BRASS

1st International Seminar

on Design and Operation of Long-Distance Transportation Pipeline Systems

26th & 27th September 2024

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PIPELINE ROUTE SELECTION

Outline

I. Issues Concerning Route Selection
II. Laboratory Testing
III. Corrosion Protection Considerations
IV. Design Clearances

Issues Concerning Route Selection

I. ISSUES CONCERNING ROUTE SELECTION

In any Long-Distance Pipeline Project endeavor, the most important aspects that affect route selection are the following issues:

1. Capital Cost Expenditure.
2. Operational Difficulties.
3. Community Issues.
4. Design Considerations

1. Capital Cost Expenditure

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Pipeline installation is the most expensive aspect of any pipeline project. Depending on the complexity of the pipeline system, the impact on cost may reach between 65% to 90% of the project cost.

Let us look at a scenario.

Case Scenario:

A 20" - 200 km pipeline with one Centrifugal Pump at the process mine.

Capex estimated installed cost will include major items, such as:

Station	Estimate Cost (MUSD)	
A Pump Station	26	With 3 pumps in Serries
B. Pipeline	410	No intermediate Stations
C. Terminal Station	24	With Filter Plant
TOTAL	460	Installed Cost

1. Capital Cost Expenditure

From the Table above, the percentage impact of the pipeline cost to the total project cost is 89%.

As shown, it is important to consider that the most savings is made through a shorter and optimized pipeline route.

1. Capital Cost Expenditure

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Actual Case Scenario:

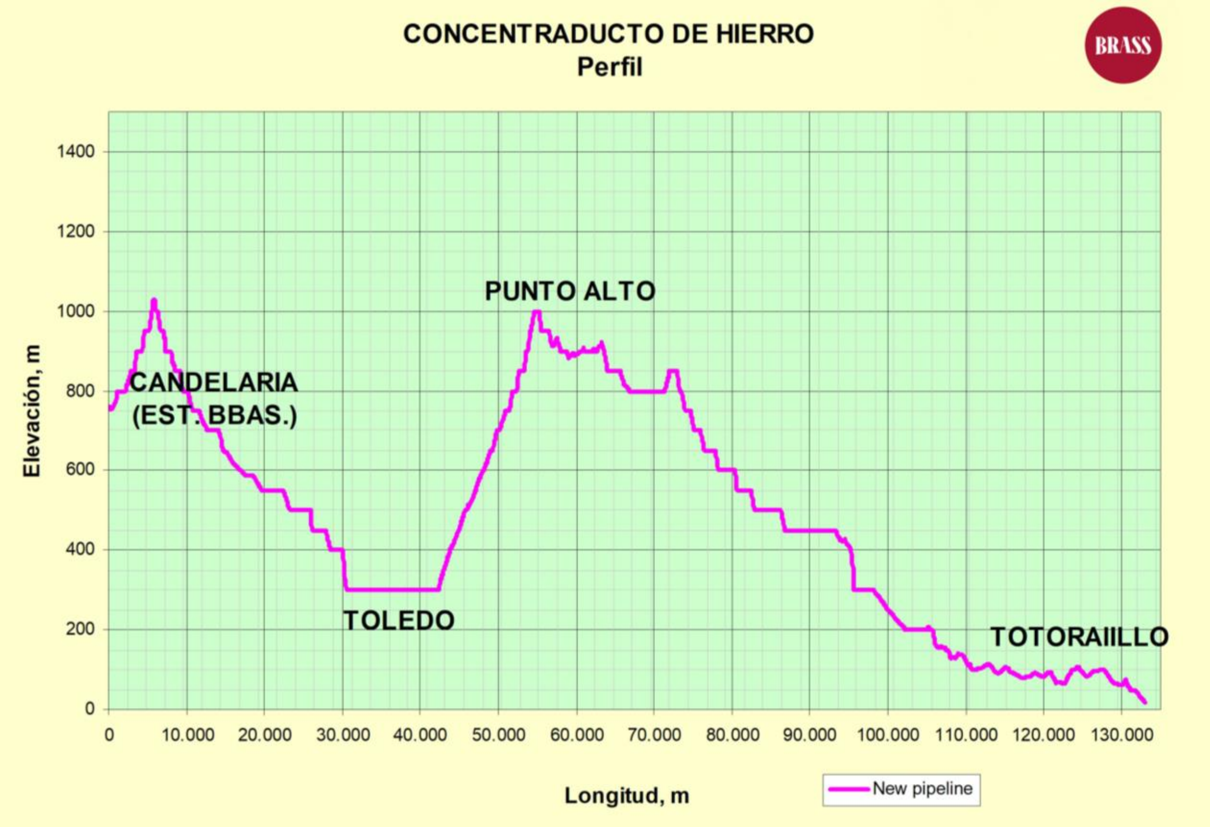

Figure 1: Route following highway ROW

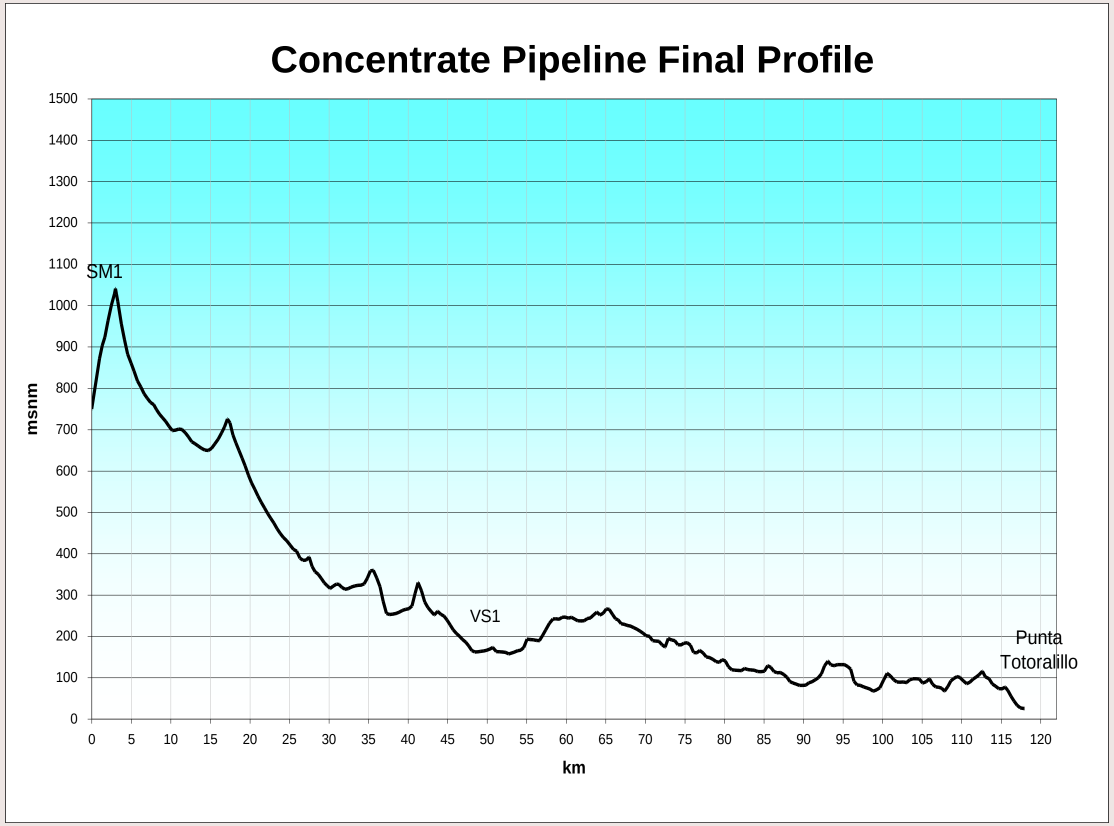

Figure 2: Alternative Route requiring new ROW

1. Capital Cost Expenditure

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The proposed original route utilizes a free ROW along the public highways but passes through towns and populated area. The route has a total pipeline length of roughly 133 km.

The proposed alternative route is more direct and passes through agricultural lands that required new environmental permitting and deals fewer landowners. It does not go through a town or populated areas. The pipeline length is 116 km.

The alternative pipeline route is 17 km shorter, which translates to a construction CAPEX reduction of roughly 20M USD.

Management finds the alternate route proposal worthy and decided to allow a project change.

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2. Operational Difficulties

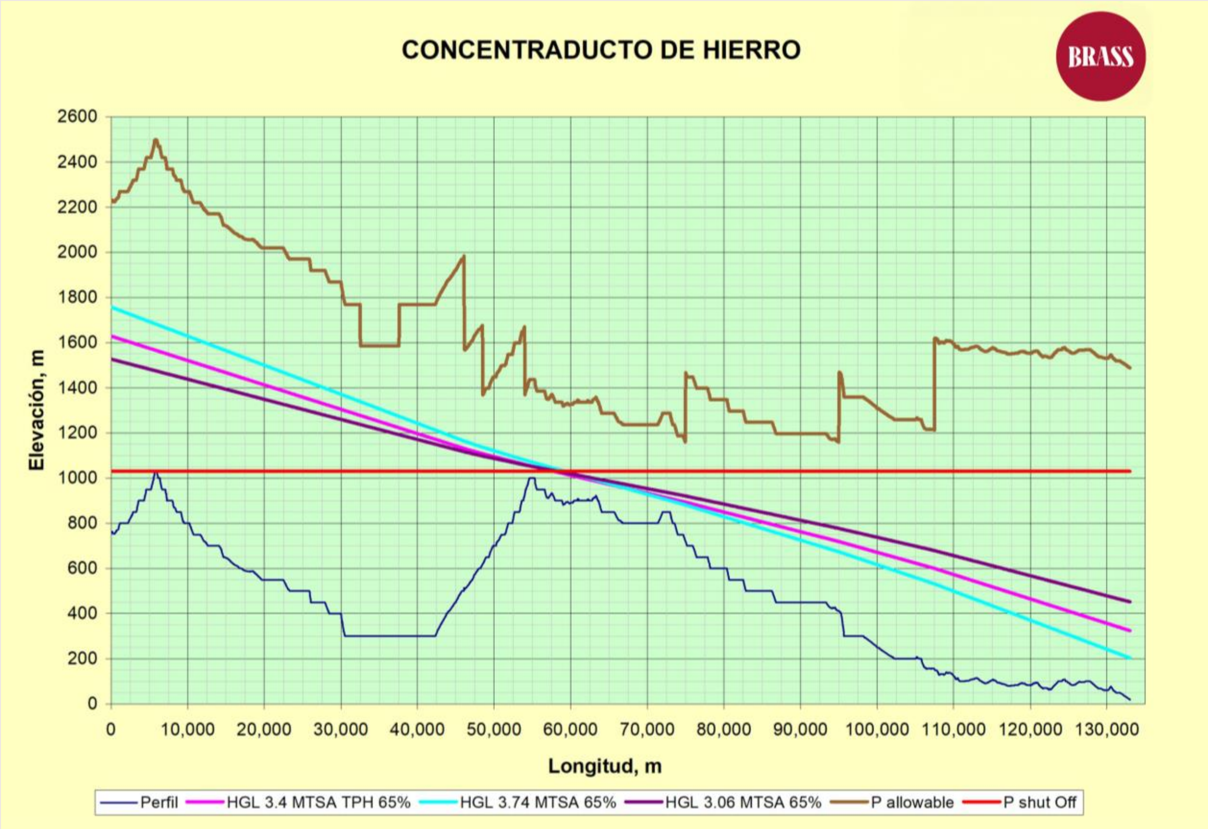

Figure 3: Profile and Gradient Diagram of Original Route.

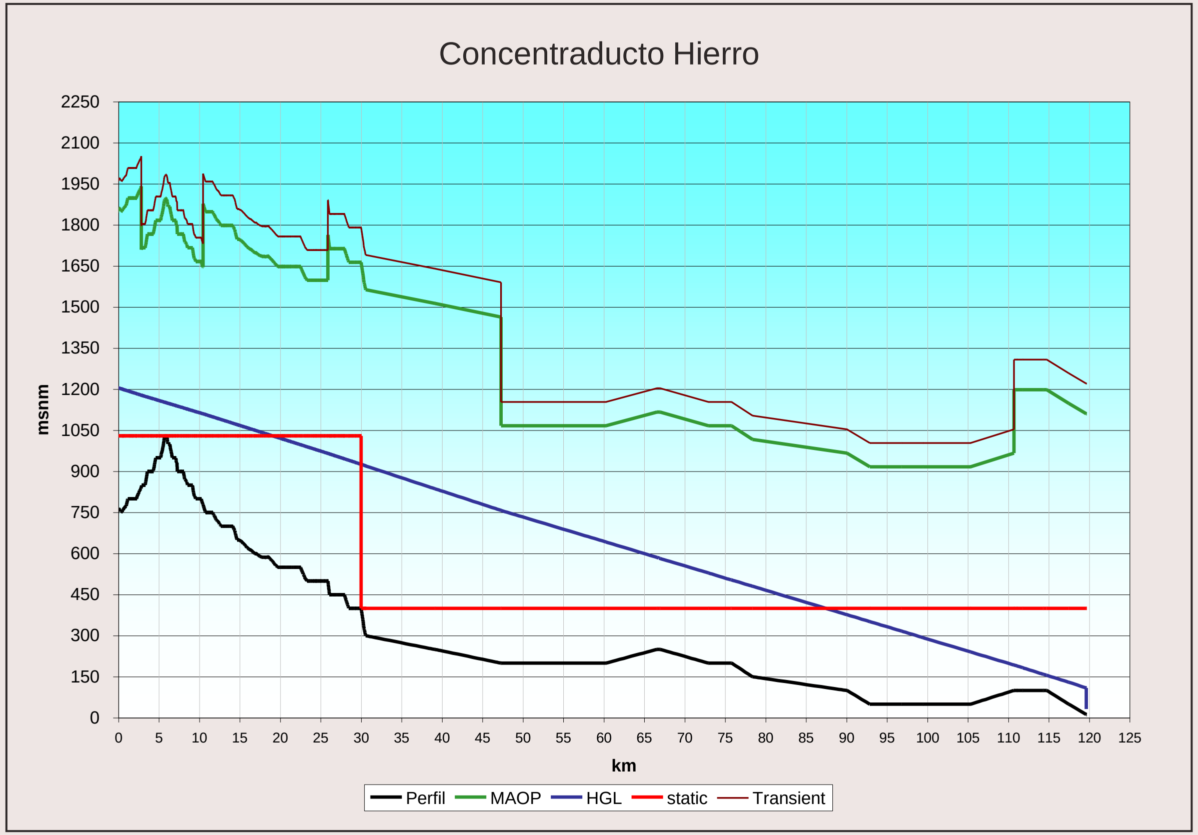

Figure 4: Profile and Gradient Diagram of the Alternative Route

2. Operational Difficulties

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Due to the existence of an intermediate high point (Figure 3), the pumping energy required is at 2,030 kW.

The existence of the low point between km 30 and 40, requires the installation of a Drain Station and a Vent Station at Km 55. This location poses difficulties during re-start to push the settled solids up the steep slope. During concentrate pumping while pushing water, the U-tube effect of the low point would require a higher pump head to get the concentrate over the high point.

The Alternative Route (Figure 4) eliminates the intermediate high point. Pumping energy is reduced to 1,050 kW. The low energy requirement for the Alternative Route reduces operating cost by roughly 1 MW per hour.

3. Community Issues

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The original proposed pipeline route will pass through a community of 200,000 people. The pipeline will interfere with at least 100 commercial installation and an estimated 500 family houses that will cut their access to the public road during construction. The risk of delay due to negotiation with the involved entities and allow construction is significant.

Experience shows that when a leak occurs in populated areas, the affected community may suffer economic and social disruption. The public may file a civil complaint that may block mining operations.

In Brazil, a 30" Iron concentrate pipeline was shutdown for 4 months by the community for a leak occurrence.

In Chile, a community shutdown pumping operations is at an average of 20 days after each pipeline failure accident. In areas that are not densely populated, repairs usually takes within 48 hours.

These are enormous losses that should be quantified and analyzed for the proper location of the pipeline route.

4. Design Considerations

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Important factors that must be considered in the pipeline design are as follows:

i. Slurry Rheology
ii. Ground Profile
iii. Production Variations

4. Design Considerations

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i. Slurry Rheology

a. Dilatant – Viscosity increases with increasing shear rate
b. Rheopectic – Viscosity increases with continuous application of shear rate (time dependent).
c. Pseudoplastic – Inverse of Dilatant. With vigorous shear, viscosity goes down.
d. Thixotropic – Inverse of rheopectic. A reduction of viscosity with the continuous application of shear rate but returns to its original state overtime upon removal of shear.

4. Design Considerations

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How are these important?

If your slurry property exhibits rheopectic behavior, you would want to avoid the use of Centrifugal pumps in the system. The slurry passing through series of pumps will shear the slurry and cause its viscosity to rise and thus increase pipeline pressures which will eventually cause a reduction in flow rate. Reduction in flow rate will produce lower line velocities that may be lower than slurry’s deposition velocity. A continuous operation under this condition can eventually cause plugging of the pipeline.

4. Design Considerations

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If pumping uses a PD Pump, slurry is not sheared and will not change its rheological properties.

However, when a slack flow occurs during low flow operation, the velocity flow in the slack point will increase, and thus shearing the slurry.

If the slurry demonstrates a Dilatant behavior, the viscosity at this point will increase causing an eventual increase in pipeline pressures.

4. Design Considerations

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ii. Ground Profile

One other aspect that should be considered in a long-distance pipeline route is the vertical slope of the pipeline. Ideally, from the mine the slope should keep a negative or downward trajectory towards the terminal. A negative slope allows transport by gravity that may require minimal or no additional pump head.

4. Design Considerations

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ii. Ground Profile

The recommended average pipeline slope is 9%. However, a maximum of 16% slope may be allowed but must be followed by a gradually decreasing slope and at any point must not be followed by a positive slope.

The purpose of the slope restrictions are 2-fold. First, it eases re-start after a long-term shutdown. Secondly, it avoids accumulation of solids at low points that could increase hydraulic losses that translates to higher pumping head requirement.

4. Design Considerations

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iii. **Production Variation**

Proper consideration should be taken for the variations in mine production in a monthly and annual basis. This would ensure that the selected diameter of the pipe is optimum, so that it will allow the most efficient transport velocity and at the same time avoid solid settling at low flow.

Pipeline should be designed most efficient when delivering nominal capacity. This is the production point at which pipeline will operate 80% to 90% of the year. However, at this point maximum pipeline capacity may be from 20% to 40% more. A balance should be made between reduction of CAPEX versus maximum capacity.

II. LABORATORY TESTING

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In the design of a long-distance slurry pipeline, the information of whether it is iron ore, copper, zinc, lead, coal or fly ash is irrelevant. The Pipeline Designer takes whatever sample he receives and analyze the material to define its optimum transport properties. These includes the following tests, as a minimum:

1. Rheological Properties of Slurry, sheared and unsheared
2. Solids Specific Gravity
3. Grind Size (PSD or particle size distribution)
4. Angle of Slide and Angle of Repose

The client must provide information such as target slurry concentration range, process temperature, and process target pH. These information will be simulated during sample testing.

III. CORROSION PROTECTION

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Corrosion protection provides additional armor for the protection of the pipe. It does not, however, guarantee a 100% security that the pipeline will not leak during its life span without the proper preventive maintenance.

In a long-distance pipeline, it is important to determine if the process water and slurry are corrosive. Based on this test, the designer will determine the proper protection needed for the slurry pipeline. In most cases, Iron Concentrate slurry is normally non-corrosive, but free oxygen entrained in the process or slurry will produce corrosion in the first kilometer section of the pipeline.

IV. DESIGN CLEARANCES

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A proper pipeline design should consider eventual changes in the characteristics of the pipeline appurtenances and material. These includes:

1. Increased pipeline roughness
   a. Corrosion pitting
   b. Internal surface wear due to erosion
   c. Incrustation buildup
   d. Accumulated coarse materials at low points

2. Changes in rheological properties
   a. Increased viscosity
   b. Increase pH
   c. Decreasing process temperature

3. External surface corrosion

THANK YOU FOR YOUR ATTENTION