Ash Management Plan

PAK: Jamshoro Power Generation Project

Project Number: 47094-001
ADB Loan/Grant Number: L3090/3091/3092-PAK
Prepared: September 2017

Prepared by the Jamshoro Power Company Limited (JPCL), with the assistance of Mott MacDonald Limited (United Kingdom) in joint venture with MM Pakistan (Pvt) Ltd (Pakistan), for the Islamic Republic of Pakistan and the Asian Development Bank (ADB).

This Ash Management Plan is a document of the borrower. The views expressed herein do not necessarily represent those of ADB's Board of Directors, Management, or staff, and may be preliminary in nature.

In preparing any country program or strategy, financing any project, or by making any designation of or reference to a particular territory or geographic area in this document, the Asian Development Bank does not intend to make any judgments as to the legal or other status of any territory or area.
2X660MW Jamshoro Power Generation Project (JPGP)

Ash Management Plan

5 September 2017
2X660MW Jamshoro Power Generation Project (JPGP)

Ash Management Plan

5 September 2017
Issue and Revision Record

<table>
<thead>
<tr>
<th>Rev</th>
<th>Date</th>
<th>Originator</th>
<th>Checker</th>
<th>Approver</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>2017.09.04</td>
<td>HKP</td>
<td>AD</td>
<td>JMV / GC</td>
<td>Original issue for review</td>
</tr>
</tbody>
</table>

Information class: Secure

This document is issued for the party which commissioned it and for specific purposes connected with the above-captioned project only. It should not be relied upon by any other party or used for any other purpose.

We accept no responsibility for the consequences of this document being relied upon by any other party, or being used for any other purpose, or containing any error or omission which is due to an error or omission in data supplied to us by other parties.

This document contains confidential information and proprietary intellectual property. It should not be shown to other parties without consent from us and from the party which commissioned it.
Contents

Executive summary 1

1 Ash & Gypsum Production and Handling 2
   1.1 Basis of Production 2
   1.2 Ash & Gypsum Production from the Project 2
   1.3 Description of Proposed Ash and Gypsum Handling Systems 2
      1.3.1 Bottom / Coarse Ash Handling System 2
      1.3.2 Fly Ash Handling System 3
      1.3.3 Lean Slurry System 3
      1.3.4 Gypsum System 3
   1.4 Ash Disposal 8
      1.4.1 Dry Ash Disposal 8
      1.4.2 Wet Ash Disposal 8
   1.5 Gypsum Disposal 9
      1.5.1 Dewatered Gypsum Disposal 9
      1.5.2 Wet Gypsum Disposal 9

2 Ash Pond 10
   2.1 Design Philosophy 10
   2.2 Feasibility of Proposed Ash Pond Location 10
   2.3 Concept Note on Proposed Ash Pond 12
      2.3.1 Lagoon Separation and Capacity of Ash Pond 12
      2.3.2 Ash Pond Recovery System 13
   2.4 Expansion of Ash Pond Storage 13
   2.5 Management of Ash Pond 14
   2.6 Conclusions 15

3 Dry Ash Utilization Options 16
   3.1 Property Values of Fly Ash 16
   3.2 Possible Utilization of Fly Ash 18
   3.3 Potential Market of Fly Ash in Pakistan 18
      3.3.1 Portland Cement/Clinker Manufacturer 18
      3.3.2 Ready Mix Concrete Manufacturer 19
      3.3.3 Market Development 20

4 Conclusions 21

Appendices 22
A. Next Steps
Executive summary

The Ash Management Plan for the Jamshoro Power Generation Project (JPGP) which follows, aligns with the salient portions of; (1) Jamshoro Power Station – 2x600 MW (net) Supercritical Coal/Lignite Fired Units Feasibility Study Report / September 14, 2013 USPC U.S. Power Consult LLC, and, (2) provisions of the Environmental Impact Assessment dated 2013.10.29.

Although the Feasibility Study Report and the EIA are not design documents and should not be taken as such, coalition of critical sections has been maintained.

- Detailed design shall be provided by the selected EPC Contractor upon the award of contract.
- Detailed design shall conform to the provisions of the EPC tender documents.
- The EIA should be updated to reflect the detailed design as prescribed by the EPC Contractor.
- Detailed design should employ current “best practice”.

In this fashion, alignment is maintained between detailed design and the EIA.

The environmental characteristics which have been considered during the generation of the JPGP bid documents include both air pollution due to dust emissions/fugitive dust, and, surface/ground water contamination.

To minimize the environmental impact of ash disposal, it is essential to manage and maintain “eco-friendly” facets of ash pond construction, operations, and, maintenance.

Various ash recycling options for the Project can also mitigate the impact of ash disposal.

As the ash pond is filled, discarded portions of the pond must continue to be managed to minimize the risk of air pollution due to fugitive dust emissions. Throughout the total life cycle, the ash pond needs constant monitoring, inspection and maintenance.

The ash management plan presents the operational characteristics of the Plant and ash pond during the total life cycle embracing; (1) ash pond sizing, (2) ash pond land requirements, (3) potential fly ash reutilization techniques, (4) planning for a safe and “eco-friendly” ash pond, and, (5) management of eventual ash disposal for the project.

Finally, the ash management plan observes the association between ash and gypsum management. Nevertheless, the Ash Management Plan has not been commissioned as a gypsum management plan and does not constitute a gypsum management plan.
1 Ash & Gypsum Production and Handling

1.1 Basis of Production

The amount of ash generation from the Project is quantified based on full load with an 85% plant load factor, while burning blended coal of a ratio; 80% sub-bituminous and 20% lignite. The ash generation quantities considered in the plan are based upon the following considerations:

- Goss Power Output for each Unit: 660 MW
- Average Unit Gross Heat Rate: 8405 KJ/kWh
- Plant Load Factor: 85%
- Type of coal: Blended coal
- Gross Calorific Value (GCV) of coal: 17949 KJ/Kg
- Ash Content by weight: 6.74%
- Fly Ash: 80% of total ash
- Bottom Ash: 20% of total ash
- Ash density of deposited ash in ash pond: 1.2 tonne/m³
- Number of Units: 2

1.2 Ash & Gypsum Production from the Project

Based upon considerations as stated in 1.1 above, the total ash generation is presented in table 1 below at various plant operating conditions:

<table>
<thead>
<tr>
<th>Plant Operation</th>
<th>Annual Fly Ash Production (tonnes)</th>
<th>Annual Bottom Ash Production (tonnes)</th>
<th>Annual Gypsum Production (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Units at 85% plant load factor (PLF)</td>
<td>248,167</td>
<td>62,042</td>
<td>71,482 ↔ 86,374</td>
</tr>
</tbody>
</table>

Source: Mott MacDonald Compilation

1Range Values provided. (Extreme variations in Thar Lignite properties)

1.3 Description of Proposed Ash and Gypsum Handling Systems

The Ash Handling System for the Project, consists of specially designed Bottom Ash and Fly Ash Handling Systems. The functional requirements of the bottom and fly ash handling systems as envisaged in the EPC Bidding document is provided below. The EPC Contractor’s design shall be established upon the requirements specified in the Bidding document.

1.3.1 Bottom / Coarse Ash Handling System

The function of the bottom ash handling system is to collect, convey and store bottom ash from outlet of boiler furnace and economizer hoppers to the Bottom Ash silos. The silos shall be designed for storing a quantity of 3-days of ash as generated through the operation of both Units. The ash from bottom ash silo shall be either transported by truck (i.e. dry form) or mixed with water (i.e. wet form) and conveyed to the ash slurry sump and forwarded to the ash pond.

An air cooled mechanical conveyor will be adopted to transport bottom ash. Bottom ash will fall into primary Air-Cooled Steel-Belt Slag Conveyor (ASSC), through the bottom ash hopper, and
hydraulic pressure gate, and crushed (through utilization of a pre-crusher and primary clinker grinder) prior to transport to the bottom ash silo.

There will be one bottom ash handling system per boiler. The bottom ash collected every eight (8) hours shall be conveyed within a four (4) hour timeframe to the bottom ash silo.

The coarse ash collected in the economizer hoppers will be evacuated continuously through utilization of a metallic conveyor. The ash generated in 4-hours of operation will be removed in 2-hours of transport time. From the metallic conveyor, ash will be further transferred to the secondary bottom ash conveyor before being transported to the bottom ash silo.

1.3.2 Fly Ash Handling System

The function of the fly ash handling system is to collect, store and transport fly ash from the outlet of the Elector Static Precipitator (ESP) and duct hoppers to the fly ash silos. The ash from the fly ash silos will be discharged in dry form (by the dry ash unloading system) to trucks. An alternate discharge system (i.e. wet) is also available from the ash conditioners. A third alternative exists in the form of discharge as slurry to ash pond.

The Fly Ash handling system will adopt a positive pressure pneumatic conveying system. One (1) pneumatic conveying system will be provided for conveying the Elector Static Precipitator (ESP) ash of one boiler. The fly ash collected every eight (8) hours shall be conveyed within a 4-hour timeframe to the Fly Ash Silo. Silos shall be designed for storage of all fly ash generated through operation of the Unit over a 3-day timeframe.

1.3.3 Lean Slurry System

The function of the lean slurry disposal system is to (1) convert dry bottom ash and fly ash, held in the ash silos into slurry, and (2) transport the slurry to ash pond. Pipe will be used to support transport.

The fly ash and bottom ash from silos shall be transported to the ash dyke through the lean slurry system. The bottom ash and fly ash generated by the Units shall be stored in ash silos. From the silos, the ash shall be evacuated by application of a wetting system and jet pump system. The system operates continuously during each unloading operation. The ash to water ratio shall be maintained at 1:3 - 1:4.

1.3.4 Gypsum System

The overall FGD and gypsum generation system is depicted in Figure 1. This Figure shows a typical simplified flow schematic found in a wet limestone forced oxidation (LSFO) process. (This is the process envisioned for JPGP.) The slurry that is removed from the scrubber will contain solids in the range of approximately 15%wt.
To operate the FGD process continuously the solid product, mainly gypsum but also other materials in the flue gas, needs to be removed from the process. Gypsum is preferably removed during the gypsum dewatering stage (discussed later). The overflow from the gypsum dewatering stage enters the wastewater treatment stage with approximately 2%wt. solids.

The other compounds are handled in the water treatment plant in various chemical and physical stages before clean water can be discharged. Chemicals as well as polymers are added to alter the pH value, adjust the COD (chemical oxygen demand), precipitate and enhance settling of particles in a clarifier. The overflow of a clarifier may be polished in a sand filter, while the thickened sludge is dewatered by a recessed filter press where a solid cake is produced. The discharged water is usually required to contain less than 0.2%wt. solids.

1.3.4.1 Gypsum Dewatering Process Stage

High quality limestone that is finely ground (typically 90% is smaller than 45µm), excellent flue gas particle removal upstream of the scrubber and a low calcium sulphite content are prerequisites for producing high quality gypsum. To qualify as a valuable gypsum product not only is the water content relevant (certainly below 10%wt. but often as low as 6-8%wt.), but the composition, crystal size and shape, and the whiteness are also important. The handling properties are also relevant. Gypsum with a water content that is too high tends to build bridges in silos and cannot be discharged smoothly. To meet the stringent requirements regarding the trace compound concentrations, a thorough washing step is required to remove mainly chlorides (less than 100 ppm), as well as heavy metals (for example lead) and other soluble salts such as magnesium and sodium. The calcium sulphite content needs to be lower than 5%mol, based on total calcium sulphate and sulphite.

Ideal gypsum particles – CaSO4·2 H2O crystals are round and larger (mean particle diameter in the range of 40-90 µm) – settle much faster than other constituents. Depending on upstream process conditions they may also form plate-like and needle shapes with much higher remaining moisture limits at 14-18% and above 18%, respectively.
Figure 2: Gypsum Dewatering

Figure 2 displays three different simplified flow sheets for the gypsum dewatering stage. Hydrocyclones and thickeners are employed for pre-thickening to give a feed of 35-70%wt. solids, although often their task is more of a classification, i.e., preferential removal of large gypsum particles. Pre-thickening might be necessary for optimal operation of subsequent filters or centrifuges. Centrifuges and filters can also cope with a more dilute feed which might render a pre-thickening unit useless. Decanters are generally not used for classification in this application, basket centrifuges can separate the easily settling fraction (gypsum) and the lighter fraction during the (over-) filling stage.

Hydrocyclones are preferred over gravity thickeners due to their smaller footprint and a more flexible way of adjusting a more distinct cut-size. But thickeners might have the advantage that a very clear effluent can be obtained by adding flocculating agents. This has advantages for the subsequent wastewater cleaning stage, but prohibits the production of a high-grade gypsum product.

1.3.4.2 Dewatering Equipment for Gypsum

Since gypsum has a high density and appreciable particle size both filtration and sedimentation are suitable for solid-liquid separation, allowing a large variety of machine types to be used. Currently, horizontal vacuum belt filters are mainly used for bulk applications and vertical filtering basket centrifuges for high end applications. However, historically decanters or drum filters have also been used or continue to be used under exceptional circumstances, for example, when a high product water content or low washing efficiency are acceptable.

Horizontal vacuum belt filters (which have been specified for the JPGP) have a large footprint and comparable dryness but the washing efficiency is generally at least as good but usually better when compared with drum filters. However, the dryness that can be accomplished practically is limited and is determined by the residence time, cake thickness and differential pressure, which is in the range of up to 0.7 bar. The trend in the development of horizontal vacuum belt filters is towards larger unit sizes, i.e., 120 m² all the way up to 200 m² and more.

Gypsum dewatering requires the handling of abrasive and corrosive slurries. The chloride content represents a serious potential chemical attack to the machine. The use of more abrasion resistant materials at critical locations reduces wear and tear, and the identification of critical parts requiring sturdy design can help. Clearly, fewer and shorter periods of downtime increase the overall machine availability and therefore the throughput.
1.3.4.3 Gypsum Dewatering Conclusions

The process stage of gypsum dewatering is a well-established part of the wet limestone-based flue gas desulphurisation process. In the upstream area, which comprises fly ash removal, limestone grinding and scrubber, it is important to understand the limits of the gypsum dewatering stage and the best gypsum product properties that can be obtained. Nevertheless, a carefully established cut size in the hydrocyclones can significantly improve the final product at perhaps the expense of a larger waste and recycle stream. In addition, a more generously designed machine size or more machines allow for longer residence times at various stages in separation, washing, drying and cleaning, for example. Therefore, better overall performance can be achieved in terms of the gypsum product and filtrate quality.

1.3.4.4 Gypsum “Wallboard Quality” Requirements

The process parameters have been carefully specified by Mott MacDonald to provide for maximum reutilization for gypsum. The dewatered spent gypsum shall comply with the following requirements:

Table 2: Applicable “Wallboard” Gypsum Specifications

<table>
<thead>
<tr>
<th>Process Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaSO₄·2H₂O</td>
<td>&gt;96%</td>
</tr>
<tr>
<td>CaSO₃·½H₂O</td>
<td>&lt;0.5-1.0%</td>
</tr>
<tr>
<td>Degree of Whiteness (Raw, Dry)</td>
<td>≥ 70% (10% &lt; CaCO₃ white)</td>
</tr>
<tr>
<td></td>
<td>Degree of whiteness is measured by the calcified, rehydrated Gypsum blocks</td>
</tr>
<tr>
<td>Chlorides Cl</td>
<td>&lt; 100 ppm</td>
</tr>
<tr>
<td>Sulphite SO₂</td>
<td>≤ 0.1 %</td>
</tr>
<tr>
<td>Fluoride F water soluble (in the eluate)</td>
<td>≤ 15 mg/l</td>
</tr>
<tr>
<td>Fluoride F water soluble (in solid matter)</td>
<td>≤ 150 ppm</td>
</tr>
<tr>
<td>Potassium Oxide K₂O water soluble, sodium -oxide Na₂O water soluble, magnesium oxide MgO water soluble</td>
<td>Total ≤ 0.03 %</td>
</tr>
<tr>
<td>Iron Oxide Fe₂O₃</td>
<td>≤ 0.1 %</td>
</tr>
<tr>
<td>Organic Carbon C</td>
<td>≤ 0.01 %</td>
</tr>
<tr>
<td>Crystalline form</td>
<td>Granular</td>
</tr>
<tr>
<td>Fine matter D₀,₀₃₂</td>
<td>20 – 40 %</td>
</tr>
<tr>
<td>Odour</td>
<td>Neutral</td>
</tr>
<tr>
<td>Cadmium Cd</td>
<td>≤ 0.03 ppm</td>
</tr>
<tr>
<td>Lead Pb</td>
<td>≤ 20 ppm</td>
</tr>
<tr>
<td>Mercury Hg</td>
<td>≤ 0.7 ppm</td>
</tr>
<tr>
<td>Manganese Mn water soluble</td>
<td>≤ 1 ppm</td>
</tr>
<tr>
<td>Toxicity</td>
<td>Nontoxic</td>
</tr>
<tr>
<td>Free Moisture</td>
<td>&lt; 10%</td>
</tr>
<tr>
<td>pH</td>
<td>7-8</td>
</tr>
<tr>
<td>MMD</td>
<td>30-40 µ</td>
</tr>
<tr>
<td>Requires Cake Washing?</td>
<td>Yes</td>
</tr>
<tr>
<td>Limestone unloading system from trucks and covered Storage for 40 days at site Provided by the Contractor?</td>
<td>Yes</td>
</tr>
<tr>
<td>Limestone Silo Provided by the Contractor as a “Buffer”</td>
<td>Yes</td>
</tr>
<tr>
<td>Capacity of Limestone Silo</td>
<td>24hrs, at MCR</td>
</tr>
<tr>
<td>Construction Materials of Limestone Silo</td>
<td>Carbon Steel Construction with Polymer or SS Hopper Lining</td>
</tr>
</tbody>
</table>
1.3.4.5 Gypsum Storage

A gypsum “dome” (Figure 3) has been specified for gypsum reutilization storage purposes. In this type of structure, the shape of the storage containment will be a semi-hemispherical form. There will be a concrete wall up to a certain height from the ground level and the structure will be erected above this wall. The dome structure is specified to accommodate 40-days of gypsum generation. As dewatered gypsum is agglomerated and not prone to dusting issues, a simple mobile front-end loader is used for reclaiming the gypsum after “stack out”. The front-end loader is also capable of breaking up larger chunks of gypsum which have remained in storage for extended periods of time.

Figure 3: Gypsum “Dome”

Source: JMV Personal Files

Utilization of silos with internal mechanical unloaders is not encouraged for storage purposes. Such silos function well as a “surge bin” so long as the gypsum is kept moving and not allowed to compact. With silos, storage for more than 48-hours can cause agglomerated gypsum to wedge within the operating mechanism and lock the mechanical drive mechanism. Freeing the
drive must be done manually, within a confined space. Clearly, this form of storage is not optimal in nature.

With application of a “dome”, gypsum will be protected from wind and rain and hence the problems associated with airstreams and moisture will be avoided. In addition, a “dome” can accommodate a higher quantity of gypsum in a smaller area as the height of storage can be increased.

1.4 Ash Disposal

1.4.1 Dry Ash Disposal

The ash from the silos will be conditioned before transportation by trucks, and ash in dry form will also be unloaded in closed dumpers through telescopic chutes. Both dry fly ash and dry bottom ash will be exported for commercial use from the Ash Silo. Fly Ash transportation from the ash silo from the two Units shall be planned @ 28tonne/hr for smooth operation of the Plant. Bottom Ash Transportation from silo from two Units shall be planned @ 8 tonne/hr for smooth operation when lean slurry system is not in operation. Dry ash utilization options are described in subsequent sections.

1.4.2 Wet Ash Disposal

The ash slurry disposal pumps dispose the ash slurry collected in the ash slurry sumps to ash dyke. Ash will settle down in the ash pond and the overflow shall be decanted through various compartments. Two (2) streams of ash disposal lines shall be provided. Slurry transportation system shall be designed based on the worst combination of ash handled by the system including bottom ash and wet fly ash disposal. The minimum capacity of ash disposal pumps shall not be less than 10% over and above the ash slurry flow corresponding to 100% Boiler Maximum Continuous Rating (BMCR) ash generation. Ash disposal pumps shall be horizontal, centrifugal, single stage, non-clog type, low speed. The disposal pumps shall have external forced water gland sealing arrangement. Seal water shall be clarified water.

Figure 4: Wet Ash Disposal System

Source: Mott MacDonald File Reference
1.5 Gypsum Disposal

1.5.1 Dewatered Gypsum Disposal

As previously stated, dewatered gypsum agglomerates. Industry accepted practice is to utilize covered lorries for transport purposes. In the event that the waste gypsum is reused in a wallboard filler, or other application covered lorries are advocated for use at Jamshoro. It is also recommended that a target value of 10 tonnes/Hr is used for the projected rate of dewatered gypsum production and mobile transport arranged accordingly.

1.5.2 Wet Gypsum Disposal

In the event that there is no reuse, the wet gypsum is diverted to the ash slurry sump for ultimate disposal as described in Article 1.4.2. However, the reader is cautioned that there are issues associated with diversion of gypsum to the ash pond.

Please note that to make a useful construction material out of fly ash, agents such as lime or cement are added to stabilize it. The enhanced fly ash is then commonly referred to as “flowable fill”. Fly ash contains the concentrated heavy metals from coal which can contaminate groundwater. Lime or cement “locks” the contaminants in place and make the use of “flowable fill” environmentally acceptable.

The reader should also note that there are implications in reutilizing fly ash when mixed with gypsum. Fly ash mixtures when blended with lime can be very effective as concrete additives. If, however, there is a source of sulphur (i.e., in the case of the scrubber residue like JPGP), a detrimental reaction occurs in the presence of moisture; a substance called ettringite develops.

The ettringite crystals in the pore spaces of the fill, create a jacking force that is quite “impressive” (i.e. 150mm to 230mm in some slabs). Coal combustion by-products for reuse such as the combined gypsum / fly ash stream must not contain appreciable quantities of sulphur. The total concentration of sulphur must be ≤ 0.5 percent of the total dry mass. Elevated concentrations are anticipated which places the mixed stream of fly ash and gypsum at risk of being unacceptable. A secondary “hurdle” for reuse of the JPGP mixed stream is a swell test run for a duration of 30-days. The swell test is run if there is any sulphur in the overall product and it is doubtful that the combined stream from JPGP would pass.

As a result, there is an elevated risk to disposal of gypsum (i.e. wet fashion) by transport to the ash pond. The result may well be that the combined process stream will be rendered unsuitable for reclamation and reuse by the construction industry.

In conclusion, disposal of wet gypsum cominglel with fly ash in the ash pond, is not recommended.
2 Ash Pond

2.1 Design Philosophy

The ash pond will be developed in two compartments with dykes all round constructed with earth. The ash bund shall be designed to be suitable under all conditions to which they may be subjected to, including self-weight, vertical loads, lateral loads, water pressure, seepage and draw down, seismic effects etc. for the ultimate stage of raising of the bund. The bunds shall be of homogenous earthen construction. The design of bund shall ensure that the phreatic (seepage) line shall not meet downstream face of the embankment. To ensure this, adequate internal drainage arrangement shall be provided. The embankment shall be safe against failure due to “piping”. The design shall ensure that the exit gradient is less than 1.0 m.

2.2 Feasibility of Proposed Ash Pond Location

For construction of an ash-pond to safely deposit coal-ash coming out of the Project, a piece of private land, measuring 100 acres (40.5 ha), situated next to the northern end of project site has been selected and is being processed for purchase against a negotiated price. The following factors were considered in selection of the location for the ash pond.

- The site should be close to the power plant for techno-economic feasibility. Piping of the ash slurry to more than 2 km is not recommended.
- The economic value of the land should be low in terms of both the current and potential uses.
- The location should not be subject to flooding.

The various alternatives were considered for ash disposal as depicted in Figure 5.

Location B is considered most suitable for the proposed ash pond. Location B situated northwest of the plant is at less than a kilometre from the plant, avoiding the low-lying area adjacent to the plant which is prone to flooding, and where agriculture lands exist. This location is about 2 km from the Indus Highway, and the land is barren as water is not available for agriculture. The land is evenly graded without much undulation. This location is preferred site for construction of ash pond.

The location B is incorporated in Plant layout and is a part of Plant EPC Bidding Documents. Proposed Ash-pond snap shot from Plant layout MM334014-Z-DR-00-00-0010 Rev01 is depicted in Figure 5 below.
Figure 5: Alternative Locations for the Ash-pond Site

Source: EIA
However, there are few challenges to deal with the proposed site of ash pond. There are six existing Transmission Towers in the proposed land. These Towers need to be relocated outside the proposed site.

The geotechnical investigation of proposed land needs to be carried out before deciding the excavation and increasing the depth of present ground level. The Geotechnical investigation at the proposed Project Plant site, which is near to proposed ash pond, revealed that the site is composed of sedimentary deposits. The strata mainly consist of alternative soft and hard layer of limestone. It is quite probable that going below natural ground level and increasing the depth of ash pond may not be viable in case hard rock is encountered.

2.3 Concept Note on Proposed Ash Pond

It is proposed to employ an ash pond associated with wet ash disposal (Reference: Section 6 of the Bid Documents, 309030913092 PAK). The EPC contractor is responsible for design in accordance with this Reference. Ash pond shall be developed with the following boundary conditions; (a.) natural ground level as invert level of ash pond, (b.) height of embankment - 6 meters, (c.) free board of 1 m (d.) top width of embankment - minimum 6 meters, (e.) WBM road, 3.75 m wide, 100mm and 150mm of base and sub base respectively.

2.3.1 Lagoon Separation and Capacity of Ash Pond

The ash pond will be developed in two compartments with a separator dyke. All starter dykes shall be constructed with homogeneous soil. Top level of bund shall be maintained at a uniform level.
Average Finished Bed level shall be maintained as even as possible. Impervious layer at the bottom shall be provided with low permeability soil blanket, HDPE sheeting 750 micron thick wherever required to prevent leaching of heavy metal.

As per the arrangement, total volume of ash pond within the starter dyke height of 6 meter with 1-meter freeboard is calculated as 1,414,000m³. Details are furnished in Figure 7.

**Figure 7: Proposed Ash-Pond Volume**

2.3.2 Ash Pond Recovery System

Water recovered from ash pond at an 80% rate will be collected into recovery water sump near Ash Pond and will be pumped back to the clarifier (located in the plant) with the help of centrifugal pumps. Necessary Chemical dosing at the inlet of clarifier will be provided to enable settling down of the particles. Clear water will flow by gravity into clear water sump.

If the gypsum and gypsum waste streams are added to the ash pond, chloride contents of the recovered water stream shall be closely monitored in respect to chloride levels. (Elevated chloride concentrations can be difficult to deal with and may cause excessive corrosion problems. Simple clarifiers which are designed for JPGP Total Suspended Solids (TSS) control, are not effective for Total Dissolved Solids (TDS) control.)

2.4 Expansion of Ash Pond Storage

The initial ash dyke height is envisaged 6 metres. To increase the capacity of ash pond, the ash dyke height shall be raised by 3 metres. The raising of ash dyke height shall be done on the
upstream side of the ash pond with the ash settled and dried. This is an effective, economic and widespread practice.

Negatives associated with raising the dyke height include;

- Dust control during the lifting of the dyke
  - Construction leads to the fly ash drying out
  - Fly ash is then easily entrained into the air by the wind
- Great care is required when working around dried fly ash.
  - When dried, fly ash looks and feels solid.
  - However, it is thixotropic - when vibrated it again acts like a liquid - vibrating objects, like bulldozers, can “sink out of sight” rather rapidly.

Operational requirements such as haul and access roads, culverts, diversion, and perimeter ditches may be constructed easily to serve the entire useful life of facility. This is the most preferred method of construction as the quantity of earthwork required is minimal. The first stage upstream construction is depicted below in Figure 8.

**Figure 8: Staged Expansion of Ash Pond**

![Figure 8: Staged Expansion of Ash Pond](Source: Mott MacDonald Files)

With this arrangement, 639,000m³ of additional volume may be added in ash pond

Further stage of expansion will drastically reduce the additional volume, due to the limited ash pond area and may not be advisable for the Project.

### 2.5 Management of Ash Pond

Management of safe ash disposal through wet disposal involves the ash lagoon arrangement within the allotted land, method of disposal, continuous inspection, monitoring and maintenance, commitment for safe disposal. To minimize the risk of failure, preventive measures are accorded top priority. Instrumentation of ash pond is necessary and shall form an integral part of monitoring mechanism.

Multi point discharge of ash slurry into the ash pond will be adopted to achieve

- uniform ash filling within the lagoon
- completely utilizing the available storage capacity
- maintain water cover throughout to avoid island formation and eliminate dust pollution.

To avoid the contamination of nearby fields, toe drain is provided all around the periphery of outer dyke which will collect the seepage water from storage lagoon. This water is pumped back for recirculation in ash recovery pump house. Water escape structure for decantation, method of discharge and recirculation of decanted water will be provided as per requirement.
Local management instruction shall be prepared by the generating station for operation and maintenance of ash disposal. The instructions cover the function and procedures to follow to ensure safety of the dyke. Periodic inspection by cross functional team will enable the plant management staff to monitor and plan safe disposal. Awareness of the safety of dyke shall be part of monitoring system. It is experienced that preventive measures and timely repair of dykes prevents avoidable damage to dyke and environment.

2.6 Conclusions

The following conclusions are drawn from the preceding ash management plan materials:

- Ash pond with starter bund height of 6 meters, has a total volume of 1,414,000m$^3$. The volume is sufficient to handle ash generated in 5.5 years of plant operation, when the Units are operating at 85% plant load factor and total ash is disposed through lean slurry system. In case single Unit is in operation, the ash pond has sufficient capacity to handle the total ash generated in 11 years.
  - If the ash pond is simultaneously utilized for gypsum disposal, the volume is sufficient to handle ash & gypsum generated for approximately 3.9 years of plant operation.
  - In the case of single Unit operation, and the ash pond is simultaneously utilized for gypsum disposal, the volume is sufficient to handle ash & gypsum generated for approximately 7.9 years of plant operation.

- Ash pond with starter bund height of 6 meters and first stage expansion of 3 meters height, has a total capacity of 2,053,000m$^3$. The capacity is sufficient to store ash generated in 8 years of plant operation, when the Units are operating at 85% plant load factor and total ash is disposed through lean slurry system.
  - If the ash pond is simultaneously utilized for gypsum disposal, the volume is sufficient to handle ash & gypsum generated for approximately 5.8 years of plant operation.

- Second stage expansion of ash dyke is not advisable due to the small gain in additional volume. It is therefore, advisable that dry ash is exported for commercial use from the Ash Silo during first five years, in a progressive manner. Dry ash disposal options are discussed in subsequent section.
3 Dry Ash Utilization Options

3.1 Property Values of Fly Ash

Expected range of characteristics of fly ash for the project is tabulated in Figure 9. It is expected that the Project will mostly use blended coal (80 % imported and 20 % local). Figure 9 demonstrates the fly ash specification which may be available for commercial use (depending upon a “yet to be finalized” Coal Supply Agreement).
### Ash Characteristics

#### Sl. No. Analysis Type & Property Unit Basis

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Analysis Type &amp; Property</th>
<th>Unit</th>
<th>Basis</th>
<th>Imported Sub-Bituminous Coal</th>
<th>Domestic Thar Lignite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Properties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Silica (SiO2)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>50.00</td>
<td>15.3</td>
</tr>
<tr>
<td>1.2</td>
<td>Alumina (Al2O3)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>19.80</td>
<td>8.2</td>
</tr>
<tr>
<td>1.3</td>
<td>Iron Oxide (Fe2O3)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>11.00</td>
<td>4.5</td>
</tr>
<tr>
<td>1.4</td>
<td>Lime (CaO)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>5.00</td>
<td>6.7</td>
</tr>
<tr>
<td>1.5</td>
<td>Magnesia (MgO)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>3.00</td>
<td>3.8</td>
</tr>
<tr>
<td>1.6</td>
<td>Alkalies (Na2O+ K2O)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>2.50</td>
<td>2.1</td>
</tr>
<tr>
<td>1.7</td>
<td>Titanium di Oxide (TiO2)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>1.00</td>
<td>1.0</td>
</tr>
<tr>
<td>1.8</td>
<td>Manganese Oxide (Mn3O4)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>0.20</td>
<td>N/A</td>
</tr>
<tr>
<td>1.9</td>
<td>Sulphuric Anhydride (SO3)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>6.90</td>
<td>N/A</td>
</tr>
<tr>
<td>1.10</td>
<td>Phosphoric Anhydride (P2O5)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>0.35</td>
<td>N/A</td>
</tr>
<tr>
<td>1.11</td>
<td>Barium Oxide (BaO)</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>Trace</td>
<td>N/A</td>
</tr>
<tr>
<td>1.12</td>
<td>Undetermined</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>0.25</td>
<td>N/A</td>
</tr>
<tr>
<td>1.13</td>
<td>Total</td>
<td>% by weight</td>
<td>Dry Basis (DB)</td>
<td>100.00</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ash Temperatures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Initial Deformation Temperature (IDT) °C</td>
<td>Reducing Atm.</td>
<td></td>
<td>1,150</td>
<td>1,075</td>
</tr>
<tr>
<td>2.2</td>
<td>Hemispherical Temperature (HT) °C</td>
<td>Reducing Atm.</td>
<td></td>
<td>1,230</td>
<td>1,100</td>
</tr>
<tr>
<td>2.3</td>
<td>Fluidic Temperature (FT)    °C</td>
<td>Reducing Atm.</td>
<td></td>
<td>1,300</td>
<td>1,110</td>
</tr>
<tr>
<td>2.4</td>
<td>Initial Deformation Temperature (IDT) °C</td>
<td>Oxidizing Atm.</td>
<td></td>
<td>1,200</td>
<td>N/A</td>
</tr>
<tr>
<td>2.5</td>
<td>Hemispherical Temperature (HT) °C</td>
<td>Oxidizing Atm.</td>
<td></td>
<td>1,280</td>
<td>N/A</td>
</tr>
<tr>
<td>2.6</td>
<td>Fluidic Temperature (FT)    °C</td>
<td>Oxidizing Atm.</td>
<td></td>
<td>1,350</td>
<td>N/A</td>
</tr>
</tbody>
</table>

---

Figure 9: Ash Characteristics
3.2 Possible Utilization of Fly Ash

The possible applications where Fly ash may be used are:

- Concrete production, as a substitute material for Portland cement and sand
- Embankments and other structural fills (usually for road construction)
- Grout and Flowable fill production
- Waste stabilization and solidification
- Cement clinkers production - (as a substitute material for clay)
- Mine reclamation
- Stabilization of soft soils
- Road sub base construction
- As Aggregate substitute material (e.g. for brick production)
- Mineral filler in asphaltic concrete
- Agricultural uses: soil amendment, fertilizer, cattle feeders, soil stabilization in stock feed yards, and agricultural stakes
- Loose application on rivers to melt ice.
- Ash brick manufacturing at location of Thermal Power Plant itself. Usually, top soil is used for brick manufacture. Top soil is suitable for Irrigation. Use of Fly ash brick stops the depletion of top soil.
- Other applications include cosmetics, toothpaste, kitchen counter tops, floor and ceiling tiles, bowling balls, flotation devices, stucco, utensils, tool handles, picture frames, auto bodies and boat hulls, cellular concrete, geo polymers, roofing tiles, roofing granules, decking, fireplace mantles, cinder block, PVC pipe, Structural Insulated Panels, house siding and trim, running tracks, blasting grit, recycled plastic lumber, utility poles and cross arms, railway sleepers, highway sound barriers, marine pilings, doors, window frames, scaffolding, sign posts, crypts, columns, railroad ties, vinyl flooring, paving stones, shower stalls, garage doors, park benches, landscape timbers, planters, pallet blocks, moulding, mail boxes, artificial reef, etc.

Note: Please refer to Article 1.5.2 regarding implications of mixing fly ash and gypsum streams in the ash pond and attempting to reclaim and utilize the materials for construction purposes.

3.3 Potential Market of Fly Ash in Pakistan

The potential end uses of fly ash in Pakistan are cement/clinker and ready mix concrete manufacturers. The expected requirement and potential market of stated end users which are in operation in 100-150 KM in radius are described below:

3.3.1 Portland Cement/Clinker Manufacturer

Pakistan Standards and Quality Control Authority (PSQCA), on the initiative of cement manufacturers have modified the Portland cement standards to allow for up to 5% blending of fly ash in the manufacturing of cement.

The cement market in Pakistan is divided into two zones: North zone and South zone. The North zone includes Punjab, Azad Kashmir, N.W.F.P. and the upper region of Baluchistan. The remaining area of the Baluchistan and entire Sindh constitute the Southern zone. There are some cement industries located at 100-150 km from the plant. They are:

- Dewan Cement Limited – Dhabeji
- Lucky Cement Limited - Indus Highway, Karachi
- Power Cement Limited - Nooribad, Dadu (Formerly Al-Abbas Cement Limited)
- Thatta Cement Limited – Thatta

Some of them are located mainly on the main highway M-9 linking Hyderabad to Karachi (Figure 7), which is also the route through which coal will be transported to Project. Project can generate revenue by a proper planning of ash disposal. Cement industry has already shown interest in utilization of ash produced at the Project.

One of the manufacturers, the Power Cement Limited, located about 60 km from the Project site has indicated that their plant can utilize about 100,000 tonnes/year of ash as finished product extender, and about 150,000 t/year as kiln feed. The Executing Agency shall explore and enter into agreements with cement factories and other construction industries for utilization of the ash.

Production of cement concrete blocks where bottom ash can be used as an aggregate is also common and widespread in the Karachi-Hyderabad area.

**Figure 10: Potential Fly Ash Utilization Sites**

![Map of Potential Fly Ash Utilization Sites](map.png)

Source: Mott MacDonald Compilation

### 3.3.2 Ready Mix Concrete Manufacturer

In Pakistan, many Ready-Mix Concrete Manufacturer existed and set up their plant during last decade. The ready mix concrete manufacturers may use fly ash as admixture. The ready mix concrete industry is the potential buyers of fly ash. The major ready mix concrete manufacturers around the project region are given below:

- Lucky Paragon Concrete Ltd
- Safe Mix Concrete Ltd
• Atlas Ready Mix
• H2 Ready Mix
• D Mix

All these units are situated at various locations in Karachi. The manufacturing/operational capacities of all these units are estimated at about 8,000 cubic meters per day on two shift basis which is on average strength in weight about 16,000 tonnes per day. The annual production of ready mix concrete by these units as per survey and assessment of an average strength of concrete is estimated 1.4 million cubic meters or about 2.8 million tonnes at about 60% capacity utilization. Thus, the existing production of ready mix concrete in the Executing Agency’s region is estimated about 2.8 million tonnes. The quantity is expected to increase every year at the rate of 5 to 10% as per the development plan and economic policies of the Government.

3.3.3 Market Development

Clearly, the market off-takers have been identified. While this is all well and good, the Executing Agency needs to establish the markets in a timely fashion. The Executing Agency should be aggressively seeking to maximise reuse of ash and thereby minimise the volume of ash to be disposed of.

However, the Executing Agency is once again cautioned that the ash property table contained in the Ash Management Plan is simply a “placeholder” until such a point in time when a Coal Supply Agreement is established. Attempts to establish the market for fly ash (and gypsum), in advance of an established Coal Supply Agreement is commercially risky and inevitably a disappointing endeavour.
4 Conclusions

The ash management plan as discussed in the foregoing sections is summarised as follows:

- Recycling of ash is the preferred option for ash disposal.
- The Executing Agency shall explore and enter into agreements with cement factories and other construction industries who have shown interest to utilize the ash.
  - If the expression of interest shown by M/s Power Cement is converted into an agreement, 50% of total generated ash will be utilized in first year of operation, itself. This may be further increased by entering into an agreement with other users.
- If required, the ash pond may be developed in two stages to store surplus ash that cannot be recycled. The proposed ash pond at site B, with starter bund height of 6 meters and first stage expansion of 3 meters height will be able to cater storage of ash generated in 8 years of plant operation, when the Units are operating with 85% plant load factor.
  - If the ash pond is simultaneously utilized for gypsum disposal, the volume is sufficient to handle ash & gypsum generated for approximately 5.8 years of plant operation.
- There are six existing Transmission Towers in the proposed land for ash pond. These Towers need to be relocated outside the proposed site.
Appendices

A. Next Steps
A. Next Steps

The Ash Management Plan must now be taken forward by the Executing Agency in terms of implementation and level of detail. Further development This action takes the Plan from a high-level strategy to the tactical level. Therefore. Further development is essential for execution.

Suggested subjects that require development include the following:

1) Clarity in Definition and Objective of the Ash Management Plan
   a) What does the Executing Agency hope to achieve or accomplish; what is the result?
   b) What would the successful outcome of the plan “look like”?
   c) Are there specific, measurable, observable events or outcomes the Executing Agency wants to achieve?
   d) What is the value in developing the plan further or going through the process of creating the plan (e.g., identify gaps, improve readiness, past events that need to be addressed, etc.)?

2) What are the Trigger Points?
   a) When does the plan get executed?
   b) What is the signal that tells people to perform the tasks defined in the plan?

3) What Tasks Need to be Done?
   a) What are the step-by-step tasks that must be done to maximize the likelihood that the plans’ objectives will be achieved?
   b) What are the specific procedures, analysis, responses that must be done? (Who, What, When, Where, Why, and How)

4) What Contingencies Need to be Considered?
   a) For each task in the plan, it may be helpful to think of potential situations that would make it impossible to perform. Then formulate alternative tasks (contingencies) if there are barriers to performance.

5) Time Duration of Each Task
   a) Each task must be realistic and feasible.
   b) Estimate and demonstrate the length of time it takes to complete each task.
   c) Ensure feasibility.
   d) Tasks that cannot be completed in the time required to achieve the plans objectives are barriers to performance.

6) Task Sequence & Dependencies
   a) Sequence – Put every task in chronological order for when they are to occur. Of course, some tasks (perhaps many) will occur simultaneously.
   b) Dependencies – Identify what task can only happen before or after other tasks (e.g., before establishing an off-taker contract for fly ash, make sure there is an accurate coal/ash property table in place.).
   c) Understand the dependencies so that people know exactly when they can perform their actions or what needs to happen before an action can occur.
7) Who is Responsible for each task?
   a) Identify the specific people or job titles responsible for completing each task.
   b) Include both internal and external resources.
   c) Every person in the plan must know his or her job and how to do it.

8) Resources & Availability
   a) Identify specific resources needed for the plan to work.
   b) Resources include people, computers, online internet access, cell phones, tools, equipment, machines, etc.
   c) Make sure all resources will be available when needed during plan execution.
   d) If there is a possibility of running out of something during plan execution, a “resupply” plan should be defined.