ANNEX 17

OPERATION OF ALFALFAL II AND LAS LAJAS POWER STATIONS

1. INTRODUCTION

Water resources are essentially of the random type and vary between years and throughout the year, according to the hydrological cycle.

PHAM hydrological study has provide complete sets of monthly mean flows at all collection points, for a period of 50 years. This makes possible to analyze the hydraulic profile of power stations for various scenarios.

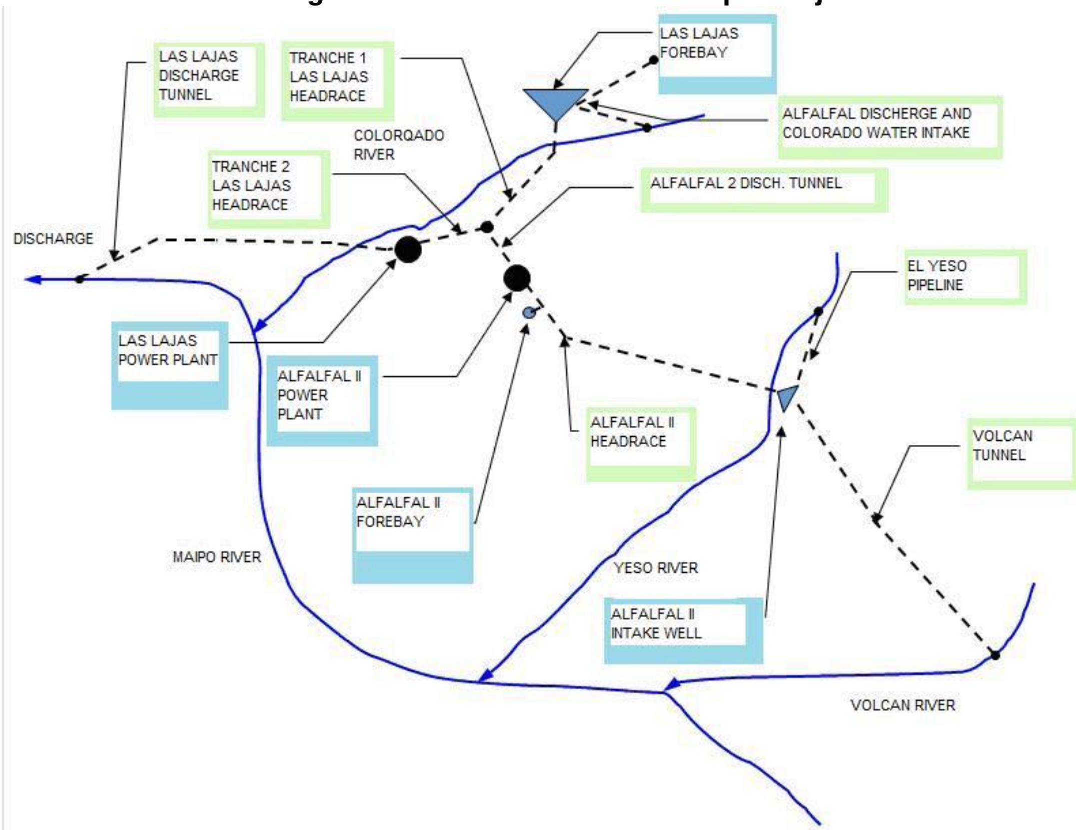
This document describes the normal operation of PHAM power stations (permanent regime), as well as contingency operation (transient arrangements) that occurs in cases of head taking or rejection (sudden starts or stops of the plant), for various combinations of flow rates.

In the case of Alfalfal II power station, the water circuit is divided into two systems: headwater works and system under pressure. Within the headwater works collections in the upper part of Volcán River, collection in Yeso River and Volcán tunnel are included. This whole system ends in an intake well located in the left bank of Yeso River, which is the linking point with the system under pressure. The piezometric profile of this system is which directly affects the degree of power generation of Alfalfal II power plant.

In the case of Las Lajas power plant, it is also possible to divide the water circuit in two systems: headwater works and tunnel system under pressure. In the headwater system, all hydraulic works that allow feed the head tank are included; the latter is the forebay of Las Lajas power plant, so that is the focal point for the calculation of system under pressure.

Figure 1.1 shows a diagram of arrangement of the works that make up the hydraulic circuit of the two power plant of Alto Maipo project.

Figure 1.1
Diagram of the Works of Alto Maipo Project



The Alto Maipo basin, where the works are located, has a hydrologic nivo-pluvial regime, so that from the operational point of view of the power plant, it is necessary to distinguish two distinct periods: the period of spring - summer, where thaws occur, and the period of fall - winter, which corresponds to the period of rainfalls, where these are manifested mostly as snow.

2. NORMAL OPERATION OR UNDER PERMANENT REGIME

2.1 ALFALFAL II POWER PLANT

To define the operational criteria of Alfalfal II power plant, two periods are identified during the year: Spring - Summer and Fall - Winter.

2.1.1 Operational criteria

a) Spring-Summer (October to April)

During the spring - summer or snowmelt, the nival regime of waterways where collections are located, allows that water intakes have flows close to or above the design. Therefore, the plant works by collecting and generating the flow available at each water intake, understanding that an available flow is that limited above by water rights and below by environmental flows in each collection point.

Effectively collected flows are subject in turn to operational and design constrains. On the design side, collected flows are limited by the maximum capacity of the water intakes and the design flow from the pipe and, on the operational side, by the availability of resources in each collection.

The main water intake of Alfalfal II power plant is located on Yeso River, downstream of El Yeso reservoir, with a capacity of about 50% of the total design flow of the plant. Ideally, during summer, the power plant will work with El Yeso collection, and complete its design flow with the water intakes of the upper basin of Volcán River.

Nevertheless, the available flow in El Yeso River depends on the operation of El Yeso reservoir by third parties. Therefore, if the operator of El Yeso reservoir keeps the effluents of the reservoir below the expected levels in summer, Alfalfal II power plant can maximize available melt flow rates, collecting up to reach the full design capacity of the water intakes of the upper basin of Volcán River.

b) Fall-Winter (May- September)

In the fall – winter period, which corresponds to the months of minimum flows, Alfalfal II power plant can only operate with the available flows in the waterways, which are lower than the design flows of the plant.

According to the hydrological study of the project and the results of power generation model developed for this project, the average flows of generation in Alfalfal II power plant are those shown in Table 2.1.

Table 2.1
Monthly Average Flow Generation Alfalfal II Power Plant (m3 / s)

Months	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	Average
Flow Gen.Alfalfal	3.9	10.7	9.6	24.0	25.3	23.2	16.7	10.5	6.4	10.0	4.9	4.8	12.5

c) Different operating scenarios

In order to calculate the piezometric levels in different parts of the headrace system, we have defined some typical scenarios of operation for the summer and winter periods, which are presented in Table 2.2. The definition of flow is explained in Figure 2.1.

Table 2.2
Type of Operation Scenarios

Period (Scenario)	**Q_{11} m³/s**	**Q_{12} m³/s**	**Q_{13} m³/s**
Maximum Flow	15.0	12.0	27.0
December 1995	0.0	12.8	12.8
November 1968	8.3	0.7	9.0
Average flow in winter	5.0	2.0	7.0

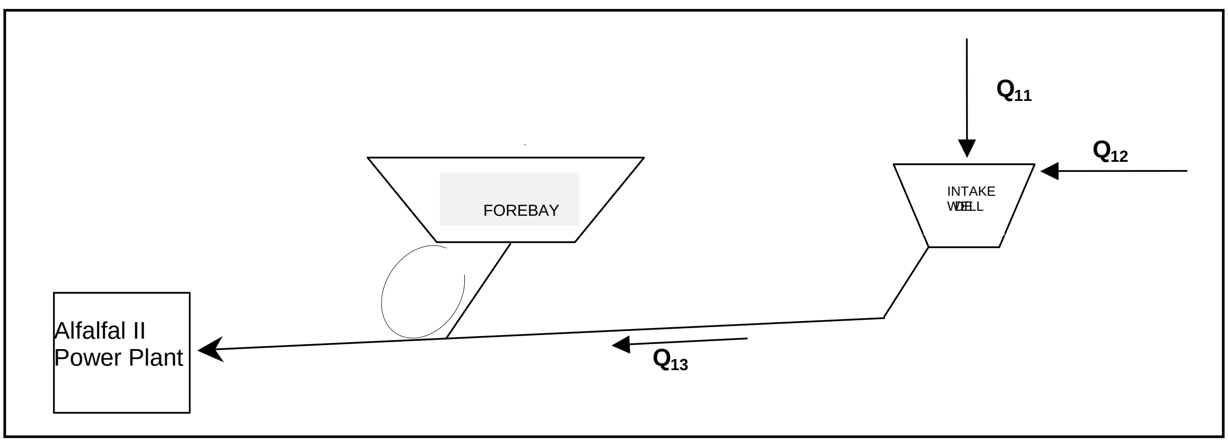


Figure 2.1: Diagram of inflows to Alfalfal II Power plant

Q_{11} = Contribution from El Yeso reservoir.
Q_{12} = Contribution from upper basin Volcán River.
Q_{13} = Headrace flow Alfalfal II power plant.

2.1.2 Piezometric levels in Headwater Works

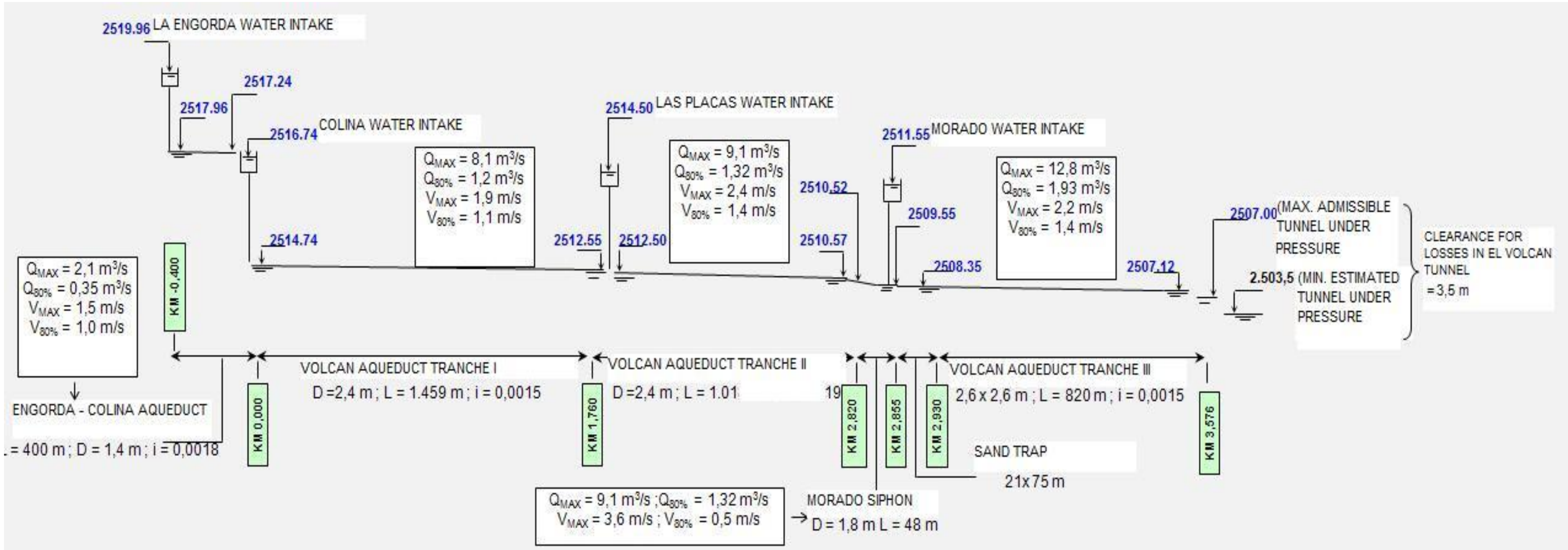
From the standpoint of the piezometric profile, Alfalfal II power plant presents two well defined systems, the intake wellbeing located in the Valley of Yeso River, the focal point of both systems. This is a small work of intake and stabilization, which ensures a stable level at the beginning of headrace of the plant. Its total volume is 14,700 m^3 and net volume 10,000 m^3.

For purposes of this description, headwater works are those located upstream of the intake well and include two spurs: the supply lines coming from the upper part of Volcán River and the supply lines where the contribution from the water intake of Yeso Ricer runs off.

The spur from the Volcán River includes the 4 water intakes of Volcán River, which deliver their flow to an aqueduct of varying dimensions. Figure 2.2 shows the piezometric profile of this tranche, which begins with La Engorda water intake and ends in the work of delivery to El Volcán tunnel.

It is worth mentioning that the design is done so that Colina water intake is located at the elevation 2,516 meters ASL, so that its position does not intervene the summer grazing area of the plain of Colina and La Engorda. This boundary condition implies that the maximum permissible level of the hydraulic axis in the entrance sluice gate of El Volcán tunnel corresponds to 2,507 meters ASL.

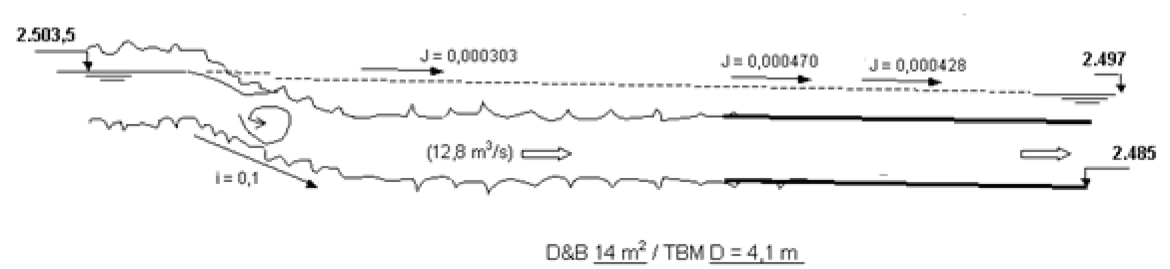
Figure 2.2
Schematic Hydraulic Profile System Alto Volcán



The piezometric profile of El Volcán tunnel corresponds to a tunnel composed of a tranche excavated with a TBM D = 4.1 m and a tranche of conventional excavation of section 14 m2, which have a runoff under pressure and whose piezometric profile appears plotted in Figure 2.3 for the maximum flow of 12.8 m^3 / s.

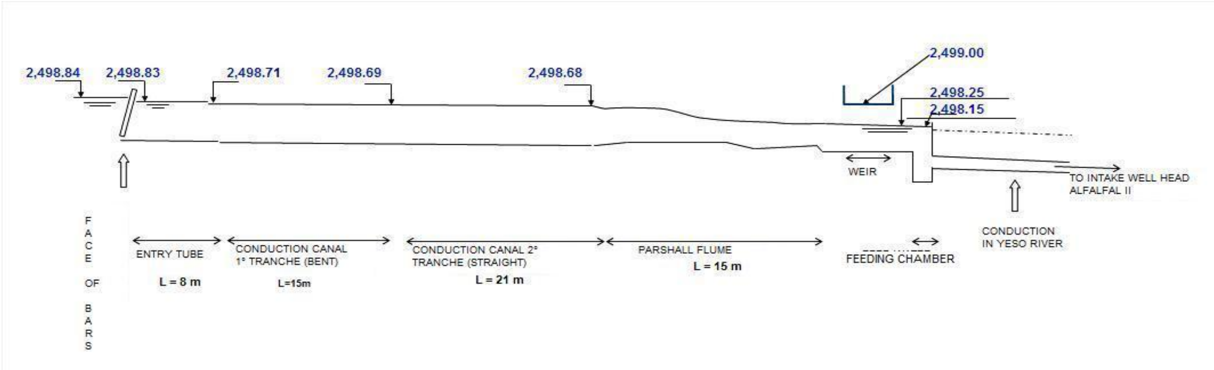
It should be noted that the runoff into El Volcán tunnel is under pressure because the piezometric level of the intake well is located at an elevation of 2,497 m ASL.

Figure 2.3
Piezometric Profile of El Volcán Tunnel

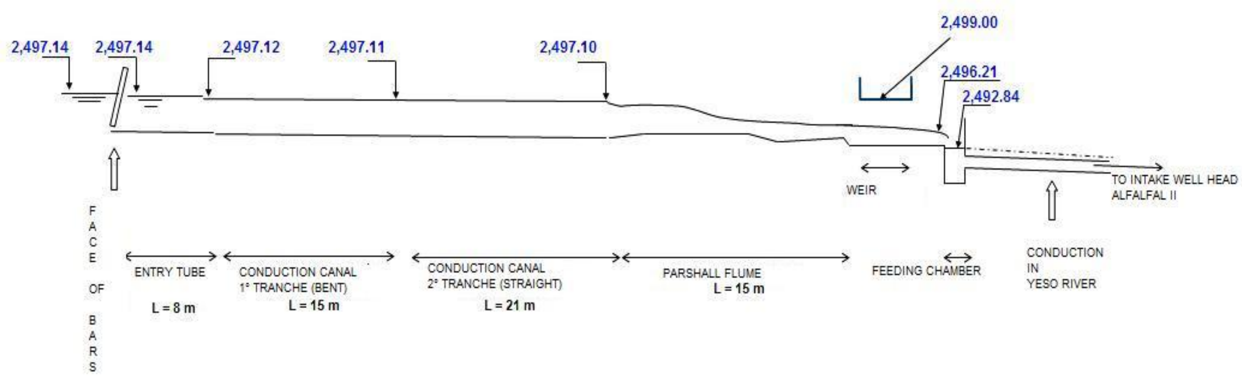


The collected flow in the water intake of Yeso River is conducted to the intake well of Alfalfal II through a pipeline of reinforced concrete of section 2.8 x 2.8 m. Piezometric profiles shown in Figures 2.4 a) and b) respectively, considers that in the Alfalfal II intake well the maximum level would be around 2,497 m ASL.

Figure 2.4
Piezometric Profile of Yeso Water Intake Headrace



a) Maximum Flow (15 m^3/s)



b) Minimum Flow (3, 4 m^3/s – 80% probability of exceedance)

As seen in Figure 2.4, the runoff from the face of bars of Yeso River water intake to downstream of Parshall flume, runs in open cut. As conduction of Alfalfal II intake well is considered under pressure, a feed chamber that allows for transitions between flow in open cut flow and flow under pressure.

2.1.3 Piezometric profiles of generation system

To determine the piezometric profile of Alfalfal II power plant, the geometric configuration shown in Figure 2.5 has been considered.

Given the variability of available water resources, operating scenarios listed in Table 2.2. have been considered. The first three scenarios correspond to a typical summer situation, while the remaining is representative of winter season.

The results are presented in Table 2.3, where the specified flows, piezometric levels of the vertex angles shown in Figure 2.5 and the net height of generation are indicated.

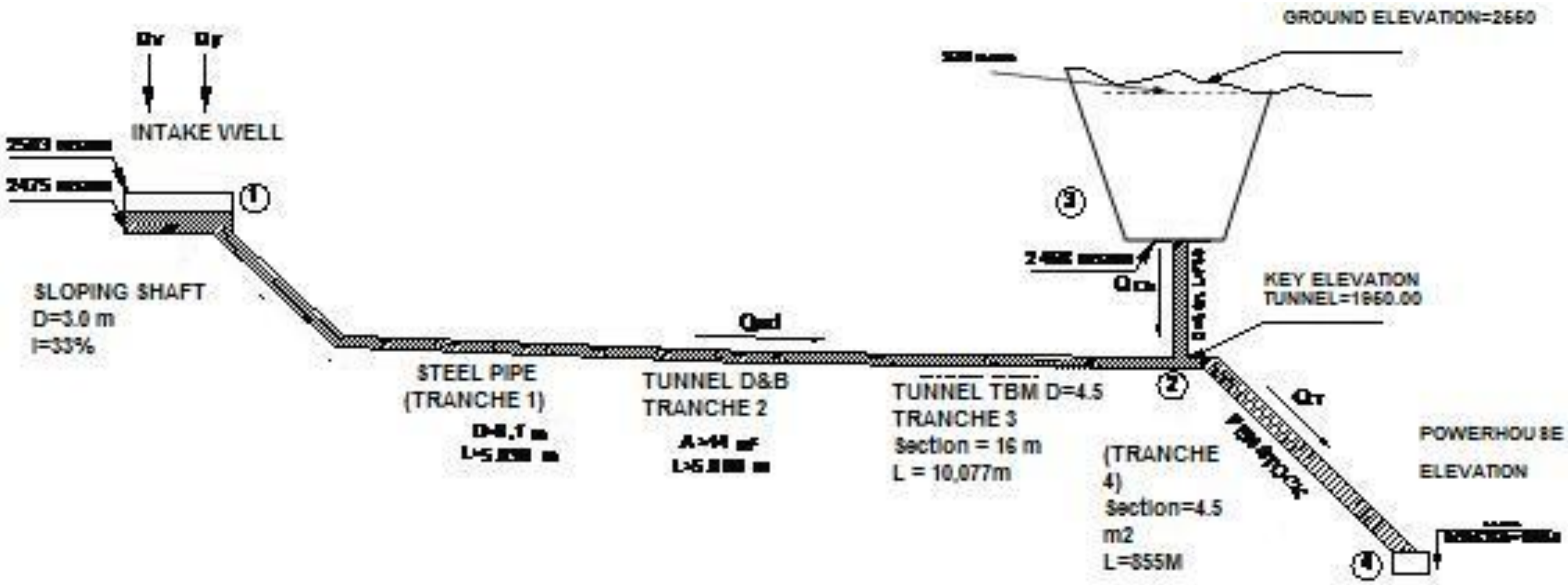
Table 2.3
Pîezometric levels Alfalfal II power plant

Scenario	Qv	Qy	Qad	Piezometric Elevation (m ASL)				Net Height
	m^3/s	m^3/s	m^3/s	Z1	Z2	Z3	Z4	(m)
Qmax	12,0	15,0	27,0	2497,0	2469,5	2469,5	2461,7	1120,3
Summer (Dec. 1995)	2,0	10,0	12,0	2497,0	2491,6	2491,6	2490,0	1148,6
Summer (Nov. 1968)	2,0	7,0	9,0	2497,0	2493,9	2493,9	2493,1	1151,7
Winter	2,0	5,0	7,0	2497,0	2495,2	2495,2	2494,6	1153,2

The results shown in the previous table consider that the piezometric level in the intake well of Yeso River (Z1) has a peak of 2.497 m ASL so not to drown the collections of El Volcán and El Yeso Rivers, a situation that if occurs would limit the ability to collect the intake works.

The last column of Table 2.3 indicates that the net height of generation varies between 1120.3 and 1153.2, the gross height of fall being equals to 1157.4 m.

Figure 2.5
Diagram of the Generation Profile of Alfalfal II Power Plant



2.2 Las Lajas Power Plant

2.2.1 Operational Criteria

a) General

Las Lajas power plant is in hydraulic series with the Alfalfal II power plant, but its operational characteristics are different.

The restoration of Maipo River natural regime requires that the operation of the surface works of Las Lajas power plant not only provides the conditions for generation of the plant but also allow to restore the flow modified by the operation, especially during a rejection of hydraulic head of the plant. Then, the forebay of Las Lajas power plant must operate as safety pond in the event that power stations are out of service. .

In addition, this forebay can collect and regulate resources from Alfalfal power plant and Colorado River basin, thus obtaining a stable level of generation for Las Lajas. This work has a useful volume of approximately 300.000 m^3.

Given the variation experienced by the flow in the waterways of the watershed, even though Las Lajas power plant is a run-of-river plant, in its operation two periods must also be distinguished: Spring - Summer and Fall- Winter.

b) Spring-Summer (October to April)

During the summer or thaw period, the nival regime of waterways where collections of Alfalfal II are located allows this plant to operate in this period as a typical run-of-river plant. In this situation, water intakes collect flows very close to their maximum or design capacities.

The operational criteria of Las Lajas power plant is then limited to collect and generate all the available flow at each water intake, understanding that an available flow is that limited above by water rights and below by environmental flows in each collection point.

Effectively collected flows are subject in turn to operational and design constrains. On the design side, collected flows are limited by the design capacity of collections and conductions and, in the operational side, by the availability of resources in each collection.

The main collections of Las Lajas power plant are from the discharge of Alfalfal power plant (up to 30 m^3 / s) of Alfalfal II power plant (up to 27 m^3 / s) and Maitenes water intake (up to 10 m^3 / s) . Las Lajas forebay receives contributions from Alfalfal discharge and Maitenes water intake, contributions whose amount is limited to a maximum flow of 38 m^3 / s while the discharge of Alfalfal II is received directly in Las Lajas tunnel, downstream of the forebay.

c) Fall – Winter (May to September)

During this period, which corresponds to the months when the minimum flows occurs in water ways, like Alfalfal II, the plant operates well below its maximum capacity. This can be seen in Table 2.4.

Table 2.4
Monthly Average Flow Generation Las Lajas Power Plant

Months	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	Average
Q Gen. Las Lajas	17.8	29.7	37.4	59.0	62.2	59.8	47.0	30.0	21.3	23.5	17.3	17.4	35.2

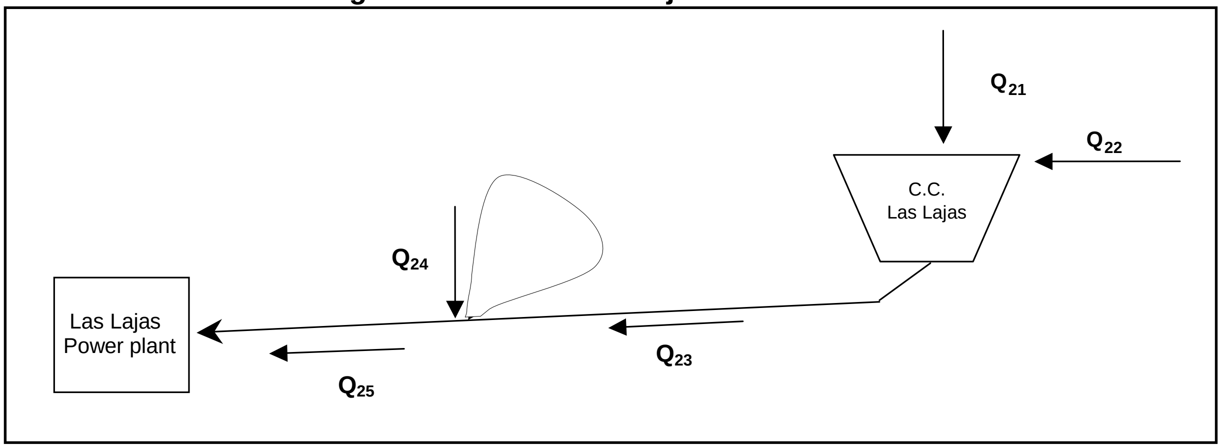
d) Different operating scenarios

In order to calculate the piezometric levels in different points of the headrace system, we have defined typical scenarios of operation for the summer and winter periods, which are presented in Table 2.2.

Table 2.5
Flows for typical Scenarios of Operation

Period (Scenario)	**Q_{21} m³/s**	**Q_{22} m³/s**	**Q_{23} m³/s**	**Q_{24} m³/s**	**Q_{25} m³/s**
January 1983	27.5	10.5	38	27	65
December 1995	27.5	10.5	38	14	53
November 1968	5.2	8.2	13.4	11	24.4
Las Lajas plant out of service (January 1983)	0	0	-27	27	0
Alfalfal II plant out of service (January 1983)	27.5	10.5	38	0	38
Period of accumulation in forebay	9.3	5.2	-1.1	27	26.0
Alfalfal II plant out of service	9.5	5.5	15	0	15.0
Las Lajas plant out of service (Peak period)	0	0	-27	27	0
Las Lajas and Alfalfal II plants out of service	0	0	0	0	0

Figure 2.6
Diagram of Inflows Las Lajas Power Station.



Q_{21} = Contribution from Alfalfal discharge.
Q_{22} = Contribution from intermediate basin (Maitenes water intake).
Q_{23} = Contribution from Las Lajas forebay.
Q_{24} = flow generated in Alfalfal II.
Q_{25} = flow generated in Las Lajas power plant.

2.2.2 Piezometric Levels in Headwater Works

The headwater works of Las Lajas power plant are divided into two types: those that feed the head pond of Las Lajas and those that feed directly into the headrace tunnel. Among the former are the work of diversion of the tailrace of Alfalfal power plant and modification of Maitenes flume. Piezometric levels of these works are linked to levels of operation in the head pond. For its part, the work that contributes directly to the headrace tunnel corresponds to the discharge of Alfalfal II power plant.

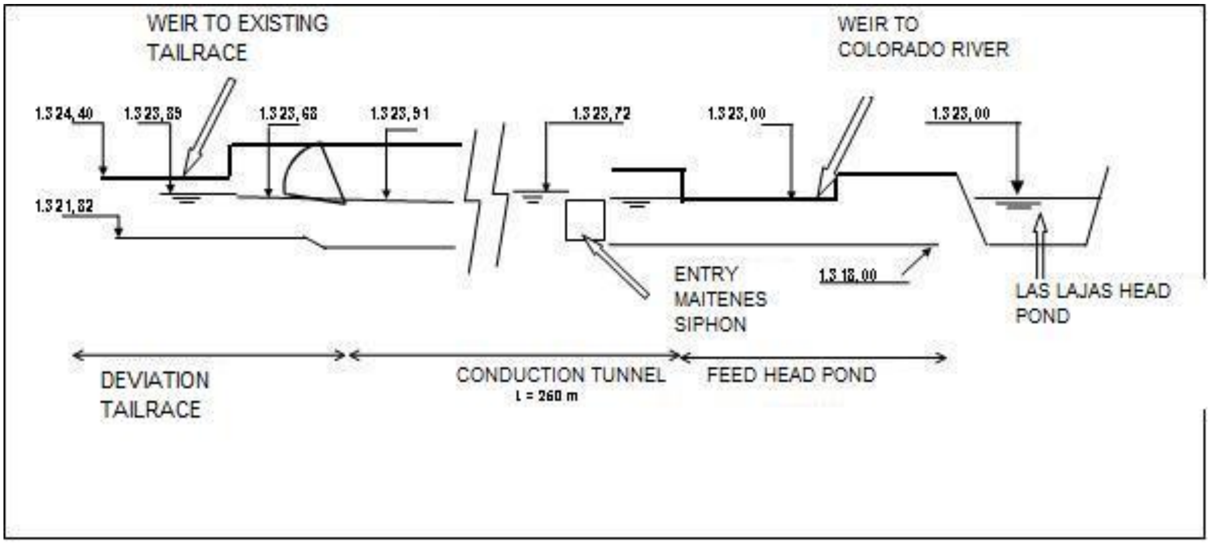
Piezometric levels in the works mentioned will be determined by the operation conditions of the power plant system as a whole, so its estimate is subject to the studies presented in the following paragraphs.

a) Collection from discharge Alfalfal Power Plant

The collection of water from Alfalfal Power Plant is performed by an extension of the existing evacuation flume, which has a design flow of 30 m³ / s. This work, called supply flume of the head pond, is connected by the right face of the evacuation flume, in the area that faces the siphon that crosses Colorado River, and currently provides some of the waters of Alfalfal power plant to Maitenes power plant.

From this point of connection, a flume of basal width of 4 m, whose elevation of concrete slabs in the starting point is 1321.82 m ASL is developed. In Figure 2.7 the piezometric profile of the feed flume of the head pond is shown.

Figure 2.7
Piezometric profile. Modification Alfalfal Tailrace.



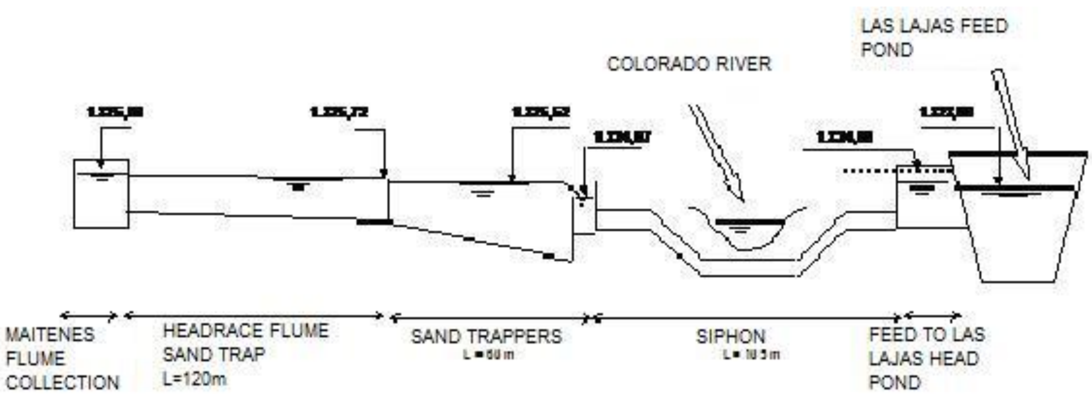
The profile of Figure 2.7 shows that the maximum water height calculated against the weir in the starting point is 1323.89. The calculation was made on the basis of considering Las Lajas head pond at its maximum level (1323 m ASL) and peak flows in both the deviation of the tailrace of Alfalfal power plant (30 m^3 / s), and Maitenes waterway (10 m^3 / s).

Therefore, the profile presented considered a flow rate equals to 30 m^3 / s from the beginning of the profile, to the point marked "entry Maitenes siphon" and 40 m^3 / s downstream. It is observed that, under these conditions, the water level reaches the connection point 1323.89 m ASL, which is a lower level than the threshold level of weir (1324.40), with a freeboard equals to 0.5 m.

b) Modification of Maitenes Flume

The flow of the middle basin of Colorado River will be collected in the current water intake of Maitenes power plant. Feeding work of the head pond has its origin at a point downstream of the existing tunnel, with a hydraulic axis at an elevation of 1325.80 m ASL, as shown in Figure 2.8.

Figure 2.8
Hydraulic Profile. Modification Maitenes Flume



From the point of origin, a headrace flume, two sand removal trappers, a siphon crossing Colorado River and connection with the feed work to the head pond are developed.

2.2.3 Piezometric Profiles of Generation System

To determine the piezometric profile of Las Lajas power plant, geometrical configuration presented in Figure 2.9 has been considered.

Given the variability of available water resources, we have considered several operating scenarios and calculated pìezometric levels in most relevant vertex angles. The cases analyzed are:

a) Cases with Alfalfal II Power Plant at full capacity

Permanent 1: It considers the normal operation of both plants at full capacity, with a flow in Alfalfal II power plant Q_{al} of 27.0 m³ / s and a flow in Las Lajas power plant Q_T = 65.0 m³ / s, so that effluent flow of the forebay is Q_{cl} = 38.0 m³ / s. The forebay operates at the peak of 1,323 m above sea level and at the minimum elevation of 1,318 m ASL.

Permanent 2: It involves the operation of only one turbine in Las Lajas power plant, so that the flow of generation in the plant is Q_T = 32.5 m³ / s, with Alfalfal II power plant operating at full capacity, Q_{al} = 27. 0 m³ / s. Thus, the effluent flow of the forebay is Q_{cl} = 5.50 m³ / s. The forebay operates at the peak of 1.323 m above sea level and at the minimum elevation of 1,318 m ASL

Permanent 3: Las Lajas power plant is out of service and Alfalfal II plant is at full capacity. Thus, Q_T = 0.0 m³ / s, Q_{al} = 27.0 m³ / s and the inflow to the forebay Qcl = -27.0 m³ / s. The forebay operates at the peak of 1,323 m above sea level and at the minimum elevation of 1,318 m ASL

b) Cases with Alfalfal II power plant operating with only one turbine at full capacity

Permanent 4: In this case only one turbine operates at Alfalfal II power plant at full generation capacity, this is Q_{al} = 13.5 m³ / s. The outflow from the forebay is Q_{cl} = 38.0 m³ / s, whereby the flow of Las Lajas power plant is Q_T = 51.5 m³ / s. The forebay operates at the peak of 1,323 m above sea level and at the minimum elevation of 1,318 m ASL.

Permanent 5: In this case we consider the operation of only one turbine at full capacity in both power plants, so that the flow of generation in Las Lajas power plant is Q_T = 32.5 m³ / s, the flow in Alfalfal II is Q_{al} = 13.5 m³ / s and therefore, the outflow of the forebay is Q_{cl} = 19.0 m³ / s. The forebay operates at the peak of 1,323 m above sea level and at the minimum elevation of 1,318 m ASL.

Permanent 6: Here Las Lajas Power Plant is out of service, being then Q_T = 0.0 m³ / s, Q_{al} = 13.5 m³ / s, with which we have an inflow to the forebay of Q_{cl} = -13.5 m³ / s. The forebay operates at the peak of 1,323 m above sea level and at the minimum elevation of 1,318 m ASL.

c) Cases with Alfalfal II Power Plant out of service

Permanent 7: In this case it is assumed Q_{al} = 0.0 m³ / s, thereby the maximum flow of generation in Las Lajas power plant under this condition is Q_T = 38.0 m³ / s, which corresponds to the outflow from the forebay Q_{cl} = 38.0 m³ / s. The forebay operates at the peak of 1,323 m ASL and at the minimum elevation of 1,318 m ASL.

Permanent 8: It has Q_{al} = 0.0 m³ / s, with a maximum flow rate of generation of a single turbine in Las Lajas power plant, i.e. Q_T = 15 m³ / s, so the outflow of the forebay is Q_{cl} = 15 m³ / s. The forebay operates at the peak of 1,323 m above sea level and at the minimum elevation of 1,318 m ASL.

Permanent 9: It has Q_{al} = 0.0 m³ / s, with a maximum flow rate of generation of a single turbine in Las Lajas power plant, i.e. Q_T = 32.5 m³ / s, so the outflow of the forebay is Q_{cl} = 32.5 m³ / s. The forebay operates at the peak of 1,323 m above sea level and at the minimum elevation of 1,318 m ASL.

d) Cases of operation during winter

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Permanent cases 10 to 12 correspond to the operation of the plant during winter, as detailed in Table 2.6.

The results are presented in Table 2.6. The specified flow, the piezometric levels of the vertex angles indicated in Figure 2.9 and the net height of generation are shown.

Figure 2.9
Diagram of Conduction under Pressure of Las Lajas Power Plant

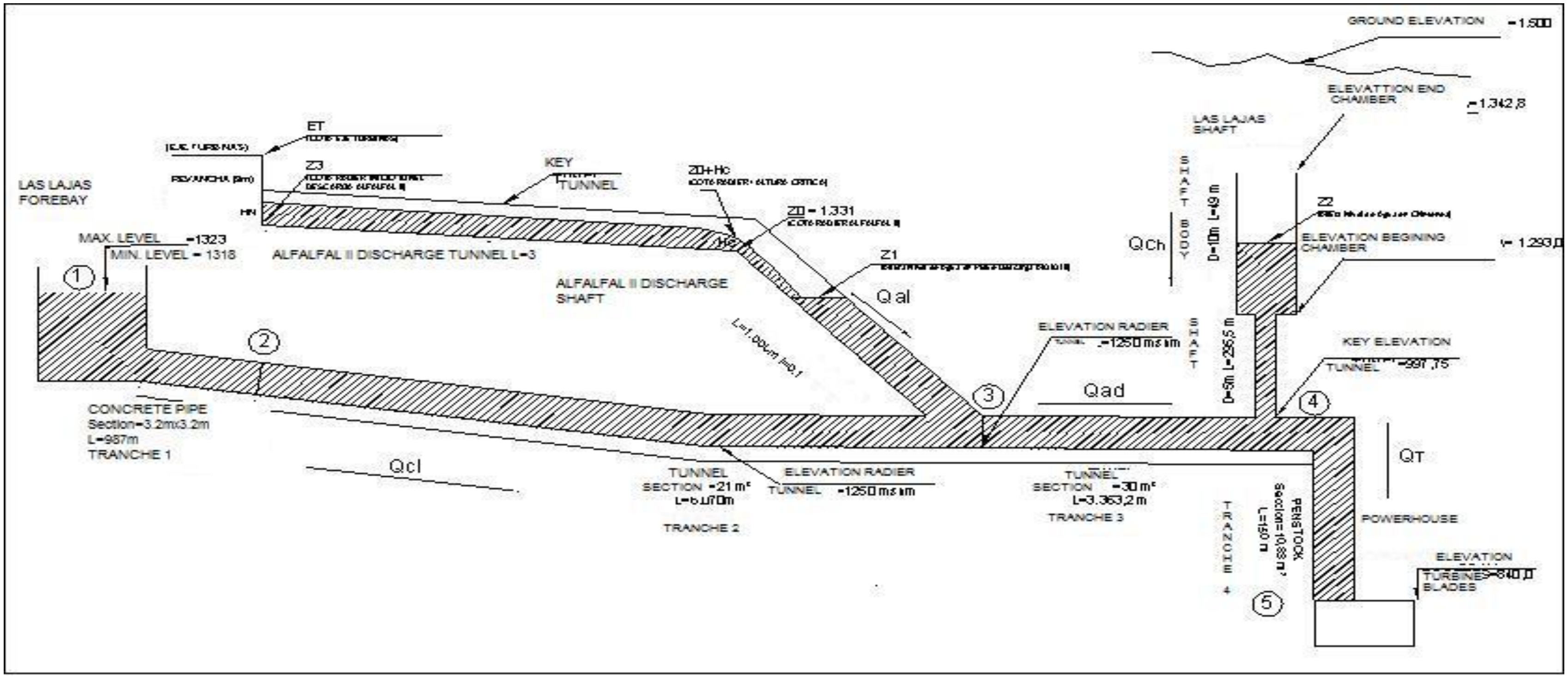


Table 2.6
Piezometric levels of Las Lajas power plant

Scenario	Flow (m^3/s)			Piezometric Elevation (m ASL)					Hn (m)
	Q_{CL}	Q_{AL}	Q_T	1	2	3	4	5	
P-1A	38.0	27.0	65.0	1323.00	1318.97	1312.60	1308.74	1308.02	468.02
P-1B	38.0	27.0	65.0	1318.00	1313.97	1307.60	1303.74	1303.02	463.02
P-2A	5.5	27.0	32.5	1323.00	1322.92	1322.78	1321.82	1321.64	481.64
P-2B	5.5	27.0	32.5	1318.00	1317.92	1317.78	1316.82	1316.64	476.64
P-3A	-27.0	27.0	0.0	1323.00	1325.04	1328.25	1328.25	1328.25	-
P-3B	-27.0	27.0	0.0	1318.00	1320.04	1323.25	1323.25	1323.25	-
P-4A	38.0	13.5	51.5	1323.00	1318.97	1312.60	1310.18	1309.73	469.73
P-4B	38.0	13.5	51.5	1318.00	1313.97	1307.60	1305.18	1304.73	464.73
P-5A	19.0	13.5	32.5	1323.00	1321.99	1320.40	1319.44	1319.26	479.26
P-5B	19.0	13.5	32.5	1318.00	1316.99	1316.99	1316.99	1316.99	476.99
P-6A	-13.5	13.5	0.0	1323.00	1323.00	1323.00	1322.83	1322.80	-
P-6B	-13.5	13.5	0.0	1318.00	1318.00	1318.00	1317.83	1317.80	-
P-7A	38.0	0.0	38.0	1323.00	1318.97	1312.60	1311.28	1311.04	471.04
P-7B	38.0	0.0	38.0	1318.00	1313.97	1307.60	1306.28	1306.04	466.04
P-8A	32.5	0.0	32.5	1323.00	1320.05	1315.39	1314.43	1314.25	474.25
P-8B	32.5	0.0	32.5	1318.00	1315.05	1310.39	1309.43	1309.25	469.25
P-9A	15.0	0.0	15.0	1323.00	1322.37	1321.38	1321.17	1321.14	481.14
P-9B	15.0	0.0	15.0	1318.00	1317.37	1316.38	1316.17	1316.14	476.14
P-10A	-0.7	27	26.3	1323.00	1323.00	1323.00	1322.37	1322.25	482.25
P-10B	-0.7	27	26.3	1318.00	1318.00	1318.00	1317.37	1317.25	477.25
P-11A	26.3	0,0	26,3	1323.00	1321.07	1318.02	1317.39	1317.27	477.27
P-11B	26.3	0,0	26,3	1318.00	1316.07	1313.02	1312.39	1312.27	472.27
P-12A	15.3	0.0	15.3	1323.00	1322.35	1321.31	1321.10	1321.06	481.06
P-12B	15.3	0.0	15.3	1318.00	1317.35	1316.31	1316.10	1316.06	476.06

The calculation of piezometric levels shown in the table above is based on the fact that the level of the head pond varies between elevations 1,323 and 1,318 ASL

The results presented in the table above indicate that the piezometric level sloping shaft that follows the discharge tunnel of Alfalfal II power plant (Z3) varies between 1307.60 and 1,328 levels, 25 m ASL, where 1,331 is the elevation of concrete slab at the beginning of the inclined tranche.

The last column of Table 2.5 shows that the height of generation varies between 463.0 and 482.3 m, the gross height of fall being equals to 483 m.

3 CONTINGENCY OPERATION OR UNDER TRANSIENT REGIME

3.1 GENERAL

The Alto Maipo project consists of two power plants operating in hydraulic series. Each plant has a system of tunnels under pressure to feed the turbines (2 units at each plant). Figure 2.5 shows the arrangement of the tunnels for Alfalfal II power plant and Figure 2.9 shows the arrangement of tunnels feeding Las Lajas power plant.

During the operation of the plants, situations that force to stop one or the two plants may occur for a certain period of time. During these events, there are two transient phenomena that are important to analyze. They are the phenomena of mass fluctuations within the tunnels under pressure and of the impact on hydrometric network of Maipo River.

3.2 MASS FLUCTUATIONS

Surge shafts are the works which function is to dampen pressure fluctuations generated in the tunnels under pressure due to the operation of the generating units. Hydraulic turbines can vary the flow of operation very quickly according to the requirements of power generation; however tunnels under pressure, due to their own inertia vary very slowly. The surge shafts are deposits which can give or receive flows from the tunnel system, through the variation of their own volume of water stored, varying their level, in order to control the sudden pressure variations in tunnels and resulting in the stoppage of water bodies.

In both plants simple shafts have been designed, in the case of Afalfal II, constituted by a shaft inclined that widens at its upper part in a forebay; in the case of Las Lajas, constituted by a cylindrical reservoir connected to the tunnel by a vertical shaft. Thus, the fluid flow enters or comes out of the tunnel to the shaft through the shaft.

- Alfalfal II Power Plant

In the case of Alfalfal II power plant, as shown in Figure 2.5, there is an intake well that allows the entry of water from El Volcán tunnel and the waters of Yeso River to the headrace of the plant. The tunnel from the intake well joins with the headrace tunnel through a pipeline system under pressure up to the junction of the tunnel with the shaft that is the shaft and forebay of the plant, located immediately upstream of the pressure shaft that feeds the two generating units.

The tunnel system, therefore, is a complex system with two shafts in series: the first at the head of the system under pressure (intake well) and the second corresponds to the shaft itself.

- Las Lajas Power Plant

Las Lajas power plant (see Figure 2.9) also has a complex tunnel system that is fed from a forebay located along the Colorado River (right bank) to section (3), where it joins the flow delivery of Alfalfal II plant consisting of a shaft inclined as shown in Figure 2.9. Finally, section (4) corresponds to the junction of the tunnel with the communication shaft of the surge shaft of the plant, immediately upstream of the start of the pressure shaft of the plant.

To design effects of a surge shaft, these two power plants must face limit switching that demand their maximum capacity, and basically they are:

a) Full head rejection of the power plant

It is a possible switching that usually occurs due to an electrical failure in the transmission system. It is also a required switching because this failure may always occur and requires the surge shaft and tunnel system under pressure are operating at its full capacity, especially with regard to maximum levels (piezometric levels) and also flows into and out of the shaft and of the outlet works. The analysis should be undertaken with the highest levels in the forebay and minor or optimistic head losses in tunnels.

b) Sudden increase from 50% to 100% of the plant power.

Unlike the above, this is normally considered a deliberate operation to properly serve to electricity of the plant.

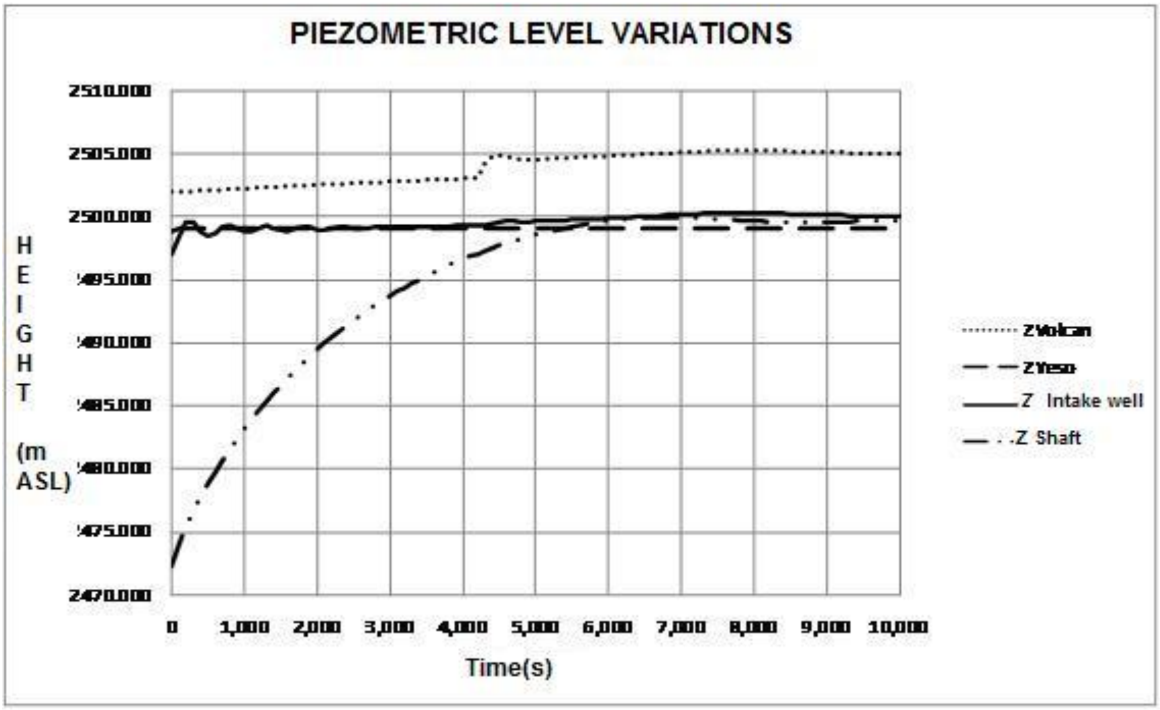
For practical purposes, the operating times of generation units (closing or opening of the turbines) do not have important significance in relation to the oscillation periods of flow and pressure in tunnels, which are much longer.

3.2.1 ALFALFAL II SYSTEM

The surge shaft consists of a pond that starts at an elevation of 2,468 m ASL, with an area of 675 m^2 and increases linearly to 2,503 m ASL in elevation having an area of 1,989 m^2. This pond is attached to the headrace tunnel of Alfalfal II by a shaft of 3.5 m in diameter and 500 m of height (see Figure 2.5).

During full head rejection of Alfalfal II Power Plant, level fluctuations in the headwater works are moderate and reach its equilibrium level quickly, as shown in Figure 3.1. According to these results, we see that the water level in the intake well of Alfalfal II is stabilized around an elevation of 2,500 m ASL and the surge shaft hardly varies, reaching its peak asymptotically ensuring good control of pressure fluctuations within the headrace tunnel of the plant.

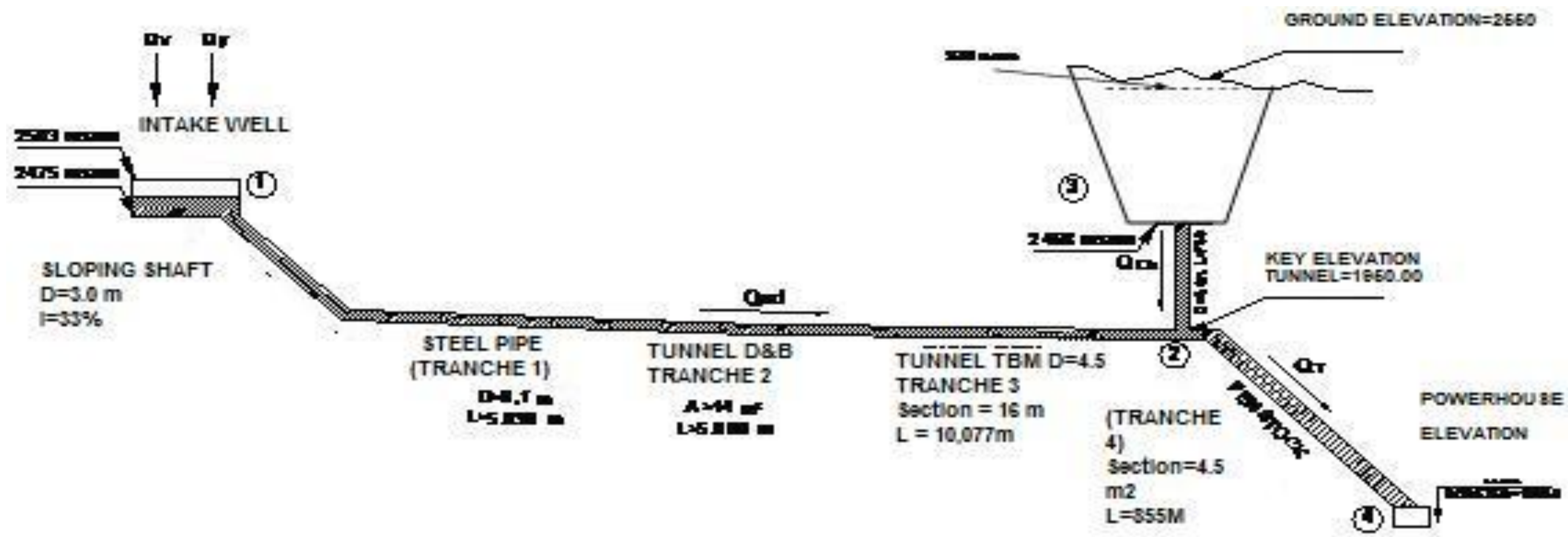
Figure 3.1
Piezometric Levels in Headwater Works for Total Head Rejection in Alfalfal II Power Plant



The values obtained for the total rejection of head modeled for this situation are as follows for the points defined in Figure 3.2:

●. - Maximum level of the shaft (3) 2499.9 m ASL
●. - Minimum level in shaft (3) 2,472.2 m ASL
●. - Maximum level in intake well (1) 2,500.28 m ASL.
●. - Minimum level in intake well (1) 2,497.0 m ASL
●.-Maximum outgoing flow by the shaft (QCh) 0.66 m^3/s
●. - Maximum incoming flow into the shaft (QCh) 14.18 m^3/s
●.-Maximum flow discharged by El Yeso weir 27. 65 m^3/s

Figure 3.2
Conduction Diagram under Pressure Alfalfal II



3.2.2 Las Lajas System

The surge shaft is composed by a cylinder diameter of 10 meters and 64 meters of height. The communication shaft with the tunnel is 5 m in diameter and 282 m of height (see Figure 3.4).

During head changes of Las Lajas Power Plant, fluctuations in flow rates of the tunnel system will be absorbed into the forebay. In the case of head rejections, excess flows are discharged to Colorado River through the safety works of the forebay.

Figure 3.3 shows a flow chart summarizing the flows discharged to the river during the full head rejection of Las Lajas Power Plant. The analysis assumes that the transient phenomenon occurs with the maximum initial level in the forebay of 1,323 m ASL (worst case).

Figure 3.3
Simulation of Head Pond in Full Head Rejection

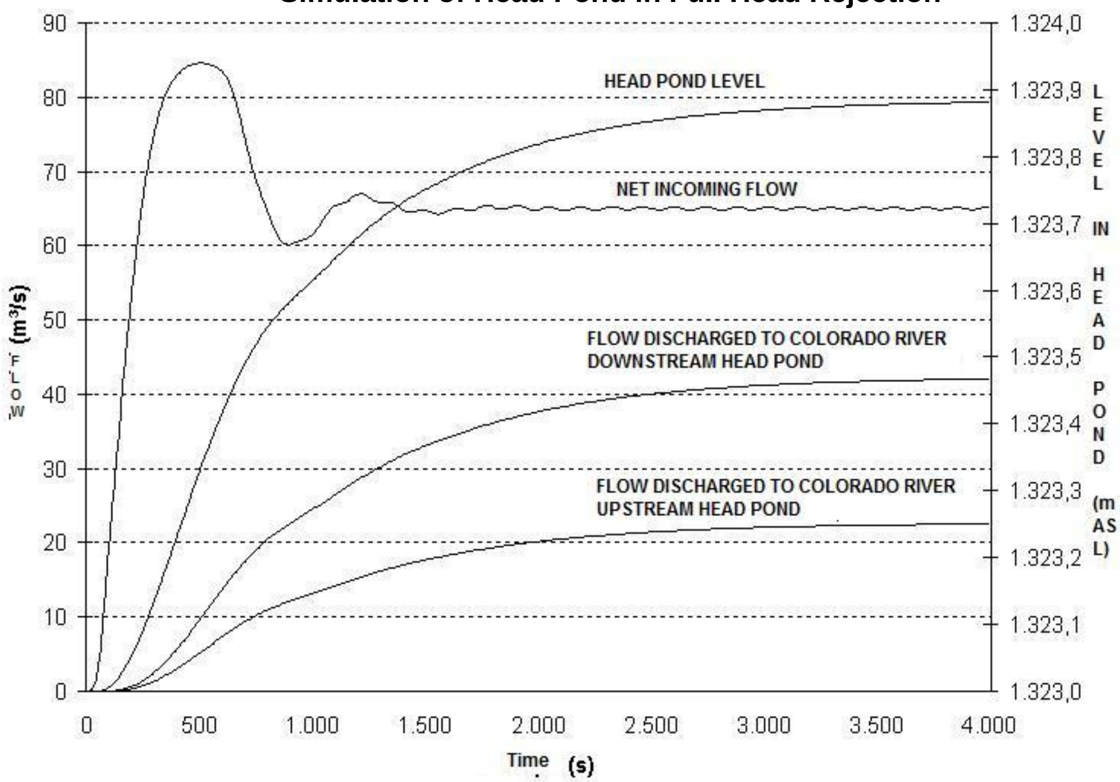


Figure 3.3 shows that the maximum incoming flow to the head pond would be 84 m3/s at 400 sec. of head rejection. Finally, from an hour after the head rejection, the flow discharged to the river corresponds to the total flow of Las Lajas Power Plant which is 65 m^3 / s (42 m^3 / s discharged downstream of the pond and 23 m^3 / s discharged upstream of the pond).

Some characteristic data of level and flow values that occur during transient phenomena are as follows, according to the numbering of Figure 3.4:

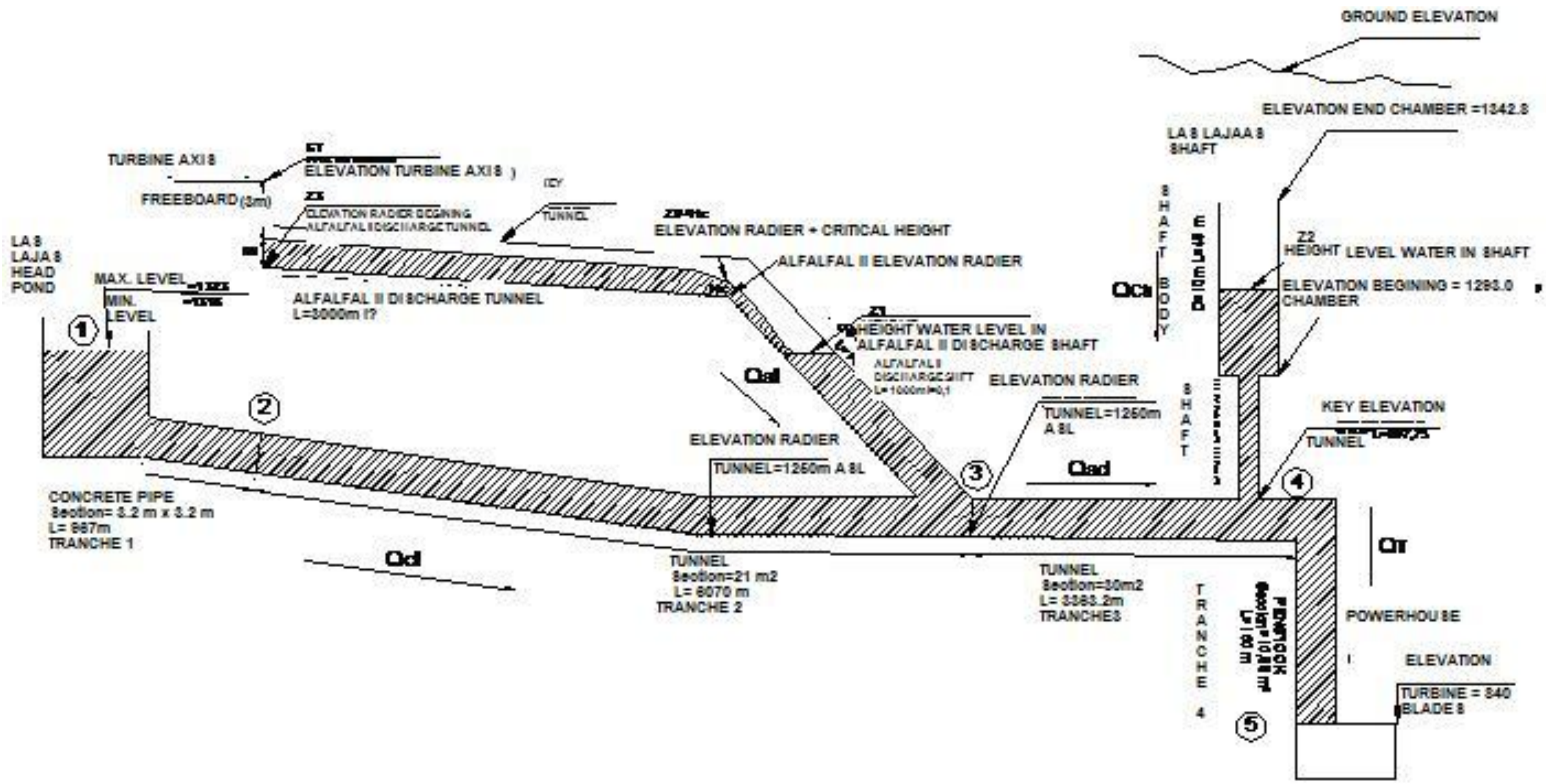
a) Total head rejection of the plant. (Forebay level at 1323 m ASL)

●. - Maximum level in the shaft (4) 1,344.1 m ASL
●. - Minimum level in the shaft (4) 1,300.0 m ASL
●. - Maximum level in (3): 1,336.9 m ASL
●. - Minimum level in (3): 1,302.5 m ASL
●. – Maximum flow delivered by the shaft (Qch) 36,6 m^3/s
●. – Maximum outgoing flow of the shaft (Qch) 63 m^3/s
●. – Maximum incoming flow to the discharge shaft Alfalfal II (Qal) 69.9 m^3/s
●. – Maximum outgoing flow from the discharge shaft Alfalfal II (Qal) 56.6 m^3/s
●. – Maximum incoming flow to the forebay Colorado (Qcl) 6.6 m^3/s
●. – Maximum outgoing flow from the forebay Colorado (Qcl) 65.0 m^3/s

b) Head increase from 50 to 100% of the power plant. (A constant level in the forebay of 1318 m is assumed).

●. Maximum level in the shaft (4) 1,316.9 m ASL
●. - Minimum level in the shaft (4) 1,283.4 m ASL
●. - Maximum level in (3): 1,317.3m ASL
●. - Minimum level in (3): 1,285.1 m ASL
●. - Maximum outgoing flow of the shaft (Qch) 29.3 m^3/s
●. - Maximum incoming flow to the shaft (Qch) 6.8 m^3/s
●. - Maximum incoming flow to discharge shaft Alfalfal II (Qal) 1 m^3/s
●. - Maximum outgoing flow from the discharge shaft Alfalfal II (Qal) 59.1 m^3/s
●. - Maximum incoming flow to the forebay Colorado (Qcl) 32.5 m^3/s
●. - Maximum outgoing flow from the forebay Colorado (Qcl) 64.9 m^3/s

Figure 3.4
Conduction Diagram under Pressure Las Lajas



3.3 IMPACT ON HYDROMETRIC NETWORK OF MAIPO RIVER.

3.3.1 Introduction

A special situation in the operation of a hydroelectric plant occurs during sudden outage of generating units or head rejection. The head rejections are caused by automatic operations due to internal or external failures:

Internal Failures. They refer to internal technical problems that force the plant to stop the turbines. This may due to the failure of some mechanism (valve or turbine) or electrical failure mechanisms operating the units or in the High Voltage switchyard (switches or circuit breakers of power lines).

External Failures. Electrical system failures (Black out), which are less frequent. It may occur by a failure in the transmission line of both power plants.

Fortunately, such events are rare, as indicated by the following Table, which summarizes the head rejections occurred in Alfalfal power plant between 2006 and 2007.

Table 3.1: Alfalfal Power Plant. Head Rejections between 2004 and 2007

Date	**Initial Power**	**Duration Failure**	**Q Power plant Pre failure**	**Q River Pre failure**	**Q River in failure**	**Unit Failure**	**Remark**
	(MW)	(hours)	(m^3/s)	(m^3/s)	(m^3/s)		
09/28/2007	62	0.10	10,5	15.5	5.0	U 1	Internal failure (*)
05/23/2007	68	0.97	11.5	14.5	3.0	U 2	Internal failure (*)
03/20/2007	170	0.11	28.8	35.8	21.4	U 1	Internal failure (*)
01/11/2007	178	9.43	30.0	43.0	24.0	BT Col	Op. Auto. Col. Water intake.
09/11/2006	61	0.46	10.3	13.3	3.0	U 2	Internal failure (*)
08/09/2006	63	1.90	10.7	12.7	2.0	U 2	Transmission line failure
06/08/2006	79	3.80	13.4	15.4	2.0	U 2	Internal failure (*)
03/03/2006	160	3.22	27.1	34.1	20.1	U 1	Internal failure (*)
02/18/2006	176	1.02	30.0	43.0	28.0	U 2	Internal failure (*)
12/25/2005	178	9.56	30.0	43.0	28.0	U 2	Internal failure (*)
11/28/2005	177	3.22	30.0	42.0	27.0	U 2	Internal failure (*)
03/22/2005	96	0.60	16.3	23.3	7.0	Central	Black Out SIC
02/11/2005	176	1.93	30.0	43.0	28.0	U 2	Internal failure (*)
11/02/2004	66	0.12	11.2	23.2	12.0	Central	Internal failure (*)
07/14/2004	54	0.68	9.2	11.2	2.0	U 1	Transmission line failure
04/10/2004	99	2.22	16.8	20.8	4.0	Central	Black Out SIC
02/24/2004	177	1.91	30.0	43.0	12.0	Central	Transmission line failure

(*): In Alfalfal has always existed a problem with the cooling water pumps that fail for water quality, causing failures in the cooling circuit and output of the power plant by high temperature indicator during breaks of the generator.

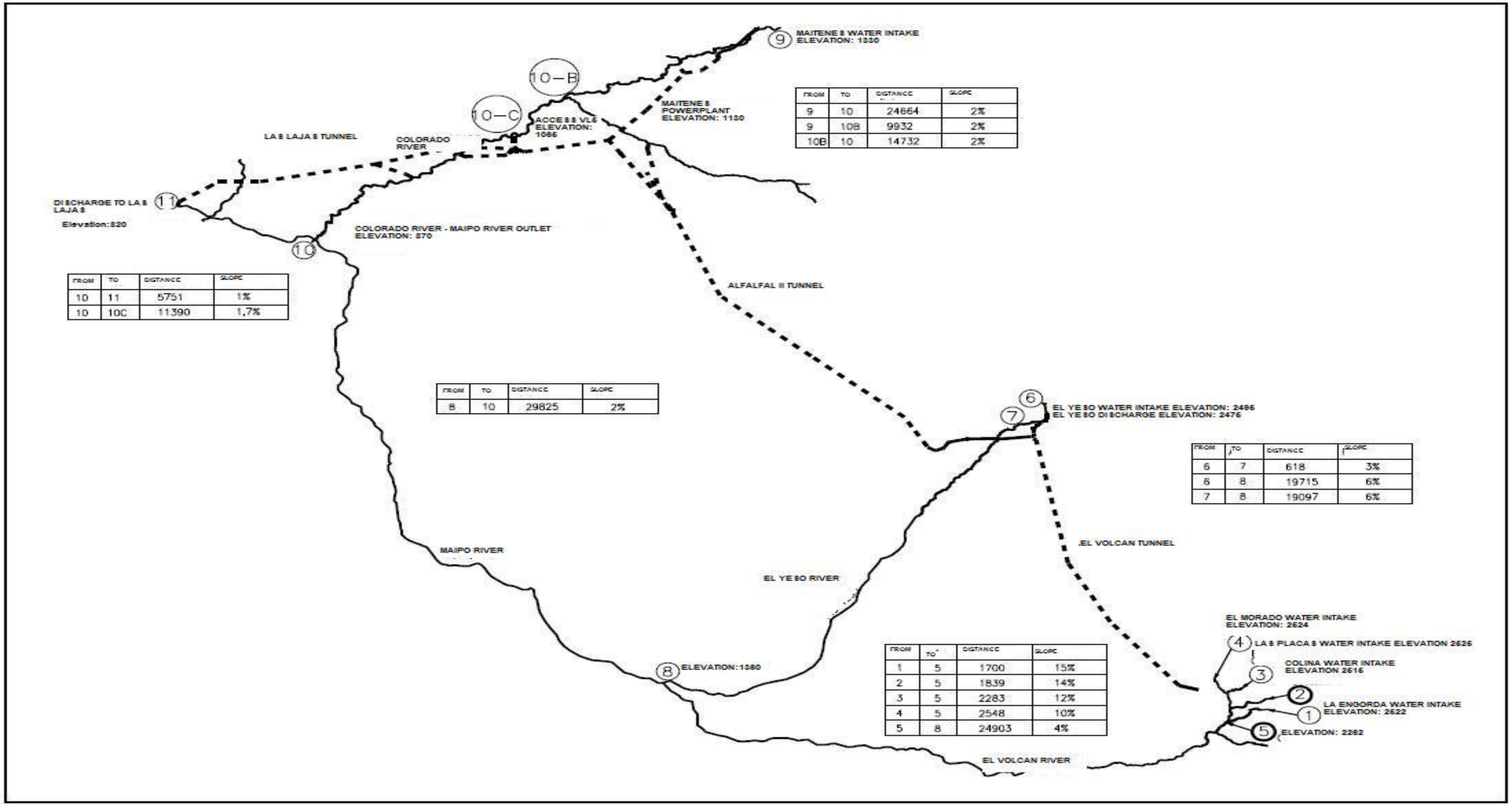
Based on the history of this plant, the number of hours that any change of flow would have occurred in the discharge area of Las Lajas to Maipo River, would be 4.9 hours on average per year (1.25 hours per event and 4 events per year, assuming that the effects are produced for fault durations between 0.5 and 3.0 hours), with an annual failure with total drop of the power plant (by Black out, transmission system or internal failure) , and 3 failures per year on average for partial service outage.

In Alfalfal II and Las Lajas power plants this situation should be substantially better, because the problem of cooling the plant that has Alfalfal power plant, which has caused most of the shutdowns of the plant, will disappear.

3.3.2. Hydrometric Network Characteristics of Maipo Alto

The hydrographic network of Alto Maipo, which can be seen in Figure 3.5, consists of a series of steep waterways, coarse-grained and widespread, with high ridges. The runoff rate on average is around 2 m / s for low flows, and greater than 5 m / s for flows in floods.

Figure 3.5
Hydrometric Network of Maipo Alto



FROM	TO	DISTANCE	SLOPE
9	10	24664	2%
9	10B	9932	2%
10B	10	14732	2%

FROM	TO	DISTANCE	SLOPE
10	11	5751	1%
10	10C	11390	1,7%

FROM	TO	DISTANCE	SLOPE
8	10	29825	2%

FROM	TO	DISTANCE	SLOPE
6	7	618	3%
6	8	19715	6%
7	8	19097	6%

FROM	TO	DISTANCE	SLOPE
1	5	1700	15%
2	5	1839	14%
3	5	2283	12%
4	5	2548	10%
5	8	24903	4%

During head rejections of Alfalfal II power plant on Yeso River (point 7 in Figure 3.5), there would be a timely discharge flow generated by the plant. The same occurs in the Colorado River (point 9 in Figure 3.5) when there is a head rejection of Las Lajas power plant. These situations produce positive waves in the waterways, which when passing they increase the flow of waterways downstream from the discharge point with a speed that exceeds the average speed in permanent regime.

Together with the above, in any of the two situations described above, in the discharge area of Las Lajas power plant in the Maipo River there is a decrease in river flow that lasts until the flow waves from Yeso and Colorado Rivers reach the discharge, restoring the river regime.

For purposes of this analysis we consider the different cases of failure of generating units of Alto Maipo power plants operating at full head. The forebay on the Colorado River is considered to the maximum level. These cases are:

- Full head rejection of Alfalfal II Power Plant, for maximum flow.
- Full head rejection of Las Lajas Power Plant, for maximum flow.
- Full head rejection of both power plants or “blackout” of the electrical system, both operating at maximum flow.

These situations are analyzed below:

- Full head rejection of Alfalfal II Power Plant

In this case the power plant fails to deliver its full head of 27 m^3/s to the headrace of Las Lajas power plant. However, this last plant can continue to operate with total outflow for about 3 hours using the water accumulated in Las Lajas forebay (300,000 m^3).

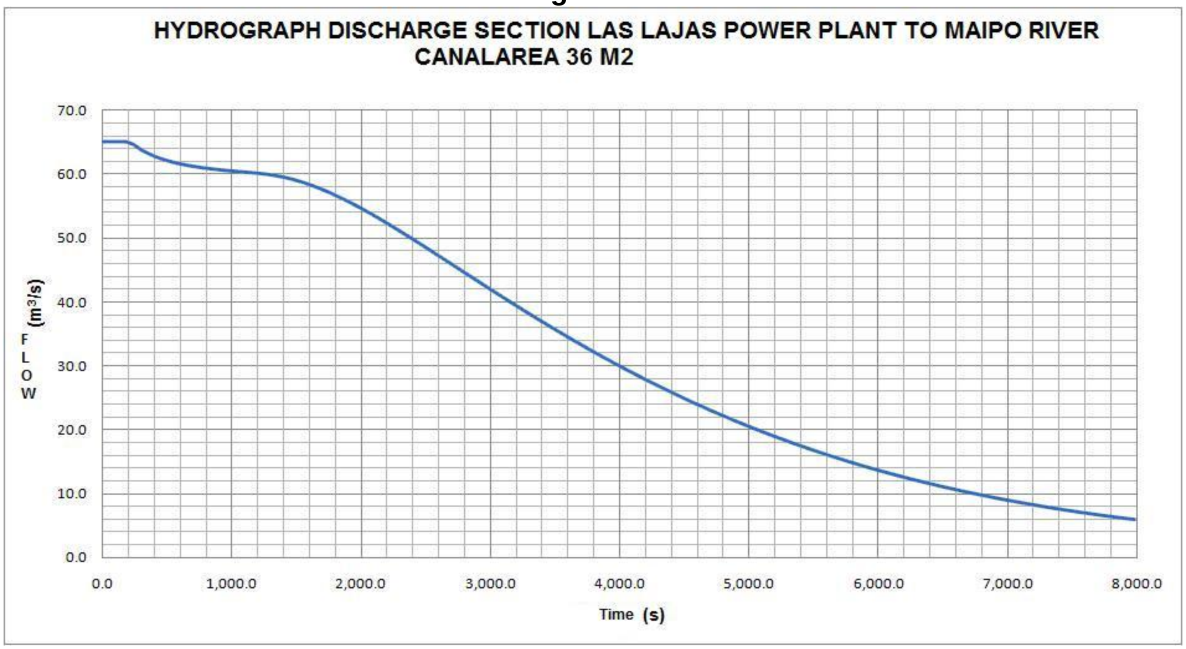
The flow of Alfalfal II power plant of 27 m^3 / s would be delivered via weir in the Yeso water intake to the river of the same name, after normalization of the transient regime of the power plant. This flow would take 5.0 hours to return to the Maipo River in the discharge area of Las Lajas power plant, considering an average speed of the wave equals to 3.0 m / s; the above mentioned is a pessimistic condition, with a low flow in Maipo River at the time of the stoppage of the plant.

- Full head rejection of Las Lajas Power Plant

In this case Las Lajas power plant fails to deliver the flow of 65 m^3 / s to the Maipo River. However, this flow will continue to deliver through the gate of the bottom of the forebay adjacent to Colorado River. This flow would return to Maipo River on its way through Colorado River after an estimated time of 3.0 hours.

However, during this period an almost constant flow would be given during the first 0.3 hours and then varying between 65 m^3/s and zero during the following 1.7 hours, which is the time of emptying of the discharge tunnel of Las Lajas power plant, with a volume of 325,000 m^3. In Figure 3.6 you can see this tunnel in the discharge section to Maipo River.

Figure 3.6



- Head rejection of both power plants or “blackout”

When stopping suddenly, the two plants for 4 hours would discharge a flow rate of 65 m^3 / s to the Colorado River, 38 m^3 / s from Alfalfal I and Maitenes water intake, and 27 m^3 / s (4 hours) from the Las Lajas forebay; this total outflow would be restored to Maipo River in the discharge area of Las Lajas after about 3.0 hours.

The flow of Alfalfal II power plant of 27 m^3 / s would be delivered through the weir from El Yeso water intake to the river of the same name, which would take an estimated time of about 5 hours to return to the waterway of Maipo River in Las Lajas discharge area.

As was mentioned in the previous case, from head rejection a volume of about 325,000 m^3 for 2.0 hours would be delivered to Maipo River from Las Lajas discharge tunnel (emptying the tunnel).

According to the above, this situation would have the following evolution in time shown in Table 3.3, assuming that the interruptions of the operation of the plants last longer than 3.0 hours and are produced under conditions of full head operation, a situation which is considered exceptional, as shown by the figures in Table 3.1:

Table 3.3
Flow variations in Maipo River during a Rejection, a "blackout"

Time (hours)	**Flow deficit in discharge to Maipo River (m^3/s)**	**Remarks**
0 – 0,3	0	Discharge T is contributing ~ 65 m^3/s
0.3 – 2.0	Variable between 65 and 0	It corresponds to the emptying period of the tunnel
2.0 to 3.0	65	
3.0 - forward	0	The wave comes from Colorado River

Based on the foregoing, the most unfavorable effects on the waterways can be seen, assuming extreme conditions of low probability of occurrence, which only last for about 1.0 hours, provided that power plants take more than 3.0 hours to operate again.

3.4 LEVEL VARIATIONS IN COLORADO, YESO AND MAIPO RIVERS

The last point that has to be analyzed is related to the increase of water level produced by the waves formed after a head rejection.

Due to the existence of Alfalfa power plant, GENER has studied in detail this problem in Colorado River. Indeed, in 2001 the study called "Project of Power Optimization of Alfalfal Power Plant - Study of Wave Propagation" was carried out; on this occasion, it was found that, given the slope of the waterway (~ 2%), increases of large-scale flow does not produce large increases in water levels. The following Table shows some results obtained in the study mentioned above.

Table 3.3
Changes in Water Levels
produced by operations in water intakes of Alfalfal and Maitenes power plants

River	**Section**	**$P_{exceedance}$ (%)**	**Min. Flow (m^3/s)**	**Max. Flow (m^3/s)**	**ΔQ (m^3/s)**	**ΔZh (m)**
Colorado	Maurino Canal	5	1	20.9	19.9	0.70
		13	7.6	33	25.4	0.37
		80	5.7	23.1	17.4	0.30
Colorado	Before joining Maipo River	5	8.5	35.7	27.2	0.34
		13	7.6	32.7	25.1	0.33
		80	5.8	22.8	17	0.28
Maipo	Water intake of La Sirena Canal	5	80.5	107.3	26.8	0.19
		13	69.6	94.3	24.7	0.19
		80	25.8	42.3	16.5	0.18

According to the results, we see that the water height variations, which do not exceed 0.5 m, are minimal compared to changes in flow, which is explained by the steep slope of the waterways. Colorado River has a slope of about 2% and Maipo River and Yeso River 2% and 6%, respectively. For these reasons, in these two waterways significant increases in runoff heights should not occurred as a result of increases in flow caused by head rejections in Alto Maipo power plants.

Particularly, in the case of Yeso River the effects of a head rejection are much lower than those originated by floods of El Yeso reservoir, whose safety weir is designed with a flow of 80 m^3 / s, well above the 27 m^3 / s to be discharged during an outage of Alfalfal II power plant.

Notwithstanding the foregoing, we can say that in all cases these potential variations in the level of runoff are considerably less than natural level variations observed in these rivers during floods.

4. COMMISSIONING PROCESS

The commissioning of the plants is scheduled to start by Las Lajas power plant, for a few months after commissioning Alfalfal II power plant. The commissioning process includes the following sequence:

- Filling Las Lajas forebay , with 300,000 m^3
- Filling the headrace tunnel of Las Lajas Power Plant, which requires a volume of 270,000 m^3, using the accumulated water in the forebay.
- Starting operation of Las Lajas power plant with minimum power (about 10% of its maximum capacity), keeping this condition for 2.5 hours.
- Recover simultaneously the volume of the forebay up to 300,000 m^3
- Normalize the power of the power plant at full capacity of the available resources in Colorado River, with which a flow of 38 m^3/s and the forebay with its peak volume would be achieved.
- The filling of headrace tunnel of Alfalfal II power plant is started to a static level equivalent to the elevation 2,485, which requires a volume of about 296,000 m^3. For this, it will be necessary to increase the operation flow of Las Lajas power plant 4.5 hours after starting the filling of Alfalfal II, in the same amount of flow used for Alfalfal II, ending 45 hours after the end of this process.
- Operation of Alfalfal II power plant is started with Yeso River resources, without increasing the power of Las Lajas until 4.5 hours after this, allowing partial recovery of Las Lajas forebay.
- Las Lajas power is increased in relation with flows discharged by Alfalfal II power plant.
- The filling of Volcán Tunnel is started with resources of the 4 streams, which requires a volume of about 189,000 m^3, using the recovered volume in the forebay of Las Lajas power plant, in order to increase its flow in the same amount that was collected in Volcán River, with 4.5 hours of phase lag required for keeping the natural regime in the discharge point without alterations-

- Operation of Alfalfal II power plant is normalized with the available resources in all its collections.
- Level is recovered in the forebay of Las Lajas power plant.
- Power of Las Lajas power plant is normalized 4,5hours after Alfalfal II was normalized.

The result of this process is that at the end of these operations both plants are operating normally, and the forebays are filled and at their normal operating level.

The only alteration of the natural regime of Maipo River in the discharge point of Las Lajas power plant occurs with the first filling of the forebay of Las Lajas power plant, for which 300,000 m^3 will be required. For this purpose, and in the event that this activity represents an infringement of downstream water rights, it is considered to obtain, via lease or purchase, the corresponding temporary consumptive rights.