ALTO MAIPO HYDROELECTRIC PROJECT

UNDERGROUND WORKS HYDROGEOLOGY

EXECUTIVE REPORT

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1. INTRODUCTION

This report is a summary description of the results of the hydrogeology studies developed as a basis for the design of the underground works of the Alto Maipo Hydroelectric Project.

These studies belong to the framework of development of the basic engineering of the project, and their results have been used as a basis for the calculation of tunnels shoring, construction programs, and costs of the underground works.

These studies are the result of the development of the following main activities:

- Analysis and critical revision of the available geological, geotechnical and hydrogeological antecedents, both as regards national cartography and that from the specific studies developed for the Alfalfal hydroelectric project, at present in operation.

- Photo-geological analysis, both of the aerial photographs taken previously for AES GENER as of those corresponding to the laser topographic survey, carried out especially for the design of the works.

- Direct field survey, both aerial and on the ground, to identify the different geologic units, Their structures and contact relationships, offering explicit data about the geologic, geotechnical and hydrogeological characteristics of the rocks, so as to anticipate conditions at the tunnels system level.

- Analysis of the results obtained from underground prospecting (drillings and geophysical survey) carried out at specific sites of the project to identify the distribution and the geological, geotechnical and underground layers of the different units in depth.

- Definition of the most probable geologic and hydrogeological model for the Alto Maipo project, by the preparation of maps and interpretation of geologic profiles, showing the distribution and conditions of the different units in depth.

- Preparation of the corresponding geologic reports, which are an integral part of the Engineering design for the Alto Maipo Project works.

Finally, this executive report is an Annex to the Environmental Impact Study of the Alto Maipo Hydroelectric Project. It is organized for that purpose according to the following main modules:

A. This text, planned as follows:

- The first section includes a general description of the expected geologic conditions along the tunnels.

▪ The second section analyzes the expected permeability based on the geologic information and hydrogeological conditions of the sector. Incorporating the experience obtained in the construction of the Alfalfal Plant, this has been in operation for over 17 years.

▪ The third section examines the problem from the point of view of the tunnels, explaining the points to be considered, including the design of the tunnels and explaining briefly the methods to reduce and control leakages.

B. Drawing N° 020-GE-PLA-010-D, Longitudinal Hydrogeological Profile, Tunnels Layout, El Volcán – Alfalfal II – Las Lajas.

2. UNDERGROUND WORKS HYDROGEOLOGY

As indicated above, the geologic and geotechnical characteristics of the materials expected to be encountered in the excavation of the underground works of the Alto Maipo Hydroelectric Project are described below.

For a better understanding the underground works are grouped in three main systems, as follows:

- Las Lajas System;
- Alfalfal II System;
- El Volcán System.

2.1. LAS LAJAS SYSTEM

Briefly, this system includes the head tunnel, the headrace works (pressure shaft, surge shaft, powerhouse cavern) and the tailrace tunnel of the Las Lajas Plant.

Regarding geology, it has been determined that this set of underground works will be excavated in a series of stratified rocks of volcanic origin and belonging to the Abanico formation (Tia), consisting mainly of breccia, sandstones and tuffs.

This geologic pattern is fairly constant along all the tunnels, only excepting what happens in the Manzano sector, where the tailrace tunnel of the plant will cross rocks belonging on an ancient volcanic caldera set in the stratified rocks of the Abanico Formation (Tia).

This situation is shown in the attached geologic maps and profiles, where the interpretation of the geologic, geotechnical and hydrogeological information obtained during the studies is shown.

The head tunnel, the powerhouse cavern complex and the first 2km of the tailrace tunnel (upstream to downstream) will cross older units of the Abanico Formation, known as Tia A.

These strata consist of banks, often massive, composed mainly by volcano-clastic breccia, besides volcano-clastic sandstones and tuffs.

From a structural point of view, the strata belonging to the Abanico Formation show up deformed into a soft anticline on the flanks of the Colorado River; this means that the units will be disposed sub-horizontally in the tunnels. Some minor microdioritic intrusions outcrop as layers and could possibly be intercepted by the tunnels.

A good example of the behavior of the described rock strata for the underground works is the old Maitenes Plant tunnel, which has operated satisfactorily for over 80 years, without records of abnormal events or loss of water through leakage.

On the other hand, the tailrace tunnel will pass through the following group of strata of the Abanico formation, individualized as Tia B, for 3 km.

This unit, which begins to appear in the tunnel, more or less 2km downstream from the Plant, is mostly made up of tuffs, sandstones and stratified volcanic breccia. It is expected that this unit will mostly show in the tunnel as strata placed in a sub horizontal or slightly sloping position.

Volcanic rocks forming part of the ancient El Manzano caldera (which cuts into the volcanic series belonging to the Tia B unit of the Abanico Formation) could be intercepted in the remaining 6km of the Las Lajas plant discharge tunnel.

Ignimbrite breccia is dominant rock type in the body of the caldera not very different from the rocks forming the Tia B stratified unit.

Within the caldera, the transition between the breccia and the ignimbrite shows gradually and it is not possible to anticipate precisely which will be the dominant rock type inside the tunnel. A granodiorite intrusion outcrops near to the north the axis of the tunnel in the caldera. Therefore, it is expected to find some dykes at the level of the tunnel, and the effects of the intrusion by a granodioritic body.

The last section of the discharge tunnel and the discharge itself onto the Maipo valley will be sited in a competent volcanic mass, of andesitic character.

The maximum rock overburden over the Las Lajas tunnels system is about 800 meters; this Condition allows anticipating that there will not be any important rock tension manifestations that could generate difficulties for the excavations.

However, if anomalous effort concentrations should appear, the design has foreseen adequate shoring for the definitive stabilization of the sections subjected to those eventual efforts.

Finally, it can be pointed out that, according to the information obtained from the drillings carried out in order to survey to rock substrate at the level of the tunnels of the system, the rocks will mostly show good geotechnical conditions and low permeability.

2.2. ALFALFAL II SYSTEM

The tunnels system for the Alfalfal II Plant comprises basically the head tunnel from the Yeso River valley, the headrace works for the Plant (pressure shaft, surge shaft, powerhouse cavern) and the corresponding discharge tunnel; go through the Abanico Formation strata (Tia).

The geological, geotechnical and hydrogeological information concerning these tunnels is shown in the geologic maps and profiles joined to this report.

The head tunnel, which starts at the western flank of the Yeso River valley, goes through the strata corresponding to the Tia C unit of the Abanico formation, approximately until kilometer 12 downstream.

The types of rocks found in this intra-formation unit, belong mainly to pyroclastic breccia, breccia and sandstones. This unit forms a soft syncline, therefore it is expected that the different banks will show up in a sub-horizontal position in the tunnel.

The remaining 2 to 3 km of the head tunnel would be sited in the upper part of the Tia B unit, formed mainly by volcano-clastic breccia, sandstones and tuffs. The lower part of the surge shaft will also be sited in this unit; the upper part will be within the Tia C unit as described for the first section of the head tunnel.

The pressure shaft and the powerhouse cavern will be set within the Tia B unit, the lower part of which also includes some pyroclastic breccia.

In general, the stratification of the rocks set is extensive with short folds. Some geologic faults, disposed in a sub-vertical manner, and NE-SW displacements have been located in the geologic mappings already carried out.

These accidents are seen on the ground as extended straight line, and at the level of the tunnels will represent not very wide banks, of rocks having a lesser geotechnical quality.

The geological framework of the Alfalfal II system is completed by the presence of an intrusive body, of granodioritic composition, placed to the SW of the projected cavern and cutting the strata series that predominate along the head tunnel and the Plant headrace works.

Considering that this body is away from the tunnels system, it is foreseen that its influence will be materialized only by the presence of some dykes in variable strikes, set in the stratified volcanic rocks.

The effective rock overburden over this system shows maximum heights nearing 1,000m; this condition allows anticipating that the residual tensions in the rocks will not be a special problem for the excavations.

However, should anomalous effort concentrations appear due to the presence of structures with local features, the design has foreseen adequate shoring for the definitive stabilization of the sections subjected to those eventual efforts.

In general, the rocks in this tunnel system will show good geotechnical conditions, and as these rocks have a dense matrix, with elements quite well welded to each other, it is foreseen that the permeability will be low.

Some very moderate leakages may occur, associated to the presence of structures of local extension, the project has foreseen an adequate waterproofing systems to this end.

2.3. EL VOLCAN SYSTEM

The layout of the Volcán system crosses the Río Damas, Lo Valdés, Colimapu formations and the youngest, Abanico Oriental. The interpretation of the available geology is shown in the geologic maps and profiles joined to the present report.

This tunnel crosses the following rock groups, from its upstream entry downwards:

- Approximately 600 m of the Río Damas formation, where the dominant rock types are conglomerates, sandstones and limonite; all these rocks are stratified. Their variable thickness banks are almost vertical and intersect the axis of the tunnel at an obtuse angle.

- Approximately 600m of the Lo Valdés formation, made up mostly of limestone, clay and carbonic sediments, all disposed in thick strata. The strike and relative inclination of the strata in the tunnel are similar to those of the Río Damas formation.

- Approximately 4,000m of the Colimapu formation, where volcanic and sedimentary stratified rocks predominate. Most of the rocks are andesite, andesitic breccia and tuffs, accompanied by limestones, sandstones and red clay levels, as well as gypsum and anhydrite lenses,

- The remaining 9km of the Volcán tunnel are placed in the Abanico Oriental Formation. This formation is mostly made up by andesite and andesitic breccia, while the sandstones and tuffs are subordinated units.

The effective rock overburden along the tunnel is generally high. Over 2000m of effective overburden are expected along the tunnel, and over 100m of effective overburden will appear in an important proportion of the tunnel.

This condition has been duly taken into account in the geotechnical evaluation of the rock mass and therefore in the design of the tunnel.

Therefore it has been foreseen that the tunnel will cross rocks whose geotechnical quality may be deficient in particular instances, eventually showing as plastic deformation of the materials and the occurrence of gypsum and anhydrite lenses.

In term of the reinforcements required by the tunnel, the most resistant shoring solutions have been envisaged, so as to guarantee safe conditions during the works, and the correct functioning of the tunnel during its useful life.

3. HYDROGEOLOGIC ANALYSIS AND EXPECTED PERMEABILITIES

3.1. INTRODUCTION

According to their origin, the rocks on which the underground works of the Alto Maipo Hydroelectric Project will be sited can be grouped in three groups, as follows:

- Volcanic rocks;
- Intrusive rocks;
- Sedimentary rocks.

The first two groups are formed in different manners from materials molten at high temperatures and different depths. The processes forming these rocks originate matrix bodies, where the constituting elements are strongly bonded to each other, without presence of effective porosity and thus watertight.

Something similar occurs in the third group, where sedimentation processes, although cold, allowed the accumulation of sediments which were compacted later on due to the lithostatic load caused by the strata deposited successively over them, besides other chemical processes which collaborated in their consolidation.

In this last case, the result is also that of very watertight matrixes, with elements well bonded to each other.

On this scenario, the permeability of the rocks is circumscribed to the fractures which at present divide the rock matrix in very variable patterns, and which are the only elements allowing interconnections to generate favored ways for water percolation (the interconnection of free spaces for water circulation can be facilitated in cases where there are soluble materials, such as Ca CO3).

In practice, given their decompression, the rocks have a permeability value at the surface, which decreases progressively as depth increases, mainly due to the higher lithostatic pressure which closes fractures and prevents the water to continue infiltrating through them.

Therefore, it is not expected that rocks fractured on the surface will generate aquifers at a determined depth.

In general, it is expected to find only dry sectors in tunnels excavated in rocks and at a depth greater than 250m (at most, presence of humidity, some dripping or lesser squirts), Except in special situations linked to the existence of geologic faults or zones of deep fractures, which are specially treated during construction.

In fact, and as is informed below, the permeability assays effected during the drillings perforated for the project, as Well as tests of the same type known in rock masses of other cordilleran regions, show that below 250m, permeability decreases to values under 10^{-9} m/s.

3.2. EXPECTED PERMEABILITIES

The study zone of the Alto Maipo Hydroelectric Project is sited in the high cordillera southeast of the city of Santiago. Precipitations take place mostly during the winter months, as a product of the fronts coming from the Pacific Ocean. These precipitations are of snows and also rains and occur preferably from May to August.

The leakage of meteoric waters to the sub-surface occurs through the sedimentary deposits and fractured rock units. However, as the subjacent rock has a much lower permeability than the sediments, underground waters mostly seeps along the sedimentary units and only a small amount infiltrates the rock (Figure 1).

The water recharge of those permeable sedimentary deposits occurs during each rainfall, and also as the effect of the snow melts normally occurring between September and March.

Some meadows were recognized in the land, along the layout of the El Volcán, Alfalfal II and Las Lajas tunnels. From observations it has been estimated that these meadows have formed by the rainwater seeping into the quaternary sediments. Corresponding generally to unconsolidated deposits covering the bedrock.

Rainwater infiltrates into these sediments though interconnected pores; going down to the sub-surface rocks, and appears again on the surface in some sectors, either because there is some change in the slope of hill and/or a change in the thickness of the sedimentary unit and/or a change in the slope of the subjacent rock (Figure 1).

In general it is considered that the underground flow does not drain in full into the meadows, part of the underground flow seeps towards lower levels, and drain at lower elevations of the mountain. Or else, continue flowing to the fluvial deposits at the bottom of the valleys.

Only one sector of underground water upwelling appearing from the fundamental rock was reconnoitered in the study area. This upwelling occurs in the rock mass near the Las Lajas Plant cavern, in a cut of the road leading to the Alfalfal Hydroelectric Plant. Immediately after crossing the El Sauce stream. The upwelling is sporadic and only occurs during winter months. No water upwelling were observed along the tunnel layouts in the other rock masses and in general it can be stated that there are no evidences of the existence of aquifers in the remainder of the Alto Maipo rock formations of the studied area.

There are different types of rocks along the layout of the tunnels considered for the Alto Maipo Project, mostly of volcanic and sedimentary origin, with few granitic or andesitic intrusions.

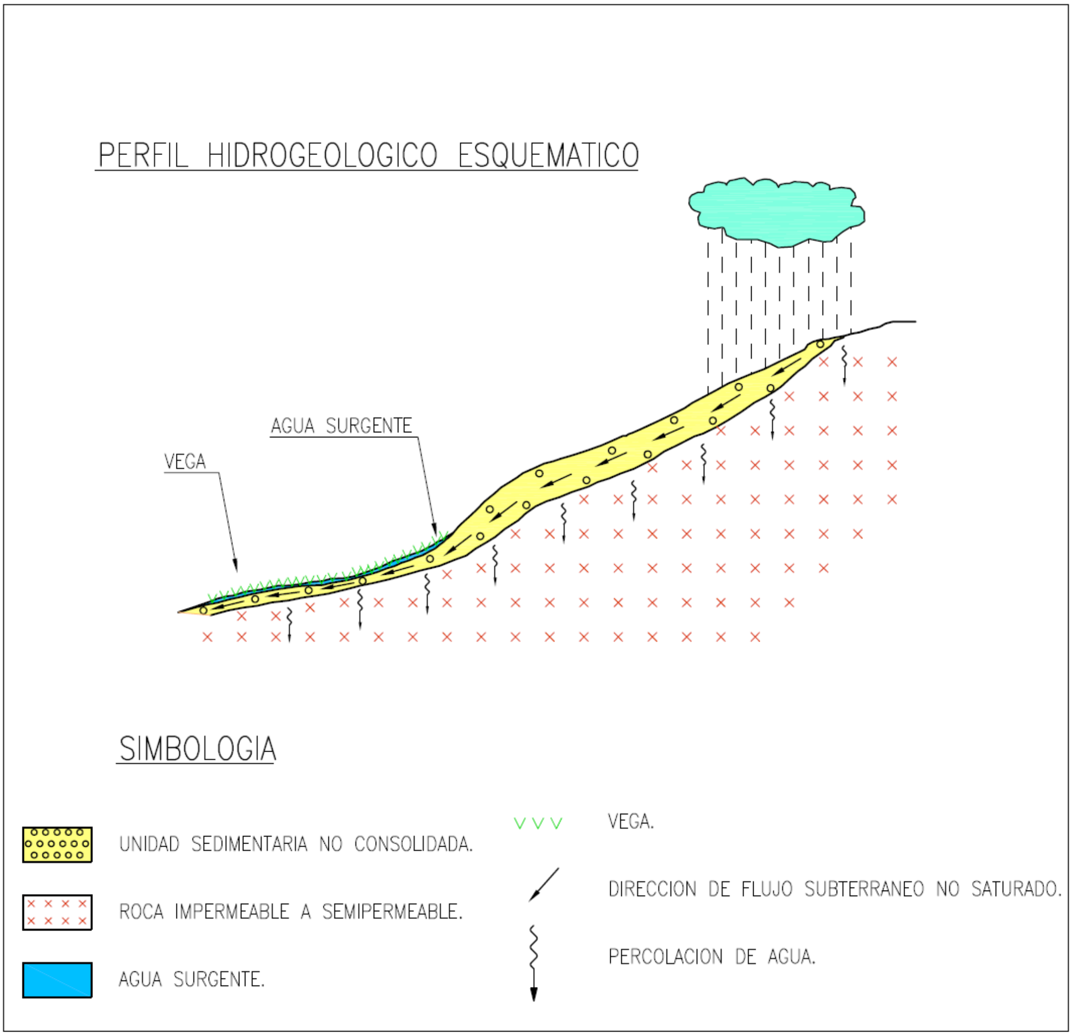

FIGURA 1.

According to the Isherwood modified study, 1979 (in Hudson and Harrison, 2000), the theoretical sound rock mass permeability values of these rocks are:

Sandstone: 10^{-5} m/s to 10^{-10} m/s.
Granite: $10^{-9\,m}$/s to $10^{-12\,m}$/s.
Lutite: $10^{-9\,m}$/s to $10^{-13\,m}$/s.
Volcanic rocks: $10^{-7\,m}$/s to $10^{-12\,m}$/s.

3.3. MEASURED PERMEABILITIES

The LUGEON values are described for the assays carried out in the exploration drillings perforated at the end of 2007 for the Alto Maipo Hydroelectric Project.

The drillings were as follows:

- SAM-1, sited in the upper sector of Aucayes-Los Maitenes, south of the Maitenes creek.

- SAM-2 sited in the Colorado River Valley, km 10 of the road to Alfalfal.

- SAM-3, sited at the old Colorado River Bridge, arriving to the Maipo river valley.

These drillings were perforated so as to survey the underground rock strata, perform geotechnical evaluation, sampling to analyze the quality of the rock and Lugeon type assays for the water admission and hydraulic fracture of the rock.

The results of the permeability calculations show that, effectively, permeability decreases as depth increases. Under 250m permeability is nil or at least does not rise above 10^{-9} m/s. Similar permeability conditions were observed in previous exploratory drillings for Alto Maipo, as Well as in geotechnical drillings in other cordilleran zones, including those carried out for Alfalfal I. The permeability values obtained in these drillings were as follows:

- SAM-1 drilling: The test values were obtained between 150 and 350m; in general they oscillate between 0 m/s and 10^{-9} m/s.

- SAM-2 drilling: The tests were carried out down to 155 and 280m. From 155 to 250m in depth the calculated values varied between 0 m/s and 10^{-7} m/s; permeability around 10^{-6} m/s predominates from 270 to 280m in depth,

- SAM-3 drilling: The tests were carried out from 15 to 40m and 75 to 120m deep. From 15 to 40m and from 75 to 100m, the calculated permeability values were in the range of 10^{-6} m/s; and from 100 to 120m permeability decreased to values of 10^{-7} m/s and 10^{-8} m/s.

Generally speaking, the information indicates that the possibility to form aquifers in rocks with a 250m or more overburden is limited. The water seeping below that depth could only do so through faults or deep sub-vertical fractures filled with some permeable material.

In general, it is believed that this situation may occur in isolated cases, with very specific conditions.

These conditions could appear in the first 1,200m of the El Volcán tunnel of the Project, and between km 2.0 and 5.0 of the Alfalfal II tunnel, from its upstream portal. The zones exposed to potential leakages will be treated applying the waterproofing methods foreseen for the Project so as to limit leakages: both those leakages entering the tunnel as well as those that could go out of it.

3.4. UNDERGROUND WATER LEVELS

As mentioned before, no evidences of water upwelling coming from fundamental rocks have been found on the surface.

The most valuable antecedents to suppose the possible presence of aquifers on the sector of the tunnels layout, comes from the measurements of the underground water levels carried out in the exploration drillings mentioned before in this report.

The measurements of the water levels were made during perforation and the execution of the assays, at the beginning and end of each work shift. The measures taken after 24 hours of rest of the well are more reliable; since fluids are injected during perforation and water is injected during the assays, the measurements taken at the end of a work shift are less reliable.

Table 1 shows the underground water level measurement values obtained from the drillings.

DRILL ING	DATE	MEASURED WATER LEVEL (m)	REMARKS
SAM-1	29/09/07	-	4.20 m perforated, no water level
SAM-1	01/10/07	6.45	Measured after one day of rest
SAM-1	22/10/07	3,12	Measured after one day of rest
SAM-2	01/10/07	16,25	Measured after one day of rest
SAM-2	05/10/07	6,80	Measured after one day of rest
SAM-2	11/10/07	9,70	Measured after one day of rest
SAM-2	16/10/07	45,80	Measured after three days of rest
SAM-2	22/10/07	45,10	Measured after two days of rest
SAM-2	23/10/07	45,10	Measured after three day of rest
SAM-2	29/10/07	44,60	Measured after one day of rest
SAM-2	05/11/07	43,77	Measured after three day of rest
SAM-3	08/10/07	13,40	Measured after one day of rest
SAM-3	09/10/07	13,00	Measured after one day of rest

The following valid conclusions, based on the above table, can be reached:

C. The underground table level in the SAM-1 drilling site is less than 3.0 meters.

D. The underground table level in the SAM-2 drilling should be most probably being situated around 45 m under the surface.

E. The underground table level in the SAM-3 drilling should be most probably being situated around 13.0m below the surface.

3.5 ALFALFAL HYDROELECTRIC PLANT CASE

The experience obtaining during the construction of the Alfalfal Hydroelectric Plant in the Colorado River Valley is the most applicable antecedent to estimate the permeability expected during the construction of the underground works for the Alto Maipo Hydroelectric Project.

The underground works for the Alfalfal Hydroelectric Plant are sited in the same geologic formations that will be crossed by the Alto Maipo Hydroelectric Project

This allows anticipating the presence of materials of similar geologic and geomechanical characteristics for the Alto Maipo Project.

As indicated by the drawings and geologic profiles prepared during the excavation of the Alfalfal underground works, wide-ranging dry segments or only humid segments were found over 95% of the total extension of the tunnels and shafts having over 200m of rock overburden - dripping or leakages were of less than 100 l/min (1.67 l/s).

Less than 5% of the tunnel segments with over 200m overburden showed spouts of the order of 100 l/min to 1,000 l/min (l,67 l/s to 16,67 l/s), which were sealed during construction.

Only two cases where larger leakages occurred but those were treated with systematic injections before advancing. One in the Chacayes tunnel, between 100 and 800m, where there were leakages of up to 80 l/s; and Another in the Common tunnel, La Gloria sector, between km 2.05 and 2.19, where there was a leakage of 5 l/s to 108 l/s and pressures up to 75 kg/cm^2 at the start.

In the Chacayes case, the overburden upon the leaking segment is less than 250m, supporting what has been said in the preceding chapters, The first half of the segment has a ceiling of rocks only and the other half, under the Chacayes creek, Has a thin rock ceiling (50 to 80m) over which there is a permeable sedimentary filling of 175m maximum thickness.

The case of the La Gloria intrusive is considered as without precedents and of a very particular hydrogeological configuration, As could be the presence of a water pocket suspended in the rock mass and not necessarily linked to a probable aquifer in the upper part of it. The geologic conditions of the two mentioned cases have not been documented in the sector where the Alto Maipo Hydroelectric Project will be sited.

3.6. CONCLUSIONS CONCERNING THE EXPECTED PERMEABILITY

- The possibility of the existence of aquifers in the area of the tunnels axis of the Alto Maipo Hydroelectric Project is minimal.

- It must be taken into consideration that about 95% if the tunnels layout has a rock overburden of over 250m and, as is maintained in this document, the load of the rock column in depths of 300m and over closes the fractures existing in the rock mass, decreasing the permeability of the rocks.

- The presence of aquifers could only be expected in sectors where the rock overburden is less than 250m and in the lower part of the main valleys.

- In this last case, the aquifer is formed in the sediments filling the valleys and the phreatic table level could be found near the river elevation.

- No upwelling from the rock mass has been observed.

- The Lungeon tests made in the drillings show that the permeability values are significantly lower in depth, showing values between 0 m/s to 10^{-9} m/s in sectors under 250m deep.

- It is expected that the permeability and leakage conditions in the rock masses of the Alto Maipo Hydroelectric Project should be similar to those found during the construction of the Alfalfal Hydroelectric Plant as present in operation.

4. METHODS TO CONTROL LEAKAGE IN THE TUNNELS

4.1 BASIC CONCEPTS

From the point of view of construction, the leakages to the tunnel must be reduced to such a level as to allow advancing in the excavations without problems due to their presence.

The following is a guide concerning the levels or values that can be considered manageable for the construction processes, without the need for special waterproofing treatments:

Normal tunnel sections: 0-4 l/s/km;
Concentrated sectors, classed as WL1 [1)]: 10 l/s/km;
Concentrated sectors, classed as WL2: 20 l/s/km.

[1)] See definition below.

As the sectors classed as WL1 and WL2 comprise a smaller percentage of the total length of the tunnels, the effects of the total maximum leakages can be considered such that they will not interfere with construction activities, as they resulted to be quite small, with values of 2 and 3 l/s/km.

The true leakage amounts might be much less during operation as a large portion of the tunnels will be under pressure. However, the design contemplates that the contractors must have the equipment to carry out injection treatments to effect an effective reduction of the leakages whenever necessary.

When strict limitations of permeability are required in specific sections of the tunnels, this is technically possible by the application of appropriate methods as described below:

<u>WL class</u>

The "WL" term refers to "Water Leakage" or "Water Filtering" and is applied to specific sections where important leakages can be expected. These are classed as:

WL 1 – Moderate:
Corresponds to water leakages of less than 30 l/s, with moderate pressures in a rock mass with median to high resistance. This also applies to small flows in low resistance and relatively dry rock masses (dripping and leakage) and in poor to very poor rock masses.

WL 2 – High:
Corresponds to water leakages over 30 l/s, with moderate to high pressures in a rock mass with median to high resistance. This also applies to average to high flows in rocks of median to low resistance and low flows in poor to extremely poor rock masses.

Some criteria can be established as a basis to limit the maximum leakages allowed in a specific runnel segment and then set the control methods to be applied. These methods can be:

- Systematic injection of the rock;

- Concrete lining, normal or reinforced, and consolidation injections between the rock and the concrete;

- Concrete living with waterproof membrane. In very severe cases, the membrane could be replaced by steel lining.

During excavation and to prevent filtrations in sectors where problems are envisaged and can be controlled beforehand, exploration drilling is carried out and injections applied if necessary.

An exploratory drillings scheme is considered for each of those filtration situations. These are known as EG1 and EG2 in answer to each of the filtration classes defined as WL1 and WL2, as follows:

EG 1:

Exploration drilling, 2 to 4 perforations, 12 - 30m long in front of the lead face. The minimum overlap between exploration drillings is of two forward blasting distances. If required, injections using 5 to 10, 12-20m long drillings in a fan pattern, in front of the lead face. Continuing with 3 to 6 drillings to check the result of the injections.

EG 2:

Exploration drilling, 3 to 6 perforations, 12 - 30m long in front of the lead face. The minimum overlap between exploration drillings is of three forward blasting distances. If required, injections using 10 to 30, 12-25m long drillings in a fan pattern, in front of the lead face. Continuing with 5 to 15 drillings to check the result of the injections.

The extension of the EG1 and EG2 class zones in specific sections of the Alto Maipo tunnels has been estimated on the basis of the available geological information. The estimate for the Las Lajas and Alfalfal II varies from 1% to 5% of the total length for Class EG1, and from 0% to 2% for Class EG2.

A higher presence has been estimated for the Volcán tunnel, up to approximately 7% for EG1 and 3% of EG2, over the total length.

4.2 CONCENTRATED FILTRATIONS

Exploration drillings will be carried out during the construction of the tunnel, to detect zones with concentrated filtrations before continuing with construction. When Class WL1 and WL2 will be detected, the injection of the zone in front of the lead face can be made, as mentioned before, so as to minimize leakages to an acceptable level before excavating. Additional injections can be made after the excavation of the zone, if necessary, to further reduce leakage.

Should the tunnel be excavated in one of those zones lacking prior exploration drillings, the principle of injection of the rock mass still applies, but the process will be more complex, as it will require to first control the leakages that will be appearing in the excavation front, And then carry out the waterproofing treatments of the rock mass ahead of the lead face.

4.3 NON CONCENTRATED FILTRATIONS

Should systematic leakages towards the tunnels show up during construction in non-concentrated segments, or it is foreseen that there would exist leakages from the tunnels during the operation of the plant, of such a magnitude requiring control, systematic injections may be applied ahead or behind the lead face; in severe cases a waterproof lining should be applied.

Instances of such cases may occur in tunnels under low rock cover such as:

- Tunnel sectors in areas where the influence of the underground waters could imply the risk of ground deformations:

- Tunnels sectors in areas where an influence of the underground waters could appear and affect wells or surface vegetation depending from those underground waters;

- Tunnels in areas where the leakage from the tunnel to the rock mass might be excessive.

4.4 LEAKAGES DURING OPERATION

A large proportion of the Alto Maipo Hydroelectric Project tunnels are pressurized. And there may be in them potential leakages to the rock mass, in sectors where the internal pressure of the water is greater than the level expected in the phreatic table. There are some indications that this could happen at the end of the Alfalfal II head tunnel, in the zone next to the headrace shaft, where the steel armor lining begins, therefore the possibility to effect systematic injections is contemplated in the design.

This sector is where the highest internal pressure of the tunnel takes place. The information concerning the permeability and tensions of the rock, based on the in situ research about rock conditions that will be effected once those tunnel sectors will have been excavated, will determine where to end the steel armor and which waterproofing treatments would be necessary.