Hydro Scheme Alto Maipo, Chile

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Abstract: The Alto Maipo hydro scheme project consists of the design, construction, financing, operation, management and maintenance (DBFOM: "design-build-finance-operate-maintenance" model) of two underground hydropower plants in the course of the river connected in series with a total designed capacity of 531 MW. The contract includes the design and construction of tunnels, caverns for engine rooms, massive earthworks, other construction works and the installation of electromechanical and hydrotechnical equipment of the hydroelectric power plant. Several tunnels and shafts with a total length of approximately 74 km will be built, of which approximately 40 km will be drilled using TBM rotary boring machines, and the other tunnels will be constructed using the conventional method of tunnel construction by blasting supporting (according to the NATM method = "New Austrian Tunnelling Method "). Also, about 1.86 km of shafts will be constructed using the method ("raise boring" (RBM)) and the method of lowering shafts ("shaft sinking").

INTRODUCTION

The Alto Maipo Hydroelectric Plant (Projecto Hydroelectrico Alto Maipo - PHAM) is located 50 km southeast of the city of Santiago, in the municipality of San José de Maipo, Cordillera Province, Region Metropolitana, in the upper basin of the Maipo River. The project includes the construction of two new underground hydropower plants: Alfalfal II (capacity 264 MW) and Las Lajas (267 MW), which are connected in series and should provide a power of 531 MW. The project is a continuation of the first part of the project with the hydroelectric plants Alfalfal I (178 MW from 1991) and Las Maitenes (30.8 MW from 1924), which were previously built and put into operation on the Colorado River. [1].

Chile's energy scheme and energy production are heavily dependent on thermoelectric power (of which 63% is based on imported fossil fuels, coal and gas), 34% on hydroelectric power and 3% on non-conventional renewable energy sources NCRE ("Non-Conventional-Renewable-Energy") according to statistics at the end of 2012. The Interamerican Development Bank is currently supporting the efforts of the Chilean government to increase the introduction of NCRE, especially solar energy sources. Behind these long-term efforts is the intention to meet the consumption of about 5% of the total energy through large hydroelectric plants, which are located in the rivers, and which are still vital for the energy needs of Chile in the foreseeable future. The current project aims to increase the share of hydropower in Chile and reduce the country's dependence on thermal energy production and the use of fossil fuels such as coal, oil and gas.

The PHAM project is an underground project in which international contractors will excavate more than 75 km of tunnels using TBM mechanical excavation and conventional construction methods in the high basin of the Maipo River and up to 2,500 m above sea level in the Chilean Andes. Mechanical excavation will be carried out using 3 TBM machines with an overburden of up to 1500 m as part of the Alto Maipo hydroelectric project in a length of about 50 km. The second part of the tunnel, about 25 km long, will be excavated by drill-and-blast or by excavation with an excavator. In addition to the tunnel, the project also has 2 underground hydroelectric power plants that were built as massive caverns for hydrotechnical equipment with turbines that together will be able to produce 531 MW of electricity to supply the electrical network of the Central Energy System (SIC).

The members of the investment consortium and the investment amount change over time. At the beginning of the project, when the first performance contracts were concluded with contractors in November 2012, the total value of the investment was estimated at 1.4 billion USD. and the overall completion of the project was expected during 2017. Although the financing was not finally concluded.

During 2013, the financing is closed in the form: the concessionaire is the project company Alto Maipo SpA. Until January 2017, it was 60% owned by AES Gener S.A. and 40% owned by Antofagasta Minerals S.A.

AES Gener is a Chilean company owned by Virginia-based AES Corporation (71%), Chilean pension funds (14%) and public investors (15%). Antofagasta Minerals is a wholly owned subsidiary of Antofagasta plc, a Chilean copper mining group with interests in energy, transportation and water distribution. Antofagasta plc is listed on the London Stock Exchange and constitutes the FTSE 100 index, and in turn is majority owned by the Chilean business consortium Grupo Lukšić.

By closing the financial structure during the summer of 2013, the decision to start work on the project could be given to the contractors, which followed in November 2013: construction contracts were signed with the construction groups STRABAG and CNM (Hochtief 70% + CMC Ravenna 30%) with a completion plan in 2018. The Las Lajas plant (267 MW) should be commissioned in the 1st quarter of 2018, while the Alfalfal II plant (264 MW) is expected to be put into operation in the 4th quarter of 2018.

By May 2014, the total cost of the project had risen to about 2.0 billion USD and was expected to include 800 million USD of invested capital in cash and up to 1.2 billion USD in loans. PHAM was financed by nine banks: The IFC provided a loan in the amount of USD 150 million, while the Inter-American Development Bank (IDB) provided USD 200 million. The American private investment corporation OIPC ("Overseas Private Investment Corporation"), DNB ASA (Norway) and KfW IPEX-banka (Germany) and four Chilean banks also invested.

During the beginning of the works in 2014 and 2015, there were minor conflicts between contractors and workers who sought improvements in working conditions and pay, partly through unions, partly through blackmail from unions or encouraged by local landowners who wanted sell own land to contractors. At that time, in late 2016, there were major labor strikes on part of the construction site from Hoctief -CMC and it was estimated that only 35% of the project was complete, the total cost of the project is now estimated at USD 2.4 billion, USD 200-400 million more compared to previous budget.

PROJECT DESCRIPTION

Location

The project is located in the area of San José de Maipo, about 60 km southeast of the city of Santiago de Chile, in the Cordillera province, in the high part of the river basin, the Alto Maipo power plant project (Project AM) will be located 50 km southeast of the city of Santiago, in the municipality of San José de Maipo, in the province of Cordillera, Region Metropolitana, in the upper basin of the Maipo River.

The location of the PHAM project (Projecto Hydroelectrico Alto Maipo) is shown on the layout (fig.1): with existing hydroelectric power plants (Alfalfal I and Los maitenes on the Rio Colorado River) and new underground hydroelectric power plants (Alfalfall II of 264 MW and Las Lajas of 267 MW) and connecting tunnels (red dotted line) from the water intake (Bocatomas Alto Rio Volcan) to the hydroelectric power plant and the final re-spout in the Rio Maipo at El Canelo. In addition to the extension of the project over 30 km in length and width, there is also a significant height difference between the catchment of the water (Bocatoma alto Rio Volcano at 2500 m above sea level and the main outlet in Rio Maipo near El Canelo at 800 m above sea level). Otherwise, the entire area, especially along roads, is marked with evacuation routes because it is an active volcanic area.

Project Development

The first contracts between the investor and the 2 contractor groups were concluded in November 2012, but the final closing of the financial structure was awaited so that the order could be given to start the works. During 2013, the financing was closed and the order to start the works followed in November 2013 with the aim of completing the project and putting it into operation in the middle of 2017, with a completion time of about 42 months or a little more than 3.5 years.

On January 19, 2017, Grupo Luksic announced that they are withdrawing from the project, at a loss of $350 million. In Luksic's absence, the Austrian construction company Strabag, which is responsible for up to 70% of the construction of the project, bought 7% of the ownership of Alto Maipo SpA.

In 2016, after several strikes and dismissals in the part of the project under the companies Hochtief and CMC, the work on that part of the project was stopped in May 2017 due to insufficient safety on the project and the withdrawal of the companies from the project.

AES Gener has seen its shares fall by around 30% in the last six months; the company is now seeking additional financing from international banks to fill the gap since Lukšić's exit. By the end of 2017 and 2018, they were looking for ways to continue financing, which were found by May 2018.

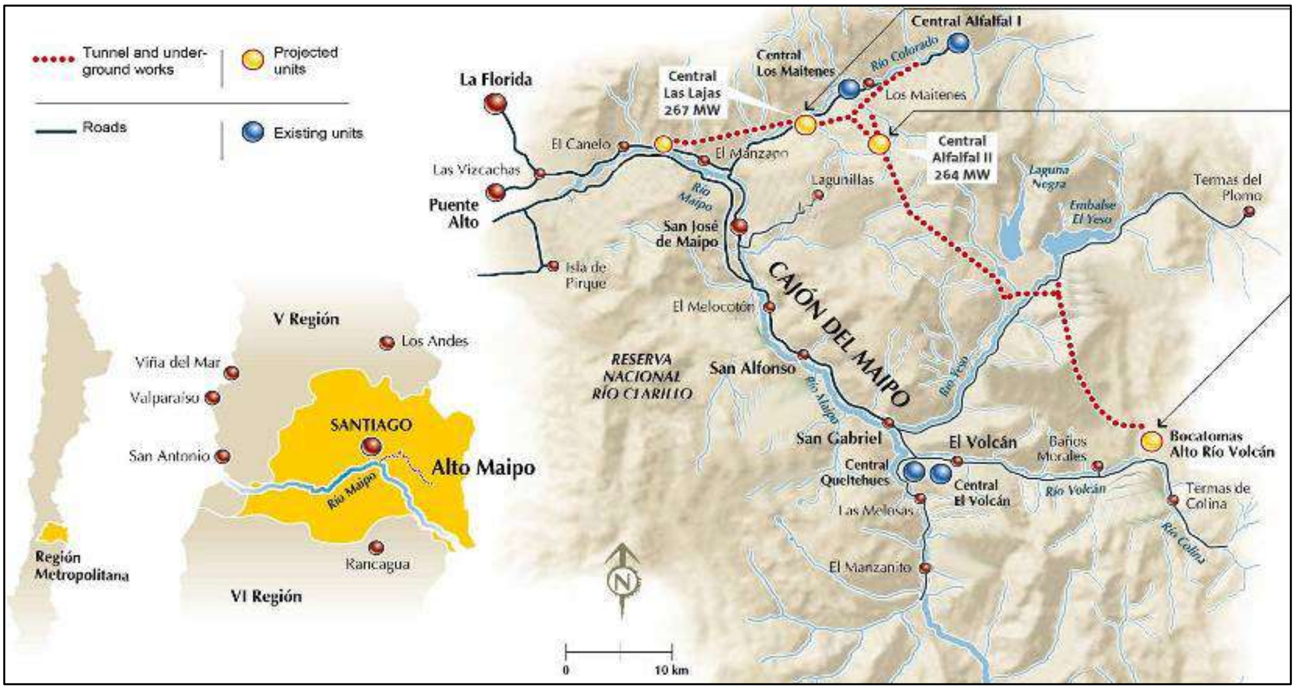

Figure 1. *Layout of the project location.*

After the refinancing, which was successfully completed on May 9, 2018, the STRABAG company took over another part of the project: the part that was previously under the contract of the Hochtief/CMC consortium of the Alto Maipo project [3]. The result of the takeover is an additional contract worth about 800 million euros, which together with the previous part makes the total amount of about 1.5 billion USD. At the time of concluding the additional deal with STRABAG in May 2018, about 63% of all works were concluded.

The total amount after the refinancing of the project shows the investment amount at the end of 2018 of about 3.05 billion USD. , i.e. at the end of 2019 it was estimated at about 3.50 billion USD. After the problems with execution, trade unions and financing there is only one contractor left, STRABAG, which should complete all works and put the entire project into operation with both hydroelectric plants in mid-2022, 5 years after the initially planned completion date.[4].

The Size of Underground and Civil Works

International contractors excavated more than 74 km of tunnels using TBM mechanical excavation and conventional construction methods in the high basin of the Maipo I River up to a height of 2,500 m above sea level in the Chilean Andes. Mechanical excavation was carried out by means of 3 TBM machines on about half the length of the tunnel with overlays up to 1500 m as part of the extensive project of the Alto Maipo hydroelectric power plant. The second part of the tunnel will be excavated by drill-and-blast and excavation with an excavator. The following TBMs will be used:

• TBM 1 (diameter 6.9m, open type with gripper, manufactured by "Herrenknecht") will excavate most of the 12.9 km Las Lajas tunnel, the Las Lajas drainage tunnel in a length of about 10 km in the direction from the L1 portal at El Canel towards the Las Lajas machine shop (performed by STRABAG)
• TBM 2 (diameter 4.53 m, open type with gripper, manufactured by "Herrenknecht") will excavate approximately 10 km of the total length of the Alfalfal II pressure tunnel of 14.5 km, in the direction from the Alfalfal II engine room upstream to the Yeso River (produced by STRABAG).
• TBM 3 (diameter 4.1 m, open type with gripper, manufacturer "Robbins") will excavate 7 km (half the length of the 14 km Volcano bypass tunnel), excavation in the downstream direction. After that part of the excavation, the machine should be taken out of the tunnel and transferred to the initial part of the Alfalfal II tunnel, adjusted to the profile needed there, and a further 3 km of tunnel should be excavated.

Table 1. *The main tunnel of the PHAM project with lengths and cross-sections*

Main tunnels	**Length (km)**	**Cross.section (m2)**
Las Lajas outlet tunnel L1, TBM1 10 km	13.0	37.4
Las Lajas pressure tunnel 1	6.0	21.0
Las Lajas pressure tunnel 2	3.5	30.0
Alfalfal II outlet tunnel	3.5	20.1
Alfalfal II pressure tunnel, TBM2 10 km, TBM3 3 km	14.5	15.9
El Volcan bypass tunnel TBM3 7 km	14.0	14.0
Alfalfal II access tunnel	2.5	35.1
Las Lajas access tunnel	2.0	35.1

In addition to the three TBM machines for excavating the vertical pressure shaft and the water chamber shaft of the Las Lajas tunnel system, a drilling machine using the "Raise Boring" method - RBM (manufactured by STRABAG) will be used. At the beginning, a TBM machine was also planned for the aforementioned shafts, the shafts were slanted at an angle of 45 degrees, but there was a change in the project, which turned the slanted shaft into a vertical one, so it can be excavated using the "raise boring" method, where the rotating boring head lifts and the excavated material falls into the starting cavern.

Additional facilities that will be located along the course of the tunnel are water intakes that will feed the turbines of the Alfalfall II hydropower plant from 5 sources, water intakes. These water intakes are La Engorda, Colina, Las Placas and El Morado, which will collect the water through a concrete intake in the form of a throat and will bring the water through a concrete pipeline about 3.6 km long to the fork of El Volcan, and further through the 14 km long El Volcan tunnel, to the distribution shaft where, through an additional tunnel of about 1.5 km, it will join the water to the El Yeso catchment. This connecting shaft is connected to the Alfalfal II pressure tunnel through a steel pipeline with a diameter of 3.1 m and an El Yeso siphon with a length of about 5.2 km. This amount of water is limited to the design flow volume of 27m3/sec and is tied to the maximum height of the water surface of 1,160m for the operation of two generator turbines with a power of about 264MW of the Alfalfal II hydroelectric plant.

The hydroelectric plant in Las Lajas will use the flow volumes discharged by the Alfalfal II plant and the existing Alfalfalla I plant, as well as the flow currently used by the Maitenes plant, by directing them through the pressure tunnel of the underground machine room. The maximum total flow of 65m3 / sec associated with the maximum height of the water surface of 483m allows the operation of two generators with a total capacity of about 267MW. Both new hydroelectric plants together have a designed capacity of 531 MW.

Design and Supervision

The initial design of the Alto Maipo project was carried out for the phases of preliminary design and the basic part of the main project by the Norwegian design firms Norconsult and Norplan under contracts concluded in 2012.

On the basis of such a basic project, a tender was held for contractors and the contractors who were selected hired designers for the implementation documentation of the project, because the project is carried out according to the principle of DBFOM, i.e. design-build, where the project implementation documentation is prepared immediately before the implementation, and it is checked by consultants from the investors. and allows its application on the construction site and execution.

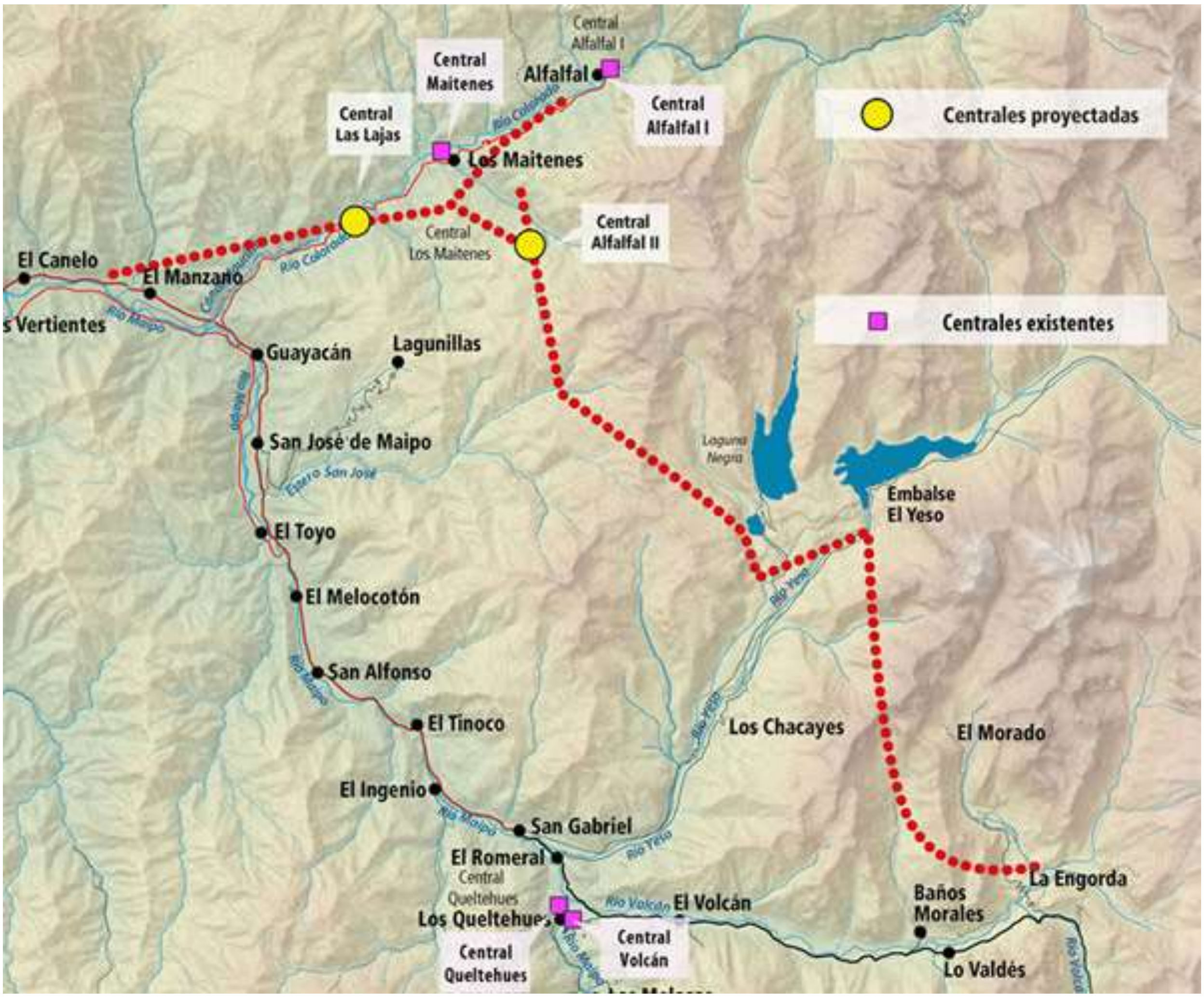

***Figure 2**. Site area.*

STRABAG concluded a contract with the Italian company GEODATA based in Turin but with on-going activities in Chile and all countries of South America. The contract was concluded on behalf of Geodata during the start of implementation period from September 2013 to February 2015. In that period of 18 months, offices in Santiago with the support of the central office in Turin produced major part of the project documentation and numerical analyzes for parts of the project under the execution of STRABAG Contract C630/620A. The projects of tunnels and underground caverns for the power plants of both hydroelectric power plants, both carried out by TBMs and those that will be carried out by drill-and -blast conventional tunnelling methods, are expected to pass through volcanic rocks that have a highly abrasive effect on the discs and teeth of tunneling machines.[2].

After the start of the works on the C630/620A contract, negotiations were started and works were contracted on the creation of the implementation documentation project for the larger part of the C620B/610 project, which was assigned to the bidder community CNM SpA.

TBM excavated tunnels are secured with anchors and sprayed concrete, in places of higher pressure with nets and sprayed concrete. For the substructure, 5 types of substructure are foreseen, which include the use of anchors, sprayed concrete and steel mesh. As shown in longitudinal section of weaker classes systematic anchoring with long anchors were used in areas of weaker geology and 20 m long preboring dewatering holes where water pressures have to be expected. Preborings were as well planned to serve for pregrouting of wider area around the cross section in the case where weaker geologic formations may influence the stability of cross sections.

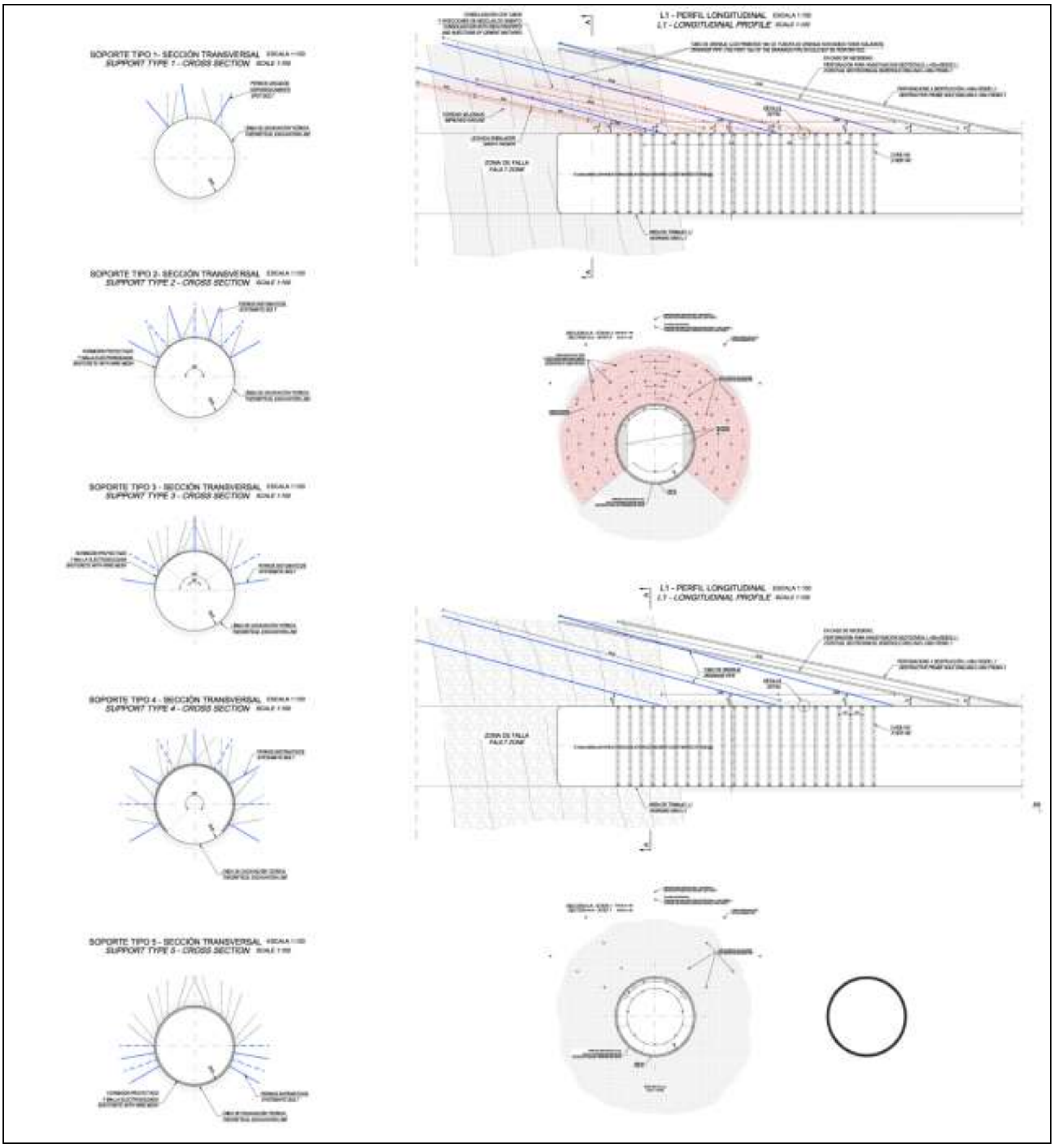

Figure 3*. Cross sections and support measures on TBM driven tunnels.*

Conventional tunnels are made by heavy blasting and protection of the excavated profile with sprayed concrete, anchors and nets, following the principles of the New Austrian tunnelling method (NATM).

The same method is also referred to in international practice as SEM ("sequential excavation method") or SCL ("sprayed concrete lining" method) and describes the approach in which, when excavating materials on the edge by blasting or cleaning the deformations of the cross-section and the entire excavation are observed and a certain type of subgrade intensity is applied that corresponds to the necessary support for that type of geology and the size of the cross-section of the excavation.

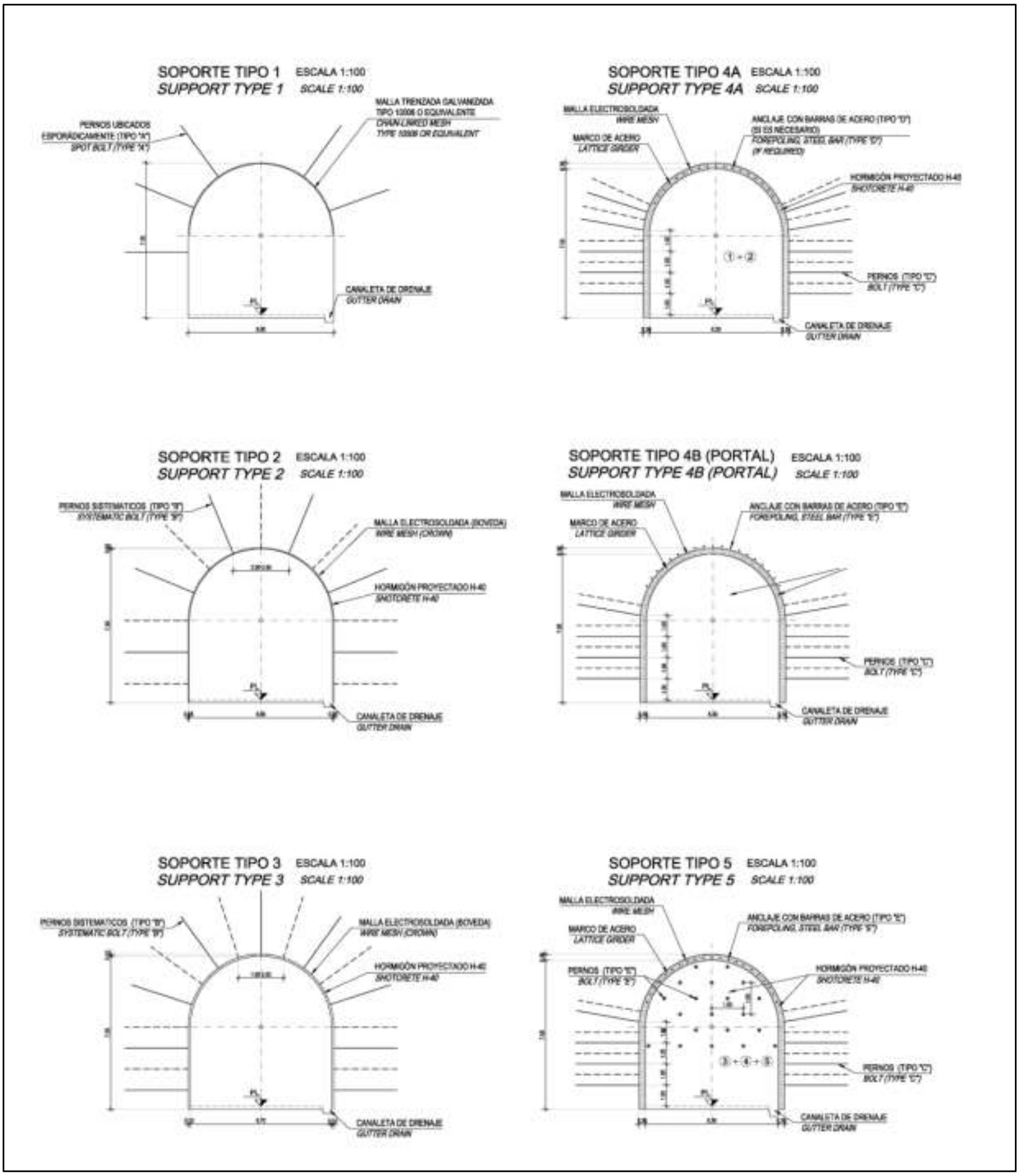

Figure 4*. In conventional tunnelling 6 support classes for different geology types and all sizes of cross sections.*

As part of the conventional tunnels, the principles of the substructure of the underground rooms were modelled on similar hydrotechnical tunnels in Norway, because the consultants of the main project were also from Norway. As it was a "design-build" type of project, significant savings were made on geo-investigation works, so that most of the knowledge about geology was based on data from the previous Alfalfal hydroelectric power plant, which was put into operation by the same developer in 1991. Due to the scope of the new PHAM project, such geological surveys were not sufficient, and the predictions of geological profiles in many places deviated significantly from the actual conditions found in the ground. Later work on the tunnels with the conventional method of excavation also led to significant changes that needed to be implemented in the executed project.

Since the project was of the design-build type, the supervision was of two types: on the one hand, the investor had a supervision service that made sure that the project took place as part of the planned project, while the contractor had his own supervision that took care of the technical conditions in which the project takes place . On the supervision side, three consulting companies were hired by the investor to check the project and supervise the implementation, namely: Skava from Chile, Amberg from Switzerland and Multiconsult from Norway.

Design Changes

The basic project documentation of the project, which was taken over from the client at the time of signing the contract between the client and the contractor, was at the level of a rough main project with a distinct lack of performed geotechnical borings and investigative works. The form of the project was "design and build" and by doing this it was predicted in advance that a lot of decisions would be made on the spot, because only during construction would details that could not have been predicted by the project be revealed. The investor hoped that he was sufficiently protected by 2 conditions: on the one hand, at the beginning of the project location, the Alfalfal I hydropower plant was put into operation in 1991 on the western side of the PHAM project, so it was assumed that the geology would be, if not the same, then very similar, so it is based on the main project.

On the other hand, the client agreed with the contractors on the price according to the "turn-key-contract" principle, which should guarantee that the total initial agreed price will be unchanged. It turned out that both assumptions were wrong, so the implementation project documentation underwent a lot of changes and changes, and the price is currently estimated to be around 3.5 billion USD instead of the initial 1.4 billion USD. Additionally, the main project was carried out by companies from Norway based on the experience of geology and rocks in Norway, which are quite different from the volcanic massifs at the location of the PHAM project in Chile.

Typical changes that were applied to a greater extent and that had an impact on the total prices of construction were e.g. changes in the shape of the cross-sections of the tunnel where the vertical walls have been transformed and a rounded line is much better for the stability of the wall of the section.

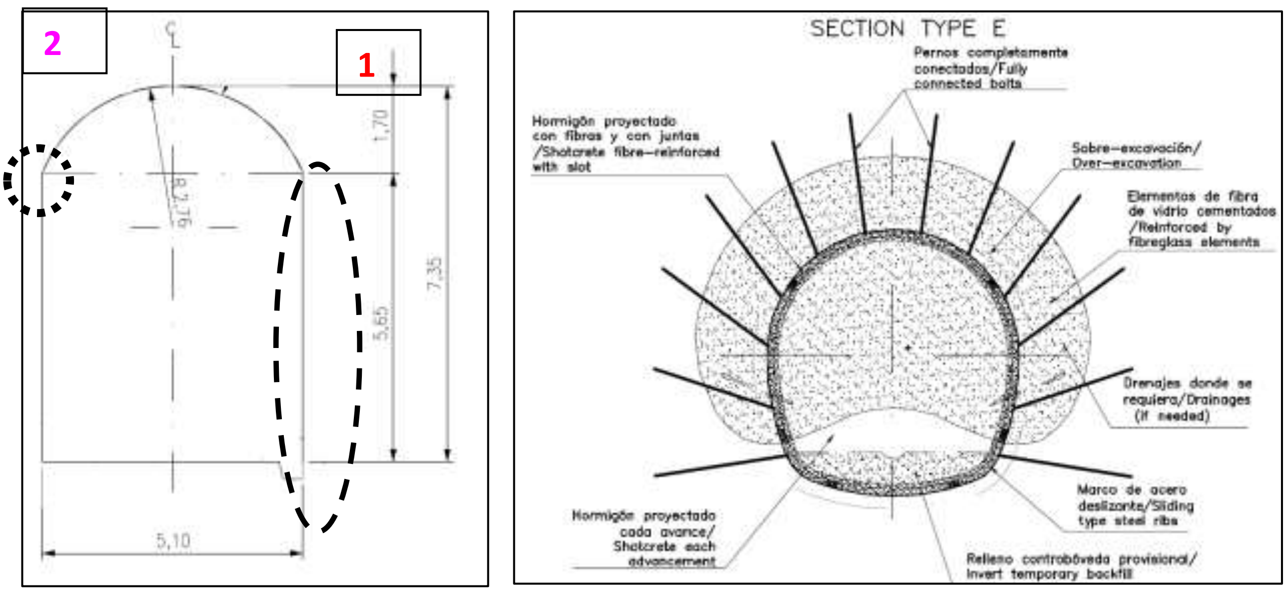

Figure 5. *The initial shape of the walls of the tunnel profiles in the cross-section (left) and the final shape of the cross-section according to the executive project (right).*

Also, one of the most significant changes was the change of inclined shafts to vertical shafts and thus the change of the initial technology of shaft construction instead of TBM for inclined shafts to the "raise-boring" performance methodology, which is much cheaper and faster when vertical shafts are made in particular.

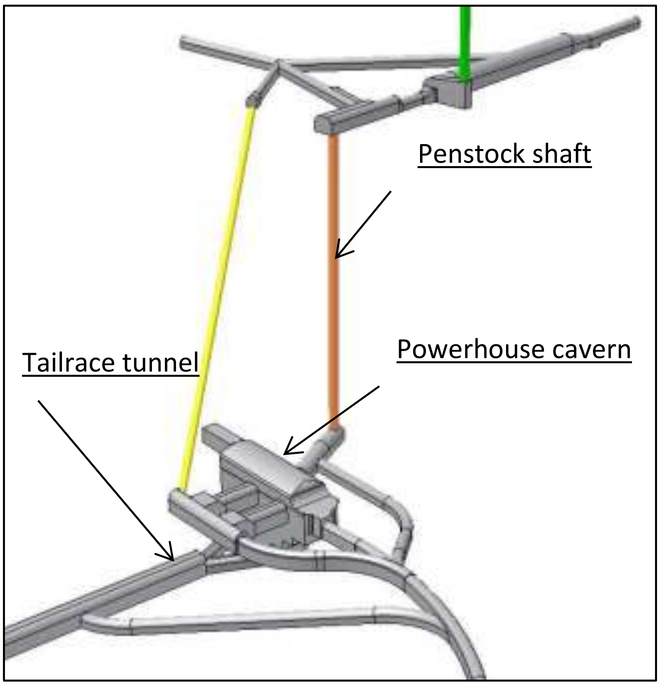

***Figure 6**. The 3d view of the shafts on the approach to the Alfalfal II engine room caverns.*

Contractor

At the beginning of the works, for which the contract was signed in November 2012, and the order to start the works was given and the works started in November 2013, the Chilean branch of the STRABAG concern (Austria) signed a contract in the amount of 490 million US dollars for the excavation of two thirds of the underground watercourse project and for 2 underground power plants Alfalfal 2 with a capacity of 264 MW and Las Lajas with a capacity of 267 MW in the basins of the rivers Rio Colorado and Rio Maipo in the north of the project. The Alfalfal 2 hydroelectric project will be located in the Colorado River basin downstream of Alfalfal 1, and the Las Lajas hydroelectric project will be located near the mouth of the Maipo River and the El Manzano wetlands.

The second part of the project, which makes up about a third of the work, is done by a community of bidders called CNM (Constructora Nuevo Maipo SpA, made up of Hochtiefa (Germany) / CMC di Ravenna (Italy) was awarded a contract worth USD 290 million for the excavation of 18.5 km of southern tunnels in the valleys of the rivers Rio Volcán and Rio Yeso. Hochtief's share is USD 195 million, and CMC's share is USD 95 million. This part of the project also included the construction of 5 intake structures where water should enter the tunnel system and the construction of a long steel pipeline work on both parts began in November 2013 and the overall completion of the project was expected during 2018.

The main construction contractors, Strabag and Hochtief / CMC JV, were joined by the Brazilian and Chilean subsidiaries of Voith Hydro (Germany) for the supply and installation of electromechanical equipment in the two underground power plants. The 275 MW and 256 MW turbines will be located in the caverns of the Alfalfal II and Las Lajas power plants.

After a series of problems with personnel on the construction site and numerous problems with the geology, which was far worse than predicted in May 2017, the community of contractors CNM SpA (Hochtief / CMC) withdrew from the project. In a later decision of the court in Chile, the investor kept the contractor's guarantee in the amount of USD$76 million, although the contractors complained that they had to abandon the project for safety reasons during the works.

After the second refinancing of the project during 2017 and the first half of 2018, in May 2018 STRABAG concludes a contract for the execution of the southern part of the project on which HOCHTIEF/CMC worked and takes over the execution of the entire project. In this way, STRABAG was able to build 18.5 km of tunnels in the Volcán and Yeso valleys in the south of the project, as well as 5 catchment structures at the very beginning of the project, as well as 5 km of steel pipeline. Additional works were contracted for a total amount of around 800 million EUR (951 million USD), which in total increased STRABAG's contract to 1.5 billion EUR.

At the end of 2017, AES Gener discovered that on some sections of the long and deep tunnel on the El Volcano section, difficult geological conditions were encountered, due to high pressures from a high layer that would require the installation of a much stronger tunnel lining, which affects the overall speed of progress of the TBM boring machines. Under these conditions, the progress of the TBM was less than 10 m/day, while in the other tunnels the progress of the TBM was in the range of 10-30 m/day. Independent rock mass quality reports commissioned by Hochtief-CMC claimed that the tunneling conditions were far more difficult than expected and that the approach to tunneling with open-type TBM, without a shield and with a gripper system for further advancement as predicted by the technical specifications is dangerous compared to TBM machines that have a shield. After the termination of the contract with Hochtief-CMC, the TBM manufacturers took over the tunnel construction activities on the critical parts until the conclusion of the contract for the final completion of the works with STRABAG in May 2018.[5].

Construction Works Experience

About 4,700 workers worked on the construction site in both parts of the project at the peak of the work, about 2,700 on the northern part of Contract C630/620A, which was performed by STRABAG, and about 2,000 on the southern part of Contract C620B/610, where in the period November 2013 - May 2017, the contractors were the CNM SpA bidder community (Hochtief and CMC Ravenna).

For TBM machine excavation of tunnels, open-type rotary boring machines are used, without a shield and with a gripper system (for the advance pressed into the rock mass laterally). The manufacturers for the T1 and T2 machines are Herrenknecht from Germany, and for the third tunnel, El Volcano, the manufacturer is Robbins from Seattle, USA. The diameters of the machines are different and the size of the diameter of the rotary head is 6.90 m at the downstream Las Lajas tunnel, while the central machine in the Alfalfal II tunnel has a diameter of 4.53 m and the southernmost, the first tunnel is dug with a machine with a diameter of 4.10 because that tunnel receives and transfers the smallest amount of water after the excavation at the beginning of the project.

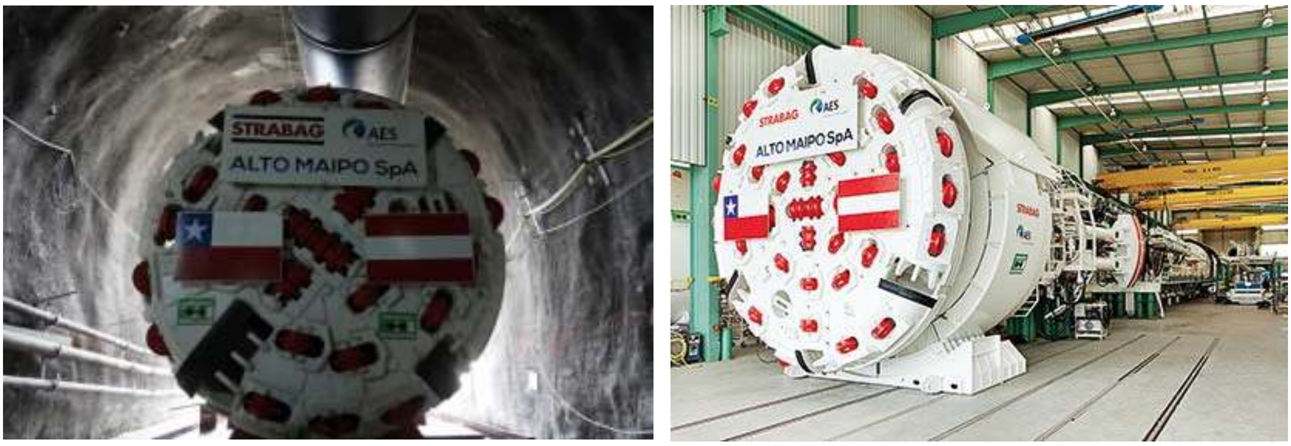

Figure 7. *TBM for tunnel L1 tunnela Las Lajas and side view by sturt-up mounting in production facility.*

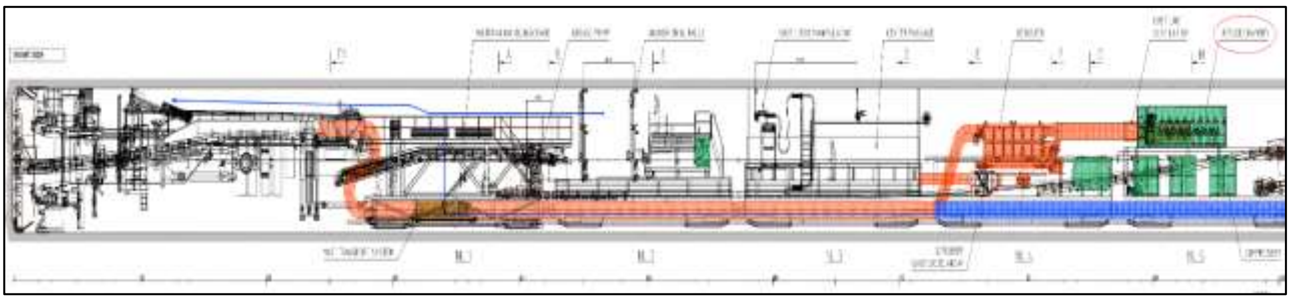

Figure 8.: *Longitudinal section of an open-type TBM, a rotary drilling machine.*

The TBM open type is without a shield with a side gripper system (gripper). This type of machine construction was used for all 3 machines that were used, although in the later stages of performance it was shown that the quality of the rock mass in the southern parts of the project in the El Volcano tunnel was far worse and would require a closed type of machine with a shield due to the "rock burst" phenomenon.

***Figure 9**.:Conventional tunnel excavation by blasting at the beginning of tunnel V1, application of a machine (boomer) with 3 arms for drilling holes for blasting and for laying anchors (left) and a view of the beginning of tunnel excavation V1 with primary support by sprayed concrete and anchors.*

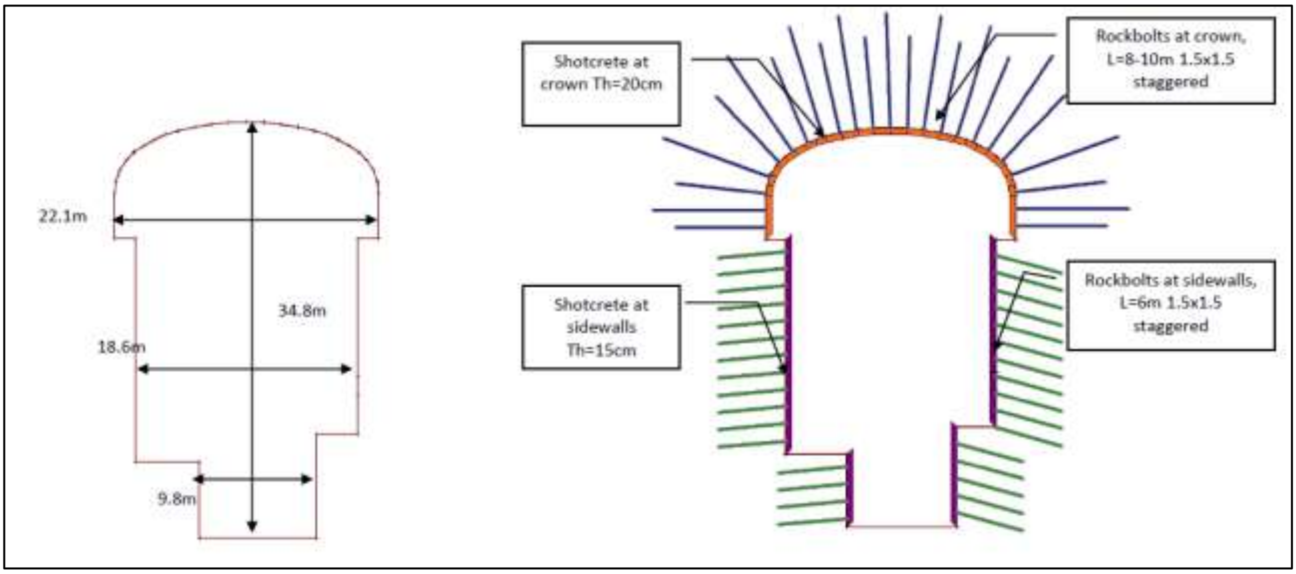

***Figure 10**.: Cross-section of the caverns for the engine rooms of both hydroelectric power plants and an example of the planned type of substructure with anchors, sprayed concrete and steel mesh.*


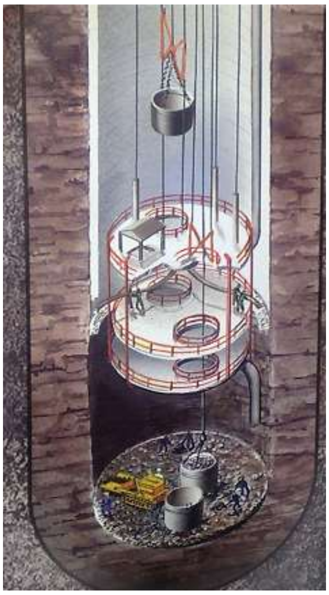

***Figure 11**.: Methodology of making shafts: "raise boring method" (left) and method of lowering shafts ("shaft sinking").*

When the project started, in November 2013, it was planned that all works would be completed and both power plants put into operation at the end of 2018, which means at least 5 years of work. Today, after several delays, commissioning is planned for the second half of 2022, which means with a 4-year delay.

There are many reasons for delays, but the main ones are as follows:

During 2014, sporadic work interruptions began due to a strike by workers on the eastern part of the project as part of the works of the CNM Spa group (Hochtief-CMC), which continued in 2015. Formal reasons were given as worse working conditions and worker safety, but the real reasons were different. Namely, in the entire area of the project, the contractor should have bought the land on which the project will be carried out from private owners. The investor and contractors bought the minimum they needed to actually carry out the project, but the land owners wanted to sell much more land, which was not the case. Therefore, the land owners engaged groups that came to the construction sites and caused riots and incited the workers to riot, and together they demolished the contractors' fleet (numerous pick-ups that the management used during the development of the project, on several occasions causing In the western part of the project (STRABAG), such requests were handled differently at the beginning with agreements on the construction of new soccer fields and similar agreements.

The peak of the riots and a longer work stoppage occurred at the end of 2016, when about 2,000 workers again went on strike on the eastern part of the project of the CNM group (Hochtief-CMC). Namely, in accordance with European customs, STRABAG paid the "Christmas bonus" towards the end of the year on the western part of the project, while on the eastern part, not only was it not paid, but it was not even planned for payment. This was also contributed to by the working conditions on the construction site, where three people had died so far, as well as poor food and the help of the trade unions, which began to become more and more involved in the protection of workers' rights. On that occasion, at the end of 2016, a strike led by the BHI union included about 2,000 workers and lasted for 32 days, who on that occasion demolished the camp and offices of the CNM group in the eastern part of the project at the location of the beginning of the Hochtief tunnel works.

2017.01- In January 2017, after all these increasing problems, the partner of the investor Antofagasta Minerals also leaves the group that deals with financing the project, it was necessary to find a new financier for a 40% share with AES Genera as the leading partner

2017.05 – In May 2017, Hochtief/CMC leave the project with the justification of the lack of safety in the construction of the tunnel, which under a large overburden and due to high pressures due to weaker than expected geology could no longer ensure the necessary safety during construction with TBM machines, which are planned as open machines without a shield. Significant problems with the workers' strike and the demolition of the office on the construction site 5 months before contributed to that decision. With the exit of the CNM group from the project, the project was formally stopped because the contract stipulated that in order to reduce the risk, the entire project should be built by at least 2 groups. With the exit of the CNM group, it was necessary to find which contractor would take over the execution of their part of the project.

At the end of 2017, the investor AES Gener declares that the geological conditions in parts of the project have actually been found in certain sections of deep and long tunnels due to high pressures caused by enormous layers over 1500 m, but also due to the local lower quality of the material ("rock burst"), which requires the installation of a primary substructure with increased load capacity, which will affect the performance time of the TBM machine. Independent reports that were prepared by the Hochtief-CMC group stated even before that the conditions of tunneling are far more difficult than anticipated and that the approach of tunneling investors using open-type TBM machines with grippers and without shields is dangerous compared to TBM machines that have shield. After abandoning the work on the project of the CNM group, further work on the tunnels until the selection of a new contractor was taken over by the machine manufacturers. (Herreknech for TBM1 and TBM 2 and Robbins for TBM 3).

2018.05 - A new contractor was finally found in the STRABAG group, which took over the eastern part of the PHAM project and thus the entire project with a new financing and construction contract signed in May 2018. With this contract, STRABAG should complete all works on both hydroelectric plants by the second half of 2022. The work continued with sporadic problems and interruptions, so short strikes took place from time to time under the leadership of the BHI trade union, such as the 12-day strike in October 2019 due to the conflict over the contract on the tariffs by which workers are paid and safety conditions on the construction site. To date, 4 deaths have been recorded on the construction site during the works.

As it looks now, thesecond financial reconstructuring of the project is just taking place that should enable the project to open for operation and start to produce electricity finally within this year, 2022 [7].

Project Acceptance by General Public

From the very beginning, the project had opponents who organized demonstrations in Santiago and at the site of the future works, a few years before the start of work on the project in 2012. The reasons were numerous:

* objections to the falsification of the environmental impact study, which shows the extent to which the project affects on the area and the region in which it works,

* the regular feeling in the masses that the class on power is doing something for its own benefit and to the detriment of the majority,

* the struggle to ensure a source of drinking water, first of all for Santiago and the wider area where almost half of the population of the whole of Chile lives,

* the general purpose of the project which, as the largest hydroelectric power plant in Chile, should provide enough electricity for the processing of copper ore into metal, and not for the electrification of parts of Chile,

* the destruction of the natural beauty of the Alto Maipo River Canyon Nature Park, which will lose the natural flow of water through the Alto Maipo River Canyon and turn river canyon into the desert.

In addition to all of the above, as well as many other reasons that come from the problems of Chilean society, further problems are certainly the change in climate conditions, especially in the region of the project, the lack of precipitation for the last 13 years (2009-2022), which is attributed to climate change and general warming. [6].

Therefore, the project is not well received by society and has serious objections due to its impact on nature and may cause further degradation of the quality of parts of the environment east of Santiago to the border with Argentina. Also, through the opposition to the project, the opposition to the political elites is supported, who in Chilean society are understood as the bearers of bad changes.

CONCLUSION

Hydro Scheme Alto Maipo is the largest hydroelectric power plant in Chile with a capacity of 531 MW. After being put into operation, it will provide the amount of electricity that will enable the processing of copper ore into copper, and thus instead of exporting raw materials in the future, it will enable the export of semi-products, copper metal, thereby increasing Chile's income.

As an engineering project, it represents one of the most demanding construction projects of this time, which, due to its complexity and demanding geology, caused the extension of the construction time, but it is also fully completed and should be put into operation in 2022.

In the financial sense, the initially assumed costs of the project were far exceeded, partly due to the far more demanding conditions on the construction site and the more difficult geology of the project, which is completely underground, but also due to the accompanying difficulties with the workforce and the conditions and relations in Chilean society, as it was constant fight with unions. The profitability of the project will further be questioned due to the drop in electricity prices on the South American market.

In an ecological sense, the project was conceived and started on the principles of environmental impact studies that were completed far before the problems of climate change and warming that we are witnessing based on the obvious changes within the last 10-15 years. The impact of the project's encroachment on the area in this case is related to the lack of water, not only on the surface in the Alto Maipo river canyon, but in the future there will also be a questionable amount of water that is needed in order to fully operate both underground hydroelectric power plants and produce the planned amount of electricity.

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