THE WORLD BANK

AFGHANISTAN RESOURCE CORRIDOR DEVELOPMENT: STRATEGIC INPUT ON THE DEVELOPMENT OF THE AYNAK COPPER MINE

FINAL REPORT ON AYNAK PROJECT

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1. Introduction and assumptions

This note briefly discusses the most likely timetable for the development of Phase I of the Aynak Copper Project. The information on which this analysis is based is drawn from the report: **"Metallurgical Corporation of China Ltd. Global Mining Assets- Independent Technical Review Report (ITRR)", dated July 2009, by Minarco-MineConsult for MCC, pages V-70 to V-96,** the **ITRR Report**, maps with the location of the archaeological antiquities in the Project area and the proposed timetable (end 2013) for their complete removal, both provided by the World Bank.

In addition, the analysis is mainly based on the experience of Chilean copper projects developed during the last years, and the consultants´ views and experience in similar projects. The note covers the development of Phase I only, as described below. At this point, it is difficult to analyze in detail the development of Phase II (underground mine, SX-EW plant and smelter) as the consultants have had no access detailed information on the proposed facilities to be built in Phase II, beyond the very succinct description included in the ITRR Report.

In any case, for the purposes of this note as per the TOR, the critical issues affecting the Project´s development are those of Phase I.

The main conclusion of the note is that, under the above assumptions, it will not be feasible to advance the time of first copper production before the second half of 2015. More specifically, the location of the antiquities in the area of the proposed open-pit mine and the timetable for their removal does not permit to extract ore before their complete removal and that; in any case, the critical development path is determined by the completion of the concentrator plant.

2. Summary of Project to be built (as per ITRR Report)

Phase I

- Open pit for 71,7 Mtpy total material movement; 9,9 Mtpy of ore, with a copper grade of 2,19%.
- Concentrator with a throughput of 9,9 Mtpy (30 ktpd), copper recovery of 91% to produce copper concentrate (cucons) of 40% copper content, for a total production of app. 197 ktpy of fine copper. Tailings dam for 393 million m3.
- Temporary diesel power plant for 150 MW for the first five years of operation.
- 17 km. water pipeline and pumping installations to bring water from underground water reserves near the Luger River including water treatment facility and a 480 kL/day reverse osmosis plant.

Phase II

- Development of underground mine planned to start production three years after Phase I, ramping-up from 1,7Mtpy ore to full capacity of 9,9 Mtpy after five years, with a copper grade of 2.19%.
- Expansion of concentrator plant to double its capacity to 19,8Mtpy of cucons with a 40% grade and fine copper content of app. 197 ktpy.
- Construction of copper smelter in year 5 to process 200 ktpy of cucons to produce 220 ktpy of copper anodes to be electro-refined into copper cathodes and a sulphuric acid plant for 205 ktpy. Acid would be used in the leaching process.
- Leaching process for 1,67 Mtpy of oxide ore through solvent extraction and electro-winning (SX-EW) to produce app. 20 ktpy of copper cathodes.
- Construction of coal fired power station of 400 MW capacity, and 280 Km transmission line.

3. Estimated timeline for Phase I (see Table 1 Aynak Project Timeline)

- **Status of feasibility and engineering studies**

  It is crucial to understand what the timetable for the completion of these studies is. Assuming that the Feasibility Study (FS) is about to be completed, detailed engineering for tendering the mine and plant equipment could commence right after. Detailed engineering usually takes one year once the FS is completed. Given the very tight market for mining and plant equipment, and long time delivery time for critical items, projects try to place orders for long lead time items even before detailed engineering is completed. We assume that in the case of Aynak this could be done by the end of 2012. These orders can be of a "pre-commitment" nature, that is; they can be cancelled by paying a fine.

  It is reasonable to assume that the Project owners will source most of the equipment from China. This could mean that the Project may have privileged access to critical equipment on a timelier basis. However, in the attached **Table 1 Aynak Project Timeline,** more conservative delivery times are assumed as per Chilean experience. This table shows the critical path of the project, in order to start copper production by 2nd half 2015.

- **Open-pit mine**

  The main assumption is that the pit cannot be opened until the antiquities are removed, except for a small area in the NE of the proposed pit (see **Figure 1**). Access to this area could speed-up the initial waste removal, but in any case, it is estimated that it would allow ore extraction to feed the plant for only one year. However, given that the critical path of the Project is the concentrator, this possibility has no real impact on the timetable.

  Given that ore outcrops, we have assumed that it will require approximately one year of waste removal to completely expose the ore to be mined. This means that mine equipment (trucks and shovels) have to be available by mid-2014. We estimate that the equipment specified as per the **ITRR Report,** could take approximately eighteen months to be delivered after the purchase order is given. Three issues should be noted:

  i) as already mentioned, Project owners may shorten the delivery time if sourced from China, and
  ii) an equipment maintenance shop must be in place by that time, which can be built outside the archeological areas.

iii) the oxide ore which is near the surface of the deposit and will be treated in Phase II, part of these ore, will have to be extracted as part of the pre-stripping stage and Phase I, and deposited in a stockpile as run-of-mine ore until the leaching and SX-EW operation starts.

- **Concentrator**

  Once detailed engineering is finished by the second half of 2013, the Project could start building the concentrator plant, which is the critical path item. It is estimated that a plant of this size should take two years to build, including earth movement, building and commissioning (based on Chilean projects´ experience). This assumes that by that time construction begins there is no interference with the antiquities in that area (see **Figure 2**).

- **Primary crusher and overland conveyor**

  Location of the primary crusher and the initial section of the overland conveyor to the plant, as per the **ITRR Report**, are in Archeological Areas Nos. 2 and 16. Therefore, earth movement cannot start until these antiquities are removed by the end of 2013. We estimate that installation of both components should take at most 18 months. Considering a delivery time of app. 18 months these items, they should be ordered by the end of 2012.

- **Earth movement**

  Earth movement needed for the installation of the crusher, conveyor, plant, tailings dam, camp, etc. can start as soon as detailed engineering for construction of the different items is completed. If some of the engineering is available by the end of 2012, it implies that the necessary equipment should be in place by the 2nd half of 2013. If the Project owners will do the earth movement by themselves, purchase orders could be made right away for delivery in early 2013. If normal practice for this kind of work is followed, a specialized contractor company should be hired in the next months. As per international practice (bidding process, hiring and mobilization), it could take until mid 2013 to have it in place.

- **Temporary diesel generators**

  Approximately 50 MW are required for Phase I. Delivery times are approximately 12 months; however, this should not be a concern as generators are also available on a rental basis in the market. Installation can be gradual as power needs build-up.

- **Pre-commitment orders**

  As already explained, once the FS is finished, pre-commitment orders for critical equipment can be made, even before detailed engineering is completed. Key equipment envisioned now as being long lead items are: Shovels, trucks, crushers, ball mills, mill drives, overland conveyors, main power transformer, and switchgears.

- **Tailings**

  According to the **ITRR Report**, the concentrator is located 4 km. WNW of the pit at an altitude of 2,160 masl and the tailings dam is located 4 km. WNW from the concentrator, with its lowest part at 1,950 masl. Figure 2 shows the layout of the pit, concentrator and tailings dam.

  From the concentrator, tailings are sent to the dam through a pipeline. The altitude difference between both is approximately 100 m. (2.5% gradient), which permits gravitational flow of the tailings.

  The area where the dam is to be built narrows in its lower part, this is where the tailings wall should be built. Initially this wall has to be built with material from the neighboring areas; future elevation of the wall can be done with the coarse portion of the tailings (Chilean practice). If the tailings composition does not allow it, it would have to be done with other material in the area or with waste material from the open-pit.

  In the tailings area, there are some houses and crops (see **Figure 3**); therefore, it can be assumed that the ground in this area is permeable. If this is the case, a battery of wells would need to be built in order to recover the water that infiltrates. In any case, the terrain´s topography is adequate to recover this water below the tailings´ wall.

  In general, the area is quite adequate for a tailings deposit, and the construction of the initial wall is a minor work which should not be in the Project´s critical path.

4. Consumption of basic inputs

Water and energy are the main inputs in the mining and copper extraction processes.

Energy is mainly used to crush and grind the ore to a range of 150-300 microns in order to liberate the copper ore which is then recovered through a flotation process. Energy consumption in this stage is determined by two variables: hardness of the ore (work index or WI) and the required grind size.

Water is used in the flotation process. The “pulp” to be floated (ore plus waste) must have a solids content of 25 to 35%. Liberated sulfide ore floats and produces a copper concentrate whose grade varies between 30 to 50% depending on the mineralogy of the ore (40% in the case of Aynak). The rest of the pulp (95-98% of the total plant feed) is the “tailings”, with a copper content between 0.05%-0.30%, depending on the plant´s copper recovery rate (91% in the case of Aynak).

Prior to depositing the tailings, it needs to be “thickened” to recover part of its water content, leaving tailings with 50 to 60% solids content. Once deposited in the dam, the fine portion of the tailings decants and a water “lagoon” covers the tailings dam from where it is re-circulated to the process.

In Chile, fresh water consumption is typically between 0.4 to 2.1 m3 per ton of ore. Higher figures correspond to operations where water is not recovered, and the lower ones to those who use high-density thickeners.

As an example, fresh water consumption of a concentrator at 3,000 masl is 0.7 m3 per ton for tailings with 52% solids density, and can be reduced to 0.65 m3 per ton for a solids density of 55%.

Additionally, water consumption will depend on the tailings rheology (1), the extension of the area exposed to evaporation, the site´s evaporation rate and ground infiltration.

Based on the above water and energy consumption dynamics in a copper operation and the average unit consumption figures for Chilean mining, the consumption figures included in **Table 2** are estimated for the Aynak Project.

As can be concluded from the Table 2, the consumption figures for both water and energy calculated for Phases I and II using standard Chilean industry parameters, coincide the total consumption figures as per the **ITRR Report.**

(1) **Rheology** is the study of the flow of matter, primarily in the liquid state, but also as 'soft solids' or solids under conditions in which they respond with plastic flow rather than deforming elastically in response to an applied force.

In order to determine with greater accuracy the concentrator´s energy consumption, the grind size and WI of the ore would need to be known.

Similarly, a more accurate estimation of fresh water consumption requires knowing the rheological characteristics of the tailings, its solids density, losses due to infiltration at the dam, how much water can be recovered from the recuperation wells and the evaporation rates of the dam and site. In principle, a consumption of 0.7 m3 per ton of ore (the one used) is considered a good estimation.

5. Smelter Construction Decision

- **Industry decision criteria:**

1) International mining companies which are primary copper producers, In general, tend not to smelt or refine their copper concentrate (cucons) production, but rather to sell cucons as the final product. This is due to:

    - high capex requirements and low returns of this processing stage compared to the mining stage,

    - environmental risks inherent to a process with high sulfur dioxide and other emissions, and

    - low treatment (i.e. smelting) and refining charges (generally known in the industry as TC/RC´s) projected for the next years. In fact, the copper concentrate market has been in a structural deficit over the last years and it is forecasted to continue so at least until mid of the present decade.

2) Copper smelters and refineries tend to be built by copper semi-fabricators and other downstream copper product producers. The key driver is a strategic decision that allows them better access to raw material. This factor has driven the rise of the Far-East smelting business, first in Japan and Korea and later in China. Other important factors are, the possibility of using of old copper scrap to mix with cucons in the smelting process, and the recirculation of the new scrap remaining from the semis fabricating process.

3) In certain circumstances primary copper producers will decide to build a smelter and refinery based on the following factors:

- transportation and other logistics costs (typical of far inland mines, such as Zambia),
- sulfuric acid demand for copper leaching operations or for other uses, such as fertilizer production,
- commercial strategies aimed at selling a more liquid commodity such as copper cathodes (this is the case of Codelco in Chile, which in any case "inherited" its smelting operations from the nationalized North American companies, at a time when primary producers were vertically integrated from mine to semi-fabrication).

- **Aynak smelter decision criteria**

In the case of the Aynak Project, the decision (apart from a contractual commitment to build it) is mainly influenced by transportation costs and the need of sulfuric acid for the proposed copper leaching operation, as explained below.

1) Transport and Logistics cost

Chilean rates for cucons transport range from USD 0.20 per ton/km by rail to USD 0.30 per ton/km by truck, however these rates are for short distances (100 to 500 km). In the case of longer distances, as in the case of Aynak, rates should range between USD 0.02-0.03 per ton/km by rail and USD 0.06-0.10 per ton/km by truck.

Given that the quantity to be moved would be relatively low (494 ktpa and later 987 ktpa), and we assume there is no rail line, the distance to be covered to the nearest port- Karachi- is app. 1,400 km. If we use the higher estimated rate of USD 0.10 per ton/km by truck, the inland transport cost per ton of cucons would amount to USD 140.

Assuming that from the port cucons would have to be shipped to a Chinese smelter, an ocean freight cost of app. USD 20-30 per ton of cucons plus some inland freight to the smelter, have to be added.

Therefore, moving Aynak cucons to a smelter in China, would cost somewhere in the region of USD 150 to USD 200 per ton. Given that Aynak cucons have a fine copper content of 40%, this equates to a transportation cost of USD 375 to 500 per ton of fine copper.

This is clearly a very high cost for a smelting business, relative to a treatment charge in today´s market of app. USD 60 per ton of cucons and a refining charge of app. USD 0.06 per lb of fine copper, which for a USD 3.00/lb copper price, is equivalent to app. USD 150 per ton of concentrate

If the smelter is built and eventually the refinery, the transportation cost either for copper anodes (the smelter´s final product) or copper cathodes (the refinery´s final product), would be also app. USD 150 to USD 200 per ton, but of fine copper, which compares to the USD 375 to 500 per fine copper if cucons are shipped.

At present there is no other closer alternative to treat the Aynak cucons. The Saindak smelter in Pakistan (see Annex 1 below) is app. 1,400 km by road and its capacity is for only 20 ktpa of copper.

2) Sulfuric acid consumption

Sulfuric acid consumption for copper leaching depends on the characteristics of the ore to be leached. It can vary between 20 to 40 kg. per ton of ore. Assuming a consumption of 30 kg/ton, acid consumption at Aynak (for the production of app. 20 ktpa of fine copper as per the **ITRR Report**), acid consumption would be app. 50 ktpa.

According to the **ITRR Report**, acid production from the smelter would be 205 ktpa during the first 10 years, rising to 305 ktpa thereafter. This means there will be surplus acid production from Aynak that will need to be used in other industries such as fertilizers or eventually other copper leaching operations. As in the case of cucons, the transport cost of exporting this acid would be too high to justify it.

6. Smelter choice of technology issues

- **Choice of technology**

The proposed smelter is for 200 ktpa of copper anodes or a smelting capacity of app. 500 ktpa of cucons (assuming cucons of 40% grade).

For a smelter of this size, the most likely technology to be used at Aynak will be either an "ISA-Smelt Furnace" or a "Bottom-Blower Furnace", which is common in Chinese smelters. Other smelting technologies in wide use, such as the "Flash Furnace", would be ruled-out given the relatively small size of the proposed smelter.

In the case of the "Bottom- Blower" furnace, it is usually connected to a boiler whose steam can be used to produce app. 2.5 to 3.0 MW of power. Installation of a power turbine is optional, but the steam, which is always produced by the process, can be also be used to dry the cucons or heat the solutions at the copper refinery.

The conversion stage of the smelter should be standard Pierce-Smith Converters, plus the rest of the equipment described in the **ITRR Report** (see p.96).

Importantly, the **ITRR Report** mentions that the smelter will only capture gases from the smelting stage, which typically accounts for 60% of total gases produced. This explains why acid production is expected to be around 300 ktpa, rather than 400 ktpa if they would also process the converting stage gases.

This means that total sulfur emission capture would amount to only 85%, which is very low for western standards (in Chile the legal limit is now going up from 90 % to 95%, and in developed countries is close to 98-99%).

- **Impact on construction time**

A smelter of the above characteristics should take app. 3 years from end of feasibility to start-up, including the refinery. The critical path items are the acid plant, blowers and electric rectifiers for the refinery.

- **Impact on power demand**

  Given the relatively small size of the proposed smelter, it should be built in one stage. What determines the capacity is the size of the smelting furnace; therefore it does not make sense to stage its construction.

  The total power demand for the smelter, for either of the technologies mentioned above, would be the same as the one estimated in the **Inception Note**, which is app. 24 MW. The same applies to the app. 12 MW demanded by the electro-refinery.

  Once the smelter and electro-refinery are built, power demand will be continuous. These processes do not allow for large variances in the usage of their capacity; in fact an unplanned stoppage can produce severe damage to the equipment. The only decrease in power consumption will take place when the facilities undergo planned major maintenance, usually once a year.

7. Conclusions and recommendations

1) Based on this note's assumptions, timing of first copper concentrate production at Aynak would be around the second half of 2015.

2) The status and expected date of completion of the FS and detailed engineering of the Project are a crucial factor to understand if there are any opportunities to advance the Project's commissioning. If these studies are delayed compared to the note's assumed dates, first production would be delayed accordingly.

3) There is an opportunity to shorten the Project's timeline if the owners source (as would be expected) most of the equipment from China, given shorter delivery times compared to more traditional sources. This requires that earth movement be also anticipated in respect to the Project´s timeline.

4) The early opening of the mine in a small area in the NE of the proposed pit, before the antiquities are completely removed by end 2013, would not affect the Project's timeline as the critical path is determined by the completion of the concentrator plant.

5) Consumption figures for both water and energy calculated for Phases I and II using standard Chilean industry parameters, coincide with the total consumption figures as per the **ITRR Report**. However, in order to determine with greater accuracy the concentrator´s energy consumption, the grind size and WI of the ore would need to be known. Similarly, a more accurate estimation of fresh water consumption requires knowing the rheological characteristics of the tailings and the characteristics of the area where the tailings dam will be built.

6) More detailed information on the proposed facilities to be built in Phase II is needed to be able to check consumption figures and the timeline for engineering and construction of this phase.

7) Given the high transportation cost for Aynak copper concentrates it is highly likely that the owners opt to build the smelter even for Phase I, which is different from what is proposed in the **ITRR Report**.

8) The need of sulfuric acid to leach the oxide ores from Phase I reinforces the above decision. This means that the solvent extraction plant and the electro-winning refinery for 20 ktpa, would need to be built in parallel with the concentrator plant and smelter.

9) If this option is taken, smelter construction would have to start together with the concentrator plant in order to be ready to process the cucons from Phase I.

10) Given that the refining process to copper cathodes does not affect the transport cost in terms of fine copper, its construction could be deferred. (It should be noted that this refinery- an electro-refinery- uses a completely different process than the electro-winning refinery for the leached copper. The electro-refinery´s input are the copper anodes produced by the smelter).

11) Conclusion 7) raises the issue of why the Project, as per the **ITRR Report**, does not consider a smelting capacity large enough for the entire concentrate production after the underground mine of Phase II starts-up. This raises the possibility that an expansion to double the smelter´s (and eventually the electro-refinery) capacity is undertaken during Phase II.

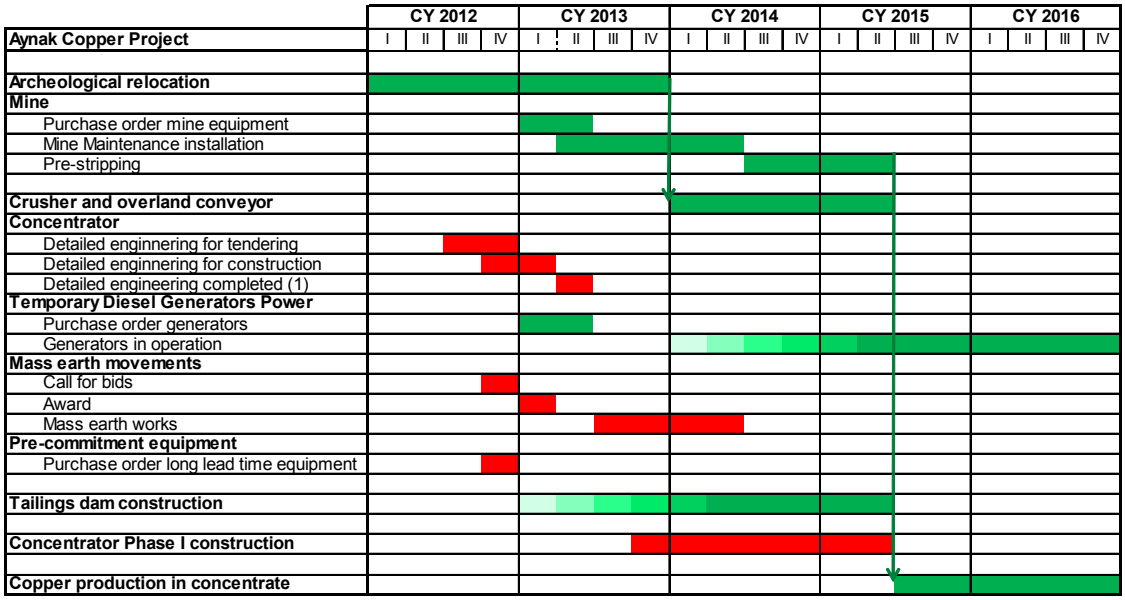
12) In terms of power usage, the proposed smelter would use app. 24 MW and the electro-refinery 12 MW and they would eventually be needed in Phase I as per 7), above. If the electro-winning refinery were to be built in Phase I, it would add 9 MW of power. If later a decision were taken to build a smelter and electro-refinery for the entire cucons production after Phase II, this would double to a total of 81 MW (i.e. 36 +12 MW for each app. 500 ktpa of cucons smelting and refining capacity) and 9 MW for electro-winning.

13) Possible sources of additional power demand could be:

- if ore is harder it could increase unit consumption by app. 50% (this would be an extreme), and power consumption of the concentrator increase by 34 MW.
- the underground mine could double consumption if intensively electrified (i.e. electric powered vehicles, etc.) from 7 to 14 MW.
- if we assume a smelting and refining capacity for the total cucons production is built, we have an additional 36 MW.

Therefore, under these assumptions, maximum power consumption could reach a total of 222 MW (145+34+7+36). If a 10% contingency is added, the total would be 244 MW.

TABLE 1: AYNAK PROJECT TIMELINE



(1) for earth movements

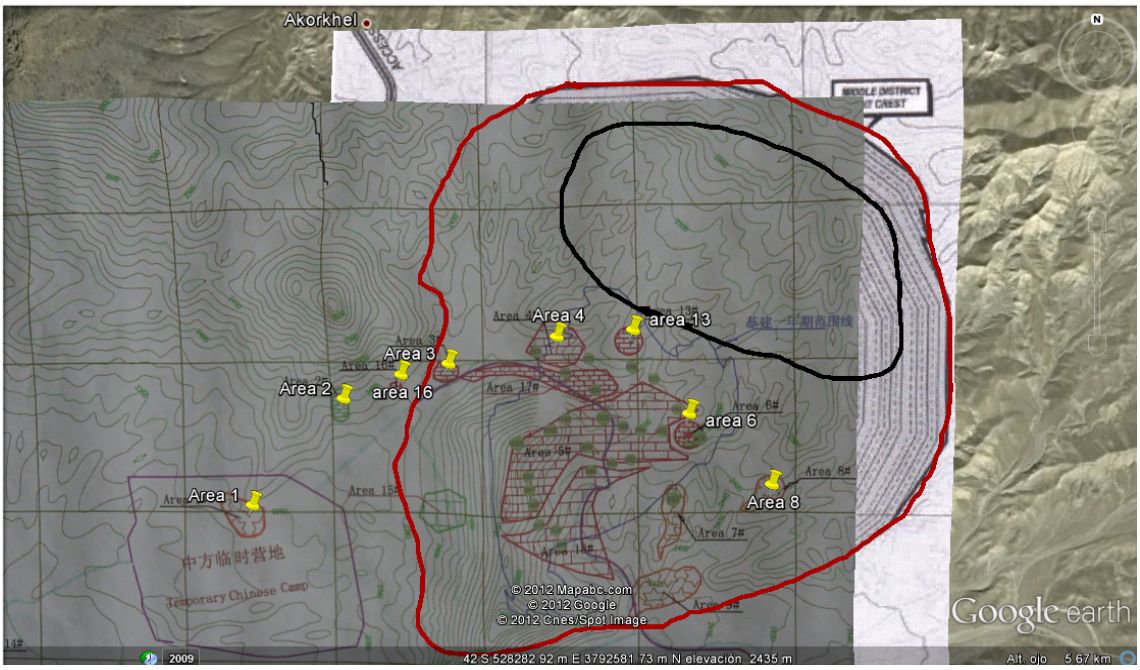
critical Path

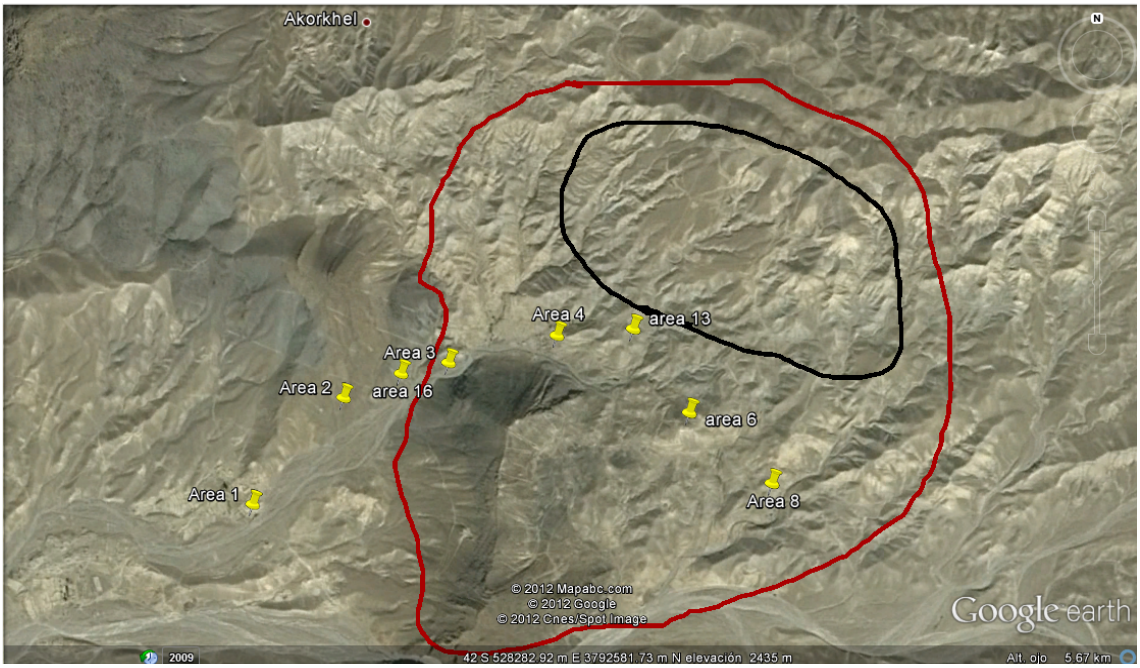
non critical path

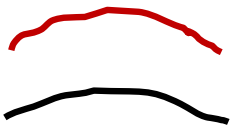
Main Assumptions:

Archeological relocation completed by the end of 2013
Archeological area only affects open-pit, primary crusher and overland conveyor
Detailed enginering start in July 2012 (all geometallurgical information available by June 2012)

FIGURE 1: ARCHEOLOGICAL AREAS AND OPEN-PIT







Boundary of the final pit

Potential boundary “early pit”

Archeological areas

FIGURE 2: LOCATION OPEN- PIT, CONCENTRATOR AND TALINGS DAM

FIGURE 3: DETAIL TAILINGS DAM AREA

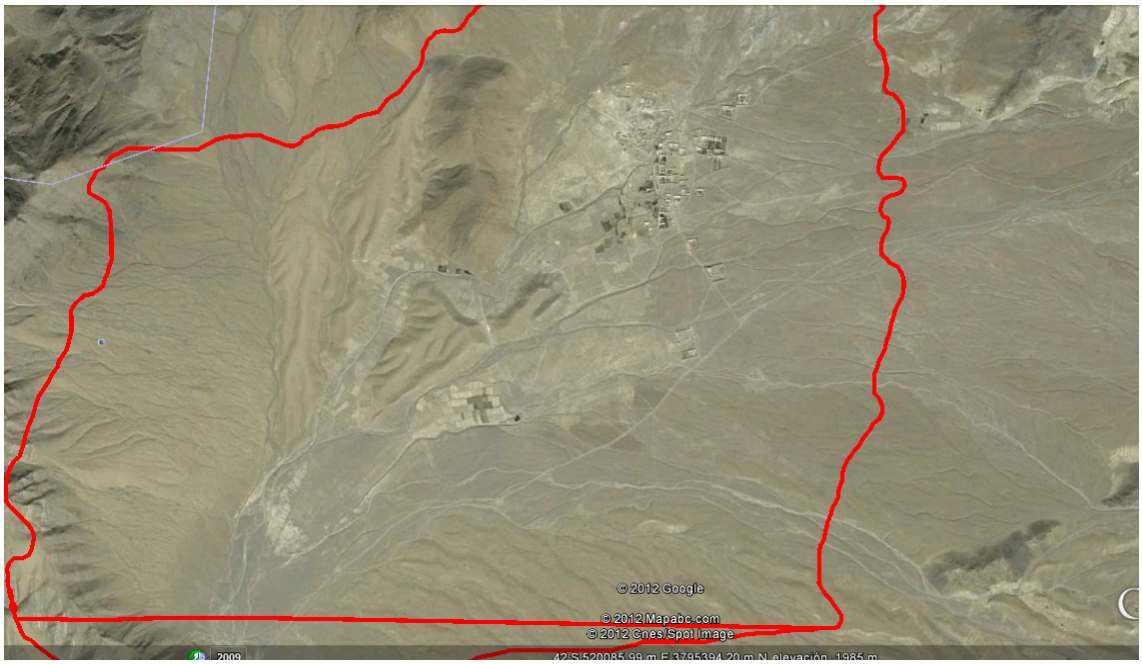


TABLE 2: AYNAK PROJECT WATER AND ENERGY CONSUMPTION

Main Operational parameters

		Phase 1	Phase 2
Open Pit	Ktpy mat	71.700	71.700
Underground mine	Ktpy ore		9.900
Concentradora	Ktpy ore	9.900	19.800
Leaching SX/EW	Ktpy ore	-	1.670
Smelting	Ktpy Conc.		500
Refining	Ktpy cat.		220
Coal Fired Power Station	MW		400

Fresh Water consumption l/s	Based on	Phase 1	Phase 2	ITRR Report
Open Pit	(1)	19	19	19
Underground Mine	(2)		-	127
Concentrator	(3) (0.7 m3/ton ore)	223	446	455
Leaching SX/EW	(3)(0.13 m3/ton ore)		7	
Smelting	(3) (3.6 m3/ton Conc)		57	120
Refining	(3) (1.2 m3/ton Cu)		8	
Power generation coal	(1) (1.8 l/KWh)		200	
Camp/services	(3)	2	5	
Total		**225**	**723**	**721**

Power required MW	Based on	Phase 1	Phase 2	ITRR Report
Open Pit	(1) (1.5 MW/shovel +20%	11	11	
Underground Mine	(3)		7	
Concentrator	(3) (30 KWh/ton ore)	34	68	
Leaching SX/EW	(3) (3,900 KWh/ton Cu)		9	
Smelting	(3) (420 KWh/ton Conc.)		24	
Refining	(3) (480 KWh/ton Cu)		12	
Camp/services	(3)	5	9	
Water Pump	(1)	2	5	
Total		**52**	**145**	**150**

(1) Estimated calculation

(2) Water consumption in UG Mine is minimum and usual there is water available on the mine

(3) Based on average consumption in Chilean mines

ANNEX 1: SAINDAK COPPER SMELTER

In 2002 the Pakistan Government signed a 10-year lease agreement with Metallurgical Construction Corporation (MCC) of China. According to the Lease Agreement MCC agreed to pay US $ 500,000 as rent annually to the Government of Pakistan and in addition the Pakistan Government would receive 50% of the amount realized by the firm through sales of copper and other products mined from Saindak.

MCC has established the necessary infrastructure for smooth mine operations. This includes a 37 kilometer water pipeline to supply water to Saindak from Tahlab, a 38 kilometer railway track linking Saindak to Taftan on the Quetta-Zahidan Railway line, a diesel generator of 50 MW capacity to meet the electrical power requirements, and a township for 2,100 persons.

Provisions have been made at the site for open-pit mining, concentration, and smelting. 4.25 million tons of sulfide ores can be processed annually. In the first phase the end product of the Saindak Project is copper blister, which would be refined outside Pakistan. In the second phase a refinery was foreseen, which would have led to the production of copper, gold silver sulfuric acid and molybdenum locally. The second phase expansion has not materialized and the project continues to export copper blister.

MCC China is producing on an average 20,000 tons of copper blister annually, which includes 1.5 tons of gold and 2.8 tons of silver.

Source: **Copper** Mining at Saindak | Socyberty