 182.00 | 17.00 | 59.56 | 22.40 | 27.00 | 17.00 | 3.32 |
| JULY | 13 | 20 | 22 | 21 | 18 | 19 | 18.83 | 22.00 | 13.00 | 2.91 | 20.00 | 22.00 | 18.00 | 1.41 |
| AUGUST | 11 | 14 | 15 | 15 | 14 | | 13.80 | 15.00 | 11.00 | 1.47 | 14.50 | 15.00 | 14.00 | 0.50 |
| SEPTEMBER | 13 | 14 | 18 | 9 | 14 | 23 | 15.17 | 23.00 | 9.00 | 4.37 | 15.60 | 23.00 | 9.00 | 4.67 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 20 | 12 | 17 | 20 | 15 | 16 | 16.67 | 20.00 | 12.00 | 2.31 | 16.00 | 20.00 | 12.00 | 2.61 |
| DECEMBER | 75 | 18 | 14 | 14 | 13 | 15 | 24.83 | 75.00 | 13.00 | 22.49 | 14.80 | 18.00 | 13.00 | 1.72 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 20 | | 25 | 29 | 24 | 15 | 22.60 | 29.00 | 15.00 | 4.76 | 23.25 | 29.00 | 15.00 | 5.12 |
| FEBRUARY | 65 | 21 | 18 | 26 | 24 | 21 | 29.17 | 65.00 | 18.00 | 16.22 | 22.00 | 26.00 | 18.00 | 2.76 |
| MARCH | 170 | 25 | 20 | 13 | 23 | 21 | 45.33 | 170.00 | 13.00 | 55.38 | 20.40 | 25.00 | 13.00 | 4.08 |
| APRIL | 296 | 50 | 38 | 40 | 44 | 49 | 86.17 | 296.00 | 38.00 | 93.94 | 44.20 | 50.00 | 38.00 | 4.75 |
| MAY | 194 | 19 | 20 | 20 | 16 | 19 | 47.33 | 194.00 | 16.00 | 65.38 | 16.60 | 20.00 | 16.00 | 1.50 |
| JUNE | 15 | 14 | 12 | 10 | 15 | 15 | 13.50 | 15.00 | 10.00 | 1.89 | 13.20 | 15.00 | 10.00 | 1.94 |
| JULY | 8 | 8 | 6 | | 7 | 15 | 8.80 | 15.00 | 6.00 | 3.19 | 9.00 | 15.00 | 6.00 | 3.54 |
| AUGUST | 20 | 15 | 12 | 7 | 16 | 15 | 15.83 | 20.00 | 7.00 | 7.61 | 13.00 | 16.00 | 7.00 | 3.29 |
| MEAN | 81.47 | 20.56 | 18.86 | 18.85 | 19.07 | 20.00 | | | | | | | | |
| MAXIMUM | 296.00 | 50.00 | 38.00 | 40.00 | 44.00 | 49.00 | | | | | | | | |
| MINIMUM | 8.00 | 8.00 | 6.00 | 7.00 | 7.00 | 15.00 | | | | | | | | |
| STD. DEV. | 86.46 | 10.93 | 7.49 | 8.78 | 8.44 | 8.79 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 8 of 12)

SO4 (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | 65 | 50 | | | | | 57.50 | 65.00 | 50.00 | 7.50 | 50.00 | 50.00 | 50.00 | 0.00 |
| JUNE | 108 | 38 | 40 | 32 | 39 | 42 | 49.83 | 108.00 | 32.00 | 26.19 | 38.20 | 42.00 | 32.00 | 3.37 |
| JULY | 28 | 18 | 17 | 16 | 8 | 30 | 19.50 | 30.00 | 8.00 | 7.45 | 17.30 | 30.00 | 8.00 | 7.05 |
| AUGUST | 19 | 22 | 28 | 25 | 25 | | 23.80 | 28.00 | 19.00 | 3.66 | 25.00 | 28.00 | 22.00 | 3.12 |
| SEPTEMBER | 9 | 8 | 16 | 19 | 17 | 15 | 14.00 | 19.00 | 8.00 | 4.38 | 15.00 | 19.00 | 8.00 | 3.74 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 30 | 29 | 27 | 25 | 26 | 30 | 27.83 | 30.00 | 25.00 | 1.95 | 27.40 | 30.00 | 25.00 | 1.85 |
| DECEMBER | 100 | 30 | 29 | 25 | 37 | 37 | 43.00 | 100.00 | 25.00 | 25.85 | 31.60 | 37.00 | 25.00 | 4.72 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 35 | | 30 | 38 | 50 | 38 | 38.20 | 50.00 | 30.00 | 6.56 | 39.00 | 50.00 | 30.00 | 7.14 |
| FEBRUARY | 100 | 48 | 46 | 80 | 100 | 44 | 69.67 | 100.00 | 44.00 | 24.61 | 63.60 | 100.00 | 44.00 | 22.50 |
| MARCH | 200 | 22 | 35 | 115 | 42 | 31 | 74.17 | 200.00 | 22.00 | 64.10 | 49.30 | 115.00 | 22.00 | 33.63 |
| APRIL | 400 | 60 | 75 | 95 | 90 | 120 | 140.00 | 400.00 | 60.00 | 117.72 | 88.00 | 120.00 | 60.00 | 20.15 |
| MAY | 160 | 60 | 70 | 120 | 70 | 60 | 90.00 | 160.00 | 60.00 | 37.42 | 76.00 | 120.00 | 60.00 | 22.45 |
| JUNE | 17 | 24 | 30 | 28 | 24 | 22 | 24.50 | 30.00 | 17.00 | 4.27 | 26.00 | 30.00 | 22.00 | 2.83 |
| JULY | 24 | 18 | 12 | | 18 | 12 | 16.80 | 24.00 | 12.00 | 4.49 | 15.00 | 18.00 | 12.00 | 3.00 |
| AUGUST | 55 | 44 | 44 | 48 | 52 | 55 | 49.67 | 55.00 | 44.00 | 4.64 | 48.60 | 55.00 | 44.00 | 4.36 |
| MEAN | 90.00 | 33.79 | 33.64 | 51.23 | 42.71 | 41.23 | | | | | | | | |
| MAXIMUM | 400.00 | 60.00 | 75.00 | 120.00 | 100.00 | 120.00 | | | | | | | | |
| MINIMUM | 9.00 | 8.00 | 12.00 | 16.00 | 8.00 | 12.00 | | | | | | | | |
| STD. DEV. | 99.07 | 15.81 | 17.85 | 36.14 | 26.55 | 26.39 | | | | | | | | |

Table G-5. Summary of Indus River Water Quali[redacted] (Continued, Page 9 of 12)

NO3 (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | 1.00 | 0.20 | | | | | 0.60 | 1.00 | 0.20 | 0.40 | 0.20 | 0.20 | 0.20 | 0.00 |
| JUNE | 1.90 | 0.30 | | 1.20 | 1.00 | 0.90 | 1.06 | 1.90 | 0.30 | 0.52 | 0.85 | 1.20 | 0.30 | 0.34 |
| JULY | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| AUGUST | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SEPTEMBER | 0.31 | 0.30 | 0.19 | 0.28 | 0.23 | 0.34 | 0.28 | 0.34 | 0.19 | 0.05 | 0.27 | 0.34 | 0.19 | 0.05 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 0.00 | 0.20 | 0.30 | 0.00 | 0.10 | 0.20 | 0.08 | 0.20 | 0.00 | 0.09 | 0.10 | 0.20 | 0.00 | 0.09 |
| DECEMBER | 0.50 | 0.16 | 0.12 | 0.00 | 0.42 | 0.20 | 0.23 | 0.50 | 0.00 | 0.17 | 0.16 | 0.42 | 0.00 | 0.14 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 0.00 | | 0.00 | 0.00 | 0.10 | 0.20 | 0.06 | 0.20 | 0.00 | 0.08 | 0.08 | 0.20 | 0.00 | 0.08 |
| FEBRUARY | 8.00 | 4.00 | 4.50 | 4.50 | 5.00 | 2.20 | 4.70 | 8.00 | 2.20 | 1.72 | 4.04 | 5.00 | 2.20 | 0.97 |
| MARCH | 3.50 | 4.00 | 6.00 | 2.00 | 0.20 | 1.80 | 2.92 | 6.00 | 0.20 | 1.85 | 2.80 | 6.00 | 0.20 | 2.00 |
| APRIL | 2.00 | 0.01 | 0.01 | 0.10 | 0.10 | 0.00 | 0.37 | 2.00 | 0.00 | 0.73 | 0.04 | 0.10 | 0.00 | 0.05 |
| MAY | 0.10 | 0.20 | 0.20 | 0.25 | 0.50 | | 0.25 | 0.50 | 0.10 | 0.13 | 0.29 | 0.50 | 0.20 | 0.12 |
| JUNE | 0.10 | | | | 0.10 | | 0.10 | 0.10 | 0.10 | 0.00 | 0.10 | 0.10 | 0.10 | 0.00 |
| JULY | 0.10 | 0.01 | 0.10 | | 0.16 | | 0.09 | 0.16 | 0.01 | 0.05 | 0.09 | 0.16 | 0.01 | 0.06 |
| AUGUST | 0.10 | 0.15 | 0.20 | 0.40 | 0.26 | 0.15 | 0.21 | 0.40 | 0.10 | 0.10 | 0.23 | 0.40 | 0.15 | 0.09 |
| MEAN | 1.17 | 0.73 | 0.94 | 0.73 | 0.58 | 0.60 | | | | | | | | |
| MAXIMUM | 8.00 | 4.00 | 6.00 | 4.50 | 5.00 | 2.20 | | | | | | | | |
| MINIMUM | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | | |
| STD. DEV. | 2.07 | 1.40 | 1.95 | 1.28 | 1.25 | 0.75 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 10 of 12)

Fe (mg/l)

| | STATION NUMBER | | | | | | ALL STATIONS | | | | STATIONS 2 - 7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 5 | 6 | 7 | MEAN | MAXIMUM | MINIMUM | STD. DEV. | MEAN | MAXIMUM | MINIMUM | STD. DEV. |
| 1985 | | | | | | | | | | | | | | |
| MAY | | | | | | | | | | | | | | |
| JUNE | 0.51 | 0.35 | | 0.35 | 3.70 | 1.30 | 1.24 | 3.70 | 0.35 | 1.28 | 1.43 | 3.70 | 0.35 | 1.37 |
| JULY | 0.23 | 0.26 | 0.35 | 0.62 | 0.31 | 0.46 | 0.35 | 0.62 | 0.23 | 0.14 | 0.40 | 0.62 | 0.26 | 0.13 |
| AUGUST | 1.50 | 0.40 | 0.13 | 0.14 | 0.09 | 0.18 | 0.43 | 1.50 | 0.09 | 0.49 | 0.21 | 0.40 | 0.09 | 0.11 |
| SEPTEMBER | 2.00 | 0.21 | 0.08 | 1.10 | 0.80 | 2.10 | 1.05 | 2.10 | 0.08 | 0.79 | 0.86 | 2.10 | 0.08 | 0.73 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 0.15 | 0.22 | 0.08 | 0.09 | 0.22 | 0.19 | 0.16 | 0.22 | 0.08 | 0.06 | 0.16 | 0.22 | 0.09 | 0.06 |
| DECEMBER | 0.41 | 0.40 | 0.25 | 0.14 | 0.09 | 0.18 | 0.25 | 0.41 | 0.09 | 0.12 | 0.21 | 0.40 | 0.09 | 0.11 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 0.08 | | 0.60 | 0.30 | 0.18 | 0.50 | 0.33 | 0.60 | 0.08 | 0.19 | 0.40 | 0.60 | 0.18 | 0.16 |
| FEBRUARY | 0.48 | 0.50 | 0.30 | 0.35 | 0.80 | 2.50 | 0.82 | 2.50 | 0.30 | 0.77 | 0.89 | 2.50 | 0.30 | 0.82 |
| MARCH | 0.80 | 1.10 | 1.10 | 0.45 | 0.70 | 0.80 | 0.76 | 1.10 | 0.30 | 0.30 | 0.75 | 1.10 | 0.30 | 0.33 |
| APRIL | 0.40 | 0.25 | 0.30 | 0.25 | 0.40 | 0.30 | 0.32 | 0.40 | 0.25 | 0.06 | 0.30 | 0.40 | 0.25 | 0.05 |
| MAY | 0.28 | 0.40 | 0.40 | 0.15 | 0.50 | 0.60 | 0.39 | 0.60 | 0.15 | 0.14 | 0.41 | 0.60 | 0.15 | 0.15 |
| JUNE | 0.28 | 0.15 | 0.50 | 1.90 | 0.70 | 0.50 | 0.67 | 1.90 | 0.15 | 0.58 | 0.75 | 1.90 | 0.15 | 0.60 |
| JULY | 0.40 | 0.50 | 0.20 | | 0.30 | 0.26 | 0.33 | 0.50 | 0.20 | 0.11 | 0.32 | 0.50 | 0.20 | 0.11 |
| AUGUST | 0.030 | 0.020 | 0.015 | 0.012 | 0.010 | 0.010 | 0.02 | 0.03 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.00 |
| MEAN | 0.54 | 0.37 | 0.34 | 0.45 | 0.60 | 0.71 | | | | | | | | |
| MAXIMUM | 2.00 | 1.10 | 1.10 | 1.90 | 3.70 | 2.50 | | | | | | | | |
| MINIMUM | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | | | | | | | | |
| STD. DEV. | 0.54 | 0.28 | 0.27 | 0.50 | 0.89 | 0.72 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 11 of 12)

TOTAL PO4 (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | | 0.15 | | | | | 0.15 | 0.15 | 0.15 | 0.00 | 0.15 | 0.15 | 0.15 | 0.00 |
| JUNE | 0.75 | 0.42 | | 2.10 | 4.00 | 4.00 | 2.25 | 4.00 | 0.42 | 1.53 | 2.63 | 4.00 | 0.42 | 1.49 |
| JULY | 0.50 | 0.60 | 0.70 | 1.20 | 1.00 | 1.80 | 0.97 | 1.80 | 0.50 | 0.44 | 1.06 | 1.80 | 0.60 | 0.43 |
| AUGUST | 0.90 | 1.00 | 0.46 | 0.64 | 1.40 | | 0.88 | 1.40 | 0.48 | 0.32 | 0.88 | 1.40 | 0.48 | 0.35 |
| SEPTEMBER | 1.60 | 1.25 | 0.95 | 1.20 | 1.60 | 1.20 | 1.30 | 1.60 | 0.95 | 0.23 | 1.24 | 1.60 | 0.95 | 0.21 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 0.49 | 1.10 | 0.40 | 0.38 | 0.52 | 0.60 | 0.58 | 1.10 | 0.38 | 0.24 | 0.60 | 1.10 | 0.38 | 0.26 |
| DECEMBER | 0.68 | 0.82 | 0.53 | 0.83 | 1.46 | 0.82 | 0.86 | 1.46 | 0.53 | 0.29 | 0.89 | 1.46 | 0.53 | 0.31 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 0.70 | | 1.30 | 0.98 | 0.92 | 1.42 | 1.06 | 1.42 | 0.70 | 0.26 | 1.16 | 1.42 | 0.92 | 0.21 |
| FEBRUARY | 0.86 | 1.10 | 0.96 | 0.65 | 0.60 | 3.50 | 1.28 | 3.50 | 0.60 | 1.01 | 1.36 | 3.50 | 0.60 | 1.09 |
| MARCH | 1.50 | 1.50 | 2.00 | 2.10 | 2.00 | 2.20 | 1.88 | 2.20 | 1.50 | 0.28 | 1.96 | 2.20 | 1.50 | 0.24 |
| APRIL | 0.70 | 0.20 | 0.75 | 0.20 | 0.50 | 0.35 | 0.45 | 0.75 | 0.20 | 0.22 | 0.49 | 0.75 | 0.20 | 0.21 |
| MAY | 2.40 | 1.20 | 0.30 | 0.60 | 1.40 | 1.15 | 1.26 | 2.40 | 0.60 | 0.57 | 1.03 | 1.40 | 0.60 | 0.29 |
| JUNE | 0.80 | 0.60 | 0.40 | 0.45 | 0.60 | 0.85 | 0.62 | 0.85 | 0.40 | 0.16 | 0.55 | 0.85 | 0.40 | 0.16 |
| JULY | 0.60 | 0.70 | 0.43 | | 0.51 | 0.30 | 0.61 | 0.80 | 0.43 | 0.13 | 0.61 | 0.80 | 0.43 | 0.15 |
| AUGUST | 0.80 | 0.60 | 0.52 | 0.45 | 0.52 | 0.42 | 0.55 | 0.80 | 0.42 | 0.13 | 0.50 | 0.60 | 0.42 | 0.07 |
| MEAN | 0.95 | 0.80 | 0.79 | 0.90 | 1.22 | 1.47 | | | | | | | | |
| MAXIMUM | 2.40 | 1.50 | 2.00 | 2.10 | 4.00 | 4.00 | | | | | | | | |
| MINIMUM | 0.49 | 0.15 | 0.40 | 0.20 | 0.50 | 0.35 | | | | | | | | |
| STD. DEV. | 0.51 | 0.39 | 0.43 | 0.59 | 0.91 | 1.10 | | | | | | | | |

Table G-5. Summary of Indus River Water Quality (Continued, Page 12 of 12)

CU (mg/l)

| | STATION NUMBER 1 | 2 | 3 | 5 | 6 | 7 | ALL STATIONS MEAN | MAXIMUM | MINIMUM | STD. DEV. | STATIONS 2 - 7 MEAN | MAXIMUM | MINIMUM | STD. DEV. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | | | | | | | | | | | | | | |
| MAY | | | | | | | | | | | | | | |
| JUNE | 0.05 | 0.02 | | 0.10 | 0.60 | 0.10 | 0.17 | 0.60 | 0.02 | 0.22 | 0.21 | 0.60 | 0.02 | 0.23 |
| JULY | 0.01 | 0.05 | 0.06 | 0.01 | 0.28 | 0.02 | 0.07 | 0.28 | 0.01 | 0.10 | 0.06 | 0.28 | 0.01 | 0.10 |
| AUGUST | 0.29 | 0.57 | 0.10 | 0.16 | 0.13 | | 0.25 | 0.57 | 0.10 | 0.17 | 0.24 | 0.57 | 0.10 | 0.19 |
| SEPTEMBER | 0.20 | 0.18 | 0.12 | 0.39 | 0.21 | 0.19 | 0.22 | 0.39 | 0.12 | 0.08 | 0.22 | 0.39 | 0.12 | 0.09 |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 0.02 | 0.20 | 0.00 | 0.00 | 0.01 | 0.09 | 0.05 | 0.20 | 0.00 | 0.07 | 0.06 | 0.20 | 0.00 | 0.08 |
| DECEMBER | 0.25 | 0.21 | 0.20 | 0.50 | 0.05 | 0.20 | 0.24 | 0.50 | 0.05 | 0.14 | 0.23 | 0.50 | 0.05 | 0.15 |
| 1986 | | | | | | | | | | | | | | |
| JANUARY | 0.09 | | 0.12 | 0.20 | 0.20 | 0.30 | 0.18 | 0.30 | 0.09 | 0.07 | 0.21 | 0.30 | 0.12 | 0.06 |
| FEBRUARY | 0.20 | 0.10 | 0.00 | 0.20 | 0.40 | 0.10 | 0.17 | 0.40 | 0.00 | 0.12 | 0.16 | 0.40 | 0.00 | 0.14 |
| MARCH | 0.10 | 0.30 | 1.10 | 0.00 | 0.00 | 0.00 | 0.25 | 1.10 | 0.00 | 0.39 | 0.28 | 1.10 | 0.00 | 0.43 |
| APRIL | 0.40 | 0.14 | 0.25 | 0.30 | 0.33 | 0.40 | 0.30 | 0.40 | 0.14 | 0.09 | 0.28 | 0.40 | 0.14 | 0.09 |
| MAY | 0.15 | 0.13 | 0.15 | 0.30 | 0.26 | 0.25 | 0.21 | 0.30 | 0.13 | 0.07 | 0.22 | 0.30 | 0.13 | 0.07 |
| JUNE | 0.05 | 0.10 | 0.10 | 0.01 | 0.10 | 0.10 | 0.09 | 0.10 | 0.01 | 0.03 | 0.08 | 0.10 | 0.01 | 0.04 |
| JULY | 0.15 | 0.10 | 0.10 | | | 0.10 | 0.11 | 0.15 | 0.10 | 0.02 | 0.10 | 0.10 | 0.10 | 0.00 |
| AUGUST | 0.010 | 0.015 | 0.012 | 0.010 | 0.012 | 0.010 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 0.02 | 0.01 | 0.00 |
| MEAN | 0.14 | 0.16 | 0.18 | 0.17 | 0.20 | 0.14 | | | | | | | | |
| MAXIMUM | 0.40 | 0.57 | 1.10 | 0.50 | 0.60 | 0.40 | | | | | | | | |
| MINIMUM | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | | |
| STD. DEV | 0.12 | 0.14 | 0.25 | 0.16 | 0.17 | 0.11 | | | | | | | | |

Source: WAPDA, Hyderabad Office, 1986.

Table G-6. Borings and Water Levels in the Lakhra Coal Field

| Boring No. | Total Depth of Boring, m | (ft) | Ground Elevation, m-msl | (ft-msl) | Water Level Elevation, m-msl | (ft-msl) | Depth of Weathering, m from surface | (ft) |
|---|---|---|---|---|---|---|---|---|
| L1 | 143 | (468) | 105 | (347) | 69 | (227) | 30 | (97) |
| L2 | 140 | (462) | 97 | (317) | 25 | (82) | 52 | (171) |
| L4 | 126 | (412) | 107 | (352) | <81 | (<267)* | 28 | (91) |
| L5 | 132 | (433) | 100 | (329) | <61 | (<199) | 30 | (100) |
| L6 | 47 | (155) | 100 | (328) | <54 | (<178) | 40 | (130) |
| L7 | 152 | (499) | 118 | (388) | 62 | (204) | 20 | (65) |
| L8 | 120 | (393) | 119 | (389) | <87 | (<285) | 18 | (58) |
| L9 | 92 | (303) | 84 | (274) | 24 | (80) | 29 | (95) |
| L10 | 130 | (426) | 107 | (350) | 45 | (148) | 50 | (165) |
| L11 | >43 | (>142) | 93 | (306) | 57 | (188) | 43 | (142) |
| L12 | 88 | (289) | 128 | (421) | 82 | (269) | 16 | (53) |
| L13 | 52 | (175) | 84 | (276) | <53 | (<174) | 34 | (111) |
| L14 | 85 | (278) | 118 | (387) | 69 | (228) | 27 | (87) |
| L15 | 122 | (400) | 99 | (324) | 58 | (191) | 52 | (170) |
| L16 | 80 | (261) | 126 | (415) | 59 | (192) | 37 | (120) |
| L17 | 59 | (194) | 95 | (313) | 36 | (119) | 51 | (168) |
| L18 | 80 | (261) | 112 | (369) | 35 | (114) | 15 | (48) |
| L19 | 63 | (208) | 89 | (291) | 29 | (94) | 19 | (63) |
| L20 | 95 | (311) | 125 | (410) | 56 | (184) | 23 | (74) |
| L21 | 66 | (217) | 72 | (236) | 24 | (78) | 17 | (55) |
| L22 | 87 | (285) | 116 | (379) | 45 | (149) | 16 | (53) |
| L24 | 108 | (354) | 118 | (387) | 27 | (87) | 29 | (96) |
| L25 | 130 | (426) | 47 | (153) | 37 | (123) | 107 | (351) |
| L26 | 144 | (471) | 130 | (427) | 95 | (311) | 35 | (116) |
| Average | | | 104 | (340) | 53 | (173) | 34 | (112) |

* Unable to measure below lowest elevation due to collapse of hole.

Source: GOP Ministry of Industries and Natural Resources, 1973.

Table G-7. Well Inventory

| Well Name | Location | Completion Zone | Well Depth (m) | Diameter (m) | Depth to Water (m) | Construction | Withdrawal Rate ($m^3$/day) |
|---|---|---|---|---|---|---|---|
| Kayee Dhoro | 15 km west of West Pit; Foothills of Laki Range | Alluvium of Kayee Dhoro | 8.2 | 2 | 7.3 | Concrete casing to 5 m; gravel to bottom | 3 |
| Habibullah | 9 km south of Lakhra Study Area | Alluvium of Lailian Nala | 12.3 | 5 | 10.0 | Concrete and brick casing to bottom | Unknown |
| Amine | 13 km south of Lakhra Study Area | Alluvium of unnamed tributary to Lailian Nala | 16.4 | 3 | 15.8 | Unlined | 15 |
| Sind | 16 km south of Lakhra Study Area | Alluvium of Lailian Nala | 7.1 | 3.5 | 6.1 | Brick lined | Unknown |
| Khanot | 15 km east of Lakhra Study Area | Alluvium of Tarai Nala (tributary to Indus River) | 6.7 | 3.8 | 6.2 | Brick lined | Unknown |

Source: J.T. Boyd Company, 1986.

Table G-8. Inventory of Flooded Mines

| Mining Company | No. of Flooded Mines | Mine Name | Estimated Water Production ($m^3$/day) | Reported Water Quality | Status | Origin of Water |
|---|---|---|---|---|---|---|
| Faiz | All dry | — | — | — | — | — |
| Sind | 3 | #5 | Low | Unknown | Active | Coal |
| | | #5A | Low | Unknown | Active | Below Coal |
| | 3 | #6 | Low | Unknown | Active | Below Coal |
| Amine | 3 | #2A | Low | Unknown | Closed | Unknown |
| | | #6A | Low | Unknown | Unknown | Unknown |
| | | #6 | Low | Unkonwn | Active | Unknown |
| Indus | 5 | #7 | 16 | Salty | Closed | Sandy shale above coal |
| | | #9 | Unknown | Salty | Closed | Sand above coal |
| | | #10 | 10 | Unknown | Unknown | Sand |
| | | #11 | Unknown | Unknown | Development | Unknown |
| | | #16 | Unknown | Unknown | Unknown | Unknown |
| Saquib | 4 | Mehran 3 | 36 | Salty | Closed | Sandy shale above coal |
| | | Mehran 17 | 1 | Salty | Active | Sandy shale 25 m above coal |
| | | Green 1 | 1500 | Salty | Closed | Coal |
| | | Sarwar 1 | 26 | Salty | Closed | Sand above coal |
| PMDC | 3 | #3 | Unknown | Unknown | Active | Unknown |
| | | #4 | Unknown | Unknown | Closed | Unknown |
| | | #5 | Unknown | Unknown | Inactive | Unknown |
| National | 2 | #4 | Unknown | Unknown | Active | Coal |
| | | #8 | 2 | Very Salty | Inactive | Sand above coal |
| Iqbal | All dry | — | — | — | — | — |

Source: J.T. Boyd Company, 1986.

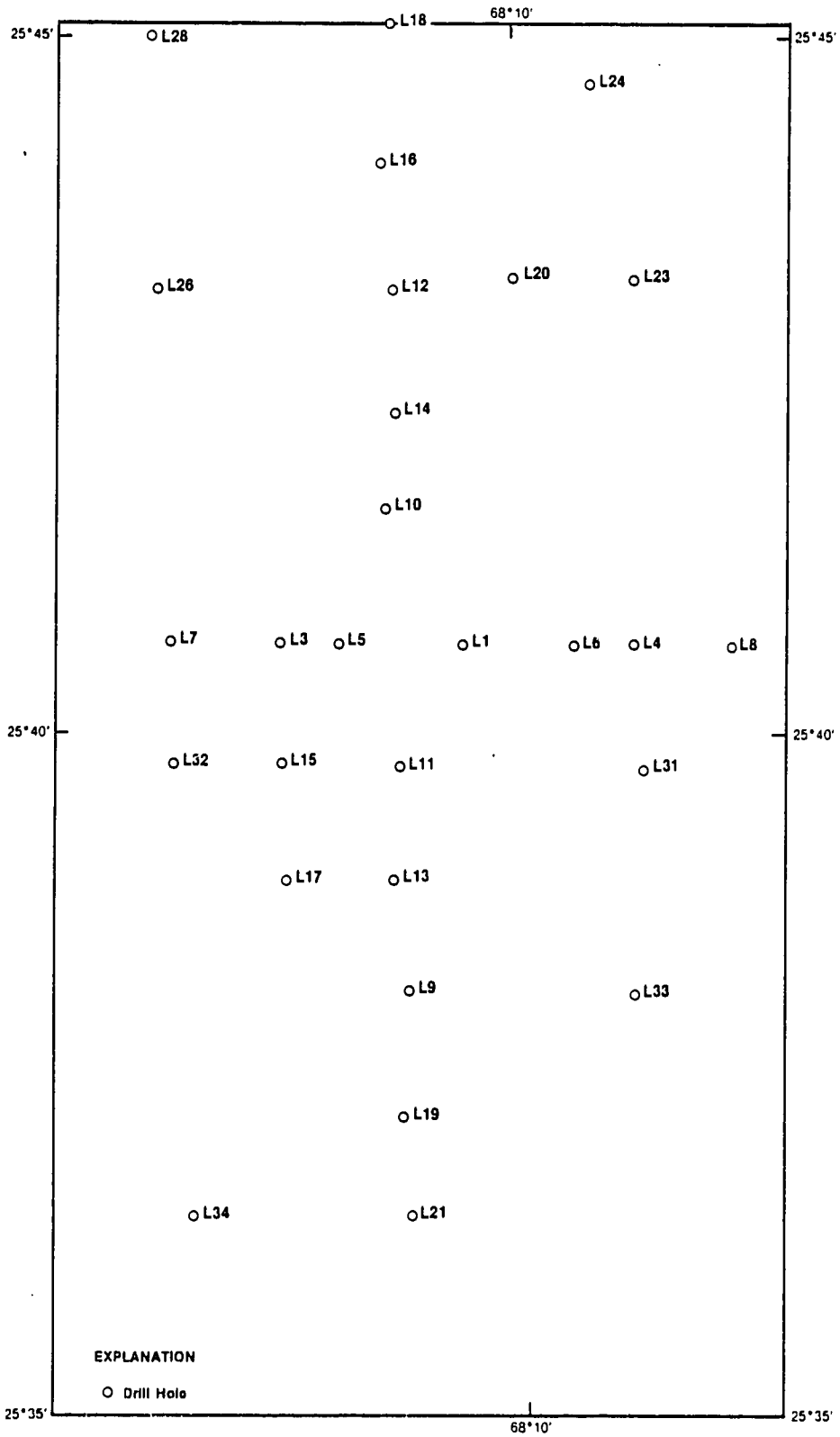


Figure G-2
BORING LOCATION PLAN, LAKHRA AREA

SOURCE: GCII, 1985.

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

Lakhra Coal Mine and Power Generation Feasibility Study

Table G-9. Mine Water Analysis (Analysis Performed by PCSIR Laboratories, Karachi)

| | Mine | | | | | | |
|---|---|---|---|---|---|---|---|
| | Saquib | | Indus | | National | PMDC | Sind |
| | Green No. 1 | Mehran No. 17 | No. 7 | No. 16 | No. 8 | No. 5 | No. 5 |
| | (All units mg/L otherwise indicated) | | | | | | |
| **MINE PARAMETERS** | | | | | | | |
| pH (dimensionless) | 6.7 | 6.1 | 5.2 | 5.8 | 5.6 | 4.8 | 5.4 |
| Iron | 6 | * | 10 | 1 | * | 90 | 90 |
| Manganese | * | 6 | * | * | * | * | * |
| Total Suspended Solids | — | — | — | — | — | — | — |
| Alkalinity (as $CaCO_3$ | 410 | 20 | 10 | 20 | 60 | 10 | — |
| **DRINKING WATER PARAMETERS** | | | | | | | |
| Microbiological | | | | | | | |
| Fecal Coliform (No./100 mL) | 1,100† | 1,100† | 1,100 | — | 93 | 3 | 3 |
| Total Coliform (No./100 mL) | 1,100† | 1,100† | 1,100† | — | 240 | 75 | 75 |
| Inorganic Health Significance | | | | | | | |
| Arsenic | * | * | * | * | * | * | * |
| Cadmium | * | * | * | * | * | * | * |
| Chromium | * | * | * | * | * | * | * |
| Cyanide | * | * | * | * | * | * | * |
| Fluoride | 0.3 | * | 0.2 | 0.7 | * | * | * |
| Lead | * | * | * | * | * | * | 24.0 |
| Mercury | * | * | * | * | * | * | * |
| Nitrate | * | * | 5.0 | * | 7.0 | * | 21.0 |
| Selenium | — | — | — | — | — | — | — |

Table G-9. Mine Water Analysis (Analysis Performed by PCSIR Laboratories, Karachi) (Continued, Page 2 of 2)

| | Mine | | | | | | |
|---|---|---|---|---|---|---|---|
| | Saquib | | Indus | | National | PMDC | Sind |
| | Green No. 1 | Mehran No. 17 | No. 7 | No. 16 | No. 8 | No. 5 | No. 5 |
| | (All units mg/L otherwise indicated) | | | | | | |
| **Aesthetic Quality** | | | | | | | |
| Aluminum | * | * | 6 | * | 2 | 28 | 3 |
| Chloride | 610 | 248 | 3,723 | 7,447 | 17,340 | 2,766 | 1,773 |
| Color | — | — | — | — | — | — | — |
| Copper | * | * | * | * | * | * | 2.76 |
| Hardness (as $CaCO_3$) | 1,220 | 2,200 | 4,600 | 6,600 | 11,200 | 4,600 | 7,500 |
| Hydrogen sulfide | * | * | * | * | * | * | * |
| Iron | 6 | * | 10 | 1 | * | 90 | 90 |
| Manganese | * | 6 | * | * | * | * | * |
| pH (dimensionless) | 6.7 | 6.1 | 5.2 | 5.8 | 5.6 | 4.8 | 5.4 |
| Sodium | 450 | 250 | 3,500 | 6,250 | 8,500 | 375 | 550 |
| Total Dissolved Solids | 3,024 | 4,010 | 18,652 | 31,186 | 41,832 | 7,774 | 15,988 |
| Sulfate | 949 | 2,402 | 7,848 | 7,784 | 6,939 | 3,284 | 8,233 |
| Turbidity (FTU) | 20 | 150 | 900 | 2,000 | 100 | 50 | 1,250 |
| Zinc | * | * | 1,125 | * | * | 1.5 | 5.62 |
| **IRRIGATION WATER PARAMETERS** | | | | | | | |
| Total Dissolved Solids | 3,024 | 4,010 | 18,652 | 31,186 | 41,832 | 7,774 | 15,988 |
| Sodium Adsorption Ratio** | 5.6 | 2.3 | 22.4 | 33.4 | 34.9 | 2.4 | 2.8 |

*Below detectable limit of method of analysis.
**BOYD calculation using hardness.
—Analysis not performed by PCSIR.

Source: J.T. Boyd Company, 1986.

Table G-10. Well Water Analysis (Analysis Performed by PCSIR Laboratories, Karachi)

| Drinking Water Parameters | Well | | | | |
|---|---|---|---|---|---|
| | Kayee Dhoro | Habibullah | Amine | Sind | Khanot |
| Microbiological | | | | | |
| Fecal Coliform (No./100 ml) | -- | -- | -- | -- | 460 |
| Total Coliform (No./100 ml) | -- | -- | -- | -- | 1,100† |
| Aesthetic Quality | | | | | |
| Aluminum | -- | -- | -- | -- | -- |
| Chloride | 25 | 20 | 20 | 34 | -- |
| Color | -- | -- | -- | -- | -- |
| Copper | -- | -- | -- | -- | -- |
| Hardness (as $CaCO_3$** | 670 | 280 | 386 | 754 | -- |
| Hydrogen Sulfide | -- | -- | -- | -- | -- |
| Iron | * | 1 | * | * | -- |
| Manganese | * | * | * | * | -- |
| pH (dimensionless) | 7.8 | 7.7 | 7.4 | 7.4 | -- |
| Sodium | 20 | 12 | 10 | 40 | -- |
| Total Dissolved Solids | 994 | 465 | 567 | 1,371 | -- |
| Sulfate | 494 | 161 | 155 | 615 | -- |
| Turbidity (FTU) | 5 | 6 | 18 | 25 | -- |
| Zinc | -- | -- | -- | -- | -- |

*Below detectable limit of method of analysis.
**BOYD calculation using calcium and magnesium.
--Analysis not performed by PCSIR.

Source: J.T. Boyd Company, 1986.

# APPENDIX H
## ECOLOGICAL DESCRIPTIONS

No ecological surveys specific for the province of Sind or for the study area are known to exist. The ecological descriptions contained in this section are based on general ecological descriptions for Pakistan from the literature, selected references, discussions with federal and provincial natural resource agencies and university scientists and two site reconnaissance visits.

The province of Sind is an arid and semi-arid land through which a great river (the Indus River) flows. The ecological resources of Sind and the study area are influenced by the Indus River and the prevailing climatic conditions. The study area can be considered divided into two sub-areas: the Indus floodplain to the east and the Piedmont area to the west. The Indus Highway or Dadu Road, running north/south, is a dividing line between these two sub-areas. The Indus River has been active in shaping the topography of the Indus floodplain area. The ecological resources in this sub-area reflect the more mesic conditions provided by the river, whereas the higher Piedmont area to the west is dramatically more arid.

The study area can be characterized in several different ways. Although little natural climatic vegetation remains, the area is classified from a forest ecosystem point of view as Tropical Scrub Forest (Arid Lands Information Center, 1981). This forest type runs north and south in the Indus Plain. The characteristic species include pilu or salvadora (Salvadora oleoides), farash or tamarix (Tamarix aphylla and T. gallica), and mesquite (Prosopis cineraria) (Arid Lands Information Center, 1981). Salvadora oleoides and a mesquite species (Prosopis glandulosa) were found at the two proposed power plant sites. Remnants of riverain forest occur along the east side of the Indus River. In their natural state these communities include bhan or poplar (Populus euphratica), babul or acacia (Acacia nilotica), and mesquite. Along the levees on the west side of the Indus River poplar and tali or shisham (Dalbergia sissoo) were observed. Acacia was commonly observed in the area. Irrigated

forest plantations also occur in the floodplain adjoining the Indus River. Large tracts occur on the east side of the river. These areas, managed by the Department of Forestry, contain planted plantations of acacia and shisham. Table H-1 lists the characteristic dominants and associated species found in these forest types. Overall, Beg (1975) classifies Pakistan into several major habitat types. The study area is made up of several climatic, edaphic, seral, and degraded stages identified as sub-habitats including tropical plains thorn forest, salvadora saline scrub, suaeda-salsola scrub, and Indus inundation forests.

The study area and much of the province of Sind has also been classified as rangeland. An ecological classification based on rangeland types has been developed by C.M.A. Khan (1974). Based on this classification, the study area is a tropical maritime region. The natural vegetation for this type of this range ecosystem includes the following monocotyledons: palwan or marvel (Dichanthium annulatum), dals or kusa (Desmostachya bipinnata), dhamn (Cenchrus ciliaris), anjandhaman (C. setigerus), khavi (Cymbopogon jwarancusa), katki (Panicum turgidum), dahlam or chhimbar (Oethochloe compressa), madhana (Dactyloctenium scindicum), and most of the trees found in the inland scrub forests. Most of the land is either under cultivation or arid and overgrazed so that little natural vegetation remains.

During the monsoon season, July and August, the non-cultivated arid areas exhibit rapid growth. Observations during this time recorded 10 to 15 percent ground cover whereas during the preceding period only shrubs were observed. During the February reconnaissance trip only about 1 percent of the area had ground cover. This plant distribution is patchy with most vegetation found in marshes. Table H-2 lists the dominant plant species observed during the August and February field reconnaissances. Stewart (1982) lists the following desert types commonly found on sand, gravel, or alkaline patches: Acacia nilotica, Aerua, Calatropis,

Table H-1. Vegetative Species Characteristics of Major Forest Types Found in Study Area

| Forest Types | Local | English | Botanical |
|---|---|---|---|
| NATURAL HARDWOOD FORESTS | | | |
| Riverain Forests | | | |
| Dominant | Babul | Acacia | Acacia nilotica |
| | Jand | Prosopis | Prosopis cineraria |
| | Bhan | Poplar | Populus euphratica |
| Associated | Pilchi | Tamarix | Tamarix dioica |
| | Farash | Tamarix | Tamarix articulata |
| | Kana | Cane | Saccharum spp. |
| ARTIFICIAL HARDWOOD FORESTS | | | |
| Irrigated Plantation, Plains areas | | | |
| Dominant | Tali | Shisham | Dalbergia sissoo |
| | Tut | Mulberry | Morus alba |
| Associated | Bakain | Melia | Melia azedarach |
| | Semal | Kapok | Samalia malabarica |
| | Babul | Acacia | Acacia nilotica |
| | Sufeda | Eucalyptus | Eucalyptus spp. |
| | Kala Shirin | Black siris | Albizzia lebbeck |
| | Chitta Shirin | White siris | Albizzia procera |
| Canalside and Roadside Plantations | | | |
| Dominant | Tali | Shisham | Dalbergia sissoo |
| | Babul | Acacia | Acacia nilotica |
| | Semal | Kapok | Salmalia malabarica |
| | Kala Shirin | Albizzia | Albizzia lebbeck |
| INLAND SHRUB FOREST | | | |
| Dominant | Pilu | Salvadora | Salvadora oleoides |
| | Farash | Tamarix | Tamarix aphylla |
| | Jand | Prosopis | Prosopis cineraria |
| Associated | Meskeet | Mesquite | Prosopis juliflora |
| | Karir | Capparis | Capparis aphylla |

Source: Modified from Arid Lands Information Center, 1981.

Table H-2. Vegetative Species Observed During Field Reconnaissance, August 1985 and February 1986

| Name of Species | | | | |
|---|---|---|---|---|
| Local | English | Scientific | Location | Uses |
| TREES | | | | |
| Bhan | poplar | Populus euphratica | Found along levees on west side of Indus River | |
| Tali | Shisham | Dalbergia sissoo | Found along levees on west side of Indus River and Reserve Forests | Furniture and carts |
| Babul | acacia | Acacia senegal | Tree species common throughout area, planted in Reserve Forests | Mine timber, gum arabia |
| SHRUBS | | | | |
| Pilu | salvidora | Salvadora oleoides | Common tree or shrub on dry, sandy low tracts, found with Prosopis | Fuel wood |
| Sihar | | Rhazya stricta | Common on dry, rocky hills and drainages | Cattle fodder and fruits |
| Davi | mesquite | Prosopis glandulosa | Xerophytic, long-thorned shrub, dominant in calcareous and sandy soils, native to U.S., naturalized in Sind | |
| | | Ochrandenus biccitus | Xerophytic, calcareous rock, sandy ground | |

Table H-2. Vegetative Species Observed During Field Reconnaissance, August 1985 and February 1986

| Name of Species | | | | |
|---|---|---|---|---|
| Local | English | Scientific | Location | Uses |
| Sanna | | *Cassia senna* | Low-growing mesophytic, calcareous rock | |
| | | *Indigofera* sp. | Xerophytic, sandy calcareous ground in drainages | |
| | | *Salsola baryosoma* | Holophytic, sandy soils | |

Source: ESE, 1985.

Capparis, Grewia, Indigofera, Leptadenia spartium, Lycium, Prosopis, Salvadora, Tamarix, Ziziphus, Asparagus, Chenchrus, Farsetia, and Zygolphyllum species. These conditions and several of these plant species were observed at the Khanot and Lakhra sites. Because of the dry conditions, ferns, liverworts, mosses, and lichens are not found (Nasir and Ali, 1982). Vegetation at Lakhra in February exhibited heavy browsing from camels and goats.

Specific information on wildlife habitats and resources of the Lakhra study area is also not available. Descriptions of wildlife resources are based on review of general wildlife descriptions and distributional records [e.g., Roberts (1977), the species list published by the Zoological Survey Department]; visits to the University of Sind, Natural History Museum; discussions with federal, provincial, and university wildlife and fisheries biologists; and observations recorded during site reconnaissance of August 1985 and February 1986.

According to the Pakistan Zoological Survey Department (Ahmed, 1986, Personal Communication), wildlife of Pakistan has suffered very much during the past three or four decades due to habitat destruction and over exploitation (or hunting pressure). Many of the common animals existing in the 40s or 50s are now facing the threat of extinction. Because of the shortage of water in the Indus River (during winter) and the expansion in agriculture, most of the riverain areas have dried up or been brought under cultivation, which resulted in a drastic decline in the important wildlife of this area, e.g., Indus dolphin, gavial, crocodile, otter, hog deer, python, Indian monitor, lizard, fishing cat, and jungle cat. In the arid zone around the study area the number of wildlife has also decreased. Sind wild goat, chinka, and urial were almost common in the hilly areas, and so were the panther, wolf, hyaena, and carocal during the early 50s; however, because of habitat destruction and overexploitation, these important animals have been exterminated from low hilly areas. They are, however, still present in the remote and high

hilly areas in the Kirthar Range. Houbara Bustard, sand grouse, partridges, monitor lizards, desert fox, Indian fox, desert cat, etc., were common in the study area, but they are almost rare at present. In general, wildlife around the study area is declining in numbers, and further disturbances caused by human activities in the future would enhance its deterioration (Zoological Survey Department, Personal Communication).

The animal assemblages represent affinities to biogeographical forms of the Palearctic region to the west and of the Oriental region to the east of the Indus. Beg (1975) presents a list of vegetation and animal associations for the general wildlife habitats potentially occurring in the study area (Table H-3).

Roberts (1977) in his book, Mammals of Pakistan, describes a number of mammalian wildlife habitats which are observed to occur in the study area. Table H-4 presents these classifications along with the comparable forest and rangeland classifications described above. Regardless of the classification system, two main ecological areas occur in the study area: (1) the semi-arid and less developed area west of the Indus Highway, and (2) the riverain and more developed areas to the east along the Indus River. Table H-5 describes the characteristics of the mammalian habitats and lists the dominant species associated with the habitats. The study areas west of the Indus Highway are likely to contain the characteristic species of the arid subtropical habitats such as the Indian fox, desert fox, desert cat, wolf, jackal, hyaena, hedgehog, and other small mammals but not the Sind Ibex which occurs farther west. The Indus side of the study area, with wildlife habitats including riverain tracts and inundation zones, is characterized by wild pigs, the small Indian civet, and the smooth-coated Indian otter. These areas are under intensive cultivation and are disturbed habitats. Table H-6 lists mammals reported by Ahmad and Ghalib (1975) to occur in the study area as well as the frequency of occurrence. Only one mammal (a desert fox, Vulpas vulpus)

Table H-3. General Widlife Habitats of Study Area Based on Classification of Beg (1975)

| Habitat | Distribution | Typical Plant Species | Associated Wildlife |
|---|---|---|---|
| Tropical Plains Thorn Forests | From near the sea-coast throughout the plains up to the foothilss in the north, west and southwest; exists today only as protected patches. | Tamarix aphylla, Salvadora oleoides, Acacia nilotica, Prosopis cineraria, Capparis decidua, Zizyphus mauritiana, Z. nummularia, Tecomella undulata, etc. | White Throated Munia, The Little Brown Dove, Common Babbler, Collared Turtle Dove, Indian Hare, Jungle cat, Chinkara, Leopard. |
| Salvadora Saline Scrub | In the southern heavy and highly saline/alkaline parts of the main zone, especially the right bank of the Indus in the south. | Salvadora persica with some Tamarix troupii and Prosopis glandulosa. | Desert Warbler, Black Partridge, Rock Python, Hog Deer, Wild Boar, Desert Fox, Jackal. |
| Suaeda-Salsola Scrub | In patches on saline soil throughout the plains of West Pakistan. | Suaeda fruticosa, S. nudiflora, and Salsola foetida, occasionally with Tamarix troupii. | Desert Warbler, Houbara Bustard, Indian Hare, Jungle Cat, Indian Fox, Desert Fox, Jackal. |
| Indus Inundation Forests | Between the banks of the active river-bed and the floodplain banks of the riverain tract along the Indus River in the southern parts of the zone, e.g., Hyderabad Region. | Acacia nilotica, Prosopis cineraria, Populus euphratica, Tamarix spp. and locally abundant clumps of Saccharum spontaneum and Saccharum bengalensa. | Ni-[illegible] Heron, Coucal, Red Munia, Black Partridge, Yellow Eyed Babbler, Jungle Cat, Hog Deer, Wild Boar, Marsh Crocodile, Monitor Lizard. |

Table H-3. General Widlife Habitats of Study Area Based on Classification of Beg (1975) (Continued, Page 2 of 2)

| Habitat | Distribution | Typical Plant Species | Associated Wildlife |
|---|---|---|---|
| Plains Irrigated Plantations | | *Dalbergia sissoo* with or without *Morus alba* | Yellow Fronted Pied Woodpecker (in canal-side plantations), Sind Pied Woodpecker, Spotted Owlet, Jungle Cat, Wild Boar, Jackal, Foxes. |
| Plains Irrigated Agriculture | Throughout the plains of Pakistan. | Wheat, maize, millet, sorghum, sugar-cane, cotton, rice, tobacco, beans, barley, oats, gram, etc. | Yellow Fronted Pied Woodpecker, Spotted Owlet, The Little Brown Dove, Collared Turtle Dove, Black Partridge, Grey Partridge. |

Source: Beg, 1975.

Table H-4. Comparison of Various Ecological Classifications for the Lakhra Coal and Power Plant Study Area and Representative Locations in Study Area

| Ecological Classifications | | | | |
|---|---|---|---|---|
| | | Wildlife Habitat | | |
| Forest Type* | Rangeland Type† | General** | Mammals†† | Locations in Study Area |
| Tropical Inland Scrub Forest | Tropical Maritime Rangeland | Tropical plain-thorn forest | Arid subtropical habitat, monsoon-influenced arid subtropical | General areas, especially west of National Highway, Khanot and Lakhra sites and mine area |
| Riverain Forest | Tropical Maritime Rangeland | Indus inundation forest | Riverain or Indus Plain habitat, riverain tract | Area east of National Highway along both sides of the Indus River |
| Forest Plantation | Tropical Maritime Rangeland | Plains irrigated plantations and plains irrigated agriculture | Inundation and seepage zones | Cultivated forest areas along Indus River |

Sources: *Arid Land Information Center, 1981.
†Khan, 1974.
††Roberts, 1977.
**Beg, 1975.

Table H-5. Mammalian Habitat Classifications and Characteristic Species

| Habitat Type | Characteristic Species |
|---|---|
| Arid subtropical habitat, monsoon-influenced arid subtropical | Plants: Euphorbia caducifolia, Zizyphus nummularia, Acacia senegal, Commiphora mukul, and in valley bottoms Nannorrhops ritchieana, Capparis decidua, Caragana ambigua, Halozylon salicornicum<br><br>Mammals: Indian Fox (Vulpes bengalensis), Desert Cat (Felis libyca), Chinkara (Gazella gazella), Pangolin (Manis crassicaudata), Hyaena (Hyaena hyaena), Ratel (Mellivora capensis), Sind Wild Goat (Capra aegagrus blythi), Porcupine (Hystrix indica), Bush Rat (Golunda ellioti), Spiny Mouse (Acomys cahirinus), Baluchistan Gerbil (Gerbillus nanus), Trident Leaf-nosed Bat (Asellia tridens), Pale Hedgehog (Paraechinus micropus) |
| Riverain plain or Indus Basin, riverain tract | Plants: Tamarix dioica, Tamarix aphylla, Saccharum spontaneum, Populus euphratica, Acacia nilotica<br><br>Mammals: Smooth-coated Indian Otter (Lutra perspicillata), Hog Deer (Axis porcinus), Wild Pig (Sus scrofa), Small Indian Civet (Viverricula indica), Short-tailed Mole Rat (Nesokia indica), Jungle Cat (Felis Chaus), Jackal (Canis aureus), Desert Hare [Lepus nigricollis (dayanus)] |
| Inundation zones, seepage zone, jheels and swamp | Plants: Saccarum spontaneum, Phragmites australis, Tamarix dioica, Typha elephantina, Typha angustata, Arundo donax, Paspalum paspalodes, Erianthus spp.<br><br>Mammals: Wild Pig (Sus scrofa), Hog Deer (Axis porcinus), Smooth-coated Indian Otter (Lutra perspicillata), Fishing Cat (Felis viverrina), Jungle Cat (Felis chaus), Yellow-bellied Scotophil Bat (Scotophilus heathi) |

Source: Roberts, 1977.

Table H-6. Mammals Reported to Occur in Study Area

| Scientific Name | Common Name | Occurrence | Relative Abundance |
|---|---|---|---|
| Hemiechinus auritus colloris | Longeared Hedgehog | Semi-arid areas | Common |
| Paraechinus micropus | Indian or Pale Hedgehog | Rocky areas | Very rare |
| P. hypomelas blanfordi | Blandfords Lesser Lowland Hedgehog | Rocky areas | Rare |
| Suncus murinus sindensis | Indian Musk Shrew | Human habitation | Common |
| Suncus stoliczkanus | Anderson's Shrew | Dry hills | Less common |
| Rousettus aegyptiacus arabicus | Egyptian Fruit Bat | Dwellings, rock caves | Rare |
| Rhinopoma microphyllum | Longer Rat-Tailed Bat | Dwellings, rock caves | Common |
| R. hardwickei hardwickei | Lesser Rat-Tailed Bat | Dwellings, rock caves | Less common |
| Taphozous nudiventris kachhensis | Kutchsheath-Tailed Bat | Dwellings, discarded man-made structures | Less common |
| Hipposideros fulvus | Bicolored Leaf-Nosed Bat | Dwellings and burrows | |
| Asellia tridens murrayana | Trident Leaf-Nosed Bat | Natural caves in arid tropical areas | |
| Tadarida aegyptiaca sindica | Egyptian Free-Tailed Bat | Cracks in rock faces and dwellings | |
| Pipistrellus minus glaucillus | Indian Pygmy Pipistrelle | Riverain areas in trees | |
| Pipistrellus kuhli | Kuhl's Pipistrelle | Semi-arid open areas, dwellings | |
| P. ceylonicus subcanus | Nelarti Pipistrelle | Dwellings in Riverain areas | |
| Nycticeus pallidus | Yellow Desert Bat | Semi-arid open areas, dwellings | |

Table H-6. Mammals Reported to Occur in Study Area (Continued, Page 2 of 4)

| Scientific Name | Common Name | Occurrence | Relative Abundance |
|---|---|---|---|
| Scotophilus heathi | Common Yellow-Bellied Bat | Semi-arid conditions dwellings | |
| Manis crassicandata | Indian Pangolin | Hilly, semi-arid areas | |
| Canis aureus aureus | Asiatic Jackal | Riverain areas and numerous irrigated forest plantations | |
| Vulpes vulpes pusilla | Desert Fox | Semi-arid open country and rocky areas* | |
| Vulpes bengalensis | Indian Fox | Semi-arid open country | |
| Mellivora capensis | Honey Badger or Ratel | Rocky, semi-arid country | |
| Lutra perspicillata sindica | Sind Otter | Riverain areas | |
| Viverricula indica | Small Indian Civet | Semi-arid and riverain areas | |
| Herpestes auropunctatus | Mongoose | Outskirts of villages | |
| H. edwardsi ferringineus | Desert Mongoose | Semi-arid tracts | |
| Hyaena hyaena | Striped Hyaena | Semi-arid, rougn, hilly country | |
| Felis libyca ornata | Indian Desert Cat | Semi-arid, hilly country | |
| F. chaus prateri | Jungle Cat | Semi-arid to riverain areas | |
| F. caracal | Caracal | Semi-arid, remote hilly country | |
| F. viverrina | Fishing Cat | Semi-arid and riverain areas | |

Table H-6. Mammals Reported to Occur in Study Area (Continued, Page 3 of 4)

| Scientific Name | Common Name | Occurrence | Relative Abundance |
|---|---|---|---|
| Axis porcinus | Hog Deer | Riverain forest in Rajhari Forest Reserve: restricted to few riverain thickets | |
| Gazella gazella bennetti | Chinkara Gazelle | Semi-arid, stony plateau and hilly areas | |
| Lepus nigricollis | Desert Hare | Semi-arid, rocky areas to cultivated areas | |
| Funambulus pennanti | Northern Palm Squirrel | Semi-arid areas with trees to villages (associated with Acacia arabica and Albizza lebbeck) | |
| Hystrix indica | Indian Crested Porcupine | Semi-arid areas to forest plantations | |
| Rattus meltada | Soft-furred Field Rat | Semi-arid areas and cultivated areas | |
| Rattus gleadowi | Sand-colored Rat | Semi-arid, stony hillsides | |
| Rattus rattus | Roof Rat | Villages | |
| Mus musculus bactrianus | House Mouse | Villages | |
| Mus boodaga | Little Indian Field Mouse | Cultivated areas | |

Table H-6. Mammals Reported to Occur in Study Area (Continued, Page 4 of 4)

| Scientific Name | Common Name | Occurrence | Relative Abundance |
|---|---|---|---|
| *Mus platythrix* | Indian Brown Spiny Mouse | Semi-arid areas | |
| *Golunda elliotti* | Indian Brush Rat | Semi-arid, rocky tracts | |
| *Acomys cahirinus* | Cairo Spiny Mouse | Semi-arid, rocky slopes | |
| *Bandicota bengalensis* | Lesser Bandicoot | Riverain areas | |
| *Nesokia indica* | Short-Tailed Mole Rat | Riverain areas, irrigated tracts | |
| *Gerbillus nanus* | Baluchistan Gerbil | Semi-arid, rocky areas | |
| *Tatera indica* | Indian Gerbil | Semi-arid and irrigated areas and villages | |
| *Meriones hurrianae* | Indian Desert Jird | Edges of cultivated areas | |
| *Platanista indi* | Indus Dolphin | Indus River | |

*Observed during February reconnaissance trip.

Sources: Ahmad and Ghalib, 1975.
Roberts, 1977.



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was observed during the site reconnaissance at Lakhra. Since observations were made during the daylight, the likelihood of mammal sightings was low.

Numerous bird species were observed in the study area (Table H-7); however, bird surveys have been made in the study area recently. Based on Khanum, Ahmed and Ahmed's (1980) Checklist of Birds of Pakistan; Collins Handguide to Birds of the Indian Sub-Continent (Woodcock, 1984); Ticehurst (1922-1924); and records of the University of Sind's Natural History Museum, a list of bird species likely to occur in the study area is presented in Table H-7.

Compared to other animal groups, few amphibian species occur in Pakistan and the study area, (Minton, 1966). Rana brevicps, the Indian burrowing frog, is found in the arid portions of the study area. Other potentially occuring species include Buto andersoni (Indus toad), common throughout except in very arid situations; Rana tigrina (tiger frog); R. limnocharis (Indian cricket frog); and R cyanophlycits, all common to Indus Valley.

Reptiles are a dominant faunal group in the area. Indian spiny-tailed lizards (Uromastyr hardwicki) were the most conspicuous ground fauna observed during the August field reconnaissance in the arid portions of the Lakhra study area. The Indian spiny-tailed lizard is a herbivorous diurnal species found in colonies. It digs vertical burrows 2 to 4 ft deep in arid flats which contain appropriate food. This species is very social and breeds early in the monsoon season. It lays 6 to 12 eggs underground that hatch in two months. The lizards grow up to 14 inches in length. This species is found only in Pakistan and adjacent districts of India (Walter Auffenberg, Florida State Museum, University of Florida, personal communication, 1987). Numerous snakes, including cobras and vipers, are commonly reported. Based on distributional checklist (Ghalib et al., 1976) and records at the Natural History Museum at the University, a list of reptiles likely to occur in the study area was developed (Table H-8). Two endangered reptiles occur in the study area. The desert monitor (Varanus griesus), occurs at the Lakhra site. The Indian monitor (Varanus bengalensis) is also found in the study area but in more rocky areas.

Table H-7. Birds Reported to Occur in the Study Area

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Podicipitiformes | | |
| Phalacrocoracidae | | |
| Phalacrocorax carbo sinensis | Large Cormorant | Riverain |
| P. fuscicollis | Indian Shag | Riverain |
| P. niger | Little Cormorant | Riverain* |
| Anhinga rufa melanogaster | Darter or Snake Bird | Riverain* |
| Ciconiiformes | | |
| Ardeidae | | |
| Ardea cinerea cinerea | European Grey Heron | Riverain† |
| A. purpurea manilensis | Eastern Purple Heron | Riverain |
| Butorides striatus chloriceps | Little Green Heron | Riverain |
| Ardeola grayii grayii | Indian Pond Heron or Paddy-bird | Riverain |
| Bubulcus ibis coromandus | Cattle Egret | Riverain* |
| Egretta intermedia intermedia | Smaller or Median Egret | Riverain (marsh) |
| E. garzetta garzetta | Little Egret | Riverain (marsh) |
| Nycticorax nycticorax nycticorax | Night Heron | Riverain (trees) |
| Dupetor flavicollis flavicollis | Black Bittern | Riverain |
| Botaurus stellaris stellaris | Bittern | Riverain† |
| Ixobrychus minutus minutus | Little Bittern | Riverain |
| I. cinnamoneus | Chestnut Bittern | Riverain |
| I. sinensis | Yellow Bittern | Riverain |
| Ciconiidae | | |
| Ibis leucocephalus | Painted Stork | Riverain (marsh) |
| Xenorhynchus asiaticus asiaticus | Blacknecked Stork | Riverain (marsh) |
| Threskiornii hidae | | |
| Threskiornis melanocephala | White Ibis | Riverain (marsh) |
| Pseudibis papillosa papillosa | Indian Black Ibis | Riverain (marsh) |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 2 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Anseriformes | | |
| Anatidae | | |
| Anser anser rubrirostris | Eastern Greylag Goose | Riverainf |
| Dendrocygna javanica | Lesser Whistling Teal or Tree Duck | Riverainf (trees) |
| Tadorna ferruginea | Ruddy Shelduck | Riverainf (trees) |
| Anas angustirostris | Marbled Teal | Riverain (trees) |
| A. acuta | Pintail | Riverainf (trees) |
| A. crecca crecca | Common Teal | Riverainf (trees) |
| A. poecilorhyncha poecilorhyncha | Spotbill Duck | Riverainf |
| A. platyrhynchos | Mallard | Riverainf |
| A. strepera strepera | Gadwall | Riverainf |
| A. falcata | Falcated Teal | Riverainf |
| A. penelope | Wigeon | Riverainf |
| A. clypeata | Shoveller | Riverainf |
| Netta rufina | Redcrested Pochard | Riverainf |
| Aythya ferina | Common Pochard | Riverainf |
| A. nyroca | White-eyed Pochard | Riverainf |
| Nettapus coromandelianus coromandelianus | Cotton Teal | Riverain (marsh) |
| Falconiformes | | |
| Accipitridae | | |
| Milvus m. govinda | Pariah Kite | Human Habitation* |
| M.m. lineatus | Blackeared Kite | Riverainf |
| Haliastur indus indus | Brahminy Kite | Riverain |
| Accipiter badius cenchroides | Central Asian Shikra | Riverain |
| A. nisus nisosimilis | Asiatic Sparrow-Hawk | Arid Subtropicalf |
| Buteo rufinus rufinus | Longlegged Buzzard | Arid Subtropical and Riverain |
| Butastur teesa | White-eyed Buzzard Eagle | Arid Subtropical and Cultivated Areas |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 3 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Hieraaetus fasciatus fasciatus | Bonelli's or Slender Hawk-Eagle | Cultivated Areas |
| H. pennatus | Booted Hawk-Eagle | Riverain† |
| Aquila heliaca heliaca | Imperial Eagle | Riverain† |
| A. rapax vindhiana | Tawny Eagle | Arid Subtropical* |
| A. clanga | Greater Spotted Eagle | Riverain |
| Haliaeetus leucoryphus | Ringtailed Fishing Eagle | Riverain† |
| Torgos calvus | Black or King Vulture | Riverain |
| Gyps fulvus fulvescens | Indian Griffon Vulture | |
| G. bengalensis | Indian Whitebacked Vulture | Arid Subtropical and Riverain |
| Neophron percnopterus percnopterus | Egyptian Vulture | Arid Subtropical and Riverain |
| Circus aeruginosus aeruginosus | Marsh Harrier | Cultivated Areas† |
| Falconidae | | |
| Falco biarmicus jugger | Laggar Falcon | Riverain (forested) |
| F. peregrinus japonensis | Eastern Peregrine Falcon | Riverain† |
| F. p. babylonicus | Redcapped or Barbary Falcon | Cultivated† |
| F. chicquera chicquera | Redheaded Merlin | Arid Subtropical |
| F. tinnunculus tinnunculus | European Kestrel | Arid Subtropical† (Lakhra area) |
| Galliformes | | |
| Phasianidae | | |
| Francolinus pondicerianus interpositus | North Indian Grey Partridge | Arid Subtropical |
| Coturnix coturnix coturnix | Grey Quail | Arid Subtropical |
| C. coromandelica | Blackbreasted or Rain Quail | Arid Subtropical† |
| Pavo cristatus | Indian Peafowl | Arid Subtropical |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 4 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Gruiformes | | |
| Turnicidae | | |
| Turnix tanki tainki | Indian Yellowlegged Button Quail | Arid Subtropical† |
| Graidae | | |
| Grus antigone antigone | Indian Sarus Crane | Riverain |
| Rallidae | | |
| Porzana parva | Little Crake | Riverain† |
| Porphyrio porphyrio seistanicus | Purple Moorhen | Riverain† |
| Fulica atra atra | Coot | Riverain* |
| Otididae | | |
| Chlamydotis undulata macqueenii | Houbara Bustard | Arid Subtropical† |
| Charadriiformes | | |
| Jacanidae | | |
| Hydrophasianus chirurgus | Pheasant-tailed Jacana | Riverain |
| Charadriidae | | |
| Charadriinae | | |
| Vanellus gregarius | Sociable Lapwing | Cultivated Areas† |
| V. indicus indicus | Redwattled Lapwing | Cultivated Areas* |
| V. malabaricus | Yellow-wattled Lapwing | Cultivated Areas |
| Charadrius dubius curonicus | European Little Ringed Plover | |
| C. d. jerdoni | Indian Little Ringed Plover | Riverain |
| C. alexandrinus alexandrinus | Kentish Plover | Riverain |
| Scolopacinae | | |
| Numenius arquata arquata | Curlew | Riverain† |
| N. a. orientalis | Eastern Curlew | Riverain† |
| Limosa limosa limosa | Blacktailed Godwit | Cultivated Area† |
| Capello gallinago gallinago | Common or Fantail Snipe | Riverain† |
| Recurvirstridae | | |
| Himantopus himantopus himantopus | Indian Blackwinged Stilt | Irrigated Areas |
| Recurvirostra avosetta | Avocet | Irrigated Areas*† |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 5 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Burhinidae | | |
| Burhinus oedicnemus indicus | Indian Stone Curlew | Cultivated Areas |
| Esacus magnirostris recurvirostris | Great Stone Plover | Riverain |
| Glareolidae | | |
| Cursorius coromandelicus | Indian Courser | Arid Subtropical† |
| Glareola pratincola pratincola | Collared Pratincole | Riverain (dryer) |
| G. p. maldivarum | Large Indian Pratincole | Riverain (dryer) |
| G. lactea | Small Indian Pratincole | Riverain (dryer) |
| Laridae | | |
| Hydroprogne caspia caspia | Caspian Tern | Riverain |
| Sterna aurantia | Indian River Tern | Riverain |
| S. acuticauda | Blackbellied Tern | Riverain |
| S. albifrons albifrons | Little Tern or Ternlet | Riverain |
| Rynchops albicollis | Indian Skimmer or Scissorbill | Riverain† |
| Columbiformes | | |
| Pteroclididae | | |
| Pterocles exustus erlangeri | Indian Sandgrouse | Arid Subtropical |
| P. senegallus | Spotted Sandgrouse | Arid Subtropical† |
| P. orientalis orientalis | Imperial Blackbellied Sandgrouse | Arid Subtropical† |
| P. coronatus atratus | Coronetted Sandgrouse | Arid Subtropical |
| P. indicus arabicus | Closebarred Sandgrouse | Arid Subtropical (Lakhra)† |
| P. i. indicus | Painted Sandgrouse | Arid Subtropical (Lakhra)† |
| Columbidae | | |
| Columba rupestris turkestanica | Turkestan Hill Pigeon | Cultivated Areas* |
| C. livia neglecta | Blue Rock Pigeon | Arid Subtropical and Riverain |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 6 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Streptopelia decaocto decaocto | Indian Ring Dove | Cultivated Areas* |
| S. senegalensis cambayensis | Indial Little Brown or Senegal Dove | Arid subtropical* |
| Cuculiformes | | |
| Cuculidae | | |
| Clamator jacobinus serratus | Pied Crested Cuckoo | Cultivated† |
| Cuculus canorus canorus | Cuckoo | Riverain (forested, cultivated)† |
| Centropus sinensis sinensis | Common Crow Pheasant or Coucal | Riverain (forested) |
| Strigiformes | | |
| Striginae | | |
| Otus brucei | Striated or Pallid Scops Owl | Riverain† (forested) |
| O. scops pulchellus | Eastern Scops Owl | Riverain† (forested) |
| O. bakkamoena deserticolor | West Pakistan Collared Scops Owl | Riverain† (forested) |
| Bubo bubo bengalensis | Indian Great Horned or Eagle Owl | Riverain† (forested) |
| B. coromandus coromandus | Dusky Horned Owl | Riverain (forested) |
| B. zeylonensis leschenauli | Brown Fish Owl | Riverain |
| Ninox scutulata lugubris | Indian Brown Hawk-Owl | |
| Athene brama indica | Northern Spotted Owlet | Arid Subtropical (Cultivated) |
| Asio otus otus | Longeared Owl | Riverain (forested) |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 7 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Caprimulgiformes | | |
| Caprimulgidae | | |
| Caprimulgus europaeus unwini | Hume's European Nightjar | Cultivated Areas† |
| C. mahrattensis | Syke's or Sind Nightjar | Cultivated Areas† |
| Apodiformes | | |
| Apodidae | | |
| Apus affinis galilejensis | Palestine House Swift | Human Habitation |
| Coraciiformes | | |
| Alcedinidae | | |
| Alcedo atthis bengalensis | Indian Small Blue Kingfisher | Riverain |
| Halcyon smyrnensis smyrnensis | Whitebreasted Kingfisher | Riverain |
| Meropidae | | |
| Merops orientalis beludschicus | Sind Small Green Bee-eater | Arid Subtropical (dry water-courses)† |
| Coraciidae | | |
| Coracias garrulus semenowi | Kashmir Roller | Cultivated areas, open country† |
| C. benghalensis benghalensis | Northern Roller or Blue Jay | Cultivated areas, open country |
| Upupidae | | |
| Upupa epops epops | European Hoopee | Arid Subtropical Cultivated Areas† |
| Piciformes | | |
| Jynx torquilla torquilla | European Wryneck | Cultivated Areas† |
| Dinopium benghalense dilutum | Sind Goldenbacked Woodpecker | Cultivated Areas |
| Picoides himalayensis albescens | Kashmir Pied Woodpecker | Riverain (forested) |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 8 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Passeriformes | | |
| Alaudidae | | |
| Mirafra erythroptera sindiana | Sind Redwinged Bush Lark | Arid Subtropical |
| Eremopterix grisea | Ashycrowned Finch-Lark | Arid Subtropical |
| E. nigriceps affinis | Blackcrowned Finch-Lark | Arid Subtropical |
| Ammomanes deserti phoenicuroides | Indian Desert Finch-Lark | Arid Subtropical (hills) |
| Alaemon alaudipes doriae | Large Desert Lark | Arid Subtropical |
| Calandrella cinerea longipennis | Yarkand Short-toed Lark | Arid Subtropical |
| C. raytal adamsi | Indus Sand Lark | Riverain |
| Galerida cristata chendoola | Indian Crested Lark | Arid Subtropical |
| Alauda gulgula inconspicua | Turkestan Small Skylark | Cultivated Areas |
| Hirundinidae | | |
| Riparia riparia diluta | Siberian Collared Sand Martin | Riverain† |
| R. paludicola chinensis | Indian Greythroated Martin | Riverain† |
| Hirundo obsoleta pallida | Pale Crag Martin | Arid Subtropical (hills) |
| H. rustica rustica | Western Swallow | Riverain |
| H. smithii tilifera | Indian Wiretailed Swallow | |
| Laniidae | | |
| Lanius excubitor lahtora | Indian Grey Shrike | Arid Subtropical |
| L. vittatus vittatus | Indian Baybacked Shrike | Cultivated |
| L. schach erythronotus | Rufousbacked Shrike | Cultivated |
| L. collurio collurio | Redbacked Shrike | Cultivated† |
| L. c. isabellinus | Pale Brown Shrike | Cultivated† |
| Oriolidae | | |
| Oriolus oriolus kundoo | Indian Golden Oriole | Deciduous forest, cultivated areas, gardens† |
| Dicruridae | | |
| Dicrurus sp. | Drongo | Riverain (acacia forest) |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 9 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Sturnidae | | |
| Sturnus pagodarum | Blackheaded or Brahminy Myna | Cultivation and Human Habiatation* |
| S. sturninus | Daurian Myna | |
| S. vulgaris poltaratskyi | Finsch's or Common Indian Starling | Cultivated Areas† |
| S. v. nobilior | Hume's or Afghan Starling | |
| S. v. minor | Sind Starling | Human Habitation* |
| Acridotheres tristis tristis | Indian Myna | Human Habitation |
| A. ginginianus | Bank Myna | Riverain |
| Corvidae | | |
| Dendrocitta vagabunda bristoli | Northwestern Tree Pie | Riverain |
| Corvus splendens zugmayeri | Sind House Crow | Cultivated Areas* |
| Campephagidae | | |
| Tephrodornis pondicerianus pallidus | Sind Wood Shrike | Riverain (forest)* |
| Pericrocotus roseus roseus | Rosy Minivet | † |
| P. cinnamomeus pallidus | Sind Small Minivet | Riverain (forest) |
| Pycnonotidae | | |
| Pycnonotus leucogenys leucotis | White-eared Bulbul | Cultivated Areas |
| Muscicapidae | | |
| Chrysomma sinense hypoleucum | Western Yellow-eyed Babbler | Riverain |
| Turdoides caudatus caudatus | Common Babbler | Arid Subtropical |
| T. striatus sindianus | Sind Jungle Babbler | Cultivated Areas |
| Muscicapinae | | |
| Muscicapa striata sarudnyi | Spotted Flycatcher | Open Forest† |
| M. parva parva | Western Redbreasted Flycatcher | Forest plantations and gardens† |
| Pyctorhis sinensis | White-eyed Babbler | |
| Rhipidura aureola aureola | Northern Whitebrowed Fantail Flycatcher | Arid Subtropical and Cultivated Areas |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 10 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Sylviinae | | |
| Lusciniola melanopogon mimica | Moustached Sedge Warbler | Riverain† |
| Cisticola juncidis cursitans | Streaked Fantail Warbler | Cultivated Areas† |
| Prinia buchanani | Rufousfronted Wren-Warbler | Arid Subtropical (desert) |
| P. gracilis lepida | Indian Streaked Wren-Warbler | Cultivated Areas |
| P. flaviventris sindiana | Sind Yellowbellied Wren-Warbler | Riverain (canals) |
| P. burnesii burnesii | Western Longtailed Grass Warbler | Riverain |
| P. criniger striatula | Sind Brown Hill Warbler | Arid Subtropical (Lakhra) |
| Scotocerca inquieta striata | Streaked Scrub Warbler | Arid Subtropical† |
| Orthotomus sutorius guzuratus | Indian Tailor Bird | Cultivated |
| Acrocephalus stentoreus brunnescens | Indian Great Reed Warbler | Riverain† |
| A. agricola agricola | Indian Paddyfield Warbler | Riverain† |
| Hippolais caligata rama | Indian Booted Tree Warbler | Cultivated Area† |
| Sylvia hortensis jerdoni | Eastern Orphean Warbler | Semi Desert† |
| S. communis icterops | Indian Whitethroat | Cultivated Area† |
| S. nana nana | Desert Warbler | Arid Subtropical† |
| S. curruca minula | Small Whitethroat | Arid Subtropical† |
| S. c. althaea | Hume's Lesser Whitethroat | † |
| Phylloscopus collybita sindianus | Sind Chiffchaff | Riverain (canals)† |
| P. neglectus | Plain Leaf Warbler | Riverain (trees)† |
| Turdinae | | |
| Erithacus svecicus svecicus | Northern Bluethroat | Cultivated† |
| Phoenicurus ochruros phoenicuroides | Kashmir Black Redstart | Cultivated† |
| Saxicola torquata indica | Indian Collared Bush Chat | Cultivated Area† |
| S. caprata bicolor | Northern Pied Bush Chat | Cultivated Area† |
| Oenanthe isabellina | Isabelline Chat | Arid Subtropical† |
| O. xanthoprymna kingi | Redtailed Chat | Arid Subtropical (Lakhra hills)† |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 11 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| O. picata | Pied Chat | Arid Subtropical (valleys)† |
| O. deserti deserti | Central Asian Desert Wheatear | Arid Subtropical† |
| O. monacha | Hooded chat | Arid Subtropical† |
| Saxicoloides fulicata cambaiensis | Brownbacked Indian Robin | Arid Subtropical |
| Turdus ruficollis atrogularis | Blackthroated Thrush | Cultivation† |
| Motacillidae | | |
| Anthus trivialis trivialis | European Tree Pipit | Cultivated Areas† |
| A. novaesee landiae richardi | Richard's Pipit | Cultivated Areas† |
| A. campestris campestris | Tawny Pipit | Arid Subtropical† |
| A. spinoletta coutellii | Central Asian Water Pipit | Cultivated Areas† |
| Motacilla flava beema | Blueheaded Yellow Wagtail | Cultivated Areas† |
| M. f. melanogrisea | Turkestan Blackheaded Wagtail | Cultivated Areas† |
| M. citreola citreola | Northern Yellowheaded Wagtail | Cultivated Areas† |
| M. c. calcarata | Blackbacked Yellowheaded Wagtail | Cultivated Areas† |
| M. alba dukhunensis | Indian White Wagtail | Cultivated Areas† |
| Nectariniidae | | |
| Nectarinia asiatica brevirostris | Sind Purple Sunbird | Cultivated Areas (trees)† |
| Ploceidae | | |
| Passer domesticus indicus | Indian House Sparrow | Cultivated Areas* Human Habitation |
| Ploceus philippinus philippinus | Indian Baya | Riverain (trees) |
| P. manyar flaviceps | Indian Streaked Weaver Bird | Cultivated Areas |
| Estrilda amandava amandava | Red Munia or Avadavat | Cultivated Areas (grasses) |
| Lonchura malabarica malabarica | Whitethroated Munia | Arid Subtropical and Cultivated Areas |

Table H-7. Birds Reported to Occur in the Study Area (Continued, Page 12 of 12)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Fringillidae | | |
| *Rhodopechys githaginea crassirostris* | Trumpeter Bullfinch | Arid Subtropical |
| Emberizidae | | |
| *Emberiza melanocephala* | Blackheaded Bunting | Cultivated Areas† |
| *E. striolata striolata* | Striolated Bunting | Arid Subtropical† |

*Indicates observation during August field reconnaissance.

†Migratory.

Sources: Ticehurst, 1922-1924.
Woodcock, 1984.
Beg, 1975.

Table H-8. Reptiles Reportedly Occurring in Study Area--Sind Providence, Dadu, and Hyderabad Districts

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Kachuga smithi | Brown River Turtle | Common, Indus River, muddy places covered with vegetation |
| Hardella thurgi | Branminy River Turtle | Common, Indus River, shallow vegetation |
| Geoclemys hamiltonii | Spotted Pond Turtle | Rare, riverain areas, associated with above species |
| Trionyx gangeticus | Indian Softshell Turtle | Common, riverain areas, turbid waters, muddy bottom and some current, endangered |
| Lissemys punctata punctata | Indian Flapshell Turtle | Common, riverain areas, shallow muddy ditches |
| Eublepharis mocularius | Fat-tailed Gecko | Common, cultivated areas, rocky deserts, sparse vegetation |
| Alsophylax tuberculatus | Baluch Rock Gecko | Common, sandy fields and scrubby vegetation |
| Stenodactylus orientalis | Sind Sand Gecko | Common in fine, loose sand |
| Hemidactylus brooki | Spotted House Gecko | Common |
| H. pericus | Persian Gecko | Common in desert and oasis habitat |
| H. flaviviridis | Yellow-bellied House Gecko | Most common |

Table H-8. Reptiles Reportedly Occurring in Study Area-Sind Province, Dadu, and Hyderabad (Continued, Page 2 of 5)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Teratolepis fasciato | Sind Broad-tailed Gecko | Rare, dry lands with scrubby vegetation |
| Calotes versicolor | Indian Garden Lizard | Common, in trees and in semi-arid areas |
| Uromastyx hardwicki* | Indian Spiny-tailed Lizard | Common, in grasslands and flat desert |
| Agama agilis isolepis | Brilliant Agama | Common in desert habitat with gravelly soil and scattered vegetation |
| A. rubrigularis | Red-throated Agama | Rare, semi-arid areas |
| Mabuya macularia | Bronze Grass Skink | Common, riverain areas, grasslands and cultivated fields |
| Mabuya dissimilis | Striped Grass Skink | Common, hillsides and zones with xeric plantations |
| Eumeces taeniolatus | Yellow-bellied Mole Skink | Common in arid low land |
| Ablepharus grayanus | Earless Dwart Skink | Common in arid and semi-arid low land, gardens, grasslands and interior buildings |
| Ophiomorus tridactylus | Indian Sand Swimmer | Common in tracts of fine, loose sand |

Table H-8. Reptiles Reportedly Occurring in Study Area--Sind Province, Dadu, and Hyderabad (Continued, Page 3 of 5)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Ophiomorus raithmai | | Very rare |
| Acanthodactylus cantoris cantoris | Indian Fringe-toad Sand Lizard | Common in sandy habitat |
| Eremias guttulata watsonana | Longtailed Desert Lacerta | Common in dry, arid areas |
| Ophisops jerdoni | Punjab Snake-Eyed Lacerta | Common in cultivated fields |
| Varanus bengalensis | Indian Monitor | Fairly common in more vegetated areas, semi-arid, endangered |
| V. griseus koniecznyi | Indian Desert Monitor | Common in Lakhra, sandy, flat semi-arid areas, endangered |
| V. griseus caspius | Transcaspian Desert Monitor | Very rare and endangered |
| Leptotyphlops macrorhynchus | Beaked Thread Snake | Rare, riverain area |
| Eryx johnii johnii | Indian Sand Boa | Very common, flat desert with loose clay soils |
| E. conicus | Sand boa | Common, sandy or loose silty soil |
| Coluber ventromaculatus | Glossy-bellied Racer | Common in arid, semi-arid habitats |
| C. rhodorachis | Cliff Racer | Common |
| C. fasciolatus | Banded Racer | Rare, dry grass-lands, loose soil |

Table H-8. Reptiles Reportedly Occurring in Study Area-Sind Province, Dadu, and Hyderabad (Continued, Page 4 of 5)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| Sphalerosophis arenarius | Red Spotted Diadem Snake | Common, sandy soil and flat desert |
| Ptyas mucosus | Dhaman | Common, cultivated fields near villages |
| Dendrelaphis tristis | The Indian Bronzeback Snake | Very rare |
| Lycodon striatus striatus | Northern Wolf Snake | Common, riverain area, cultivated areas |
| L. travancoricus | Travancore Wolf Snake | Very rare, riverain area |
| Oligodon taeniolatus | Streaked Kukri Snake | Common, flat dry desert |
| Xenochrophis piscator piscator | Checkered Keelback | Very common |
| X. cerosagaster | Dark-bellied Marsh Snake | Common, riverain area |
| Bioga trigonata trigonata | Indian Gamma Snake | Common in desert scrub, oasis, urban habitat |
| Psammophis schokari | Afro Asian Sandsnake | Common, sandy desert, sparse vegetation |
| Bungarus caeruleus | Indian Krait | Common, suburban gardens, semi-arid areas with loose soil |

Table H-8. Reptiles Reportedly Occurring in Study Area-Sind Province, Dadu, and Hyderabad (Continued, Page 5 of 5)

| Scientific Name | Common Name | Occurrence |
|---|---|---|
| *Naja naja naja* | Indian Cobra | Common, damp grassland and urban gardens |
| *Echis carinatus* | Sawscaled Viper | Common, rocky, sandy and alluvial soil with some vegetation |

*Observed at Lakhra.

Sources: Minton, 1962; 1966.
Ghalib *et al.*, 1976.

From this analysis there is potentially a great diversity of wildlife (birds, mammals, and reptiles) in the area. Information does not exist, however, on abundance or actual occurrences of most species. As noted on the various faunal lists, a number of species considered rare, endangered, or vulnerable by the Government of Pakistan and the United States potentially occur in the study area. Table H-9 presents a compilation of these groups.

The dominant and only permanent aquatic habitat in the study area is the Indus River. With the dam at Kotri, the water volume above the dam is more constant than in the past. A significant fishery is supported in the study area above the dam. Numerous commercially important fish are found in the river in this area, including pallu or Indian shad (Hilsa ilish), rohu/dumbra or carp (labe rohita), Dahi/calbans (L. calbasu), Mirgal/mori or Murakhi (Cirrihius mrigala), thaila or theli (Catla catla), sole or snakehead (Charnus sp.), and singari or cattish (Wallago attu and Rita vita). Although no specific siting records were found, the Indus dolphin is suspected to occur above the Kotri Barrage. No unique aquatic habitats supporting the fishery occur in the vicinity of the proposed cooling water intake site.

Table H-9. Endangered and Vulnerable Species Potentially Occurring in the Study Area

| Scientific Name | Common Name | Status | Potential Habitat/ Locality |
|---|---|---|---|
| BIRDS | | | |
| Anas poecilorhyncha | Spotbill Duck | Endangered-GOP | Riverain, migrant |
| Grus antigone | Sarus Crane | Endangered-GOP | Riverain |
| Chlamydotis undulata macqueenii | Houbara Bustard | Endangered-GOP | Semi arid, Lakhra area |
| Francolinus pondicerianus | Grey Partridge | Endangered-GOP | Semi arid, Lakhra area |
| MAMMALS | | | |
| Felis caracal | Caracal | Rare-GOP | Semi arid, Lakhra |
| F. viverrina | Fishing Cat | Endangered-GOP | Riverain area |
| Gazella gazella | Chinkara | Endangered-USA/GOP | Semi arid, Lakhra region |
| Axis porcinus | Hog Deer | Endangered-GOP | Riverain Forest |
| Mellivora capensis | Honey Badger | Vulnerable-GOP | Semi arid, Lakhra |
| Platanista indi | Indus Dolphin | Endangered-GOP | Indus River |
| REPTILES | | | |
| Varanus bengalensis | Indian monitor | Endangered-USA/GOP | Semi arid, Khanot |
| Varanus griseus | Desert monitor | Endangered-USA/GOP | Semi arid, Lakhra |
| Trionyx gangeticus | Indian softshell turtle | Endangered-USA | Riverain area |

Source: U.S. Department of Interior, 1985.
Zoological Survey Department, 1986.



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# APPENDIX I
# DERIVATION OF FUGITIVE DUST EMISSIONS FOR MINING OPERATION

## I.1 INTRODUCTION

The proposed Lakhra lignite mining operation will be a source of fugitive particulate matter (PM) emissions due to materials handling operations and vehicular traffic. This section presents a description of the emission-generating activities, emission factor equations, and emissions estimate for the Lakhra mine. In addition, the source and receptor data used in dispersion modeling analysis are presented.

Fugitive dust emissions are dependent upon a number of factors, including meteorological conditions, soil/material conditions, source activity, and control measures. Emissions can vary considerably from hour-to-hour and day-to-day. For the purposes of the modeling analysis, the proposed power plant at Lakhra will consume 3,071,000 megagrams (Mg) of lignite annually. The analysis presented in this section assumes average annual source activities based upon the annual lignite requirements. The East Pit and West Pit will supply 2,000,000 Mg and 745,000 Mg of lignite annually, respectively. The underground (UG) mine will supply 326,000 Mg/yr of lignite.

## I.2 LAKHRA MINE CHARACTERISTICS

Meteorological characteristics and characteristics of materials and equipment for the Lakhra mining operation are presented in Table I-1. These characteristics are necessary for determining fugitive PM emission factors and the magnitude of source activities. Site-specific characteristics were used wherever available.

Meteorological data are required for certain fugitive emission factor equations, as are the silt and moisture content of various materials, i.e., topsoil, overburden/interburden, lignite, and haul road surface material. Material densities and device capacities are used in the calculation of the number of trips required to transport a given quantity of material (i.e., haul truck travel). Vehicle weights, vehicle speeds,

Table I-1. CHARACTERISTICS OF LAKHRA COAL PROJECT

| PARAMETER | SYMBOL | VALUE | REFERENCE |
|---|---|---|---|
| METEOROLOGICAL | | | |
| MEAN WIND SPEED | U | 8.94 m/sec | 1 |
| NUMBER OF DRY DAYS PER YEAR | d | 356 | 2 |
| PERCENT WIND SPEEDS ABOVE 12 MPH | F | 77% | 1 |
| MATERIALS | | | |
| MOISTURE CONTENT | M | | |
| TOP SOIL | | 3% | 3 |
| OVERBURDEN/INTERBURDEN | | 8% | 3 |
| HAUL ROAD SURFACE (GRAVEL) | | 1% | 3 |
| LIGNITE (AS MINED) | | 30% | 2 |
| LIGNITE (AFTER CRUSHING) | | 15% | 5 |
| SILT CONTENT | s | | |
| TOP SOIL | | 11% | 2 |
| OVERBURDEN/INTERBURDEN | | 7% | 3 |
| HAUL ROAD SURFACE (GRAVEL) | | 12% | 2 |
| LIGNITE (AS MINED) | | 5% | 4 |
| LIGNITE (AFTER CRUSHING) | | 10% | 5 |
| DENSITY | p | | |
| TOPSOIL | | 2.00 Mg/BCM | 5 |
| OVERBURDEN/INTERBURDEN | | 2.36 Mg/BCM | 2 |
| LIGNITE | | 1.67 Mg/BCM | 2 |
| EQUIPMENT | | | |
| MEAN VEHICLE WEIGHT | W | | |
| SCRAPERS (TOPSOIL-EMPTY) | | 8.4 Mg | 4 |
| SCRAPERS (TOPSOIL-LOADED) | | 48.4 Mg | 6 |
| 136 tonne TRUCKS (EMPTY) | | 82.5 Mg | 4 |
| 136 tonne TRUCKS (LOADED) | | 218.5 Mg | 6 |
| 30 tonne TRUCKS (EMPTY) | | 27.1 Mg | 4 |
| 30 tonne TRUCKS (LOADED) | | 57.1 Mg | 6 |
| MEAN VEHICLE SPEED | S | | |
| GRADERS | | 10 km/hr | 4 |
| 136 tonne TRUCKS (EMPTY) | | 32 km/hr | 2 |
| 136 tonne TRUCKS (LOADED) | | 40 km/hr | 2 |
| 30 tonne TRUCKS (EMPTY) | | 32 km/hr | 2 |
| 30 tonne TRUCKS (LOADED) | | 40 km/hr | 2 |
| NUMBER OF WHEELS | w | | |
| 136 tonne TRUCKS (LOADED) | | 6 | 2 |
| 30 tonne TRUCKS (EMPTY) | | 6 | 2 |
| DEVICE CAPACITY | Y | | |
| SCRAPERS (TOPSOIL) | | 20 BCM (27 CM) | 2 |
| SHOVEL (OVERBURDEN) | | 27 CM | 2 |
| DRAGLINES (OVERBURDEN) | | 57 CM | 2 |
| BACKHOE (INTERBURDEN) | | 12 CM | 2 |
| BACKHOE (LIGNITE) | | 12 CM | 2 |
| HAUL TRUCK (136 tonne) | | 56 BCM (76 CM) | 4 |
| HAUL TRUCK (30 tonne) | | 18 BCM (24 CM) | 4 |
| FRONT-END LOADER (UG MINE) | | 12 CM | 5 |

NOTES: tonne= 1000 kg= Mg
CM= cubic meter
BCM= Bank cubic meter

REFERENCES: 1) ESE, 1986
2) John Boyd Co., 1986
3) "Compilation of Air Pollutant Emission Factors", USEPA Publication AP-42, Section 8.24
4) John T. Boyd Co., Personal Communication
5) Estimated value
6) Calculated

and number of tires for haul equipment are also used in the emission factor equations for travel over unpaved roads.

## I.3 MINING ACTIVITIES AND EMISSION FACTORS

The various source activities conducted at the Lakhra mine and associated uncontrolled fugitive PM emission factor equations are summarized in Table I-2. The source activities were identified primarily from a previous environmental assessment of the Lakhra coal project (John T. Boyd Co., 1986) as well as discussions with John T. Boyd Co. staff. These activities are described in further detail in the following sections.

A survey was conducted of available fugitive PM emission factor equations. The latest, and most representative emission factors applicable to open pit surface mining operations and coal handling operations were selected for use in this study. These factors all relate to "suspended PM," i.e., PM less than 30 micrometers (μm) in diameter. Suspended particulate represents the particulate which would generally remain suspended in the atmosphere and not fall out or deposit within a short distance of the source. This is consistent with the World Bank's Environmental Guidelines for ambient "dust" levels, which apply beyond the plant boundaries and are based on USEPA Guidelines.

Uncontrolled fugitive PM emission factors for each identifiable operation, based on the emission factor equations presented in Table I-2 and the Lakhra mine characteristics presented in Table I-1, are shown in Table I-3. For each activity, the emission factor equation used is referenced to Table I-2. The necessary input parameters are also shown, along with the resulting uncontrolled emission factor.

Annual source extents for each activity associated with the mining operation are presented in Table I-4. The activities are separated by

Table I-2. Fugitive PM Emission Factor Equations for Lakhra Mine

| Emission Factor Equation Number | Source Activity | Emission Factor* Equation | Units | Reference |
|---|---|---|---|---|
| 1 | Topsoil removal by scraper | 0.029 | kg/Mg | USEPA, 1985 |
| 2 | Scrapers (travel mode) | $9.6\times10^{-6}(s)^{1.3}(w)^{2.4}$ | kg/VKT | USEPA, 1985 |
| 3 | Batch load-in | $0.0009\,\dfrac{\left(\frac{s}{5}\right)\left(\frac{U}{2.2}\right)\left(\frac{H}{1.5}\right)}{\left(\frac{M}{2}\right)^{2}\left(\frac{Y}{6}\right)^{0.33}}$ | kg/Mg | USEPA, 1985 |
| 4 | Bulldozing-Overburden/ Topsoil | $\dfrac{2.6(s)^{1.2}}{M^{1.3}}$ | kg/hr | USEPA, 1985 |
| 5 | Drilling-Overburden/ Interburden | 0.59 | kg/hole | USEPA, 1985 |
| 6 | Blasting-Overburden/ Interburden | 0.00045 | kg/Mg | Jutze, et al. 1980 |
| 7 | Unpaved Roads | $1.7\left(\frac{s}{12}\right)\left(\frac{S}{48}\right)\left(\frac{W}{2.7}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{d}{365}\right)$ | kg/VKT | USEPA, 1985 |
| 8 | Dragline-Overburden/ Interburden | $\dfrac{0.0046\ H^{1.1}}{M^{0.3}}$ | $kg/m^3$ | USEPA, 1985 |

Table I-2. Fugitive PM Emission Factor Equations for Lakhra Mine (Continued Page 2 of 2)

| Emission Factor Equation Number | Source Activity | Emission Factor* Equation | Units | Reference |
|---|---|---|---|---|
| 9 | Lignite Crushing | 0.009 | kg/Mg | Jutze, et al. 1980 |
| 10 | Continous Load-in | $0.0009 \frac{\left(\frac{s}{5}\right)\left(\frac{U}{2.2}\right)\left(\frac{H}{3.0}\right)}{\left(\frac{M}{2}\right)^2}$ | kg/Mg | USEPA, 1985 |
| 11 | Active Lignite Storage Pile (wind erosion maintenance) | 1.8 U | kg/hectare-hr | USEPA, 1985 |
| 12 | Grading (roads) | $0.0034\ S^{2.5}$ | kg/VKT | USEPA, 1985 |
| 13 | Truck Loading-Lignite | $\frac{0.580}{M^{1.2}}$ | kg/Mg | USEPA, 1985 |

*Symbols for equations:
s = material silt content (%)
S = mean vehicle speed (km/hr)
w = mean number of wheels on vehicle
W = mean vehicle weight (Mg)
U = wind speed (m/sec)
H = drop height (m)
M = material moisture content
d = number of dry days per year

Source: KBN, 1986.

Table I-3. ANNUAL EMISSION FACTORS - LAKHRA COAL PROJECT

| SOURCE | EMISSION FACTOR EQUATION | s SILT CONTENT (%) | M MOISTURE CONTENT (%) | U WIND SPEED (m/s) | H DROP HEIGHT (m) | Y DEVICE CAPACITY (m**3) | W VEHICLE WEIGHT (Mg) | S VEHICLE SPEED (km/hr) | w NUMBER OF WHEELS | TSP UNCONTROLLED EMISSION FACTOR |
|---|---|---|---|---|---|---|---|---|---|---|
| TOPSOIL REMOVAL (scraper) | 1 | - | - | - | - | - | - | - | - | 0.029 kg/Mg |
| TOPSOIL HAULING-LOADED | 2 | 12 | - | - | - | - | 48.4 | - | - | 2.684 kg/VKT |
| TOPSOIL HAULING-EMPTY | 2 | 12 | - | - | - | - | 8.4 | - | - | 0.040 kg/VKT |
| TOPSOIL DUMP | 3 | 11 | 3 | 8.9 | 3.0 | 27 | - | - | - | 0.00435 kg/Mg |
| TOPSOIL (DOZER ASSIST) | 4 | 11 | 3 | - | - | - | - | - | - | 11.076 kg/hr |
| DRILLING OVER/INTER-BURDEN | 5 | - | - | - | - | - | - | - | - | 0.590 kg/hole |
| BLASTING OVER/INTER-BURDEN | 6 | - | - | - | - | - | - | - | - | 0.000450 kg/Mg |
| OVERBURDEN REMOVAL-SHOVEL | 3 | 7 | 8 | 8.9 | 3 | 27 | - | - | - | 0.000388 kg/Mg |
| OVERBURDEN HAULING-LOADED | 7 | 12 | 1 | - | - | - | 218.5 | 32 | 6 | 29.324 kg/VKT |
| OVERBURDEN HAULING-EMPTY | 7 | 12 | 1 | - | - | - | 92.5 | 40 | 6 | 18.537 kg/VKT |
| OVERBURDEN TRUCK DUMP | 3 | 7 | 8 | 8.9 | 3 | 76 | - | - | - | 0.000276 kg/Mg |
| OB/IB REMOVAL-DRAGLINE | 8 | - | 8 | - | 30 | - | - | - | - | 0.104 kg/m**3 |
| PAD PREPERATION (BULLDOZER) | 4 | 7 | 8 | - | - | - | - | - | - | 1.799 kg/hr |
| INTERBURDEN LOADING | 3 | 7 | 8 | 8.9 | 3 | 12 | - | - | - | 0.000507 kg/Mg |
| INTERBURDEN HAULING-LOADED | 7 | 12 | 1 | - | - | - | 218.5 | 32 | 6 | 29.324 kg/VKT |
| INTERBURDEN HAULING-EMPTY | 7 | 12 | 1 | - | - | - | 82.5 | 40 | 6 | 18.537 kg/VKT |
| INTERBURDEN TRUCK DUMP | 3 | 7 | 8 | 8.9 | 3 | 76 | - | - | - | 0.000276 kg/Mg |
| LIGNITE LOADING | 13 | - | 30 | - | - | - | - | - | - | 0.00979 kg/Mg |
| LIGNITE HAULING-LOADED | 7 | 12 | 1 | - | - | - | 218.5 | 32 | 6 | 29.324 kg/VKT |
| LIGNITE HAULING-EMPTY | 7 | 12 | 1 | - | - | - | 82.5 | 40 | 6 | 18.537 kg/VKT |
| LIGNITE DUMPING | 3 | 5 | 30 | 8.9 | 3 | 76 | - | - | - | 0.000014 kg/Mg |
| LIGNITE CRUSHING | 9 | - | - | - | - | - | - | - | - | 0.0090 kg/Mg |
| LIGNITE-STOCKPILE LOADING | 10 | 10 | 15 | 8.9 | 10 | - | - | - | - | 0.000432 kg/Mg |
| LIGNITE PILE-TRAFFIC/WIND | 11 | - | - | 8.9 | - | - | - | - | - | 16.020 kg/hectare/h |
| LIGNITE- LOADOUT TO RAILCAR | 10 | 10 | 15 | 8.9 | 3 | - | - | - | - | 0.000129 kg/Mg |
| LIGNITE- LOADOUT TO TRUCK | 13 | - | 15 | - | - | - | - | - | - | 0.022 kg/Mg |
| LIG. HAUL- UG TO ROM (LOADED) | 7 | 12 | 1 | - | - | - | 57.1 | 32 | 6 | 11.462 kg/VKT |
| LIG. HAUL- UG TO ROM (EMPTY) | 7 | 12 | 1 | - | - | - | 27.1 | 40 | 6 | 8.503 kg/VKT |
| LIGNITE DUMP (FROM UG MINE) | 3 | 10 | 15 | 8.9 | 3 | 24 | - | - | - | 0.000184 kg/Mg |
| LIGNITE - PILE LOAD (FROM UG) | 10 | 10 | 15 | 8.9 | 10 | - | - | - | - | 0.000432 kg/Mg |
| RECLAMATION-DOZER | 4 | 11 | 3 | - | - | - | - | - | - | 11.076 kg/hr |
| ROAD MAINTENANCE (GRADERS) | 12 | - | - | - | - | - | - | 10 | - | 1.075 kg/VKT |

Source: KBN, 1986.

Table I-4. CALCULATION OF ANNUAL SOURCE EXTENTS - LAHKRA COAL PROJECT

| PARAMETER | EAST PIT | WEST PIT | UNDERGROUND MINE | ROM HANDLING FACILITY |
|---|---|---|---|---|
| **TOPSOIL REMOVAL** | | | | |
| TOPSOIL REMOVED (BCM/yr) | 187000 | 75000 | - | - |
| (Mg/yr) | 374000 | 150000 | - | - |
| HAUL DISTANCE (km) | 2 | 2 | - | - |
| HAUL DISTANCE- LOADED (VKT/yr) | 18700 | 7500 | - | - |
| HAUL DISTANCE- EMPTY (VKT/yr) | 18700 | 7500 | - | - |
| TOPSOIL - DOZER ASSIST (hr/yr) | 1200 | 1200 | - | - |
| **OVERBURDEN/INTERBURDEN REMOVAL** | | | | |
| DRILLING (holes/yr) | 12518 | 4730 | - | - |
| BLASTING (BCM/yr) | 28710000 | 7303000 | - | - |
| (Mg/yr) | 67755600 | 17233080 | - | - |
| OB REMOVAL- SHOVEL (BCM/yr) | 11780000 | 1780000 | - | - |
| (Mg/yr) | 27800800 | 4200800 | - | - |
| OB- HAUL DISTANCE (km) | 3 | 3 | - | - |
| OB- HAUL DISTANCE-LOADED (VKT/yr) | 613253 | 92665 | - | - |
| OB- HAUL DISTANCE- EMPTY (VKT/yr) | 613253 | 92665 | - | - |
| OB/IB REMOVAL- DRAGLINE (BCM/yr) | 20520000 | 4875000 | - | - |
| (Mg/yr) | 48368800 | 11505000 | - | - |
| PAD PREP.- BULLDOZER (hr/yr) | 2850 | 675 | - | - |
| IB/REMOVAL- BACKHOE (BCM/yr) | 1000000 | 880000 | - | - |
| (Mg/yr) | 2360000 | 2076800 | - | - |
| IB- HAUL DISTANCE (km) | 3 | 3 | - | - |
| IB- HAUL DISTANCE-LOADED (VKT/yr) | 52059 | 45812 | - | - |
| IB- HAUL DISTANCE-EMPTY (VKT/yr) | 52059 | 45812 | - | - |
| **LIGNITE HANDLING** | | | | |
| LIGNITE PROCESSED (Mg/yr) | 2000000 | 745000 | 326000 | 3071000 |
| LIGNITE HAUL DISTANCE (km) | 6 | 4 | 0.2 | - |
| LIG. HAUL DISTANCE-LOADED (VKT/yr) | 88235 | 21912 | 2173 | - |
| LIG. HAUL DISTANCE-EMPTY (VKT/yr) | 88235 | 21912 | 2173 | - |
| LIG. STORAGE-ROM FACILITY (hectares) | - | - | 0.10 | 0.48 |
| LIG. STORAGE- UG MINE (hectares) | - | - | 0.10 | 0.00 |
| **RECLAMATION/MAINTENANCE** | | | | |
| RECLAMATION- BULLDOZER (hr/yr) | 2400 | 2400 | - | - |
| ROAD MAINTENANCE- GRADER (hr/yr) | 1460 | 1460 | - | - |

NOTES: VKT= Vehicle kilometers traveled

Source: KBN, 1986.

each major mine component: the East Pit, West Pit, UG Mine and Run-Of-Mine (ROM) Handling Facility. Annual source extents are based on 2 million Mg/yr lignite production from the East Pit; 745,000 Mg/yr from the West Pit; 326,000 Mg/yr from the UG Mine; and the ROM facility processing the entire 3,071,000 Mg/yr lignite production. Truck haul distances are based on average travel distances during the life of the project. The table does not include the power plant, which will handle the entire 3,071,000 Mg/yr lignite production for consumption at the plant. The individual source activities associated with the Lakhra coal project are described in greater detail in the following sections.

### I.3.1 TOPSOIL REMOVAL

Scrapers will work in advance of the draglines to remove topsoil. The topsoil will be stripped and then hauled to and dumped at the topsoil disposal area. Topsoil removal operations will be conducted during one shift per day, 300 days per year. The haul roads will have gravel surfaces and will be watered periodically to reduce fugitive dust emissions. An average one-way haul distance is 2 km. A bulldozer will be used in each pit to assist the scraper activities. The bulldozer is estimated to work 50 percent of an 8-hour shift each working day (John T. Boyd Co., 1986).

### I.3.2 DRILLING AND BLASTING: OVERBURDEN/INTERBURDEN

Material overlying and lying between lignite layers will consist primarily of limestone, laterite, sandstone, and claystone. Drilling and blasting will be required prior to removal of a portion of this material. The annual drilling requirements are based on hole depths and volumes, and the annual volume of material drilled.

### I.3.3 OVERBURDEN REMOVAL BY SHOVELS

Two electric shovels will be used in the East Pit and one in the West Pit to prestrip the uppermost 15 m of overburden in advance of the dragline. Overburden will be loaded by the shovels into 136-Mg haulers for

transport to the overburden disposal area. The average one-way travel distance is 3 km. The haul road will have a gravel surface and will be watered periodically to reduce fugitive dust emissions.

### I.3.4 OVERBURDEN/INTERBURDEN REMOVAL BY DRAGLINE

Two electric draglines will be used in each pit to remove overburden down to the top of the lignite seams. Overburden above the intermediate seams will be dumped in an area that has been mined previously. Interburden between the seams and dragline bench spoil rehandle will also be moved by the draglines. To be conservative, a material drop height of 30 m into the pit was assumed.

Bulldozers assumed to handle 750 $m^3$/hr will be used for pad preparation for the draglines.

### I.3.5 INTERBURDEN REMOVAL BY BACKHOE

Interburden material between the No. 1 and No. 2 Seams will be excavated using a hydraulic backhoe. Two backhoes will operate in the West Pit and one in the East Pit. Interburden will be loaded into 136-Mg haul trucks for transport to the spoil site of the pit. As discussed previously, regular watering of the gravel overburden haul road will be provided. Average one-way travel distance from each pit is 3 km.

### I.3.6 LIGNITE MINING

A hydraulic backhoe will be used to load lignite into 136-Mg haulers. The lignite will be transported over a gravel road to the ROM handling facility. Average one-way haul distance is 6 km for the East Pit and 4 km for the West Pit. The haul road will be watered periodically to reduce fugitive dust emissions.

### I.3.7 RECLAMATION/ROAD MAINTENANCE

Two bulldozers in each pit will assist the topsoil scrapers in the reclamation operation and regrading the spoil pits. It is assumed that each bulldozer will operate 4 hours per day.

A grader will be used for removal of loose debris and for roadway maintenance. Grader operating hours are assumed to be 8 hours per day, 365 days per year.

### I.3.8 UG MINE

Lignite mined from the UG mine will be processed at the UG mine facility. The lignite will be crushed, stockpiled, and then loaded into 30-Mg trucks by front-end loaders for transport to the ROM facility. One-way haul distance from the UG mine to the ROM, facility is 0.2 km.

### I.3.9 ROM FACILITY

Lignite mined in the East and West Pits will be brought to the ROM facility by 136-Mg trucks and dumped into a 400-Mg hopper. The lignite then will be conveyed to a crusher and to a 30,000-Mg storage site. A rubber-tired bulldozer will be used in the storage pile area to maintain the pile. From the storage pile, the lignite will be reclaimed by underground reclaim hoppers and then conveyed to and loaded into railcars for transport to the power plant.

Crushed lignite from the UG mine operation will also be transported to the ROM facility and dumped by haul trucks into two 40-Mg hoppers. The lignite will then be conveyed to a separate 6,000-Mg storage pile, reclaimed underground, and loaded into railcars. A rubber-tired dozer will also be used to maintain this storage pile.

### I.3.10 POWER PLANT

Lignite will be transported to the power plant from the ROM facility by railcar. The lignite will be dumped from the railcar bottom into a hopper, and conveyed to a 26,000-Mg storage pile. The storage pile size is based on a 3-day supply of lignite to the power plant.

From the storage pile, the lignite is reclaimed into underground hoppers, then routed through a crusher to the coal bunkers in the powerhouse. An

inactive lignite storage pile will also be maintained at the power plant (approximately 90-day supply) to fuel the plant in case of an interruption to the lignite supply from the ROM facility. The inactive pile will be compacted, and insignificant emissions are anticipated.

## I.4 FUGITIVE PM EMISSION ESTIMATES

Fugitive PM emission estimates for the Lakhra mining project are presented in Tables I-5, I-6, and I-7. These estimates are the result of the source extents and uncontrolled emission factors discussed previously.

Fugitive PM emissions from haul road traffic will be minimized by watering. The effectiveness of watering depends on the application rate and frequency of application. A recent study has shown that water applied at a rate of 0.6 $L/m^2$ to haul roads was 95 percent, 86 percent and 55 percent efficient in controlling PM emissions at 0.5, 1.4, and 4.4 hours after application, respectively (MRI, 1983). The haul road was heavily traveled (78 vehicle passes per hour). The relationship between control efficiency and time after application is shown in Figure I-1. A similar study was conducted on surface mine haul roads in the United States (PEDCo., 1984). This study showed that watering at 2.3 $L/m^2$ was 60 to 70 percent effective in controlling fugitive PM emissions for at least 1 hour after application.

For the proposed Lakhra mine, a water application rate of 0.6 $L/m^2$ every 3 hours was assumed. From Figure I-1, this would result in a control efficiency of approximately 70 percent on all particle size categories.

Table I-5. ANNUAL EMISSION ESTIMATES - EAST PIT

| SOURCE NUMBER | SOURCE | ANNUAL SOURCE EXTENT | UNCONTROLLED EMISSION FACTOR | CONTROL METHOD | CONTROL EFFICIENCY (%) | CONTROLLED EMISSION FACTOR | ANNUAL EMISSIONS (kg/yr) |
|---|---|---|---|---|---|---|---|
| | TOPSOIL REMOVAL (SCRAPER) | 374000 Mg/yr | 0.029 kg/Mg | NONE | 0 | 0.029 kg/Mg | 10846 |
| | TOPSOIL HAUL (LOADED) | 18700 VKT/yr | 2.684 kg/VKT | WATERING | 70 | 0.805 kg/VKT | 15057 |
| | TOPSOIL HAUL (UNLOADED) | 18700 VKT/yr | 0.040 kg/VKT | WATERING | 70 | 0.012 kg/VKT | 224 |
| | TOPSOIL DUMP | 374000 Mg/yr | 0.00435 kg/Mg | NONE | 0 | 0.00435 kg/Mg | 1627 |
| | TOPSOIL- DOZER ASSIST | 1200 hr/yr | 11.076 kg/hr | NONE | 0 | 11.076 kg/hr | 13291 |
| | OB/IB DRILLING | 12518 holes/yr | 0.590 kg/hole | NONE | 0 | 0.590 kg/hole | 7386 |
| | OB/IB BLASTING | 67755600 Mg/yr | 0.00045 kg/Mg | NONE | 0 | 0.00045 kg/Mg | 30490 |
| | OB REMOVAL- SHOVEL | 27800800 Mg/yr | 0.000388 kg/Mg | NONE | 0 | 0.000388 kg/Mg | 10787 |
| | OB HAUL (LOADED) | 613253 VKT/yr | 29.324 kg/VKT | WATERING | 70 | 8.797 kg/VKT | 5394909 |
| | OB HAUL (EMPTY) | 613253 VKT/yr | 18.537 kg/VKT | WATERING | 70 | 5.561 kg/VKT | 3410361 |
| | OB TRUCK DUMP | 27800800 Mg/yr | 0.000276 kg/Mg | NONE | 0 | 0.000276 kg/Mg | 7673 |
| | OB/IB REMOVAL- DRAGLINE | 20580000 BCM/yr | 0.104 kg/m**3 | NONE | 0 | 0.104 kg/m**3 | 2140320 |
| | PAD PREP.- BULLDOZER | 2850 hr/yr | 1.799 kg/hr | NONE | 0 | 1.799 kg/hr | 5127 |
| | IB REMOVAL- BACKHOE | 2360000 Mg/yr | 0.000507 kg/Mg | NONE | 0 | 0.000507 kg/Mg | 1197 |
| | IB HAUL (LOADED) | 52059 VKT/yr | 29.324 kg/VKT | WATERING | 70 | 8.797 kg/VKT | 457973 |
| | IB HAUL (EMPTY) | 52059 VKT/yr | 18.537 kg/VKT | WATERING | 70 | 5.561 kg/VKT | 289505 |
| | IB TRUCK DUMP | 2360000 Mg/YR | 0.000276 kg/Mg | NONE | 0 | 0.000276 kg/Mg | 651 |
| | LIGNITE LOADING | 2000000 Mg/yr | 0.00979 kg/Mg | NONE | 0 | 0.00979 kg/Mg | 19584 |
| | LIGNITE HAULING (LOADED) | 88235 VKT/yr | 29.324 kg/VKT | WATERING | 70 | 8.797 kg/VKT | 776221 |
| | LIGNITE HAULING (UNLOADED) | 88235 VKT/yr | 18.537 kg/VKT | WATERING | 70 | 5.561 kg/VKT | 490684 |
| | RECLAMATION- DOZER | 2400 hr/yr | 11.076 kg/hr | NONE | 0 | 11.076 kg/hr | 26582 |
| | ROAD MAINTENANCE (GRADERS) | 14600 VKT/yr | 1.075 kg/VKT | NONE | 0 | 1.075 kg/VKT | 15695 |
| | TOTAL ANNUAL EMISSIONS | | | | | | 13126191 |

ANNUAL EMISSION ESTIMATES - WEST PIT

Source: KBN,1986.

Table I-6. ANNUAL EMISSION ESTIMATES - WEST PIT

| SOURCE NUMBER | SOURCE | ANNUAL SOURCE EXTENT | UNCONTROLLED EMISSION FACTOR | CONTROL METHOD | CONTROL EFFICIENCY (%) | CONTROLLED EMISSION FACTOR | ANNUAL EMISSIONS (kg/yr) |
|---|---|---|---|---|---|---|---|
| | TOPSOIL REMOVAL (SCRAPER) | 150000 Mg/yr | 0.029 kg/Mg | NONE | 0 | 0.029 kg/Mg | 4350 |
| | TOPSOIL HAUL (LOADED) | 7500 VKT/yr | 2.684 kg/VKT | WATERING | 70 | 0.805 kg/VKT | 6039 |
| | TOPSOIL HAUL (UNLOADED) | 7500 VKT/yr | 0.040 kg/VKT | WATERING | 70 | 0.012 kg/VKT | 90 |
| | TOPSOIL DUMP | 150000 Mg/yr | 0.00435 kg/Mg | NONE | 0 | 0.00435 kg/Mg | 653 |
| | TOPSOIL- DOZER ASSIST | 1200 hr/yr | 11.076 kg/hr | NONE | 0 | 11.076 kg/hr | 13291 |
| | OB/IB DRILLING | 4730 holes/yr | 0.590 kg/hole | NONE | 0 | 0.590 kg/hole | 2791 |
| | OB/IB BLASTING | 17235080 Mg/yr | 0.00045 kg/Mg | NONE | 0 | 0.00045 kg/Mg | 7756 |
| | OB REMOVAL- SHOVEL | 4200800 Mg/yr | 0.000388 kg/Mg | NONE | 0 | 0.000388 kg/Mg | 1630 |
| | OB HAUL (LOADED) | 92665 VKT/yr | 29.324 kg/VKT | WATERING | 70 | 8.797 kg/VKT | 815173 |
| | OB HAUL (EMPTY) | 92665 VKT/yr | 18.537 kg/VKT | WATERING | 70 | 5.561 kg/VKT | 515219 |
| | OB TRUCK DUMP | 4200800 Mg/yr | 0.000276 kg/Mg | NONE | 0 | 0.000276 kg/Mg | 1159 |
| | OB/IB REMOVAL- DRAGLINE | 4875000 BCM/yr | 0.104 kg/m**3 | NONE | 0 | 0.104 kg/m**3 | 507000 |
| | PAD PREP.- BULLDOZER | 675 hr/yr | 1.799 kg/hr | NONE | 0 | 1.799 kg/hr | 1214 |
| | IB REMOVAL- BACKHOE | 2076800 Mg/yr | 0.000507 kg/Mg | NONE | 0 | 0.00051 kg/Mg | 1052 |
| | IB HAUL (LOADED) | 45812 VKT/yr | 29.324 kg/VKT | WATERING | 70 | 8.797 kg/VKT | 403017 |
| | IB HAUL (EMPTY) | 45812 VKT/yr | 18.537 kg/VKT | WATERING | 70 | 5.561 kg/VKT | 254765 |
| | IB TRUCK DUMP | 2076800 Mg/yr | 0.000276 kg/Mg | NONE | 0 | 0.00028 kg/Mg | 573 |
| | LIGNITE LOADING | 745000 Mg/yr | 0.00979 kg/Mg | NONE | 0 | 0.010 kg/Mg | 72[illegible] |
| | LIGNITE HAULING (LOADED) | 21912 VKT/yr | 29.324 kg/VKT | WATERING | 70 | 8.797 kg/VKT | 192764 |
| | LIGNITE HAULING (UNLOADED) | 21912 VKT/yr | 18.537 kg/VKT | WATERING | 70 | 5.561 kg/VKT | 121855 |
| | RECLAMATION- DOZER | 2400 hr/yr | 11.076 kg/hr | NONE | 0 | 11.076 kg/hr | 26582 |
| | ROAD MAINTENANCE (GRADERS) | 14600 VKT/yr | 1.075 kg/VKT | NONE | 0 | 1.075 kg/VKT | 15695 |
| | TOTAL ANNUAL EMISSIONS | | | | | | 2900085 |

Source: KBN, 1986.

Table I-7. ANNUAL EMISSION ESTIMATES - ROM/ UG MINE/ POWER PLANT

| SOURCE NUMBER | SOURCE | ANNUAL SOURCE EXTENT | | UNCONTROLLED EMISSION FACTOR | CONTROL METHOD | CONTROL EFFICIENCY (%) | CONTROLLED EMISSION FACTOR | ANNUAL EMISSIONS (kg/yr) |
|---|---|---|---|---|---|---|---|---|
| | ROM HANDLING FACILITY | | | | | | | |
| | ROM LIGNITE | | | | | | | |
| | TRUCK DUMP | 2745000 | Mg/yr | 0.000014 kg/Mg | NONE | 0 | 0.000014 kg/Mg | 38 |
| | CRUSHING | 2745000 | Mg/yr | 0.009 kg/Mg | NONE | 0 | 0.009 kg/Mg | 24705 |
| | STORAGE PILE- LOADING | 2745000 | Mg/yr | 0.000432 kg/Mg | NONE | 0 | 0.000432 kg/Mg | 1186 |
| | STORAGE PILE- TRAFFIC/WIND | 0.48 | hectares | 16.02 kg/hct/hr | NONE | 0 | 16.02 kg/hct/hr | 8 |
| | UNDERGROUND RECLAIM | 2745000 | Mg/yr | 0.000129 kg/Mg | NONE | 0 | 0.000129 kg/Mg | 354 |
| | RAILCAR LOADING | 2745000 | Mg/yr | 0.000129 kg/Mg | NONE | 0 | 0.000129 kg/Mg | 354 |
| | UG MINE LIGNITE | | | | | | | |
| | TRUCK DUMP | 326000 | Mg/yr | 0.000164 kg/Mg | NONE | 0 | 0.000164 kg/Mg | 53 |
| | STORAGE PILE- LOADING | 326000 | Mg/yr | 0.000432 kg/Mg | NONE | 0 | 0.000432 kg/Mg | 141 |
| | STORAGE PILE- TRAFFIC/WIND | 0.1 | hectares | 16.02 kg/hct/hr | NONE | 0 | 16.02 kg/hct/hr | 2 |
| | UNDERGROUND RECLAIM | 326000 | Mg/yr | 0.000129 kg/Mg | NONE | 0 | 0.000129 kg/Mg | 42 |
| | RAILCAR LOADING | 326000 | Mg/yr | 0.000129 kg/Mg | NONE | 0 | 0.000129 kg/Mg | 42 |
| | UNDERGROUND MINE | | | | | | | |
| | LIGNITE CRUSHING | 326000 | Mg/yr | 0.009 kg/Mg | NONE | 0 | 0.009 kg/Mg | 2934 |
| | STORAGE PILE- LOADING | 326000 | Mg/yr | 0.000432 kg/Mg | NONE | 0 | 0.000432 kg/Mg | 141 |
| | STORAGE PILE- TRAFFIC/WIND | 0.1 | hectares | 16.02 kg/hct/hr | NONE | 0 | 16.02 kg/hct/hr | 2 |
| | TRUCK LOADOUT | 326000 | Mg/yr | 0.022 kg/Mg | NONE | 0 | 0.022 kg/Mg | 7172 |
| | POWER PLANT | | | | | | | |
| | RAILCAR DUMP | 3100000 | Mg/yr | 0.000164 kg/Mg | NONE | 0 | 0.000164 kg/Mg | 508 |
| | HOPPER-TO-BELT TRANSFER | 3100000 | Mg/yr | 0.000129 kg/Mg | NONE | 0 | 0.000129 kg/Mg | 400 |
| | STORAGE PILE- LOADING | 3100000 | Mg/yr | 0.000432 kg/Mg | NONE | 0 | 0.000432 kg/Mg | 1339 |
| | STORAGE PILE- TRAFFIC/WIND | 0.41 | hectares | 16.02 kg/hct/hr | NONE | 0 | 16.02 kg/hct/hr | 7 |
| | UNDERGROUND RECLAIM | 3100000 | Mg/yr | 0.000129 kg/Mg | NONE | 0 | 0.000129 kg/Mg | 130 |
| | LIGNITE CRUSHING | 3100000 | Mg/yr | 0.009 kg/Mg | NONE | 0 | 0.009 kg/Mg | 27900 |
| | TOTAL ANNUAL EMISSIONS | | | | | | | 67728 |

Source: KBN, 1986.

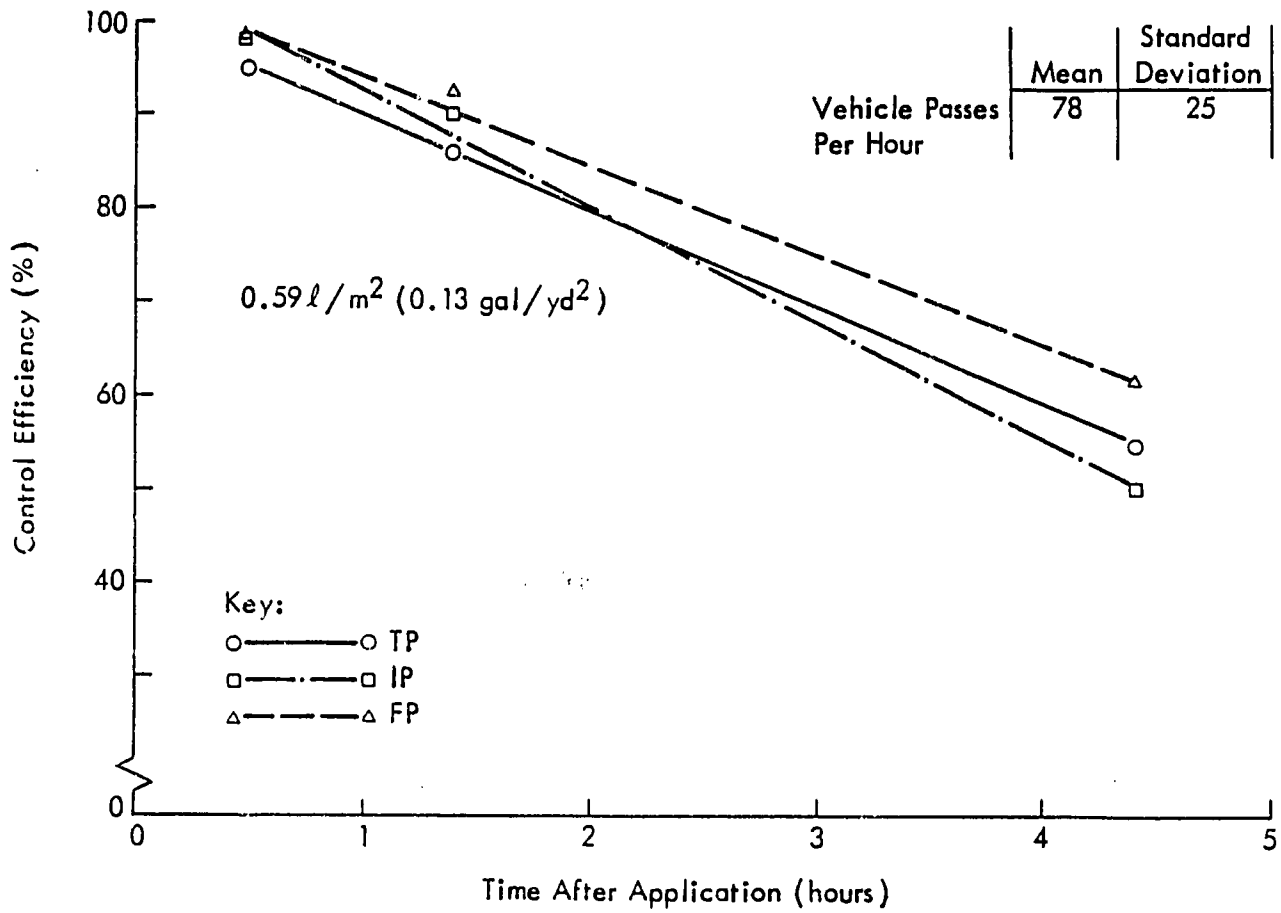


Figure I-1
DECAY IN CONTROL EFFICIENCY OF WATERING AN UNPAVED ROAD WITH HEAVY-DUTY TRAFFIC

SOURCE: MRI, 1983.

**UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT**

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

**Lakhra Coal Mine and Power Generation Feasibility Study**

As shown in Tables I-5 through I-7, the mine haul roads will be the major source of PM emissions at the mine. Total fugitive PM emissions from the Lakhra project are summarized below:

| Source | Fugitive PM Emissions (Mg/yr) |
|---|---|
| East Pit | 13,126 |
| West Pit | 2,900 |
| ROM/UG Mine/Power Plant | 68 |
| TOTAL | 16,094 |

# APPENDIX J

# TRANSBOUNDARY AIR QUALITY CONSIDERATIONS

## J.1 EMISSIONS AND ACID DEPOSITION

With greater downwind distances than those evaluated through dispersion modeling, the $SO_2$ emissions from the Lakhra plant could be converted via gas-phase and aqueous-phase reactions to acidic (or potentially acidic) compounds. The mechanisms for such conversions and subsequent deposition are complex both physically and chemically. The current state of knowledge in the U.S. indicates that gas phase conversion from $SO_2$ to $SO_4^{-2}$ in polluted atmospheres would approach 16.4 percent/24 hours in summer and 3 percent/24 hours in the winter. In water, $SO_2$ oxidation is rapid and often approaches 100 percent/hour. In clouds such conversion approaches that for gas phase oxidation. Deposition can occur by both dry (gaseous and aerosol) and wet (precipitation) processes at various rates. The mechanisms for dry deposition involve the type of surface, atmospheric stability, and the phase of atmospheric pollutant (gas or aerosol).

Since such complex transformation and deposition mechanisms are associated with distance scales of 100's to 1000's of kilometers, it is not possible to predict the environmental effects, especially where there are little data from which an assessment can be made. Extensive studies made in the U.S., many of which will be ongoing for many years, may lead to some insight into the potential problems.

The concern about acid rain in the U.S. has existed since the mid-1970's. Specifically, certain areas in the northeastern U.S. and Canada have presumably experienced an increase in acidity and/or environmental effects. Although there is considerable disagreement concerning the exact causal relationships between emissions, deposition, and effects, certain data are available that can assist in evaluating potential impacts due to the Lakhra plant.

For the eastern U.S., the following $SO_2$ emissions and deposition were observed:

$SO_2$ Emissions: 22,717,000 Tons (1980)
(35 states) (Ohio alone: 1,880,000 tons)

Deposition: $H^+$ = 583 equivalents/hectare (eq/ha) (1983)
(NE U.S.) $SO_4^{-2}$ = 545 eq/ha (1983)

Concentrations: pH = 4.33 (precipitation) (1983)
(NE U.S.) $H^+$ = 47 micronormal (μn) (1983)
$SO_4^{-2}$ = 43.5 μn (1983)

Data from the eastern U.S. are probably not representative of the Lakhra situation because the $SO_2$ emissions are much lower for most plants. Florida, however, is about the same latitude as Pakistan where sufficient oxidants occur, such as $O_3$ and $H_2O_2$, to convert $SO_2$ to its more oxidized forms $SO_3^-$ and $SO_4^{-2}$. A comparison of Florida and Pakistan is believed conservative since Florida's environment is probably more conducive to aqueous-phase oxidation because of higher oxident concentrations and humidity. The data for Florida are listed below:

$SO_2$ Emissions: 936,712 tons (1983)

Deposition: $H^+$ = 228 eq/ha (1983)
$SO_4^{-2}$ = 257 eq/ha

Concentrations: pH = 4.7 (precipitation) (1983)
$H^+$ = 19.8 μn
$SO_4^{-2}$ = 20.4 μn

In unpolluted environments, the pH of rainfall ranges from about 4.8 to 5.2. This concentration in rain is equivalent to a deposition of $H^+$ concentration of between about 60 and 160 eq/ha/yr for a rainfall of 1,000 mm/yr.

The emissions from Lakhra will be 272,000 tons/yr at a capacity factor of 70 percent. It is not known to what extent the emissions at this level will influence precipitation pH and increased dry deposition; however, a comparison with the data from Florida suggests the following:

1. The emissions at Lakhra are less than a third of the annual $SO_2$ emissions for Florida.
2. If all $SO_2$ emissions in Florida cause the observed acidity in Florida (a conservative assumption), the levels from the Lakhra plant will likely be no greater than those observed in Florida which are near background levels of acidity measured in remote areas of the world.

## J.2 LONG-RANGE TRANSPORT

Because of the physical and chemical complexity of atmospheric transport over large distances (i.e., several hundred kilometers), it is not possible to accurately predict deposition for the Lakhra project on these spatial scales. However, long-range transport studies performed in the southeastern U.S. suggest that $SO_2$ sources as large as Lakhra can contribute up to 10 percent of the observed deposition of receptor regions that are approximately 400 km from the source (ESE, 1986). At distances of about 800 km, percent contribution would be reduced to about 1 percent or less of the observed values.

## J.3 ACIDIC DEPOSITION EFFECTS

The following is an edited summary of the U.S. EPA discussion on acid deposition taken from their Criteria Document (1982).

The occurrence of acidic deposition has become a matter of environmental concern. Acidic precipitation in various regions of the world has been associated with acidification of ponds, lakes, and streams. Acidic

precipitation is also believed to have the potential for leaching elements from sensitive soils and causing direct and indirect injury to forests and vegetation.

The pH level can vary during a precipitation event, from event to event, from season to season, and from geographical area to geographical area. Other substances in the atmosphere besides oxides of sulfur and nitrogen can also cause a shift in the pH of the precipitation by making it more acidic or more basic. Dust and debris swept up from the ground by winds may become components of precipitation and affect its pH. In the western and midwestern U.S., soil particles tend to be basic, but in the Eastern United States they tend to be acidic. Furthermore, in coastal areas sea spray strongly influences precipitation chemistry by contributing calcium, potassium, chlorine, and sulfates. In Pakistan, the role of other substances, especially dust, is a major atmospheric component. The relationship to acid deposition, however, is unknown.

Although wet deposition is usually emphasized, it is not the only process by which acids or acidifying substances are added to bodies of water or to the land. Dry deposition also occurs. Dry-deposition processes include gravitational settling of particles, impaction of aerosols, and absorption of gases by soil or water or by objects at the earth's surface. Dew, fog, and frost are also involved in deposition processes but do not strictly fall into the category of wet or dry deposition. Dry deposition of particulate matter is not as well understood as wet deposition; however, it is known that both deposition processes contribute to the gradual accumulation of acidic or acidifying substances in the environment.

The chemistry of freshwaters is determined primarily by the geological structure (soil system and bedrock) of the lake or stream catchment basin, by the ground cover and by land use. In coastal regions marine salts also may be important in determining the chemical composition of

freshwater streams, rivers, and lakes. The capability of a lake and its drainage basin to neutralize incoming acidic substances, however, is determined largely by the composition of the bedrock. Acidification of surface waters results when the sources of hydrogen ion exceed the ability of an ecosystem to neutralize the hydrogen ion. In general, the soils and crust of the earth are composed principally of basic materials with large capacities to buffer acids. Areas where bedrock is particularly resistant to weathering and where soils are thin and poorly developed have much less neutralizing ability. This inability to neutralize hydrogen ions does not usually arise from a limited soil or mineral buffering capacity. Instead, low cation exchange capacity and slow mineral dissolution rates in relation to the relatively short retention time of water within the soil system may result in incomplete neutralization of soil waters and acidification of surface waters.

Soils may become gradually acidified from an influx of hydrogen ions. Leaching of the mobilizable forms of mineral nutrients may occur. The rate of leaching is determined by the buffering capacity of the soil and the amount and composition of precipitation. Anion mobility is also an important factor in the leaching of soil nutrients, for cations cannot leach without the associated anions also leaching. The capacity of soils to adsorb and retain anions increases when hydrated oxides of iron and of aluminum are present.

Sulfur and nitrogen are essential for optimal plant growth. Plants usually obtain sulfur in the form of sulfate from organic matter during microbial decomposition. Wet and dry deposition of atmospheric sulfur is also a major source. In soils where sulfur and nitrogen are limiting nutrients, such deposition may increase growth in some plant species. The amount of sulfur entering the soil system from the atmosphere depends on proximity to industrial areas, sea coast, and marshlands. The prevailing winds and the amount of precipitation in a given region are also important. Near fossil-fuel power plants and industrial

APPENDIX K--SOCIAL SOUNDNESS ASSESSMENT PAPER, LAKHRA COAL MINE AND POWER GENERATION PROJECT

# APPENDIX K--

## SOCIAL SOUNDNESS ASSESSMENT PAPER

## Lakhra Coal and Power Generation Project

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## I. PROJECT DESCRIPTION

The Lakhra Coal Mine and Power Generation Project will involve coal mines and a 300 MW power plant to be located about 100 miles northeast of Karachi in Sind Province (see Figure 1). The coal mining element will include: (1) several underground mines situated on the Lakhra field, and possibly an additional surface mine; (2) possibly a surface coal preparation facility; (3) a colony for personnel; and, (4) a system to transport coal from the mine to the power plant.

The power generation facility to be located at either Jamshoro, Khanot or mine mouth, will include: (1) a coal receiving and handling facility; (2) a 300 MW coal-fired, steam turbine power plant; (3) electrical connection facilities to WAPDA's existing transmission network; (4) an intake water system; and, (5) a colony for personnel.

This project will involve WAPDA, PMDC and the domestic and expatriate private sector in combinations that have yet to be established. A total of more than 3,000 new jobs will likely be created once all elements are constructed. This figure is based on the more labor-intensive, all underground mining option, which will employ a labor force of 2,500, with up to an additional 500 people being needed for power plant operation.

At the time of writing, crucial decisions as to the preferred mining method and optimum power plant site had not been taken. As a result, this report makes assessments of the social impacts of the project given several options.

This report will focus on the feasibility of the undertaking, given its socio-cultural context, and provide recommendations to minimize the social costs inherent in the construction and operation of the proposed facilities.

## II. METHODOLOGY

Research for this report was undertaken by a three-person team* of anthropologists from late January to May 1985. The team employed techniques developed by the Rapid Rural Appraisal (RRA) school of social research, designed to facilitate the assessment of issues in a timely and cost-effective manner. Specifically, the team reviewed the relevant literature (see References) and consulted knowledgable people. The proposed mine and power plant sites were then visited. A trip to the Guddu power plant was included because of its parallels with the proposed Lakhra plant. A questionnaire for mine workers and residents was developed, along with [illegible] target communities and knowledgable informants.

After training researchers hired from Sind University, the team and researchers began a detailed study of village and worker colony life as it related to this project. Questionnaires were revised after a trial period. Responses to the revised versions (Appendix A) formed the basis

*The Social Soundness A[illegible] [illegible] of Arthur Helweg, Iqbal Niazi and Saskia Vloer.



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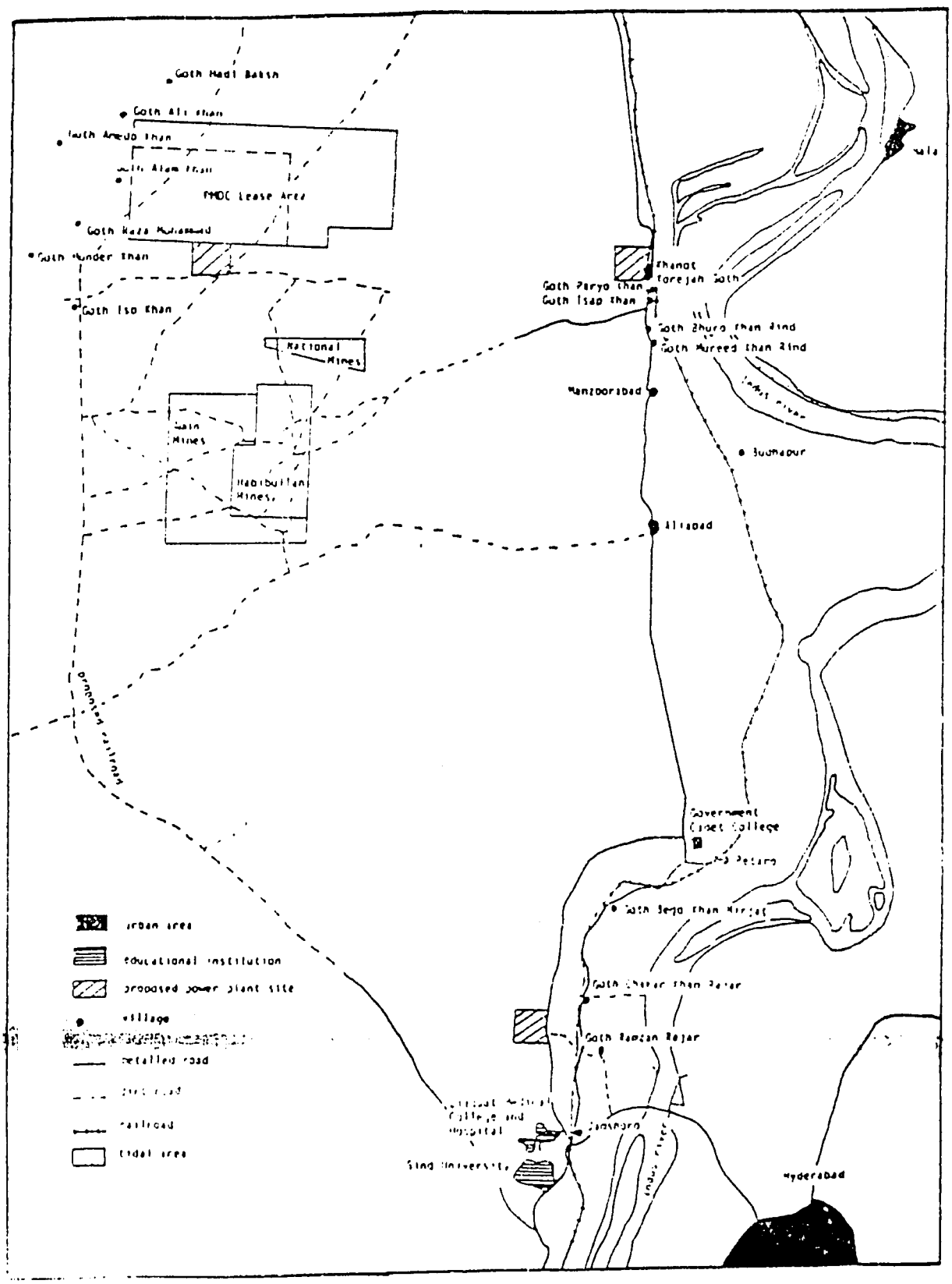
FIGURE 1 : Lakhra / Jamshoro / Khanot area ; Proposed sites and Villages studied



for this report and are presented in detail in Appendix H. A total of 415 people (Appendix C) responded to the questionnaire. Figure 1 shows the 7 Lakhra villages (enumerated in Appendix B) that were studied in depth. Formal interviews of 101 key informants (Appendix D) were undertaken by team members. Opposing views were solicited to obtain all perspectives; people, communities and key informants were chosen to ensure that all relevant groups were represented.

## III. SOCIO-CULTURAL CONTEXT

### A. Cultural Diversity

The traditions and culture of Pakistan have roots going back thousands of years to the Dravadian-based Indus Valley Civilization. That foundation has since been modified by Aryans, Turks, Greeks, Persians, Afghans, Arabs, Moghuls, British and tribal influences over the centuries. Although there is a commonality of principles guiding social behavior, and Islamization is being implemented throughout the country, ethnic diversity and separateness among the country's four major groups (Baluchis, Pathans, Punjabis and Sindhis) are prominent.

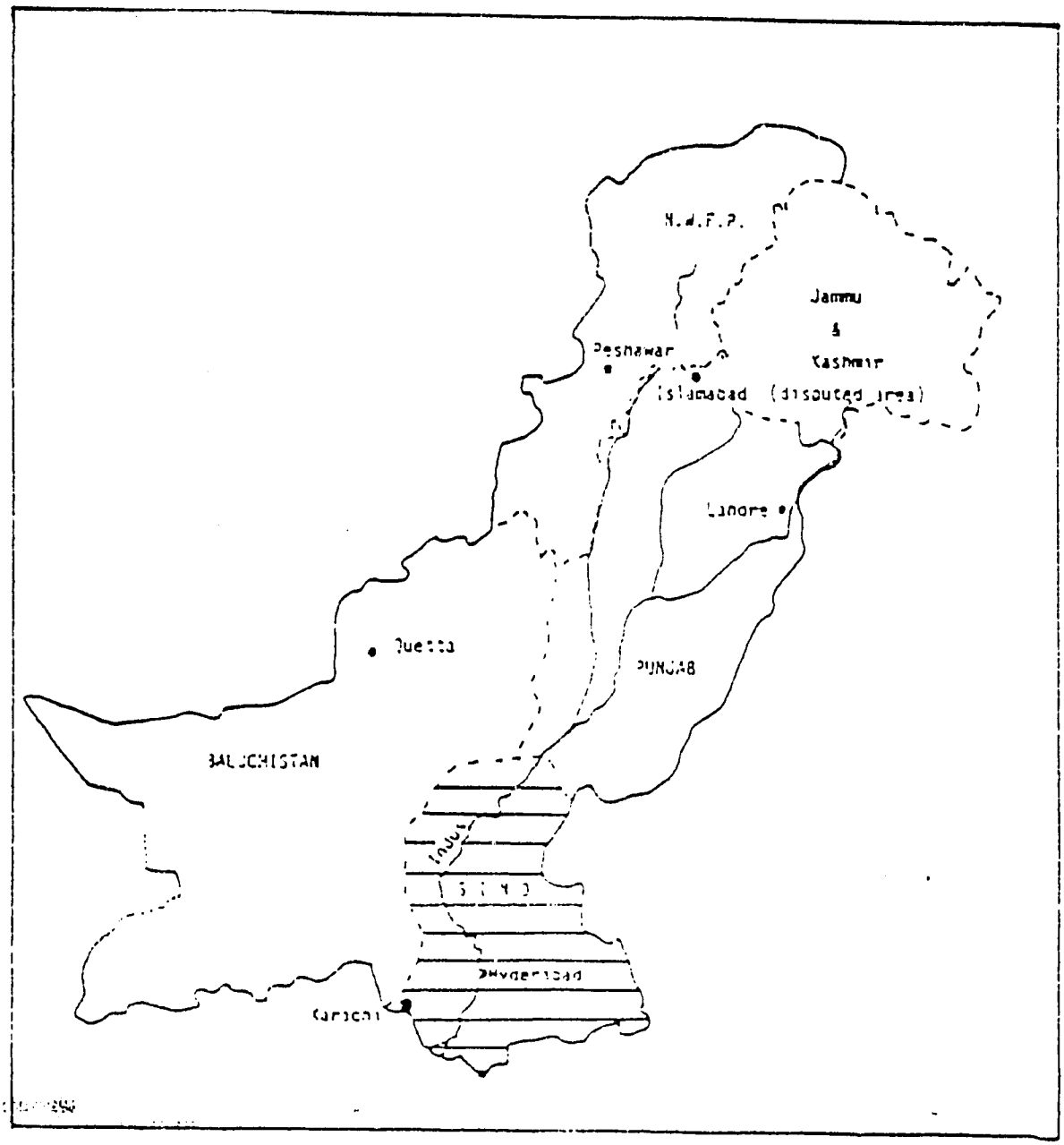
There are more than 99 million people in Pakistan.* The approximately 4 million Baluchis live mainly in Baluchistan (see Figure 2), but they are a strong ethnic element in the Lakhra area in Sind province. They place a high value on freedom and independence, and although they live compatibly with Sindhis, they carefully maintain close adherence to their own tribal structures and traditions. The Baluchis are divided into numerous tribes, with the Khosas and Rinds dominating at Lakhra. The Rind community was the first to settle; its members were later driven off their land by the more aggressive Khosas. At present, members of the Rind tribe live on the banks of the Indus among the Sindhis, while the Khosa people inhabit the semi-arid region near the proposed coal mine sites.

In Pakistan, Pathans make up approximately 12 million of the population. They reside mainly in the North-West Frontier Province (NWFP) and provide the bulk of the underground miners in the Lakhra field (see Appendix M).

Sindhis number over 19 million and continue to practice a traditional agricultural culture that can be traced to the ancient Indus Valley civilization. Sind is also the home of several million Urdu-speaking migrants who came from India at the time of partition. These people tend to live in Karachi rather than in rural Sind. The attitudes of Sindhis will have a significant effect on the successful construction and operation of the project.

* The population statistics cited below do not add up to 99 million because several smaller groups are not included, and given figures are approximations only.

FIGURE 2 : Geographical Position



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The largest population group is that of Punjabis, who number over 50 million. They dominate the country's military, civilian and industrial institutions. They will be among the private mine owners and managers, the construction managers and the senior operational power plant staff reflecting a significant participation in the planning, construction and operation of the project.

B. Lakhra Today

1. Economic System

The proposed site for the Lakhra Project is located in the Kotri Taluka (subdivision) of Dadu District, a hot and dry region with scant rainfall of 5.5 inches per year and annual mean temperatures that fluctuate between 70 and 80° F. Almost 80% of Kotri's population of 216, 000 live in rural areas. The density of population to agricultural land is 771 persons per square kilometer, (see Appendix E). Agriculture provides the economic base; sorghum, sesame and millet, wheat, rice, sugarcane and cotton are the main crops cultivated. Most land is beyond the reach of canal water and therefore barren. Sub-surface water is brackish and not suitable for irrigation.

Scattered villages ranging in size from 20 to 100 people (3 to 50 dwellings) are sparsely dispersed among the various coal mines in the area (see Figure 1). In the peak mining period, up to a thousand 10-ton trucks a day transport coal excavated by the area's 10 privately owned mining companies (see Appendix L).

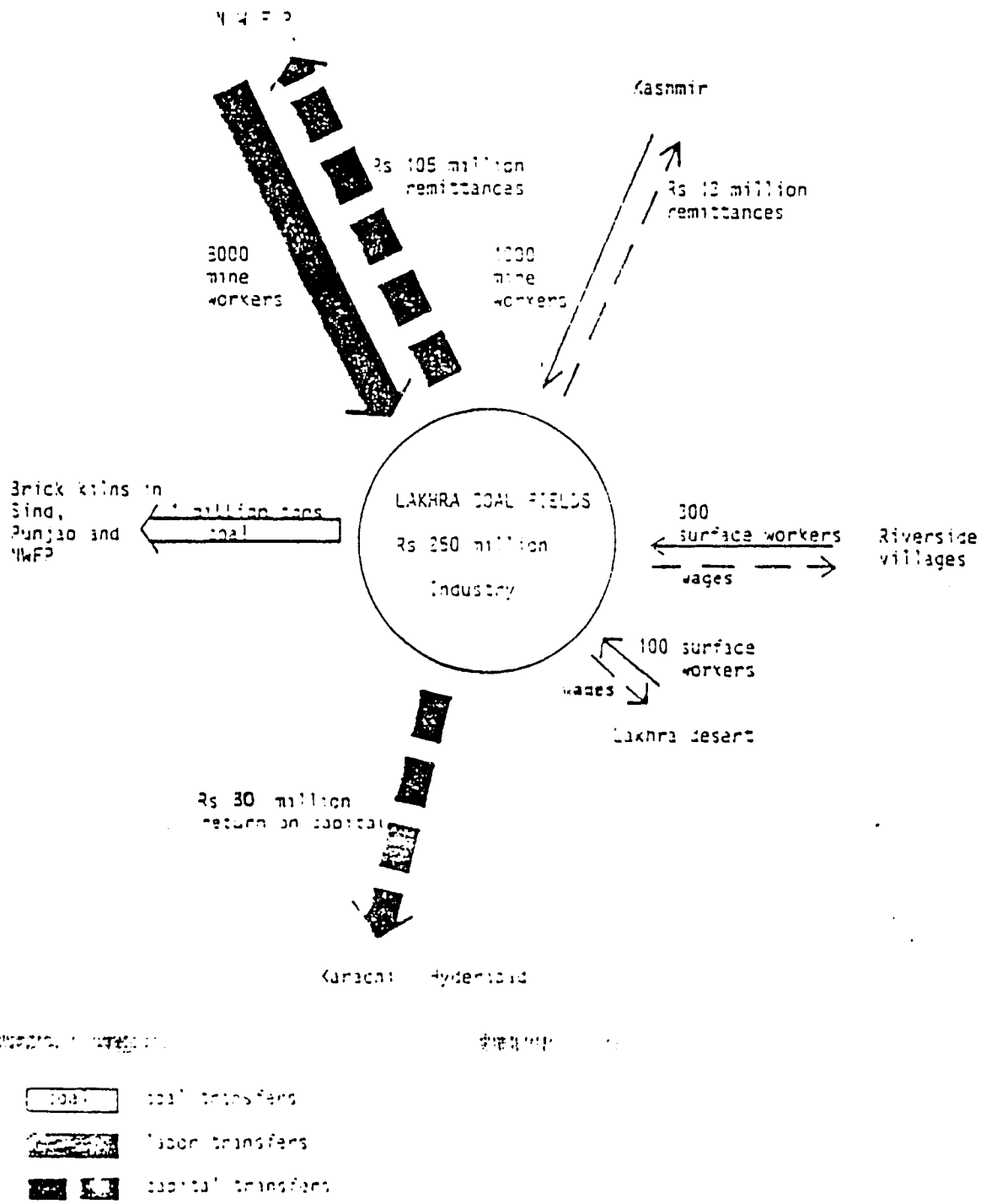
Lakhra coal is a vital part of an integrated economic system which extends north to Gilgit, east to Lahore and south to Karachi (see Figure 3). The 8,000 coal cutters* from NWFP and 1,000 from Kashmir support 45,000 people in their home regions by remitting Rs 120 million ($7.5 million)** annually.

Lakhra's current production of one million tons a year is used in brick kilns throughout Pakistan. The owners of the three largest Lakhra mining companies belong to Pakistan's top 22 industrial families. Within the Lakhra area, 300 Indus river area inhabitants and 100 Khosa Baluch provide support services such as loading, timbering and shafting for mining operations. Underground mining is done only by Swatis and Kashmiris. The indigenous population does not mine coal even though the pay rate for coal cutting is twice the national average for physical labor.

* The coal cutter labor force is mobile. They are not all in Lakhra at the same time.

** At an exchange rate of $1.00 = Rs. 16.00

FIGURE 3: The Lakhra Economic System



## 2. The Khosa Baluch

The people potentially affected by this project include: transhumance* Baluchis, settled Sindhis and Swati immigrants. The 2,000 Khosa Baluch inhabit tiny villages interspersed among the mine shafts of Lakhra, living in temporary dwellings, often made of sticks, from July until April. Planting takes place with the July rains, and crops are harvested in November. Thereafter animals are herded until the water supply is depleted, usually around April. For the 3 dry months of the year, the Khosa move to the Indus river area where they work as agricultural laborers in the Sindhi villages.

The Khosa Baluch own their land, feel a strong sense of permanence and emotional attachment to it. When questioned about working at the mines and living in colonies, they express a willingness to have their sons undertake surface work so long as a male remains on the land to plant, harvest and maintain livestock. They claim they will not move into a colony unless forced. Like many herding people, they prefer the spaciousness of their semi-nomadic existence and the comfort of ancestral land to living in confined buildings they do not own.

The Khosa Baluch live very frugally, their most urgent need being for a regular supply of water. Some mine companies regularly distribute water in drums and receptacles scattered throughout the region, to ensure a cooperative relationship between mine owners and the local inhabitants. Although they have benefited from this practice, the Khosa Baluch strongly distrust outsiders and the government. One of their greatest concerns with the proposed project is that the government will seize their land.

With this concern in mind, if the coal for the power plant is extracted only by underground mining, there could be relatively little disruption to the Khosa's life. The technology being advocated is a modification and upgrading of current labor-intensive practices, although a mine employing 500 coal cutters is considerably larger than any installation currently in operation. However, the Khosa could benefit from the water, schooling and medical facilities that will form part of the project mines.

Ultimately, it seems likely that the Khosa lifestyle will have to change. Zeal-Pak and other major industries are thinking of moving into the area if electricity becomes available. Industrial job opportunities and experiences will radically alter the relationship between sons and elders. Traditional cultural values and beliefs will no longer be sustaining. Over time, education will be the only way to prepare the Khosas for their uncertain future and to provide intellectual ways to avoid anomie.

---

* Transhumance, a mixed food-producing economy involving pastoralism and gardening according to the season of the year.

3. Indus Village Inhabitants

The settled area to which the Khosa Baluch migrate each dry season consists of multi-caste and single caste Baluch, Sindhi and Sindhi/Baluch villages scattered along the Indus river (see Appendix H). This is an agricultural area where wheat, pulses, sorghum, rice, cotton and sugarcane are the major crops. Water is pumped from the Indus by electrified float pumps. The villages vary in size from several hundred people to 4,000, with houses ranging from solid brick to mud.

The population of these villages share the Khosa's perception that the best jobs and resources available in their area are going to outsiders. The Pathan coal cutters at Lakhra undertake work which is seen by local people as risky, hard and undesirable; they are therefore not resented but easily tolerated. Similarly, Rind Baluchis and Sindhis have been living in peaceful coexistence for a century, and although they have not merged with the larger Sind society, the Baluchis do not pose a threat to Sindhi self-esteem and status.

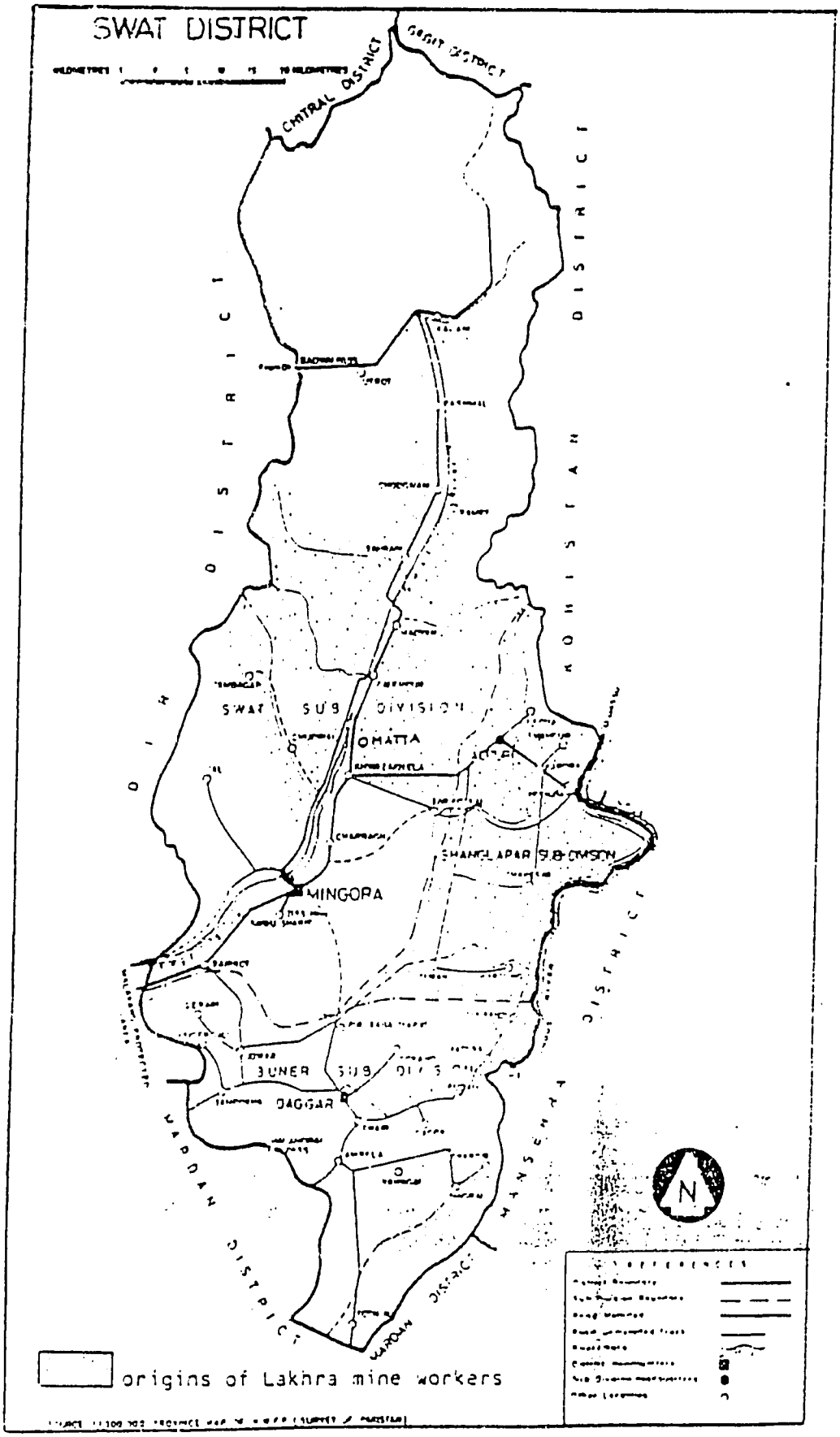
Because of the high man-to-land ratio, the Indus river-bank agriculture cannot sustain its present population. Therefore many villagers have taken employment at the coal mines in less risky above-ground jobs, or moved to cities like Hyderabad (see Annex H). Typical work might include driving, truck loading, stone gathering and rock crushing. The most sought-after occupation is that of chowkidar or watchman. Generally, Sindhis will only undertake light physical labor, although a very few work in the mines as timbermen to shore up tunnels, and as loaders to fill trucks.

4. Swati Coal-Cutters

Prior to 1965, Kashmir was the major labor supplier for the Lakhra coal mines. At that time Kashmiris started migrating to the Middle East in search of higher paying work, and the Alpuri region of Swat became the major supplier of Lakhra coal cutters (see Appendix M and Figure 4). In this region, the population far exceeds resources at over 1000 people per sq km of arable land. It is therefore not surprising that most Swatis can earn only 10 to 50 percent of their livelihood locally (see Appendix Q ). For them, emigration is necessary for survival.

The poor low "caste" Gujjars who reside in the less productive higher altitudes of the valley dominate the Swat-Lakhra population flow. They are dependent on employment in the Lakhra mines, since without it, they and their average-sized families of six would be destitute. At present, the high salaries to be made in the Middle East make it the preferred target for Swati migrants, but a work permit for a Gulf State costs from Rs 40,000 to Rs 60,000 and is beyond the means of most Swaties. Karachi is the second choice as there are many Pathans and various work opportunities in that port city, while Quetta and Lakhra have third priority and are the target for the poorer Gujjars who are prepared to work hard under difficult conditions.

FIGURE 1: Map of Swat District



Those who cut Lakhra coal stay at the mines for a total of only four to six months each year, since for health reasons miners cannot physically work any longer. Furthermore coal production is suspended during the summer months when the brick kilns close down during the monsoon season. Periodically, therefore, the cutters return to Swat to rest, plant, harvest and fulfill social obligations such as attending weddings and other ceremonies.

Apart from the economic incentives, working at Lakhra also allows Swati migrants to enjoy higher social status among their kinsmen and villagemates. There are many laborers in Swat, and given the right conditions, more will work in the Lakhra mines.

The bulk of the miners start arriving in Lakhra in October and work until March. They live under fairly basic conditions, sleeping in 20 ft. by 15 ft. brick rooms containing eight to ten men per room. Communal kitchens attached to the buildings provide cooking facilities; and a nearby tea stall provides a place to relax. There is no potable water in these camps, and water-borne diseases are common. Many miners suffer from respiratory infections as men, soaked with sweat, are chilled by winter breezes when they reach the surface after a shift of cutting underground. Improved sanitation and work practices can contribute to a healthier labor force and potentially increase coal production.

5. Lakhra Social Systems

For Pakistani society in general and the affected people of this project in particular, there are common principles guiding the social structure, economic system and political relationships.

Any interaction between individuals of different ranks is governed by strict social norms, based on the concepts of separation and hierarchy. Separateness is demonstrated by the fact that ethnic groups prefer living in residences with their own kind. In a colony, Pathans prefer living among their own people rather than being interspersed with Baluchis. In villages, Baluchis have their own areas while Sindhis stay in their territory. Within these larger groups, caste* and kin groups tend to cluster.

Educated officials maintain a social distance from the uneducated workers they supervise. There is little or no social mobility among workers who almost never rise to the managerial class. Birth is the major determinant of ranking and opportunities.

However, these values apply differently to the various groups affected by

* Pakistanis do not perceive themselves as being organized into "castes". The term is used in the report to describe social groups whose members have similar roots and socio-economic status, and a sense of identity with each other.

the proposed project. For example, among the Khosa Baluch there is little hierarchical differentiation. Their villages are composed of equal kin group members. There is also little specialization of labor, and differentiation is primarily on economic grounds. The primary exception is the position of chief, which is generally passed on from father to son. All Khosa Baluch perceive themselves to be superior to Sindhis, Pathans and other outsiders.

In contrast to the Khosa Baluch, the Sindhi villages along the river are much more hierarchical in their social structure. Within the village, ranking is strict and apparent in all interactions, residential patterns and power relationships. Low caste members show deference to higher caste groups and reside outside the village or in isolated sections of the community. Higher caste families maintain autocratic control of village affairs commensurate with their standing in Sind society.

Amongst the Swati coal cutters, caste is also important. The two main groups are the Pathans (rulers, soldiers, landholders), and the Gujjars (landless, low caste, subordinates). Caste distinction appear to be less rigid than in Sind. In this context, emigration for economic gain is views as a means of maintaining or raising a family's position. The work of mining is not seen by fellow Swatis as a menial task, which provides encouragement to the emigrant laborers.

The mines employ workers in three categories of people: managers, cutters and support personnel (see Figure 5). The coal cutters are by far the largest group and are formed into gangs (Joris), mostly based on kinship and village ties (Appendix N). There is a comradeship among Jori members who help each other to maximize earnings. Their leader is a Jorisar who handles their problems and mediates between them and the major labor contractor called a Jamadar. Support services such as shafting, timbering and loading trucks are undertaken by Swatis as well as Baluchis, Sindhis and Punjabis. This surface work is not considered as strenuous as mining but is less well paid.

6. Organization of Labor

All labor in Lakhra is organized around a central figure who is either a wealthy land owner or a labor contractor. That key individual hires, fires and guides his laborers. He also acts as confidante and adviser and as the mediator between his workers and the wider society.

In Sind, labor is organized around the Zamindar or land owner (see Figure 6). There may be several Zamindars in a village, but one is generally dominant. In the traditional system, carpenters, washermen, barbers, blacksmiths and other groups provided their services to the Zamindars in return for a portion of harvest. For example, a carpenter who repaired the Zamindar's plough, received 1/20th of the harvest. Work not covered by the traditional agreement was paid on a piece basis. The system assured craftsmen of income and security, since even if dissatisfied with his work, the Zamindar had to use the carpenter's services for no other

FIGURE 5. Mine Organization Chart

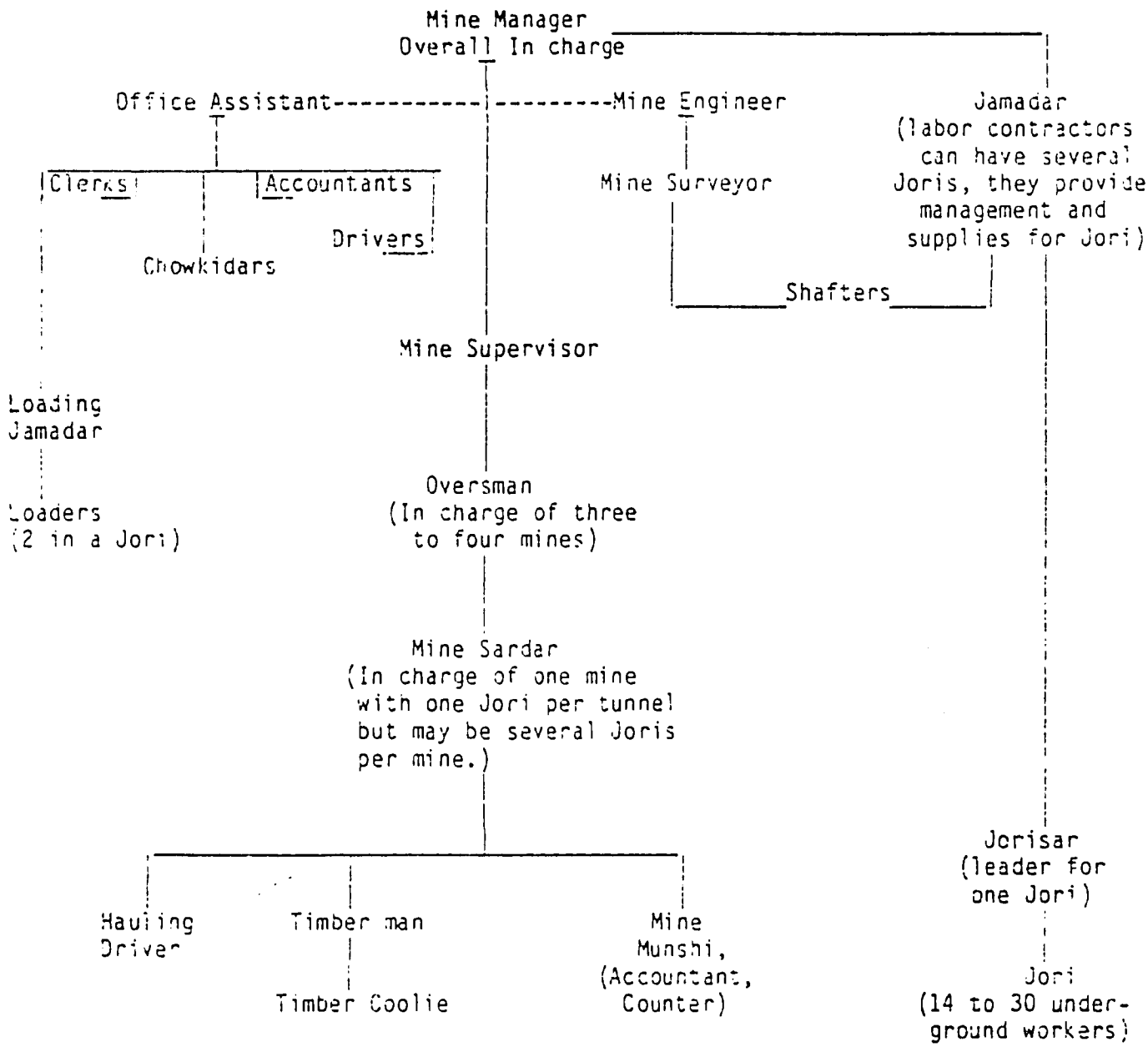
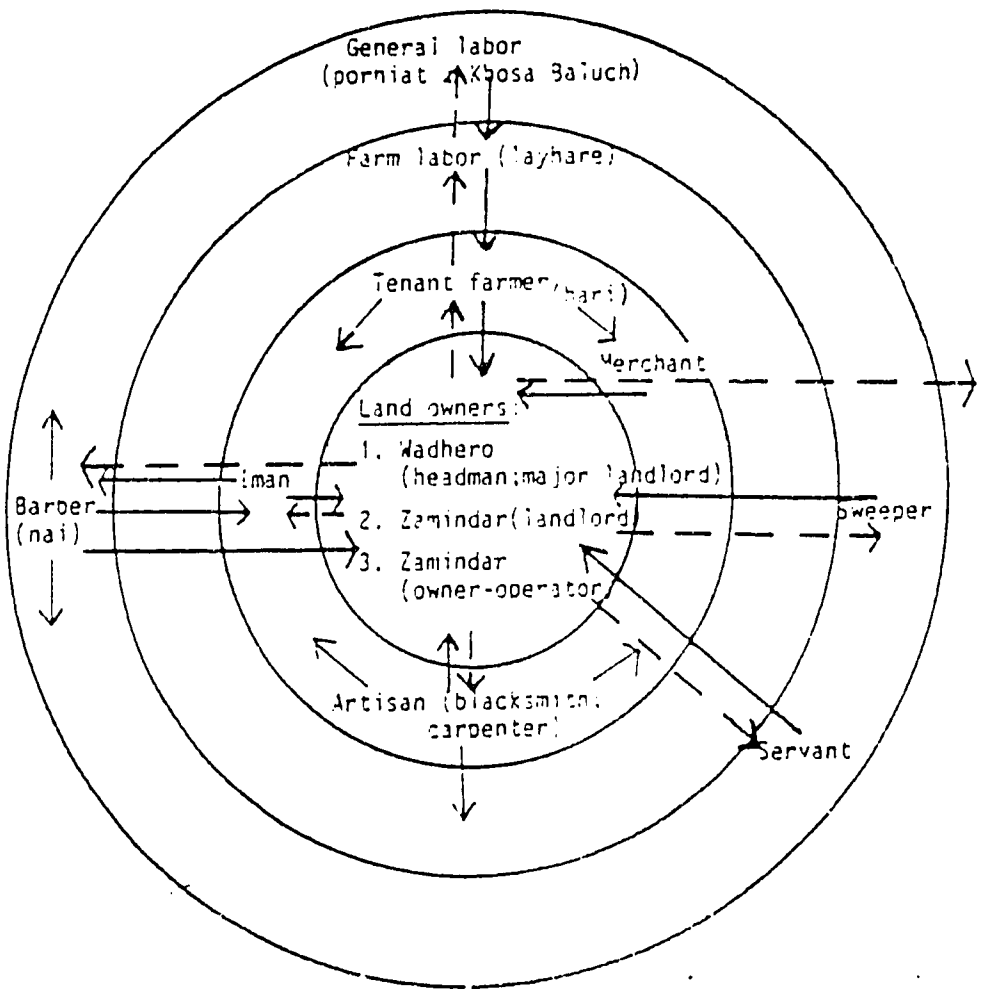


FIGURE 6 : The Village Economic System




factor of production

output distribution (cash or kind)

1. The factors of production are directly or indirectly designed to to flow to the center.

2. The center distributes assets to the community and through the merchants.

3. Political and economic power is concentrated inthe center. The closer to the center the position of the group is, the more power it has.

4. The center does not serve the outer circles.

member of that caste would work for him. Wage labor is replacing many of these traditional relationships. Today, artisans, cobblers and others work for cash, according to production. Many specialized skills are no longer available in the village because artisans have moved to urban areas or the Gulf.

Nonetheless, old customs still remain. The Zamindar still controls the means of production, and distributes the outputs. Figure 6 shows the central role of the Zamindar in today's village economy. In turn, like the tribal chief, the Zamindar has many obligations. He mediates on behalf of his workers with the police, officials and merchants. He also provides help and advice to his clients if they are poor or destitute; he is the patron par excellence. He cannot, however, retain a continued hold on all his clients in the village (Appendix H), as available resources cannot meet the demands of a growing population. Throughout Sind the zamindar system of labor operates in the construction, mining and industrial sectors. For construction, the Mistri acts as the central labor contractor. Like the tribal chief and the Zamindar, the Mistri mediates between his workers and the outside world and is their adviser, confidante and patron. He also manages their housing and board.

The labor economy of rural Swat operates on principles similar to those in Sind (Appendix R). The Swati Zamindar is also part of an elaborate system of rights and obligations on both sides. The repayment of loans is a strong motivating factor for Swatis to return to mine labor each year. Mine owners give Jamadars an advance of funds, and the Jamadars, in turn, advance money to their Jori members. Swatis are also motivated by their relationship to their colleagues. Their miners are paid by piece work rates, and feel a moral obligation to do their share. If they do not contribute to production, those closest to them suffer. For all the above reasons, Swatis make industrious Lakhra employees.

Unlike the leaders of settled areas, leaders in the Lakhra economic systems cannot be overly autocratic. Village headmen of the settled areas are more authoritarian than tribal leaders, as they control the land and the mobility of villagers. For the semi-nomadic Baluch however, leadership is based upon the willingness of the group to follow an individual and the leader's ability to provide goods and services to those in his fold. Khosas follow a founding family which heads the community. However, if a headman becomes too tyrannical, the members will follow a new individual and settle in another village. The chief must continually be sensitive to his people, asking their opinions on issues, and ensuring that respected individuals feel their advice is being heard and followed.

In the Jori system, the Jorisar also holds his position only because his kinsmen and villagemates trust his judgment and believe that he will find them well-paid employment. In general, the Jorisar, aware that autocratic behavior could make him lose his position, takes pains to seek the advice of elders and caters to the needs and desires of his workers. However, the power of a given Jorisar can vary with the supply and demand for labor. When laborers are scarce and work is easy to find, the Jorisar is relatively weak. On the other hand, when there is a surplus of labor

laborers must depend on the Jorisar to find work. Under these conditions the Jorisar exercises considerable authority over his laborers.

7. Role of Women:

The life of women varies according to region, social level and type of village. Purdah (keeping women secluded in the home) is practiced in all areas of Sind, but its application varies. For example, in a Sind single caste village, women have some freedom of movement and may participate in agricultural activities. In multi-caste villages, their movements are more restricted and instead of working in the fields, women make handicrafts at home. In Swat, women do not contribute to the family income but are restricted to handling domestic chores and working on the family land.

Purdah does not mean that females are powerless or ignorant of the outside world. They do make inputs to family financial decisions, and generally the domestic realm is their domain. But most major decisions, including the choice of the home location, are made by males. With access to television, village women are quickly becoming aware of what is available to them from the outside world. In Manzoorabad, Sind for instance, village women informed the Social Soundness Assessment Team that a girls high school and a female doctor were among their top priorities.

## IV. SOCIO-CULTURAL IMPACT

The socio-cultural issues that will affect the people who live near the proposed Lakhra sites were investigated by looking at three separate phases of the project: the planning phase, the construction phase and the operations phase. Roughly, the schedule for these phases is:

| | |
|---|---|
| Present - January 1987 | Planning Phase |
| February 1987 - June 1991 | Construction Phase |
| July 1991 - July 2021 | Operations Phase |

### A. Planning Phase

This is the period after the publication of the feasibility studies, when donors and investors are appraising the project. It will involve coordinated interaction and planning among GOP agencies, such as WAPDA and PMDC,* donors, such as USAID, the World Bank and the Asian Development Bank and private Pakistani and expatriate companies.

The two most important issues during this phase will be: (1) overcoming the basic distrust between the Lakhra private coal sector and WAPDA; and (2) maintaining good relations with local officials.

* Pakistan Mineral Development Corporation, owners of the lease area from where coal may be extracted.

1. Private and Public Sector Cooperation

The plans for the project currently call for the power plant to be owned and operated by WAPDA, with expatriate assistance in the early years of operation. As a potential major donor, and the financier of the feasibility studies, USAID is insisting on majority private sector control and ownership of the coal supply system.

Past interactions between the public and private sector in the coal arena have not been harmonious. The public sector can and does cite cases of cheating and poor coal deliveries that have proved very costly to the Pakistan Government. The private sector has experienced expropriation in the past, and given the current laws on the books, has every right to be nervous about the possibility of future Government interference or worse. If the project is to maximize benefits to both private and public sectors, providing jobs and increased power generation for the Government of Pakistan, and increased profits for the private sector, the relationship between the two sectors will have to improve during the planning phase. One method that is being instituted, albeit slowly, is the negotiation of long term coal supply contracts between private mine owners and WAPDA to deliver fixed amounts of coal to the power plant. This mechanism, widely used in free market countries, provides a proven method for bringing together parties with inherently antithetical desires.

A number of other public-private issues will arise during the construction and operations phases, and these are discussed below. However, the initial thinking about these problems should be done during the planning phase.

2. Maintaining Good Relations with the Local Population

Sind is a volatile area. Sindhis tend to be distrustful of outsiders and federal government officials. Local attitudes can be judged from the fact that when the Social Soundness Assessment Team (SSAT) visited villages, informants assumed that the power plant would take Sindhi coal to supply electricity to Punjab and other places.

By the end of the field work undertaken for this paper, there had been no official contact between the GOP and the union or district council members, or any other local officials representing the people of the area about the implications of the project. However, in June 1985 the Government of Sind started to take an active role in the review of the project. Government of Sind officials have recently offered to investigate the feasibility of provincial financing for some infrastructure elements (such as roads, schools or water systems). Communication among federal provincial and local officials will be essential to avoid bureaucratic delays, lack of laborers and non-availability of public services.

Given the history of events in the Sind region, communication between officials at all levels and the public will be required to maintain a peaceful environment for the construction phase.

B. Construction Phase

This is the period following the award of contracts during which the facilities will be built. The construction of the power plant is likely to take at least four years, a longer period than needed for the development of underground mines. If surface mining is part of the project, the long lead time required for the removal of overburden may make mine development the critical path.

This phase will create jobs and incomes for the host region. Local people will be hired and local businesses and industries will develop to provide workers with food, recreation and other amenities. Three issues are seen as important in this phase: (1) the need to construct appropriate public works; (2) labor availability and acquisition; and (3) the danger of recession when the construction phase is completed. Certain other issues are discussed at the end of this section in the context of specific project options.

1. Public Works

Telephones, roads, electricity, water, sewage, police protection and other support systems will be required by the project. Various elements may be financed by the mines or power plant developers, but local governing bodies are sure to be involved in the provision of many items. Informants from a Pakistani construction company noted that it was their policy to liaise with local leaders as soon as they were awarded a project in a particular locality. They found the support of officials imperative to obtaining the required amenities and to operating effectively. This elementary precaution was overlooked in the construction of the Guddu project. Workers arrived at this remote site without the full cooperation of local officials having been negotiated. As a result, the project experienced much difficulty in obtaining telephone, water and other needed facilities. The recent expressions of interest by the Government of Sind officials is encouraging in this regard.

2. Labor Issues

a. Availability

In general, Pakistan has an abundance of labor since unemployment and under-employment are major problems in all provinces. Contractors, employment officials and university professors interviewed (Appendix D) testify to the availability of potential long-term professionals for the Lakhra project. WAPDA managers receive hundreds of applications when an engineering position is advertised. The unemployment register of the Hyderabad area (Appendix I) lists 90 unemployed engineers of various specialties, which is likely to be an under-representation.

By contrast, the attraction of higher paid positions for craftsmen and artisans in the Gulf has resulted in a shortage of skilled manpower. The Hyderabad unemployment register lists only one bricklayer, one carpenter, one blacksmith, three diesel mechanics and four welders looking for work.

Contractors interviewed, however, assured the team that sufficient skilled labor would be available for the project's needs, especially since the pace of Gulf construction was slowing down.

Unskilled workers pose no problem. There are plenty of men from the local region as well as in Swat and Punjab who are willing to work on construction sites. In the Hyderabad area almost 4,000 unskilled men were registered as unemployed in March 1985.

b. Acquisition

To obtain reliable employees, construction subcontractors usually recruit professionals such as engineers and architects from their own informal communication networks. Most companies have a small skeleton staff and hire temporary workers for individual projects. It is unlikely that construction managers will be drawn from local sources, since the head offices of most large builders are located in Karachi or Lahore.

To obtain skilled workers, a company will work with a Munshi (labor contractor). For Lakhra, the lack of local artisans will mean that the majority of skilled workers are also likely to come from outside rural Sind. If this state of affairs is misperceived, the public may become enraged, and attempt to disrupt the construction phase of the project. Construction managers will be wise to maximize local participation by using a Zamindar or Jamadar or Mistri to recruit all available unskilled labor. To ensure good work habits, managers should pay according to production, and provide simple housing or a shuttle transport service. As the local people enter the wage economy, their desire for newly-affordable consumer products will be a motivating factor for their continued willingness to work.

3. Recession

In planning and implementing the construction phase, managers should remember that at the end of the construction phase, the number of workers is likely to decline substantially, certainly at the power plant. and, to a lesser extent, at the mines. The sharp decrease in demand for support services could have a significant effect on the local economy. In order to minimize the negative impact of the cessation of construction activities, managers should communicate with the local private sector, and try to make the down-turn as gradual as possible.

4. Issues Specific to Coal Mine Construction

The proposed mining operations will be principally centered on the 52 sq km project tract about 20 km west of Khanot. To supply the 1.4 million tons of Lakhra coal required each year to fuel the 300 MW power plant, several alternatives are being considered: (1) several semi-mechanized sub-surface mines, (2) a combined drag line and truck/shovel surface mine, (3) a combination of both, and (4) supply contracts with private mine owners. The following issues are specific to the construction phase of the mining element.

a. Underground Mining Labor Availability

The proposed underground mining option builds on existing Lakhra mining practices. It is planned to construct four or more mines involving about 200 workers in digging access shafts and inclines. Although local people have worked on shaft development, most previous mine development work has been done by people from NWFP and other northern areas. Finding shafters and support workers will not be a problem since both Swat and Dadu Districts have many unemployed or underemployed workers.

b. Mechanization

The mining method that has been recommended for underground extraction is called "semi-mechanized", and builds on the unsophisticated techniques currently being practiced in Lakhra mines. It will be important for mine managers to gradually introduce the new techniques during the later years of the construction phase, on an experimental basis, to ensure that workers are familiar and comfortable with the new methods in advance of the requirement to supply the power plant at fixed production levels.

5. Issues Specific to the Power Plant Construction

a. Labor Issues

Construction of the plant will take about four years and will involve a variety of inputs including highly educated managerial and professional staff and unskilled workers. WAPDA will provide the professional personnel, while about 2,000 laborers will be recruited by Pakistani sub-contractors as described in Section 2 above.

The development of the Guddu power plant (Appendix G) provides valuable experience for this phase. At Guddu, operational personnel were not sufficiently knowledgeable about the operation of the plant when it was commissioned. For Lakhra, WAPDA officials suggest that operations personnel should be on site at least one year before the plant goes into operation. They also suggest that construction engineers and other skilled workers employed in the construction phase be hired for the operation of the plant. Since they will have built the facility, they will be familiar with it. Contractors interviewed saw no problem in releasing their personnel, since they would be temporarily hired for the life of the Lakhra project only. At Guddu, resentment between operational and construction personnel was caused by housing problems, as construction crews moved into house designated for operational people, and refused to leave. The problem was a source of friction for several months.

During the construction period, training of potential Lakhra power plant staff will be underway. WAPDA is planning to obtain 25 percent of the required professional staff from other plants to form the core force of experienced personnel. These people as well as the new recruits will require training since the project will introduce a new technology for Pakistan.

A major problem at Guddu was attracting good people to work at the remote and isolated facility. Plant managers did not want to give up their good people, while personnel did not want to leave friends and family. WAPDA overcame this problem by providing generous allowances, good housing and colony support facilities including good schools, a fine medical center, a club for the management staff, recreation areas and a mosque.

b. Site Specific Issues:

The three sites being considered for the 300 MW power plant are Jamshoro, Khanot and Lakhra (See Figure 1).

i. Jamshoro Site

The Jamshoro site is located about 15 km east of Hyderabad, 4 km from Jamshoro itself and 7 km from the University of Sind. The nearest village is Chakar Khan which has 1,000 people and is located several kilometers east across unsettled land. Tokyo Electric Power and Supply Company (TEPSCO) of Japan has been contracted to build a 250 MW oil-fired facility with a worker colony on a plot immediately adjacent. Negotiations are presently being conducted with the Chinese to build a 210 MW oil-fired plant, with worker colony, in the immediate vicinity. WAPDA has long range plans to develop four 300 MW coal fired plants using Lakhra coal, possibly to be co-located at the Jamshoro power complex. This Lakhra undertaking project is seen as the first of the four coal-fired facilities.

(a) Labor Relations

The choice of the Jamshoro site would ease potential labor problems. Commuting from Jamshoro and Hyderabad is easy, so that local workers could live at home. More skilled workers would be readily available than at any other site, and fewer worker dwellings would have to be provided. Jamshoro already has a commercial center, and although a few enterprises would spring up around the site, the development of a new potential slum area outside the plant walls would be unlikely. As far as labor relations and land management are concerned, Jamshoro would cause little disruption.

(b) Relations with the WAPDA Colony and the Local Community

A WAPDA colony will be constructed for the Japanese-financed unit which will be operational long before the Lakhra coal-fired plant. When operations personnel for the oil-fired unit move into their colony, construction on the Lakhra coal-fired plant, were it to be located at Jamshoro, would still be underway at an adjacent site. Experience suggests that a clear division should be made between the operation and construction worker settlements. In response to the social soundness surveys, women made a point of emphasizing the need for distance between family houses and bachelor accommodations. Since the construction workers will not be bringing their families, they should be housed apart from the operations personnel's married quarters.

ii. Khanot Site

The actual site for the plant at Khanot had not been determined at the time of writing. WAPDA has a grid station which is a potential site for the power plant opposite the village of Khanot, but the District Commissioner of Dadu would prefer to locate the power plant at the junction where the access road to the Lakhra fields meets the Khanot/Jamshoro highway. His reasons are: (a) the site is more accessible to coal coming from the mines; (b) it is located halfway between two major population centers, Khanot and Manzoorabad; and (c) it will help the economic development of the region. Khanot with a population of 1,500, and Manzoorabad with a population of 1,300 are the two largest villages in the area. Although these villages are predominantly agricultural, the proposed sites are not on crop land.

Three issues are of particular importance to construction in this area: (a) labor management, (b) relations with the local population, and (c) labor recruitment.

(a) Labor management

Managers should learn from Guddu the importance of providing organized leisure activities for workers at remote and isolated sites to improve morale. This need was not immediately recognized at Guddu, with serious social consequences for the construction schedule. At the existing mines at Lakhra, sports have proved popular. Mosques and tea stalls are also provided.

(b) Relations with the Local Community

An influx of 2,000 workers to the Khanot area would certainly lead to problems if villagers came to resent outsiders taking jobs they feel were rightfully theirs and causing inflation and/or product scarcities. Social disruption would result unless the local people were hired to the maximum extent, were included in the benefits of new services, and were the recipients of a good public relations effort.

(c) Labor Recruitment

Surveys conducted by the Social Soundness Team indicated that local Sindhis were willing to work at the construction sites. Local headmen and Zamindars might act as labor contractors, while as land owners, they might have conflicting interests. On the one hand, they might want to help their clients, but on the other, they would also want the supply of workers for their lands to continue. They might also be tempted to charge excessive fees for the workers or exploit them in other ways. The resentment felt by the dissatisfied workers might in turn cause further problems.

iii. Lakhra Site

Workers might be even more reluctant to move to Lakhra than Khanot, since the site is 20 KM away and more remote. Appropriate incentives would have to be provided and generous recreational facilities and programs included in the plans for the worker colonies.

C. Operational Phase

1. Coal Mine Specific Issues

Over the life of the project it is almost certain that the majority of undergound coal cutters will be people from NWFP or the Northern Areas. Of these, most will form a transient labor force which regards Lakhra as a temporary work location but not a place to which they would bring their families. These are many reasons why the Swatis will not emigrate permanently. Their major concerns will be with providing for their parents and other family members (who will stay in Swat), arranging for security in their old age and enjoying the respect of their home society. Most importantly, they will want to remain residents of their native areas. People of this community think of the family as a unit of security and source of welfare for its members. If a Swati moved his wife to Lakhra, he would be going against his family's wishes by depriving his parents of her labor and comfort and similarly depriving his wife. This selfishness might cause the man unbearable shame. The importance of the family in Swat can be seen by the fact that it is common for brothers to work alternately at Lakhra to ensure that at least one son is available to support the home group. Swatis see land as a source of power and esteem, and land would likely be lost through a permanent move to Lakhra. While most coal cutters realize they must take care to return home to a better climate to rest, maintain contacts and to fulfill social obligations, responses to the team's survey questions suggest that up to 30 or 40 percent of the coal cutters may be willing to become permanent settlers in Lakhra. These are people with no ties, land, nor close relatives to pull them home. With improved working conditions, it is possible that more Kashmiris, Punjabis and Sindhis will be attracted to underground work in the mines. But the tendency in this culture is for groups to specialize, and cutting coal is considered a specialty of those from the north. It is therefore most probable that Swatis will dominate coal cutting operations for years to come.

The traditional Jori system of management has worked successfully in the past and appears to have many advantages of relevance to the Lakhra Project. Supervisors can deal directly with the Jamadar or Mistri and not with each worker individually. The leader knows his workers and can get the most production from them by relying primarily on peer pressure which works effectively in the Jori system. The disadvantages of this system are that management loses direct control of its workers, and a contractor can hold the management ransom by calling a strike and halting production until his terms are met. Management can prevent this possibility by engaging multiple labor contractors.

The currently recommended, semi-mechanized underground mining operation will add a cadre of technical people to the mine staff. Unless willing Sindhis can be found and trained, it is likely that these people will be Swatis hired on an individual basis and trained by the mining company.

2. Power Plant Specific Issues

A work force of about 700 workers (a total colony population of about 5,000) will be required to keep the power plant operational. To ensure that staff are properly qualified and motivated to do this important work, proper training and an appropriate rewards systems will be required.

a. Labor Management and Training

In studying the Guddu plant, the Social Soundness Assessment Team observed two disturbing personnel issues: (i) that trainers were usually the least qualified personnel because training jobs are regarded as having low status, and (ii) there was no system of positive motivation to increase productivity.

(i) Training Staff

Instructors at the Guddu training facility receive less pay than their colleagues since they do not qualify for the generation allowance* (see Appendix G). Workers do not want to move to the training office, nor do operations managers want to lose their good workers. As a result, the quality of training suffers, potentially jeopardizing the safe and efficient operation of the power plant.

(ii) Reward System

At Guddu, as at many other large Pakistani institutions, a worker does not receive a reward for working well, nor can he assess or monitor his progress on the job by receiving direct criticism or praise for his work. An evaluation does no good if the person being judged does not have immediate feedback. Positive reinforcement could help raise morale. Special caps, coveralls, patches or shirts with an attractive design would give the workers a symbol of pride and prestige. Communications from management on the quality of their work would allow workers to identify with plant objectives. Rewards should be given to individuals or groups that do exceptionally well or have a good accident-free record. Group rewards in this culture are generally more effective than individual praise.

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* A generation allowance is a bonus paid to certain WAPDA employees who work in a power generating facility. The amount varies according to the remoteness of the plant and the negotiating ability and persistence of its Chief Engineer. A generous allowance would be an additional 50 percent of base salary.

b. Colony Conditions

The Social Soundness Team found that many elements of the Guddu colony were worthy of the praise it received from WAPDA officials. But living conditions for pay grades 16 and below were crowded and inadequate (Appendix G). Lower grade employees complained that they did not have access to proper facilities. At all grade levels, informants suggested that their wives needed improved educational programs and community activities.

D. Benefits of Electricity

The main benefits of the project will be the increased generation of electricity power to provide for the agricultural and industrial sectors, and for domestic use. The benefits of electricity are well documented. They have particular significance in Pakistan today, which is beset by frequent and major power shortages during more than six months of the year.

The Social Soundness Team had wanted to quantify the benefits and discuss their impact in some detail, but WAPDA officials and other feasibility contractors explained that the power generated by the project would be released into the national grid, and available throughout the country. It was not possible to say how much electricity would be channeled to a particular region or a particular sector. The overall benefits of the project, therefore, are discussed in more detail in the economic feasibility report.

WAPDA has a policy of arranging for the electrification of villages in the immediate vicinity of any new power station. The villages of Dadu district will receive these benefits if the station is sited in either Khanot or Lakhra. Even if the plant is sited at Jamshoro, some locations previously without access of power will benefit. In all cases, in addition to domestic, commercial, and industrial use, the electricity will be used to power tube well pumps for irrigated agriculture.

E. Benefits to Women

The project will have only indirect benefits for women. A few females may be hired by WAPDA for the power plant. Only six are currently employed at Guddu. The advantages that accrue to women will result from their husband's employment, household electrification and/or colony life (see Appendix F).

If the male spouse becomes newly employed because of the project, his regular paycheck will give his wife greater security. Both he and she will derive greater esteem and status in the family. Her husband, being independent of parental and family control, will not need help from others, even in times of a poor harvest.

If the village is electrified, the wife will benefit from good lighting to do housework, handicrafts or socialize into the night. With

electricity comes television, bringing the awareness of and desire for education, medical facilities and other amenities, and women become more knowledgeable about opportunities and prospects for themselves and their families as a result.

If the women move to a colony, the amenities available to them are markedly improved. They will have a superior dwelling, clean surroundings and pure water. In the villages the Social Soundness Team studied, there was no clean water and in some cases, water came from a source several miles away. One of the biggest assets of a WAPDA colony for women, is the availability of a lady medical practitioner. Pakistani females rarely consult male doctors.

Socially, however, the colony can have debits as well as assets. Minority groups fear going to a colony because other members of their ethnic group will be absent. They fear loneliness and insecurity in the absence of members of their kingroup to support them in time of need. Those of the more dominant communities will enjoy the colony because they can find others to gossip with and share in their joys and sorrows. Overall, the Lakhra project will most likely have a positive impact on women.

## V. RECOMMENDATIONS

This section presents recommendations on ways to enhance the benefits and minimize the social costs of the project.

### A. Planning Phase

1. To further the communications and understanding between the private and pubic sector operations, current efforts to develop coal supply contracts between WAPDA and private sector mine operators should continue.

2. To enlist local support and to minimize social costs, a WAPDA official as well as a representative from the prime contracting firm should have monthly meetings with the local civil servants and village, union, district and provincial representatives. At that time, project officials should enlist local concerns.

3. To avoid the squatter settlement that is likely to form outside the gates of the power plant, the infrastructure for potential shops and businesses should be planned and built under the supervision of local government. This should include streets, water drainage and other required facilities. The possibility of using the power plant contractor for this work should be investigated.

4. The disparity between facilities available for colony residents and the infrastructure supporting the local residents will be great. To alleviate the resentment that is likely to develop toward those inside the colonies, plans should be made by the project managers to provide water, medical facilities and better educational institutions to the people of the surrounding area.

5. The personnel operating the coal mines will comprise both permanent members with their families and transient workers. The power plant workers will be settled families. The structure of the two worker colonies should consider the different types of labor to be housed in each. Bachelor quarters should be separated from family dwellings and residential patterns should consider class and ethnic membership.

6. Plans should be made to deal with the economic recession that will hit the area after the construction phase ends. The emigration of numerous workers, the closing of construction facilities and the elimination of local employment will create considerable problems. A plan should be developed by project managers with the help of local economists and social scientists, and representatives from the local union and district councils to mitigate the bad effects of this inevitability.

B. Construction Phase

1. To obtain and manage laborers most efficiently for the mine construction phase, it is recommended that Jamadars be used to hire Joris and that work be managed through them. However, to prevent a concentration of power in the hands of the labor leaders, more than one Jamadar should be used. Workers should not all be recruited from the same region, such as Alpuri in Swat. Joris of different ethnic groups are to be preferred.

2. Local Sindhis should be hired whenever possible to promote good community relations. The prime contractor should closely monitor labor recruitment and watch for any irregularities. If local leaders are discouraging their people's participation in the project, a direct hire system should be instituted.

3. To help Sindhi workers maintain regular working hours and responsibility on the job, construction firms should: (a) use a labor contractor such as Jamadar, village headman or tribal chief; (b) pay for work received, rather than a regular wage; and (c) house even local workers in a colony, and if that is not possible, transport laborers by company vehicles.

4. To ensure that qualified labor is available for this project, the prime contractor should develop a list of needed professional and technical skills and meet with the regional employment exchange offices in Hyderabad and Dadu as well as with potential sub-contractors. Paper qualifications should be checked against performance.

5. To ensure that professional and skilled workers have the necessary expertise by the operational phase, and to develop good relations with the wider community, project managers might set up training programs at the local polytechnics at Hyderabad and Dadu and at NED (Engineering) University, Karachi and Mehran Engineering University, Hyderabad. This training would continue into the operational phase.



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Courses might include internships at the coal mine and power plant, during later years. Good salaries and equal status with "generation" employees for trainers would attract high quality instruction as would job mobility (i.e. the ability to move to operational and other positions rather than being locked into a "dead end" job as a trainer). Ongoing provisions should be made to keep texts up to date and to have available sufficient spare parts for training equipment.

6. To avoid the poor results of previous mechanization schemes, mining managers should introduce the new technologies in three stages: investigation, trial, and implementation. The investigation phase will last only a week or two, during which a social scientist and a mining technician will visit other operations to determine problems and prospects. The trial stage is undertaken at an existing public or private sector mine, where the desired technology is tested as long as necessary to determine how it will work under Lakhra conditions. After the machinery is modified to suit the local situation, the technology is gradually introduced into the project operations. The implementation program should be undertaken in carefully and cautiously selected stages, depending on how the workers respond.

7. If the power plant is located at Jamshoro or Khanot, the site manager should have biweekly meetings with the Assistant Commissioner, Dadu, as well as village, union and district council representatives to discuss such matters as police patrols and social services as well as other issues of mutual concern.

8. To keep this project from increasing the social instability of the area, project managers, the District Commissioner of Dadu and representatives from the local union and district councils should agree on the number and method by which Sindhis will be employed in this project. A concerted effort should be made to advertize the fact that Sindhis are being employed, and that the Lakhra power plant and coal mine is benefitting the local area.

9. To improve morale, unity, and allow a release of tensions by the work force, it is recommended that the prime contractor provide sports facilities, tea stalls, televisions, a cinema and a mosque for the construction colony.

10. A special effort should be made by mine managers to win the confidence of the Khosa Baluch, whose cooperation could prevent disruption by outsiders. The provision of water for human and animal use, and frequent social/business interactions with tribal traders are recommended.

C. Operation Phase

1. To ensure a smooth operation of the power plant in the initial months after commissioning, as many construction workers as possible should be hired by WAPDA as operational personnel. In this way, operators will be familiar with the plant and construction workers ; 11

have a greater incentive for doing a good job. For positions that cannot be filled by construction workers, operational personnel under the supervision of competent training staff should be on the site one year before plant commissioning to become fully familiar with plant equipment.

2. To ensure good training at the power plant, WAPDA should provide trainers with an allowance that slightly exceeds the generation allowance. The plant supervisor should be made responsible for releasing well qualified and highly motivated workers to the training office. Since the Lakhra project is instituting a new technology (large scale coal-fired power generation) the prime power plant contractor should institute a specialized training program for operational personnel. The program should include generous provision of training aids (texts, films, simulations and programmed instruction).

3. WAPDA already has a policy of hiring local persons for positions at pay grades 16 and below. For the Lakhra project, a special effort should be made to recruit Sindhis for the senior positions also. If successful, this strategy would defuse the belief that the project is an outside imposition.

4. To enhance the overall development of the coal sector in Pakistan, and to ensure maximum private sector participation in the project, mine managers should hold regular meetings with other private miners to discuss pricing, labor conditions and other topics of mutual interest. Public sector groups, such as PMDC and WAPDA, might take part in meetings if invited.

5. To avoid conflict between the construction workers and operational staff, plans for providing adequate housing for both groups of workers should be studied in the planning phase. Residences of construction and operations personnel should be separate and take into account the fact that operational personnel are more likely to be accompanied by their families whose wives will not want to live close to bachelor dwellings for reasons of safety and modesty.

6. If the power plant is sited at either Khanot or Lakhra, the isolated colonies should have amenities similar to those provided at Guddu. Benefits include a 50 percent generation allowance, good housing and colony support facilities (such as separate educational facilities for boys and girls, a medical center with a female staff member, a club for the management staff, recreation areas and a mosque). A subsidized transportation system should be instituted for power plant workers who reside locally as well as those who want to travel to Hyderabad.

7. To keep female morale high in the worker colony, a special community education program for women at all grade levels would be helpful. A female social worker should be hired to identify and develop solutions for community problems, especially those concerning women. A woman doctor at all health facilities is essential.

8. To help alleviate their uncertain future, the Khosa Baluch should have access to education: some boys should be sent to



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boarding school. Ideally, Khosa children would attend school with mine workers, but the Pathan children speak Pashto not Baluchi. Facilities will have to be modified to meet the needs of each ethnic group. These issues should be discussed with the Khosa Chief in Manjhand.

9. Project managers should create an Advisory Council to be composed of the Chief Engineer of the Power Plant, the head of the coal mine operation, a representative from the Government of Sind's office, the head of the Private Miners' Association, the head of the Miners' Union and representatives from the local union and district councils. This group will meet regularly to provide guidance to management on topics such as hiring policies, plant/community relations, and infrastructure needs. An important topic for the Advisory Council will be to ensure that the local community benefits from the project. The structure of the new body should be modeled after the Area Development Authority now in existence.

10. Mine managers should institute flexible work schedules for Swati workers, such as allowing for four months of work followed by two months off. Swatis will work in the summer for extra fees (See Appendix J), but will require regular leave, for social, economic and health reasons. If this is not officially granted, it will be unofficially taken. By not allowing for regular vacations, managers may lose reliable and experienced workers.

11. The people affected by the Lakhra project are of varied ethnic backgrounds whose response to the project will take many varied forms. A full-time social scientist should be employed to monitor such topics as community attitudes towards the project and problems in colony life and report to coal mine and power plant leaders. The individual picked to do this work should have a proven capability to relate to and understand rural people as well as communicate with public sector officials and private sector managers.

D. Conclusion

With the implementation of the Lakhra project, Pakistan has a unique opportunity to enhance the economy and lives of her population. The Social Soundness Assessment team finds the project is based on existing feasible technologies in the case of the mining element and on proven technologies in the case of the power plant. Within the socio-cultural context, the project will be socially sound if sensitivity to local people and issues is maintained. The above recommendations should be seriously considered to minimize the social costs that can result from a project of this magnitude.



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