Cabildo Mine Backfill System

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Abstract

Minera Las Cenizas is planning to fill mined out sections of the Cabildo Mine (located 150 km north of Santiago) with tailings, to delay the construction of a new surface tailings storage facility for the mine. About 2.0 million cubic metres of void space is available to backfill tailings at a rate of 2,500 ton/d.

The paper presents a study conducted to establish the feasibility of placing tailings into the mine voids. A trade-off study indicated that the optimum concentration to place the tailings is in the range of 62% to 64% by mass (i.e. as a high density thickened tailings).

The paper describes the following aspects of the system:

- Test work conducted for the project (rheology and sedimentation tests).
- Conceptual trade-off study for optimum concentration deposition.
- Thickened tailings pump and pipeline distribution system.
- Method for filling the mine voids with tailings and recovery supernatant water.
- Project initial costs.

It is expected that the system will be commissioned in March 2006.

1. Introduction

Cabildo Mine of Minera Las Cenizas S. A. is located about 150 km north of Santiago in Chile and exploit copper minerals by flotation process.

The copper mineral is extracted and then concentrated, producing finally tailings that are now transported by centrifugal pumps to the Nº4 deposit. The life of this deposit extends until end of year 2006.

In order to maintain the continuity of the operations of the mine and the plant, Las Cenizas has developed this new project named "Cabildo Mine Backfill System".

The project of underground tailings deposition in Cabildo Mine, consist in make use of the mined out sections by filling them with tailings produced by the concentrator plant.

It is considered to place about 2.5 million tonnes of dry solids, corresponding approximately to 2.7 years of operation. It is expected that the system will be commissioned in March 2006.

2. Special Studies Carried Out

There were made two specific studies, one related with rheology and the other on sedimentation behaviour.

2.1. General Tailings Data

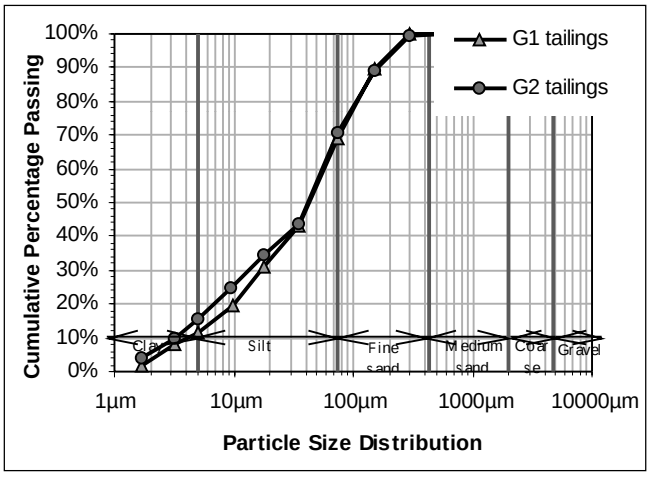

Figure 1: Particle Size Distribution of Tailings Material.

Cabildo Mine has two type of mineral, G1 and G2.

Property	Value
Solids density	2.9 t/m^3
d_{90} particle size	157 µm
d_{85} particle size	128 µm
d_{50} particle size	42 µm
d_{10} particle size	4 µm
Liquid limit	19 %
Plastic limit	18 %
Shrinkage factor	0.75 %
Average slurry pH	9.7
Freely settled bed packing concentration, C_{bfree} (by weight)	60 % [1,2]
Maximum settled bed packing concentration, C_{bmax} (by weight)	74.4 % [2]

Notes:
[1] Freely settled tests were conducted using flocculated samples.
[2] Separate tests were conducted for C_{bfree} and C_{bmax} using both samples, but the results were the same.

Table 1: Physical properties for Cabildo Tailings.

2.2. Rheology Testing

The rheology tests indicated Cabildo tailings, as much the G1 type as the G2 type, had a similar behaviour, getting to classify itself like conventional tailings until a solid content of 60% and like thickened tailings up to 71%. Over this solid content was established that tailings behaves like a paste (τ_y > 100 Pa). It was determined the tailing has a Non-Newtonian behaviour, suitably adjusting a Bingham rheological model.

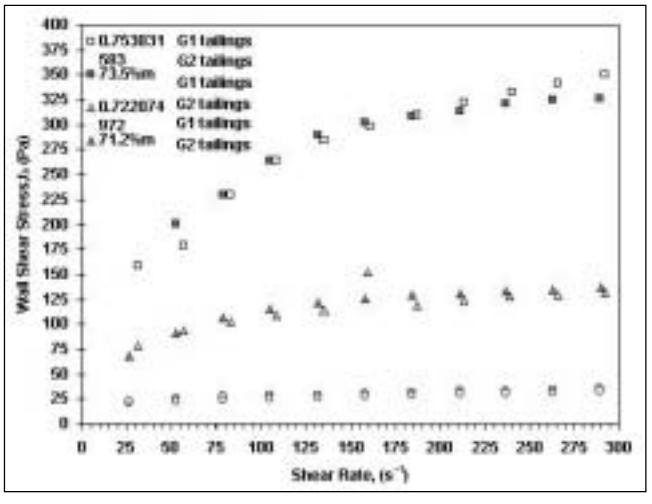

Figure 2: Comparison between G1 and G2 tailings rheogram for similar concentrations.

Both slurries behave similar at approximately the same concentrations. This study considers the following classifications for Cabildo Mine tailings.

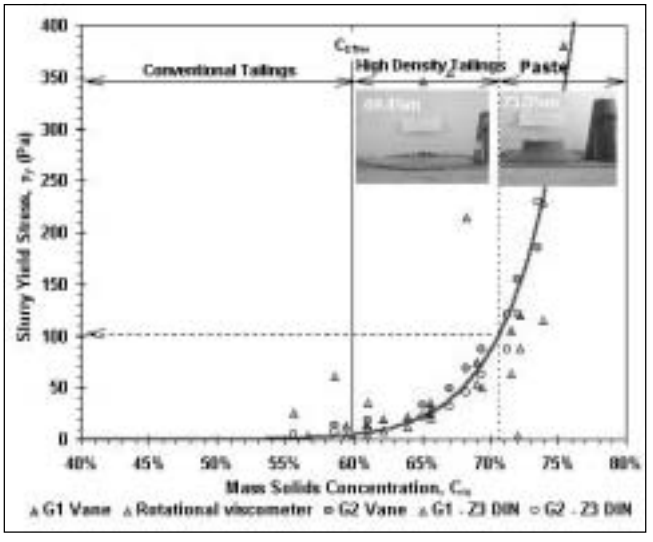

Figure 3: Slurry Classification for G1 and G2 Tailings.

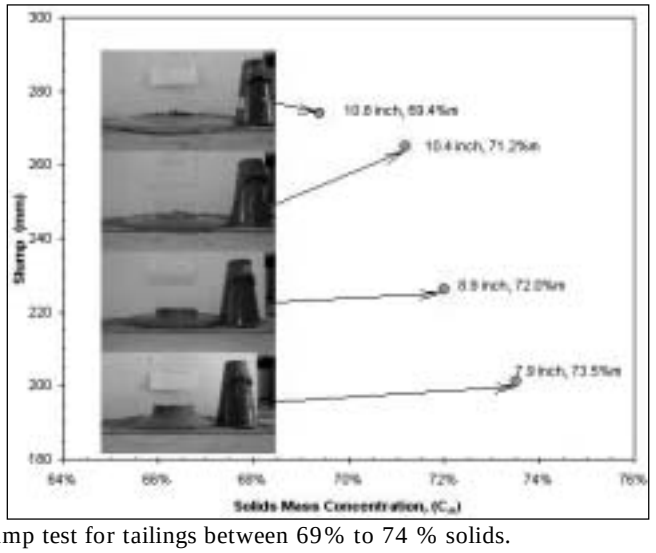

Figure 4: Slump test for tailings between 69% to 74 % solids.

The mass concentration limit for conventional tailings is considered to be less than 59.9%. This value corresponds to C_{bfree} determined for both slurries. The yield stress at this concentration is 4.8 Pa. At concentrations higher than this the slurry yield stress increases exponentially.

High density slurry can be considered for slurry concentrations greater than C_{bfree} (59.9%m, yield stress = 4.8 Pa) and less than 70.6%m (yield stress = 100 Pa).

The authors consider slurries with a yield stress of higher than 100 Pa to be a paste.

Parameter	Conventional slurry	High density slurry	Paste
Yield stress range	0 Pa < τ_y < 4.8 Pa	4.8 Pa < τ_y < 100 Pa	100 Pa < τ_y
G1 and G2 tailings concentration range	0 < C_m < 59.9%m	59.9%m < C_m < 70.6%m	70.6% < C_m
Slump	No slump	10 inch < slump < 11.5 inch	7 inch < slump < 10 inch

Table 2: Cabildo Mine Slurry Classification summary.

2.3. Sedimentation Tests

The sedimentation study was made in laboratory test tubes and also at site using 2 m columns.

At the plant two different tailings were tested, G1 and G2, during 15 days. For the testing, two 30 cm diameter 200 cm height acrylic tubes were used. To the samples 15 gr/ton flocculent (Superfloc A-110) was added.

They determined that after 3 days practically the total compaction of the solid material was obtained. For deposit aims in the mine void spaces, it was determined that a reasonable solid concentration to consider as a final value in a normal operation, would be of 68% by weight.

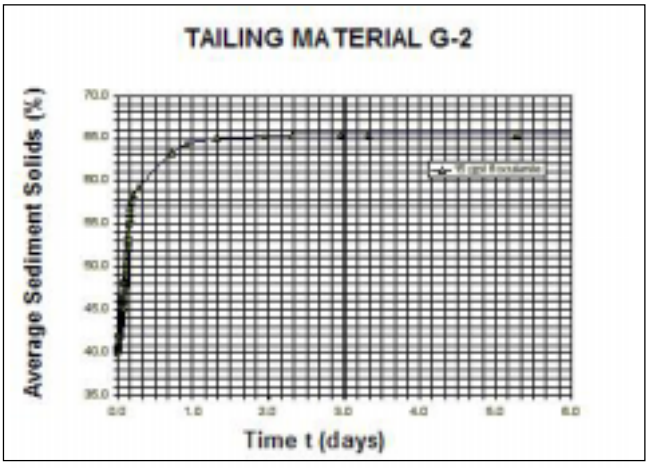

Figure 5: Sedimentation-consolidation of flocculated material in 2 m high column.

As can be seen in Figure 5, in 10 days the consolidation is practically complete.

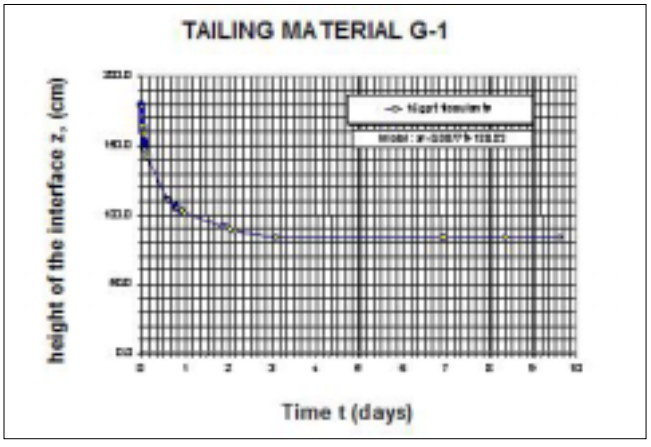

Figure 6: Solids content of flocculated material in 2 m height column.

The conclusions of the sedimentation study are the following:

- The sedimentation-consolidation of Las Cenizas tailing, treated with 15 gr/ton of flocculent Superfloc A-110, is fast and after 3 days it has eliminated practically all the available water.
- The average final solid concentration after 10 days is 66% for G1 mineral and 65.5% for G2.
- Considering these results and a simulation model for a 20 m column, it was determined that a 68% of solids would be an unadventurous final condition in mine disposal.

3. Analysis of Optimal Concentration

3.1. Assessment Basis

3.1.1. Technical basis

The following table shows the technical basis used for the analysis.

Slurry properties	Average solids density taken as 2.9 t/m^3.
Backfilling rate	800,000 tones per year 104 t/h (7,500 operating hours per year).
Mine void space available for backfilling	2 x 10^6 m^3
Concentration of settled solids in mine excavations	68 % (long term)
Percentage of supernatant water that can be recovered	50% (average)
Pipeline length	4,150 m
Static head difference	314 m

Table 3: Technical basis used for the analysis.

3.1.2. Costing basis

The Table 4 details the used costs basis for the analysis.

Positive displacement pumps cost (piston diaphragm pump including variable speed drive)	US$ 3.245 / kW
Centrifugal pump cost	US$ 311 / kW
Steel pipeline supply and install cost	US$ 2.40 / kg
Electrical power cost	US$ 0.05 / kW-h
Operating life	2 years

Table 4: Cost Analysis Basis.

3.2. Findings of the Analysis

Cost of Pumping Versus Solid Concentration:

- *Capital Cost:* Capital cost include the pump piston diaphragm, load centrifugal pump, seal water pump , the thickener and the main pipeline. The following costs are excluded: civil works, engineering and costs related to the contractor.
- *Energy Costs:* this is the electrical energy cost to operate the system during 2 years. Maintenance costs and manual labour are not included.

The N°3 figure shows the variation of the unit pumping cost (capital and energy cost divided by total tonnes backfill) with slurry concentration.

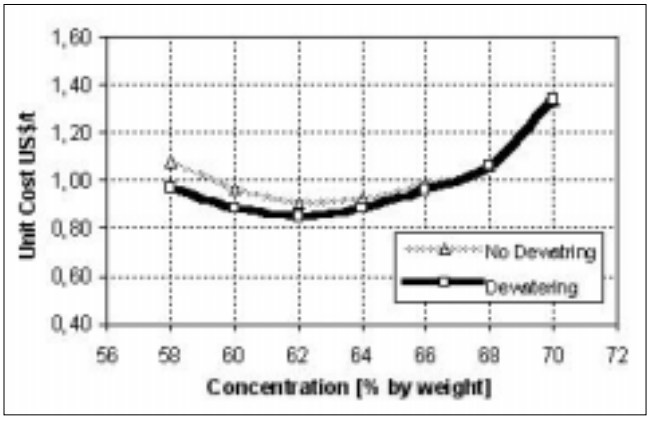

Figure 7: Unit Pumping Cost Versus Slurry Concentration (2 million m^3 backfilled).

The minimum pumping cost is for a slurry concentration between 62% and 64%.

3.3. Recommendations

It is recommended the following for the Cabildo filling system:

The design concentration for tailing transportation should be between 62% and 64% by weight. Then tailings would be compacted naturally up to 68%. This difference of the solid concentration will involve a recovery of water at the interior of the mines.

In order to pump the mixture of tailing one positive displacement pump should be used (piston-diaphragm). Centrifugal pumps will be more expensive to operate and will be significantly less reliable.

4. Description of the Adopted Solution

Tailing produced in Cabildo concentrator plant will be pumped to a thickener (190 masl) located, about 350 m towards the South East of the existing tailing pumps, where also will be located the planned positive displacement pumping station.

This first section of the pipeline will be made through a 280 mm HDPE pipe, with tailings at a concentration by weight of 25% and will use the present system of centrifugal pumps that pumps tailing until deposit (impoundment) N° 4. In this station of three pumps in series, it will be necessary to use only two of the pumps in series, reason why it is necessary to install a by-pass after the second pump, that connects directly with the discharge.

After thickening the pulp to a concentration between 62% to 64% by weight of solids, it will be pumped through a pipe of approximately 2,900 m of length, to reach one of the two mines mouth. In this section the pipe will be steel 141 mm (5" inch) diameter, without internal lining. From the mine entrance to the mine voids the pipe will follow underground galleries of about 1,500 m length, to its final disposal.

The tailings pumping will use one 300 kW positive displacement pump. This pump will delivery a flow of 28 l/s to 85 bar pressure. In the underground mine zone, the pipe will be of HDPE, with diameter of 140 mm and 110 mm, depending on the topographical conditions. A fast connectors system will be used, like type Hugger 995, so the task of distributing the pulp in the different sectors and to retire the sections once made the corresponding filling stage, will be easier.

The proposed process flow diagram and a topographical plan view of the project are presented at the end of the paper.

5. Deposition Sequence

In general lines the idea is to deposit from the lowest sectors towards the highest, in order to be leaving the flooded zones and to direct the filling towards higher sectors. In this sense, it will begin with South Sauce, then North Sauce, later Claudia and finally Eugenia.

Filling the greatest mine voids will be made in several phases: first will fill up with tailing and let decant, so that the supernatant water extraction generates an additional volume, for a second phase of filling with tailings.

The four old mine sectors and that will be filled up, are shown in the following table, with their volumes and respective elevations:

Filling Order	Mine to Fill	Total Volume (m^3)	Fraction (%)	Elevation (masl)	
				Low	High
1	South Sauce	626.900	31	285	400
2	North Sauce	900.000	44	395	510
3	Claudia	298.000	14	350	435
4	Eugenia	236.000	11	405	530
	Total	**2.060.900**	100		

Table 5: Summary of Mine Data of Volumes and Elevations to Fill.

It will be necessary to extract the supernatant water in each filled zone. This water could be retired before finishing the filling of the zone, every time its extraction is found relevant. For this operation is considered to use a barge mounted pump.

Filling Order	Mine to Fill	Filling Time (days)	Water Extraction Time (days)
1	South Sauce	302	45
2	North Sauce	435	97
3	Claudia	145	22
4	Eugenia	105	15
	TOTAL	**987**	**179**

Table 6: Filling and water extraction time for the mines

The reclaimed water will be pumped, parallel to the tailing pipeline layout, up to the recycled water pond, located in the concentrator plant, for their reuse in the process.

The operation considers to maintain available the existent pumping system to the deposit N°4, to redirect tailings towards this deposit during maintenance, or during certain periods of time if the operation needs it.

The tailing pumping will be done to an average rate of 104 tonnes of solid per hour.

Previous to initiate the filling of each sector, it will be necessary to seal some galleries, to allow the confinement of tailings, avoiding tailings to flow to lower sectors than those in which it is being deposited. These seals (corks) will be materialized by filling a section of the gallery with reinforced concrete.

According to this study, it will be required 24 plugs, in addition to the construction of 480 m of by pass gallery.

A sectional view of the South Sauce mine is presented at the end of the paper.

6. Project Costs

The final costs analysis results are the following:

Total estimated cost for the project: US$ 3,900,000.

The evaluation considered the details engineering, the owner general administration costs, constructor expenses and utilities, and a 20% in unexpected items.

The resulting cost per ton was 1.57 US$/ton.

This cost includes the tailing thickener, the pumping systems, the ponds, the pipeline, the seals in galleries, the electrical supplying systems for the tailing and reclaimed water pumps, the instrumentation and the recovered water line, its pumps and tanks.

The following are the most relevant and expensive elements:

P.D. pump	: 25%
Seals in galleries	: 17%
Thickener	: 11%
Electrical equipment	: 6%
Steel pipeline	: 4%
Water recovery pumps	: 2%
Engineering	: 2%
HDPE pipes	: 1%
Steel tanks	: 1%

7. Safety Considerations

In the projected pumping station next to the thickener an emergency pond will be constructed, to receive tailings drainage from the pipeline, as a safety measure if the pumps should stop and also for any other unexpected event. Possibly, if it is required, other emergency ponds will be included in the layout.

The pipe that goes in the surface will be placed at the bottom of an open ditch, to conduit possible spills towards the emergency ponds.

With the same aim, within the mine a small ditch under the pipe will be disposed, to direct the pulp towards adequate spaces located in lower points of the layout.

Acknowledgements

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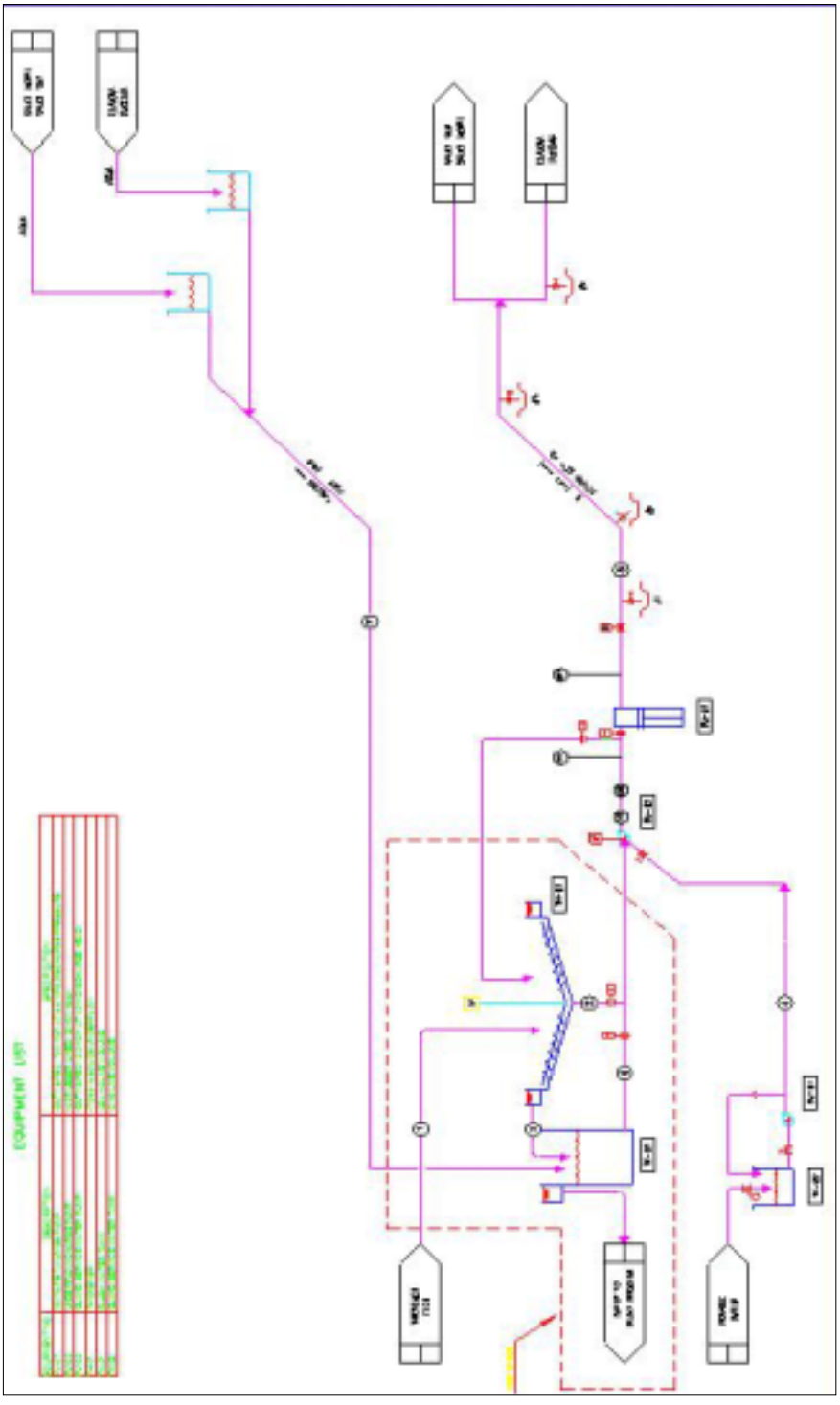
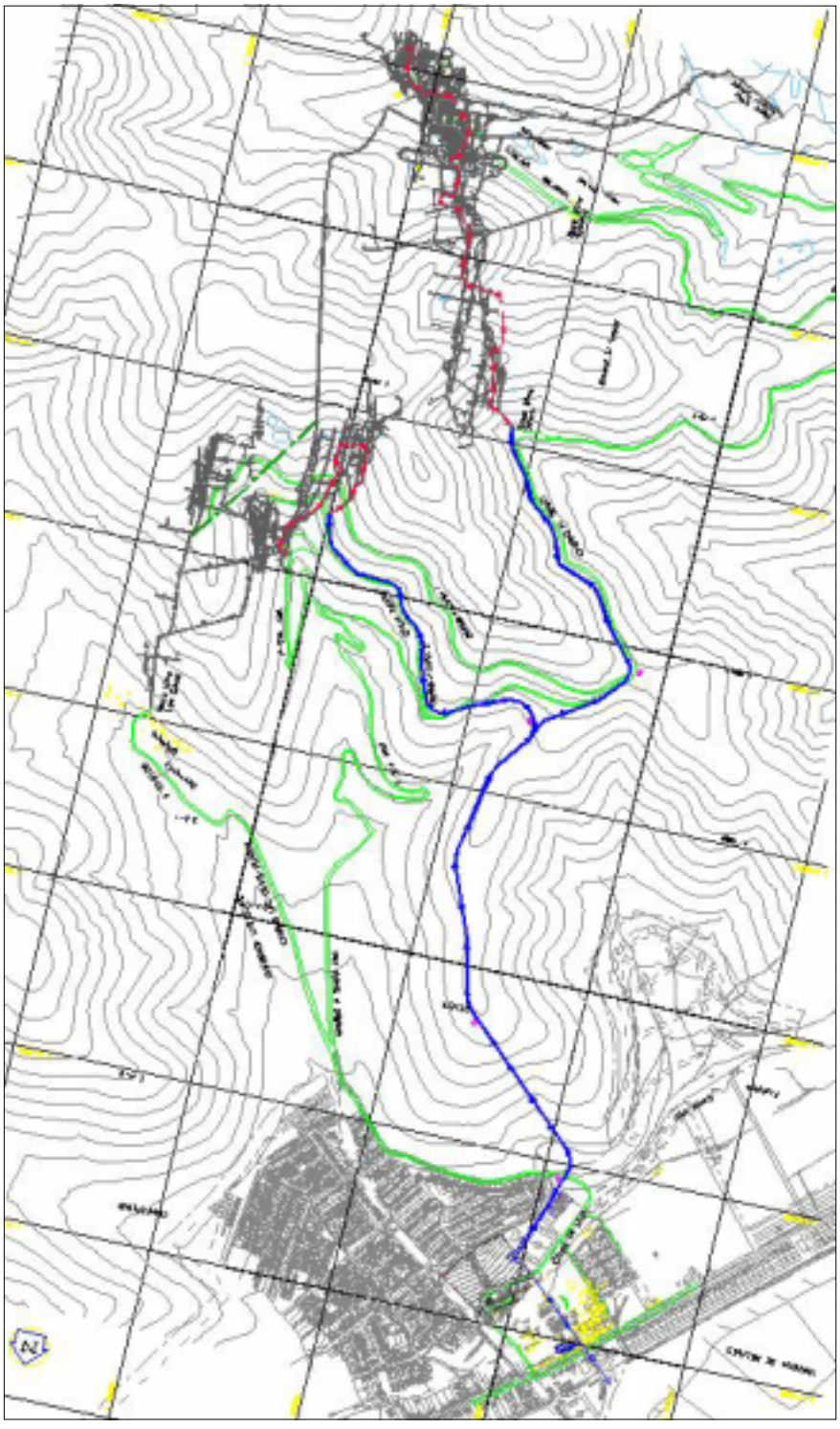
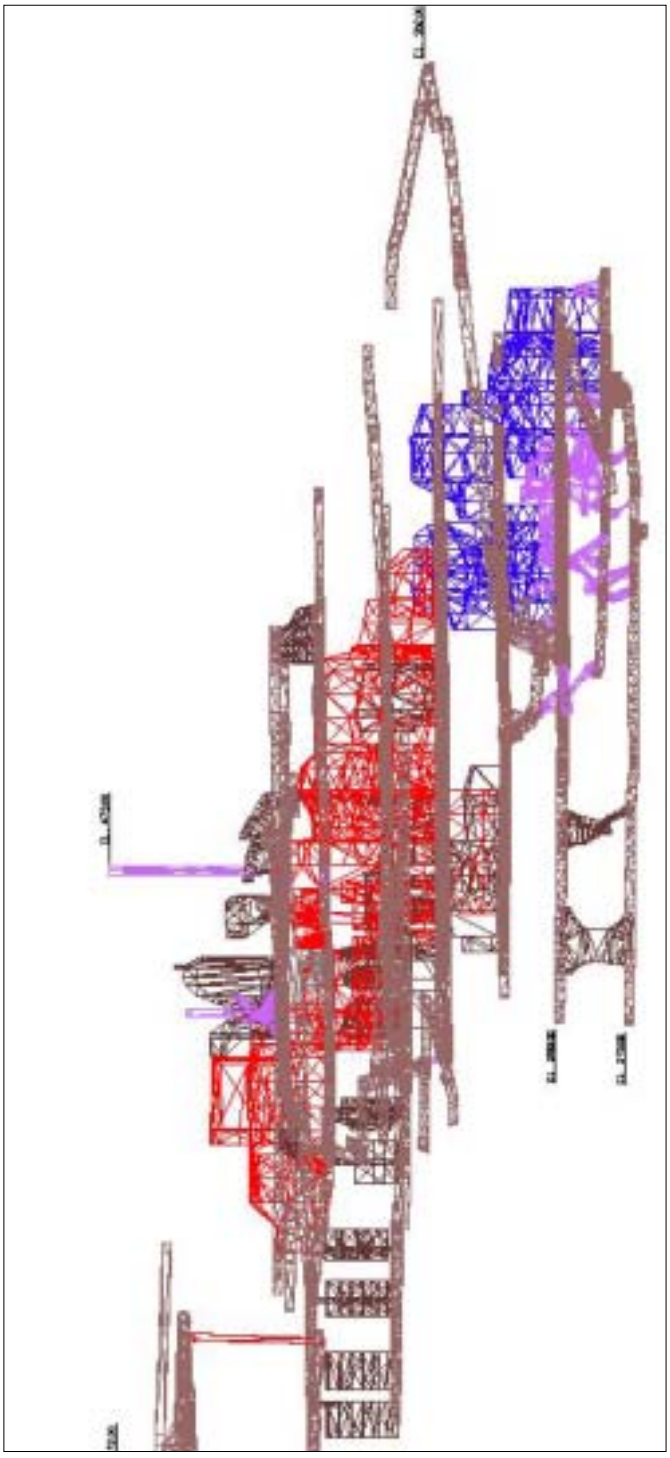


Proposed Flowsheet for the Project.



Topographic plan view of the Project.



South Sauce Mine.