

Due-Diligence of a Small Hydropower Plant

Case Study Peru HPP

Training Workshop “EBRD: Financing Small Hydropower Plants in Ukraine”

Kiev, 05.10.2011



CONSULTING & IT



ENERGY



ENVIRONMENT



WATER & INFRASTRUCTURE

Program



Due Diligence of a Small Hydropower Plant,
Case Study SPP Peru



Economical Optimization of Installed Capacity of a Small Hydropower Plant
Case Study Gegharot SHPP, Armenia



Chances and Risks from Pre-Feasibility Study to Operation



Questions and Discussions

Program



Due Diligence of a Small Hydropower Plant,
Case Study Peru HPP



Economical Optimization of Installed Capacity of a Small Hydropower Plant
Case Study Gegharot SHPP, Armenia



Chances and Risks from Identification to Operation



Questions and Discussions

Important issues as part of a Due Diligence



Reliability of Basic Design Parameters, such as Topography, Geology, Hydrology

Careful recalculation of hydrological analysis

Detailed calculation of power and energy calculations

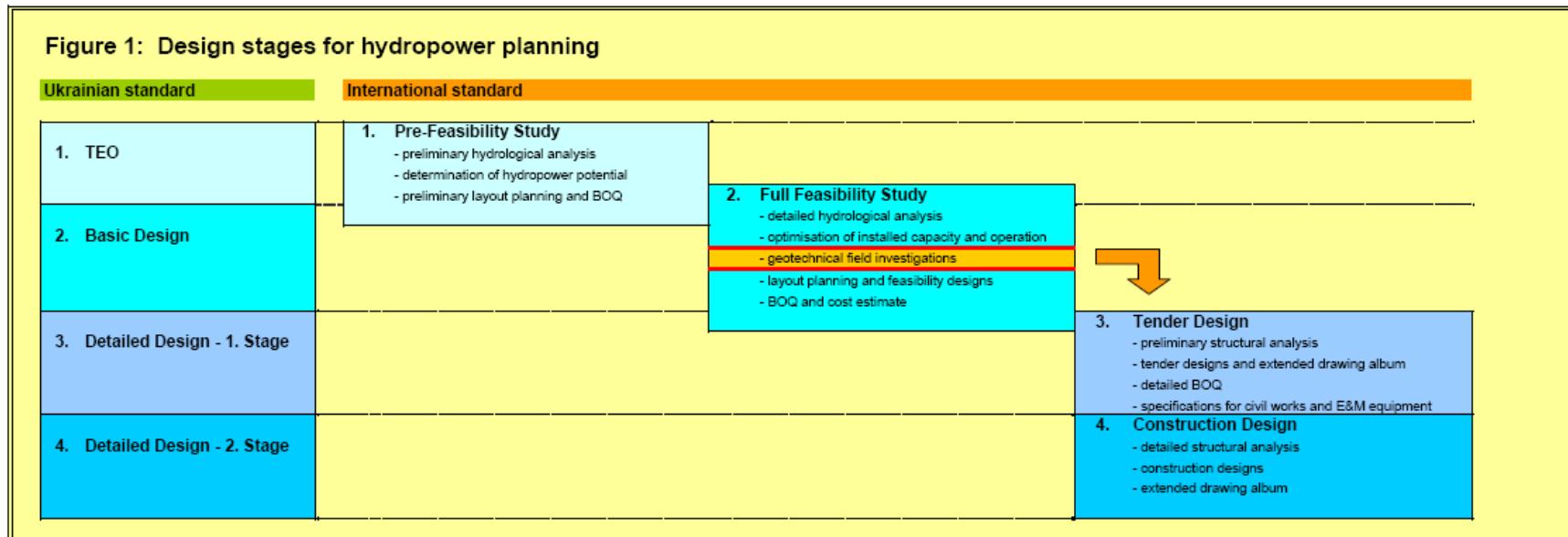
Review of Layout and technical design, assessment of optimization of design discharge

Detailed analysis of cost based on Bill of quantities and unit rates

Approval of environmental and social impact assessments

Financial Feasibility of the project

Comparison of Design Stages



Project Overview

Main Features

- **Type of plant:** RoR
- **Installed capacity:** 18,6 MW
- **Annual energy:** 108,9 GWh
- **Gross Head:** 110,8 m
- **Net Head:** 106,8 m
- **Design discharge:** 20 m³/s
- **Dam Height:** 19,5 m
- **Dam Length:** 63 m
- **Total storage vol.:** 84.400 m³
- **Type of turbine:** Francis
- **No. of units:** 2
- **Tunnel:** app. 2400 m
- **Penstock:** app. 230 m

Main results of the technical pre-due diligence

Available
Documentation

- The documentation made available is listed below:
 - Topographic Survey (September 2008)
 - Hydrological analysis (December 2008)
 - Geological and Geotechnical Appraisal (February 2009)
 - Geophysical Survey – Seismic Refraction (April 2009)
 - Geological & Geotechnical Report (June 2009)
 - Basic Design – Final Report – Analysis of Alternatives (August 2009)
 - Basic design of the Plant (November 2009)
 - Seismic Hazard Analysis (2010)

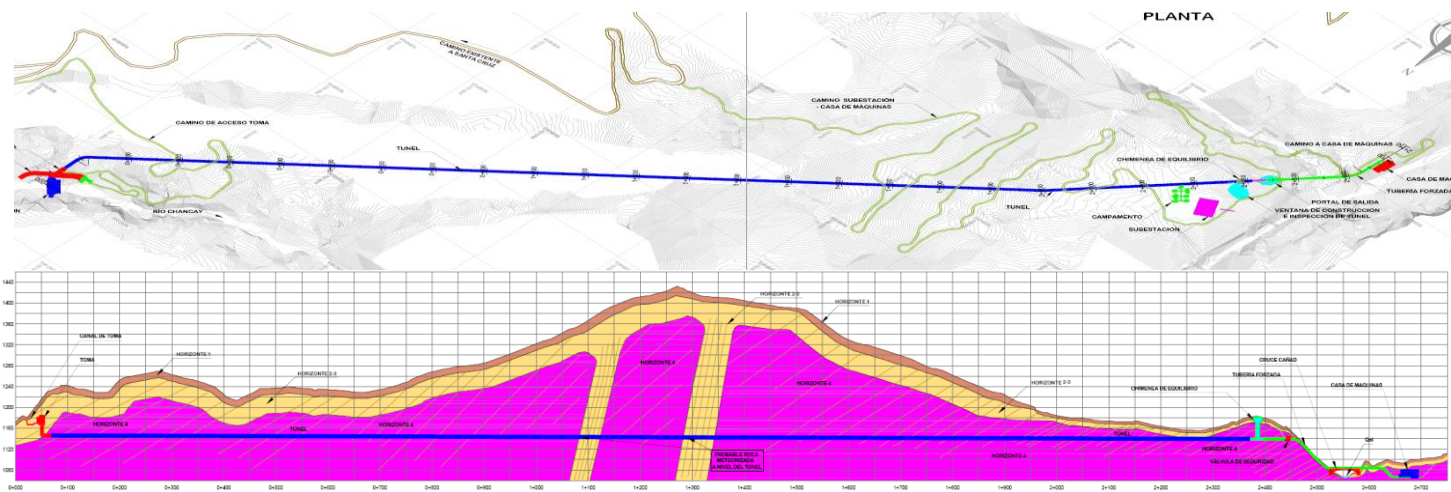
Layout
&
Design

- Run of river scheme
- Head Works constituted of a concrete weir with free flow discharge, provided also of gated bottom outlet. Elevation of dam crest 1177,50 m.a.s.l.
- Approach channel on the left side of the river, which also operates as desander. During construction used as diversion channel
- Shaft Intake on the left margin of the river, aside of the approach channel
- 2,4 km long pressurized tunnel, width 3,6 m; height 3,8 m.
- Surge tank, height 40,50 m, diameter 16 m on the top and 7m at shaft.
- Penstock on a 1V:1H slope, diameter 2,30 m, Penstock Bridge 53 m long
- After the slope the penstock is carried on a bridge across a tributary to the powerhouse.
- Surface powerhouse, located on the left margin of the Chancay river
- According to the legal framework, hydropower projects below 20 MW do not require an EIA in Peru. Projects with international financing however require an EIA.

Main results of the technical pre-due diligence

Technical Aspects

- Hydrology was checked and approved.
- The design of the intake with attached desander will most probably not work. Modifications would be necessary, e.g. shifting the location of the dam further upstream.
- A drilling campaign was ongoing, and core samples of the already performed boreholes were also made available at site for inspection.
- The global geological situation was explained by the site geologist and some detailed aspects were discussed.
- The zone presents an overburden of soil, followed by a thick strata of sedimentary conglomerate cemented by siliceous material. Approximately at the river level, outcrops of very hard and competent rock can be found. The only exception to the above defined strata is the area of the power house which is formed by weak and erodible material until the rock base at river level.
- **The accurate geological information, in regard to elevation and thickness of the different strata, needs to be processed and is not yet available. The report of the present campaign is expected to be issued within two to three weeks. (End of April 2010)**

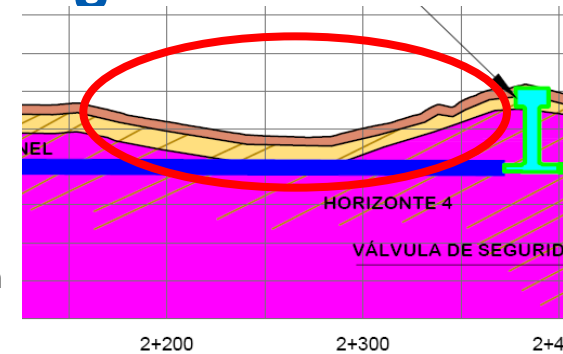


Main results of the technical pre-due diligence

Technical Aspects

Tunnel

- Right upstream of the surge tank, the topography shows a depression that leaves the tunnel with little covering (approx. 15 m). The boreholes in that zone show presence in depth of highly weathered soil-like material.
- It is recommended to further investigate that area and evaluate modifications to the tunnel design.
- **A Consultant** has already commenced some evaluation of possible alternatives to overcome this problem.
- Classification of Rock comprises 4 Rock Classes, 5 would be more adequate.
- Excavation Progress per day considered to be realistic
- Unit Prices for Excavation for Rock Classes I-II probably too low, for Rock Classes III-IV adequate.
- In geological Classification of Rock no transition between Class II and IV considered. Class III in between necessary, probably leading to higher costs for tunnel excavation.
- Section between surge tank and penstock considered to be Rock Class II. This appears rather unlikely and it is recommended to set up Class III or IV.
- Distribution of Rock Classes along the tunnel routing: 75% Class II, 16% Class III, 9% Class IV. 75% Class II is considered to be too optimistic, 50% more realistic, probably leading to higher costs.
- To counteract delays in excavation progress probably further addits have to be established.

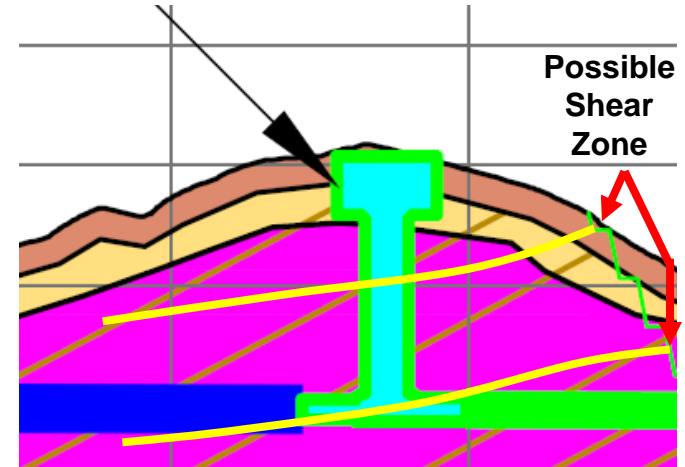


Main results of the technical pre-due diligence

Technical Aspects

Surge Tank

- Drillings have been executed at the surge tank location, up to a depth of approximately 50 m below natural field.
- Results from the drilling show that the hill where the surge tank is planned is constituted by the previously mentioned sedimentary conglomerate.
- The upper part of the conglomerate shows low fragmentation with RQD values around 80%. The quality of the rock decreases in depth where the samples show RQD values between 0% and 30%.
- At the end of the drilling, the quality of the rock increases again.
- Possible explanation for this outcome is the presence of a fault near the hill, which may have shifted resulting on a shear zone.
- The fragmentation and shearing of the rock will complicate the excavation of the surge tank.
- Measures to stabilize the rock surrounding the surge tank could become necessary.
- It is highly recommended to further analyse the activity of the fault, in order to exclude potential future activity



Main results of the technical pre-due diligence

Technical Aspects

Power House

- The power house location is planned on the left margin of **the river**, approximately in the position indicated below.
- Drillings on the area, as well as superficial geological appraisal, show an important mass of weak and erodible material. The material is stable when dry, but as the cementing matrix is mostly clay, it will behave practically as a high density fluid in presence of groundwater coming from rainfall. Big size waterways would channel the rain water, producing important erosion.
- The necessary excavation to reach the foundation for the power house, will pose even more strain on that soil mass, making the entire power house location very vulnerable to landslides.
- Deep water ways, eroded in the weak material
- The location selected for the Power House in the Basic design, in light of the findings of the drilling campaign is very vulnerable to landslides during the rainy season, making the location practically unfeasible.
- An alternative location needs to be studied. At first sight, the location at the foot of the penstock hill seems to be the most convenient one.
- **The Consultant** has already identified the problem, has carried out drillings at the foot of the slope and is evaluating alternatives to overcome the diverse geological problems.



Main results of the technical pre-due diligence

Cost Estimation

- Cost Estimate in Basic Design did not contain contingencies, Consultant applied 10% for present project stage
- Unit Rates for Excavation of Tunnel (Rock Class I-II) too low, Consultant applied 20% contingencies for Excavation and Construction of Tunnel and Surge Tank
- Remaining Unit Rates for Construction are in line with benchmarks
- Costs for both Turbines incl. E&M Equipment in Basic Design amount to approx. 7 M US \$, compared to 6,5 M US \$ as benchmark for *one* Turbine incl. E&M Equipment. Consultant calculated with 14 M US \$ adding 5% contingencies for *both* Turbines incl. E&M Equipment
- Investment Costs amount to approx. 38,5 M US \$

Financial Analysis

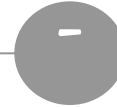
- Assumptions for Financial Analysis:
 - Generated Energy (validated): 108,9 GWh/a
 - Feed-in Tariff: 4,8 US-Cent/kWh
 - Capacity Tariff: 4,67 US \$/kW
 - O&M Expenses: 2 % of revenues + 2 US \$/MWh
 - No Taxes
 - No Salaries
 - Lifetime: 30 years
 - Discount Rate: 10 %
 - Contingencies: 10 %
- Results of Financial Analysis:
 - B.C. Ratio: 1,22
 - IRR: 12,46 %
 - Cost/kWh: 0,045 US \$

Chances and Risks



Chances

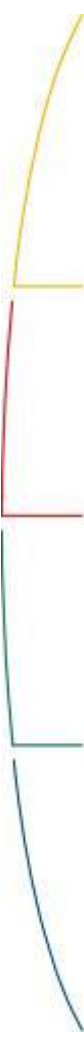
- The project includes certain risks, which appear to be manageable.
- At present geological investigations are ongoing which help lowering the risks related to geology. Results are yet pending.
- Changes in design and location of structures are yet possible to mitigate identified risks as far as possible.
- A financial analysis showed that even with higher investment costs and 10% contingencies applied the project remains feasible.
- The indicative IRR amounts to 12,5% and specific costs are in the range of approx. 2100 US \$/kW and 4,5 US-\$ cent/kWh, which is considered as financially feasible.



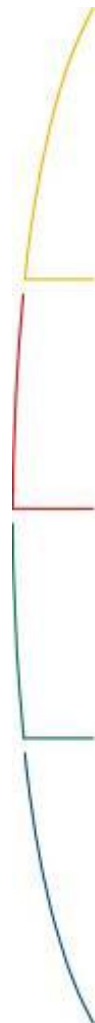
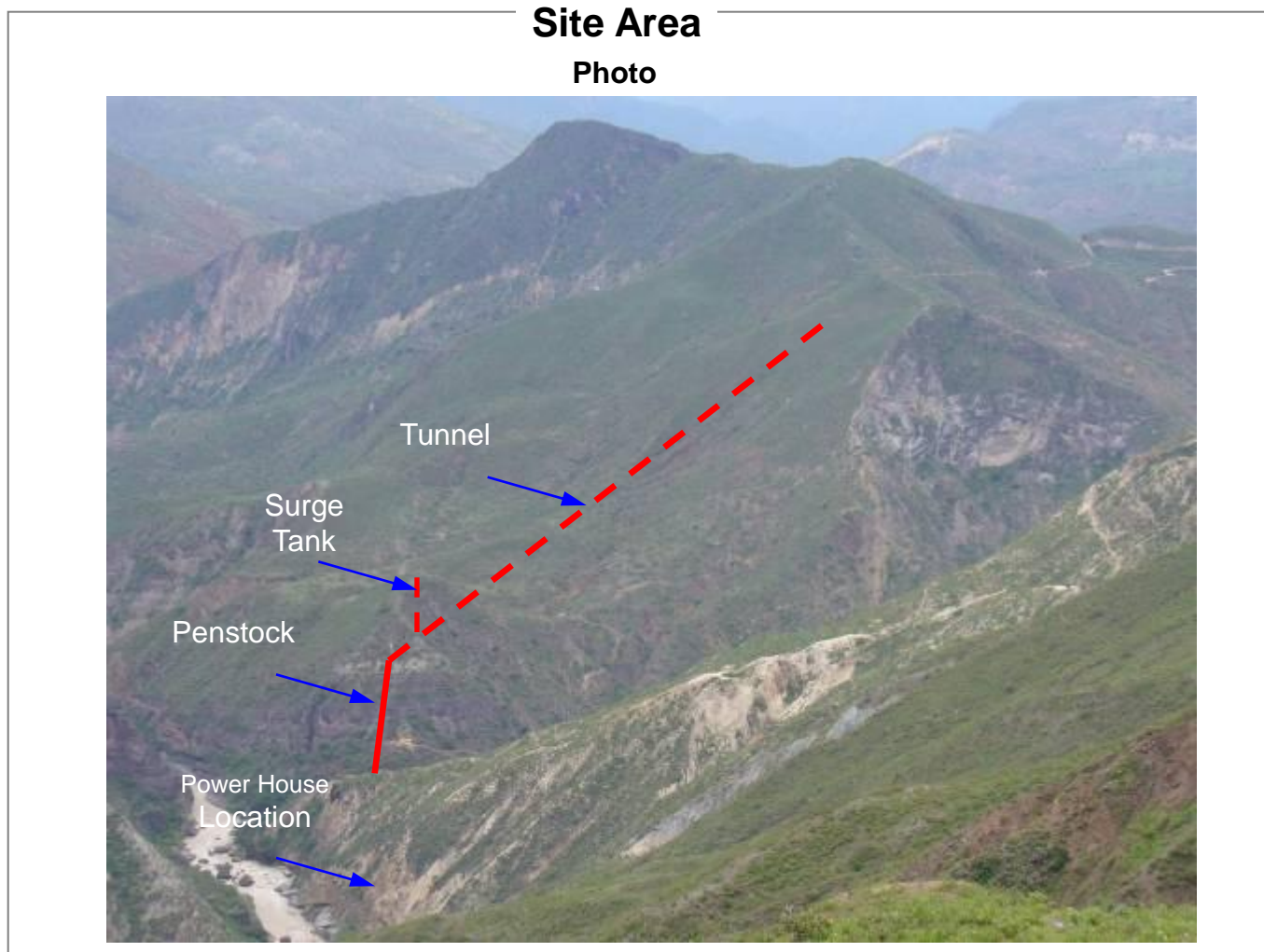
Risks

- Investment Costs higher than anticipated in Basic Design
- Powerhouse threatened by landslides
- Partly weathered strata above tunnel lining
- Bad rock conditions
- Possible shear zone next to surge tank

Backup

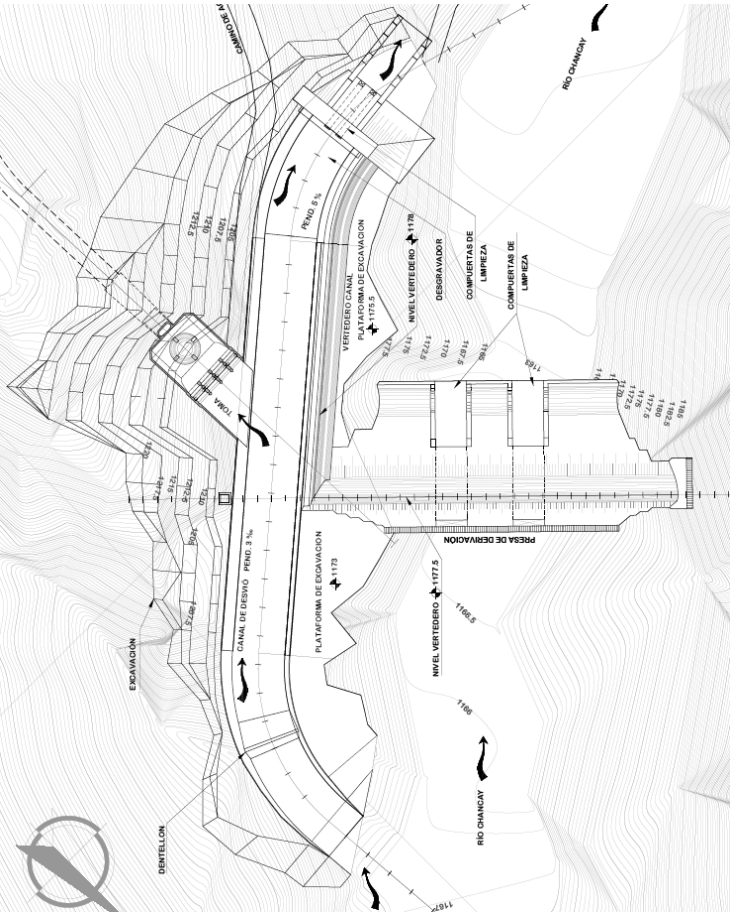


Pictures of Project

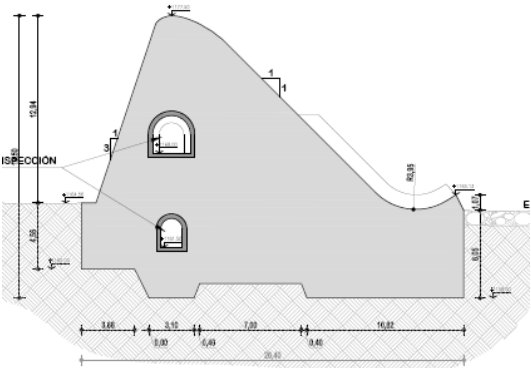


Head Works

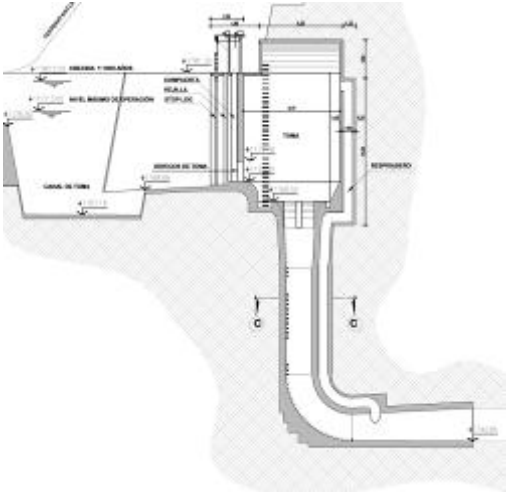
Layout &
 Design



Plan View of Dam, Channel and Intake



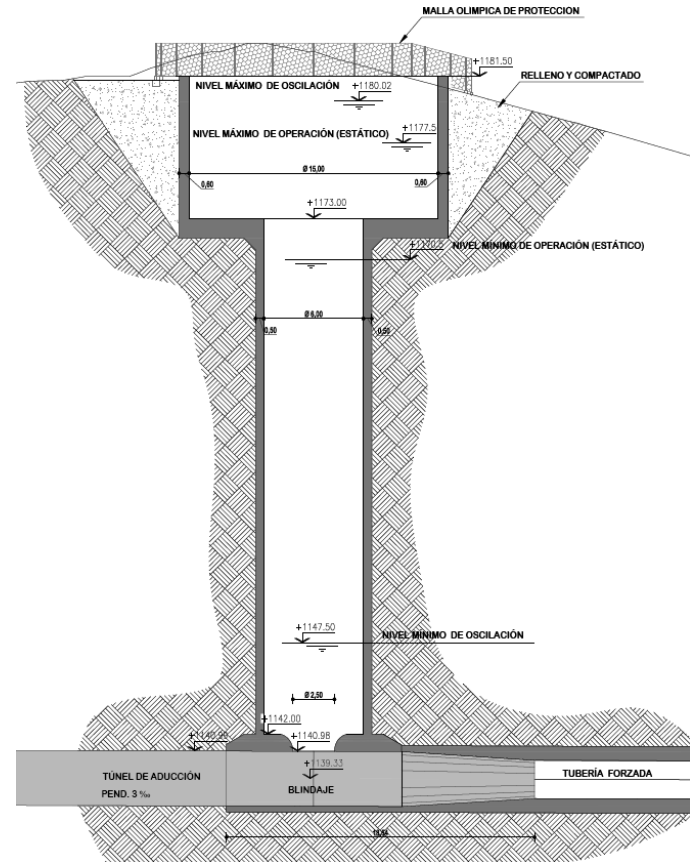
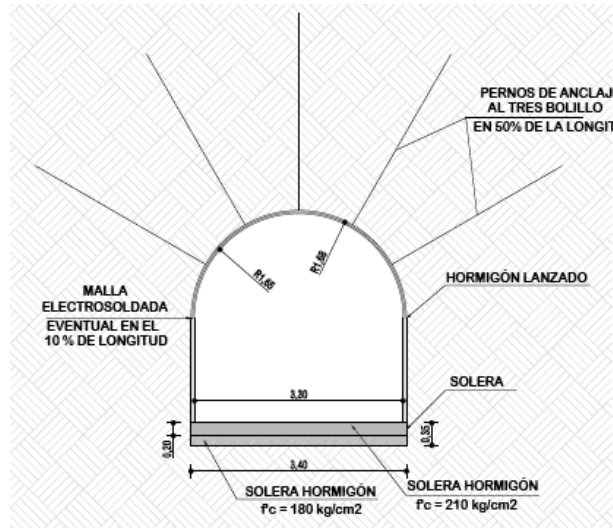
Section of the Dam



Section of the Intake

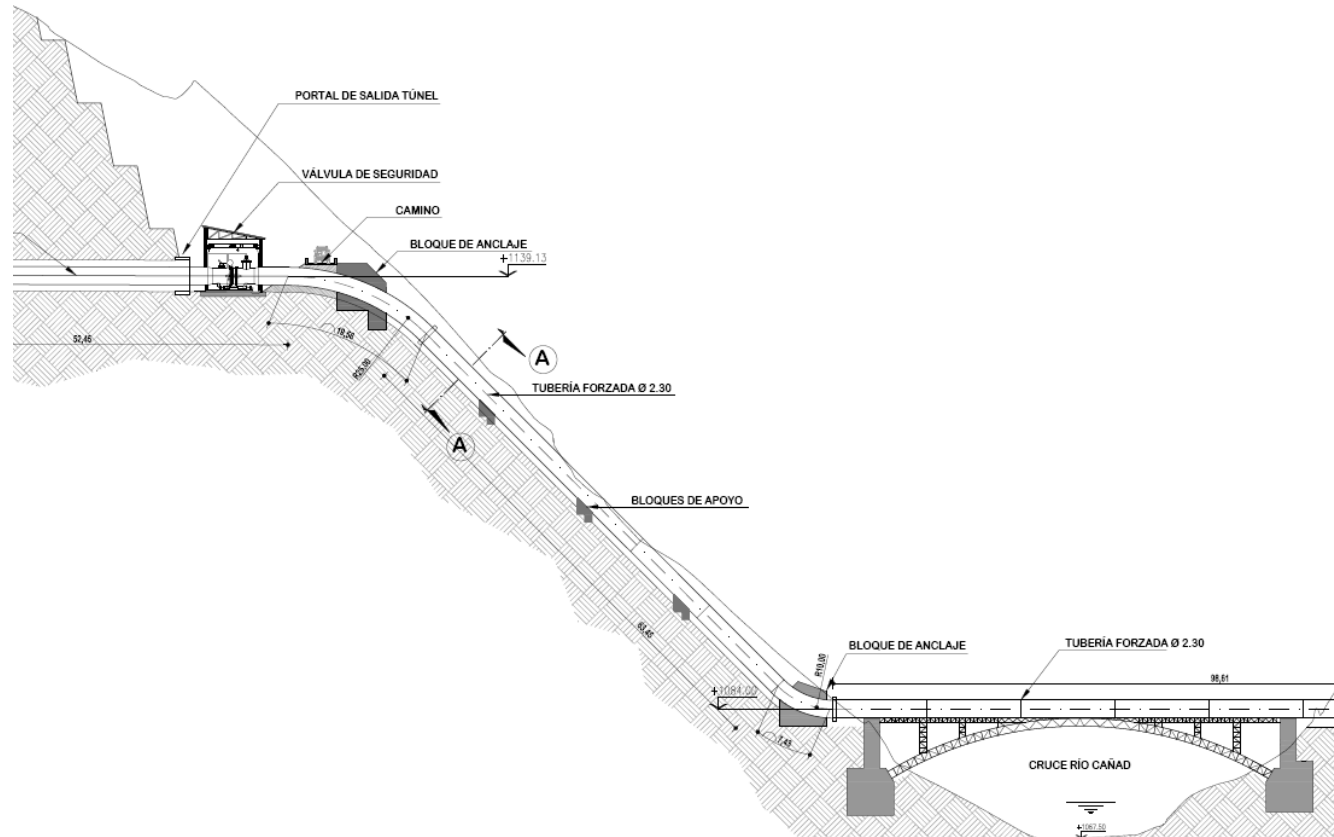
Tunnel Section and Surge Tank

Layout
&
Design



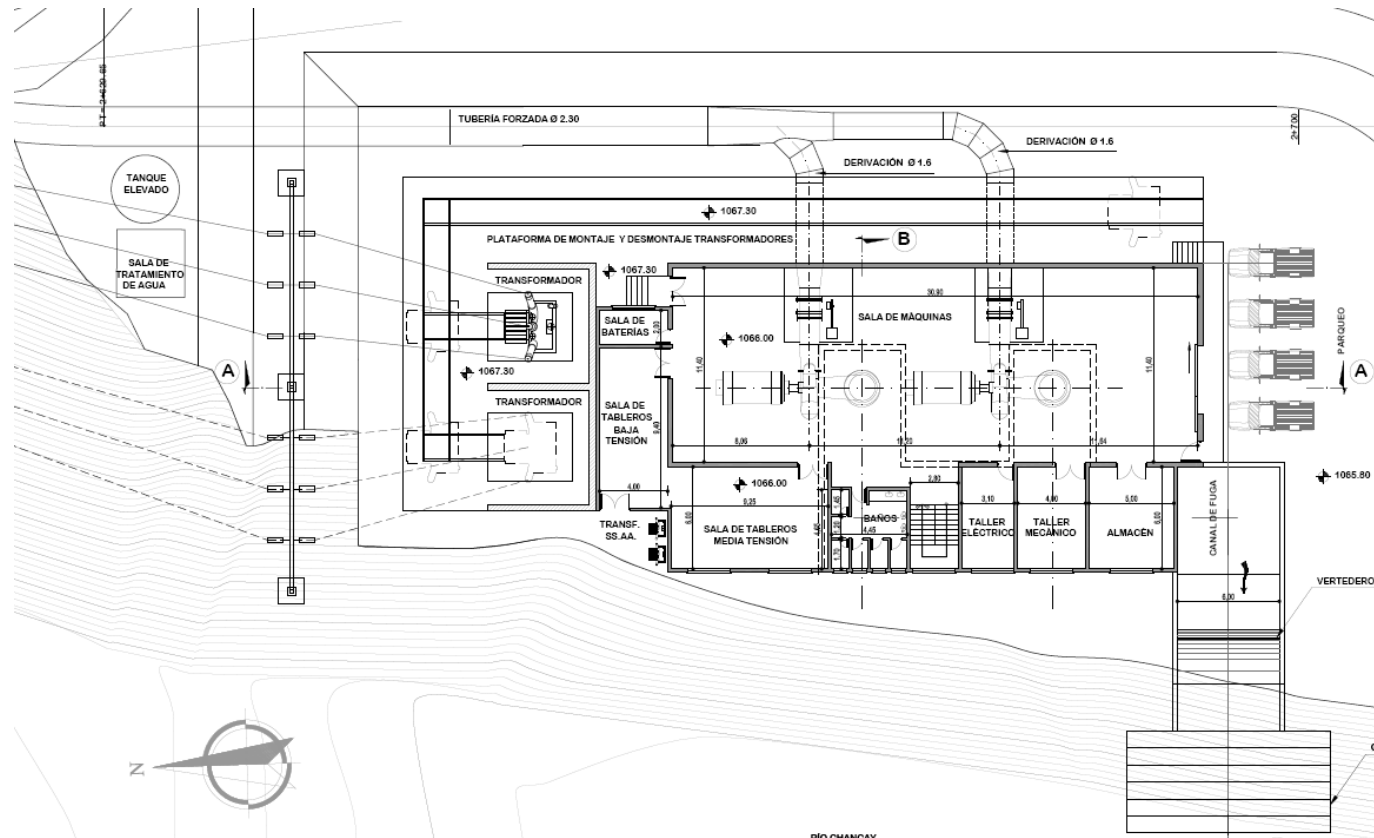
Penstock, Valve Chamber and Bridge

Layout
&
Design



Powerhouse

Layout
&
Design



Outcrops in River Bed

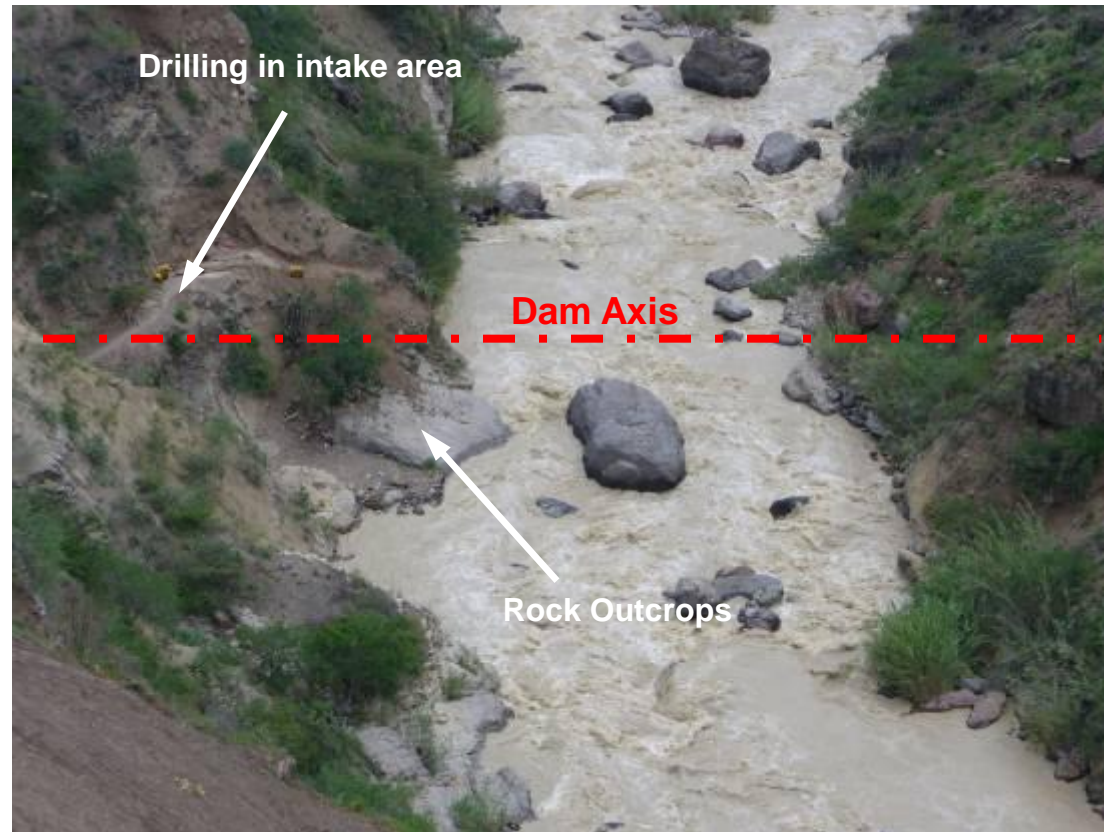
Technical
Aspects

- Along the river, outcrops of very competent rock are visualized close to the river bed



Dam and Intake Area

Technical Aspects

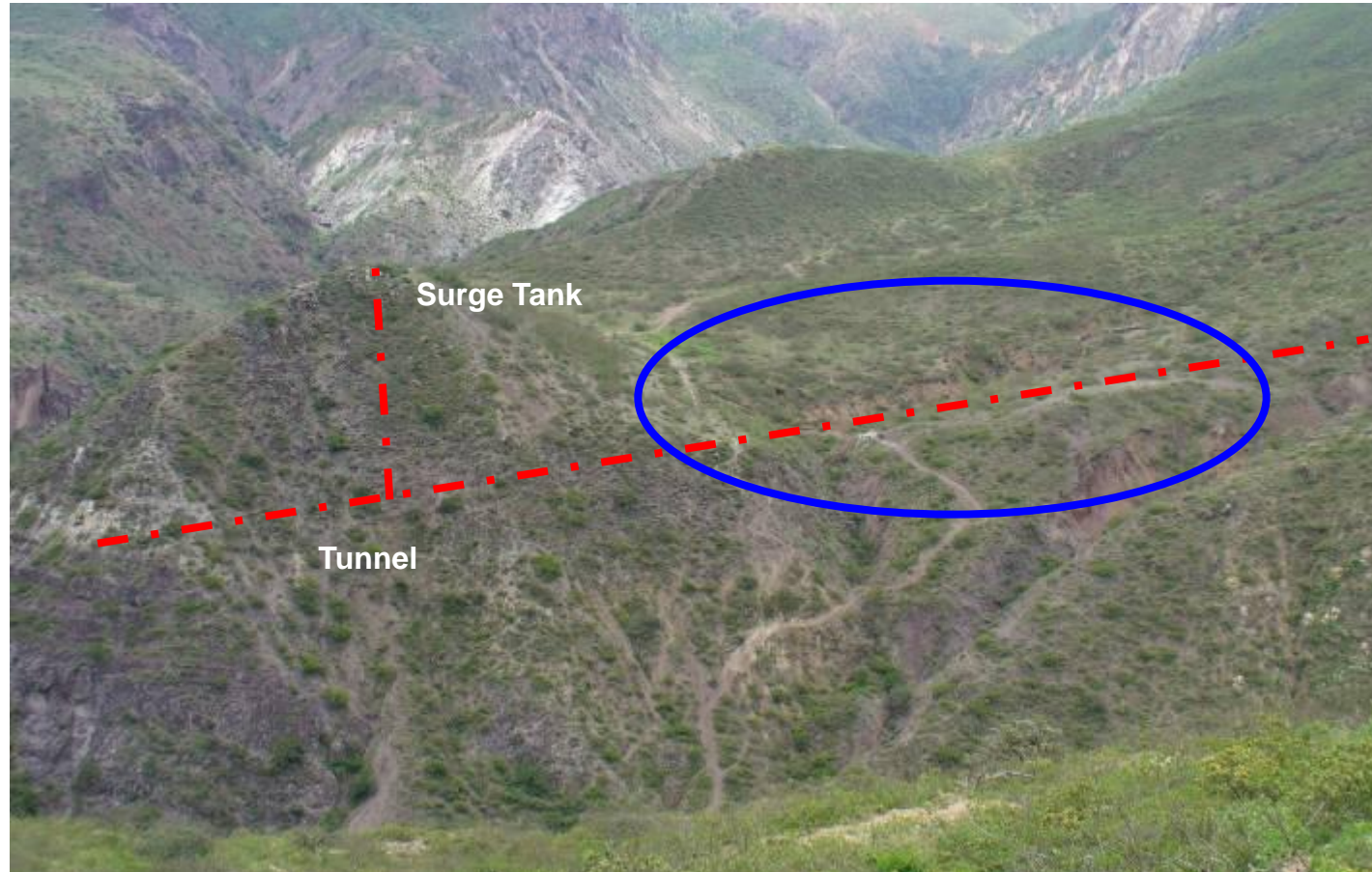


- According to boreholes carried out on both sides of the river, there seem to be competent rock in the location of the dam and intake.

Surge Tank

Technical Aspects

- View of the topographical Depression, upstream of Surge Tank



Drilling at Powerhouse Location

Technical Aspects

- View of the drilling rigs and the samples on the Power House location



- Cutting samples of the drilling

Conglomerate

Technical Aspects

- The conglomerate, when fresh or slightly weathered, presents good conditions for foundation



- Vertical formation of conglomerate



- Close view to the structure of the sedimentary conglomerate