THE TENO - CHIMBARONGO CANAL: AN EXAMPLE OF COORDINATION AND COOPERATION

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ABSTRACT

The Teno River, which belongs to the Mataquito River basin, and the Estero Chimbarongo, which belongs to the Rapel River basin, are located in the Central Zone of Chile, where the Mediterranean climate predominates and irrigated agriculture is the basis of the economic activity in the area. The Teno-Chimbarongo transbasin water transfer canal is a fundamental factor in this development. Additionally, this canal supports hydroelectric generation, a highly profitable factor for this sector since the investment has been fully recovered. The initial purpose was to build a canal with capacity of 25 m3/s (882.25 ft3/s) for hydroelectric generation, but an additional 40 m3/s (1,411.6 ft3/s) was considered adequate in order to satisfy the irrigation demands in areas located before the hydropower dam. In this way, the canal became an hydraulic work with two pre-established purposes: to provide hydraulic resources for hydroelectric generation and to increase the security of irrigation. In the history of this canal, after 25 years of operation, the different stakeholders related to this project are fully satisfied with the results and both objectives have been reached. This paper presents the historic development, the difficulties, the achievements and the experience obtained from the point of view of the parties involved, emphasizing the example of coordination and cooperation and effective results, as well as the future perspectives associated with this canal.

INTRODUCTION

The Teno – Chimbarongo Canal is a transbasin water transfer canal built at the beginning of the decade of 1970, and has resulted in an important mixed development, of irrigation and hydroelectricity, in the central zone of Chile. This case is a practical example which shows that the satisfaction of the different interests of the parties is possible, a key factor in the present and future water resources management. This canal is the second work that joined, by an

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artificial canal, two natural river courses belonging to two different river basins[2]. It is economically important because with a small investment and without constructing another electric hydropower plant it was possible to produce a significant amount of energy. To regulate the operation of the canal and coordinate the different parties involved an agreement was signed.

GENERAL BACKGROUND

Geographic location

The Teno-Chimbarongo canal connects the basins of the River Teno, which is a sub-basin of the Mataquito River, and the basin of Estero Chimbarongo, which is a sub-basin of the Rapel River. The water resources are taken from the River Teno and transported to the Estero Chimbarongo. In the last basin, the water is a source for the hydroelectric generation power plant of Rapel. This hydropower plant is located in the basin of the same name and receives, in addition to the water carried by the canal, the resources from Estero Chimbarongo, the Tinguiririca River, the Cachapoal River and Estero Alhue. In the future, the water transferred by the canal would be used as a feeder for the Convento Viejo Dam and would be used for the irrigation of the area located downstream of this reservoir. A location map is shown in Figure 1, and includes the canal and dam.

Objectives and history

The canal is a project designed by the Department of Civil Engineering of the National Electricity Company (ENDESA) in order to conduct the water, through the natural streams, to the Rapel hydropower dam to increase the electricity generation until the Irrigation Directorate could finish the construction and put in operation the Convento Viejo Dam. The Teno – Chimbarongo canal takes the water from the excess waters of the Teno River. It is a feeder canal to the Convento Viejo Irrigation Dam, which is located in the Rapel river basin. In this way the water transported by the canal has two uses, for irrigation and as water for hydroelectric production.

In 1960 ENDESA performed preliminary studies to divert water from the Teno River to the Estero Chimbarongo in order to use those resources in electric

[2] The first canal was the Canal San Carlos, with consruction started during the 18th century (1742) and finished at the beginning of the 19th century (1825). The canal was built because of the necessity to satisfy the demand for water from the city of Santiago and the increase of the irrigation area which made insufficient the water from the Mapocho River. The canal takes water from the Maipo River Basin and transfers it to the Mapocho River Basin.

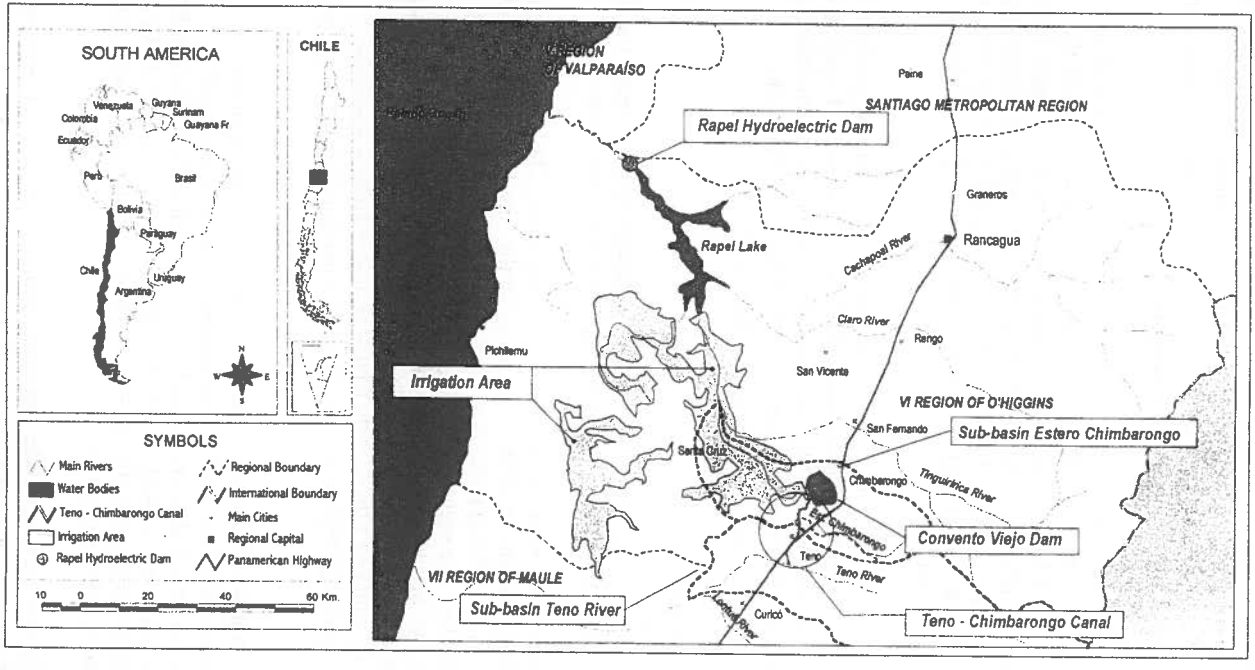


Figure 1: General Layout

generation at the Rapel hydropower plant. In 1968 the Irrigation Directorate from the Ministry of Public Works developed a project called Convento Viejo Irrigation Project in which a water transfer of surplus waters from the river Teno was considered by means of a canal of 40 m3/s (1,411.6 ft3/s).

The objectives of the Convento Viejo project were to increase the amount of irrigated land and to improve the irrigation security of the area served by the resources of the Estero Chimbarongo and Tinguiririca River, in the Rapel River Basin. Later studies performed by ENDESA in 1972 determined the capability to increase the maximum capacity of the canal to 65 m3/s (2,293.85 ft3/s), so that 40 m3/s (1,411.6 ft3/s) would be used for irrigation and 25 m3/s (882.25 ft3/s) in hydroelectric generation.

The construction of the Convento Viejo Dam started in 1970 and stopped in 1975. Later, the works continued during the years 1978 – 1979, but stopped again, up to 1993, the year in which the First Step was finished, which is at present operating with 27 million cubic meters of capacity (952.83 million ft3). The Teno-Chimbarongo canal was built and started its operation in 1975.

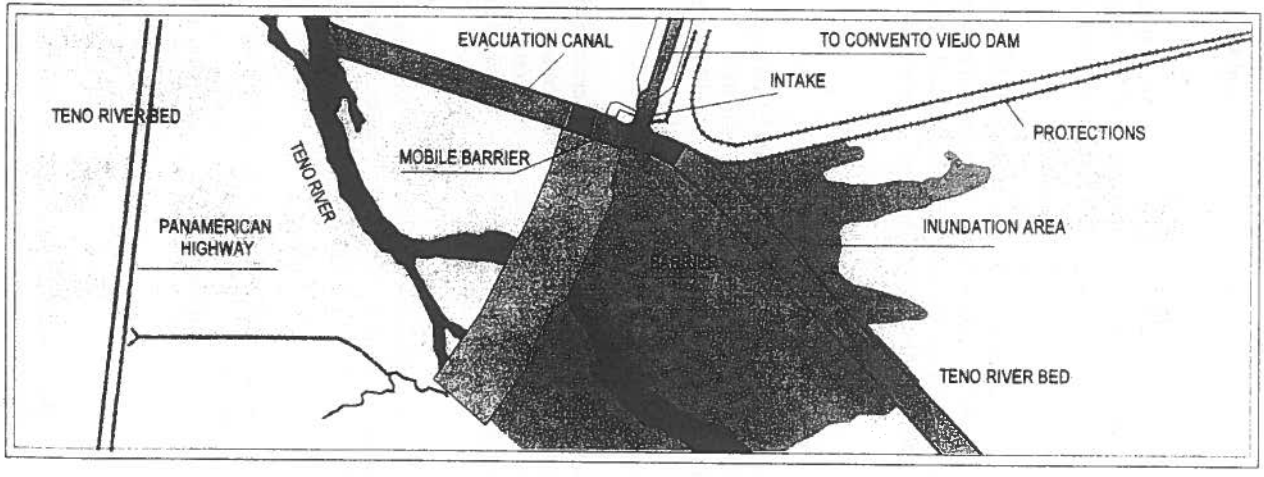
The works of the system

The principal works of the system are: the Teno-Chimbarongo transbasin canal, the Convento Viejo First Step Dam and the Rapel Hydroelectric Plant.

The canal consists of an intake, a canal and a delivery work. The intake is located at 470 m (1,541.6 ft) upstream of the Teno bridge at the Pan-American highway. It consists of a barrier, 272 m (892.16 ft) long, which closes the river; a mobile barrier, composed by five sector gates of 4,20 m (13.78 ft) wide and 4,05 m (13.28 ft) high, two of which are used to clean sediments and the other three are operating as evacuators during floods; and an intake work with four flat gates of 3,60 m (11.81 ft) with and 1,70 m (5.78 ft) height, which allow a maximum discharge of 65 m3/s (2,2983.85 ft3) . In Figure 2 a general plan of the intake is shown.

The canal has a trapezoidal section, 13,66 km (7.38 miles) long, without revetments. Some short stretches have compacted earthfill. The typical dimensions are two: the first, between km 0,00 to 2,00 (mile 0 to 1.08) is of 8,25 m (27,06 ft) wide at the base, 4,50 m (14.76 ft) depth and slopes of 2:1=H:V; and the second, between km 2,00 and 13,66 (mile 1.08 to 7.38) the base wide is 10,25 m (33.62 ft) and the slopes are H:V=1,5:1.

The canal discharges the water to the Quebrada Quinta, a natural river bed that arrives at the Estero Chimbarongo after travelling approximately 3 km (1.62 miles). The canal has five small spillways with the purpose to lose elevation, the



Source: ENDESA, 1975.

Figure 2: General Plan of the Intake

necessary works to cross irrigation canals and other watercourses, and some bridges and local roads.

The Convento Viejo First Step consists in a earth wall of 16,5 m (54.12 ft) height and 450.000 m3 (15,880,500 ft3) of embankment, with 500 m (1,625 ft) length. It has a spillway of maximum capacity of 1.160 m3/s (40,936.4 ft3/s), controlled by five tank gates with manual control

The Rapel Hydroelectric plant is located in the Rapel River Basin and was built in 1968. The generation capacity is 350 MW and has an average annual production of 1.038 GWh. The work consists of a concrete arch gravity dam, and a reservoir of 696 million cubic meters (24,561.84 million ft3). This hydropower plant operates during peak hours.

Parties Involved

This work involves the following principal parties: the National Electricity Company (Empresa Nacional de Electricidad -ENDESA), the Irrigation Directorate of the Ministry of Public Works (Dirección de Riego del Ministerio de Obras Públicas) and the irrigation users from the Teno River and from the Estero Chimbarongo.

At the time when the project was constructed, ENDESA was a governmental company and its objective was the execution of the electrification projects of the country. On the other hand, the Irrigation Directorate was also a governmental organization in charge of the design, studies and construction of the irrigation works.

The private sector, represented by the irrigation water users, were well organized in the Teno River through a Vigilance Committee (Junta de Vigilancia), but the situation was not the same in the Estero Chimbarongo where the organization was more precarious.

At present, ENDESA is a private company, and the Irrigation Directorate was transformed into the Hydraulic Works Directorate and continues as a governmental organization. On the other hand, the farmer's organization at the Estero Chimbarongo has improved.

Legal Framework

The Chilean Water Code in force at the moment of the design and construction of the project, and also in the present Water Code in force since 1981, does not include any special consideration for the regulation of the transbasin water

transfers. There is only one condition that should be fulfilled, which is applicable in general for all the uses, and requires that any use should not affect the use of the water rights of third parties (Article n°14).

To regulate the use of the resources of the canal, in 1971 a convention was signed between ENDESA and the Irrigation Directorate in which it was established that from the moment in which the Convento Viejo Dam was finished and started to operate, the Irrigation Directorate would have a preferential right for the use of the flows diverted by the canal, up to 40 m3/s (1,411.6 ft3/s). Then, ENDESA would have the right to use the rest of the flow, up to the maximum capacity of the canal. On other hand, ENDESA would have right to use all the excess water produced by the system, and to demand the operation of the canal even if the Irrigation Directorate does not need the water for the Convento Viejo Dam.

With regard to this, at this moment a clarification of the water rights associated with the canal is in process. The Irrigation Directorate requested a water right of consumptive type and of permanent and discontinue use, for a maximum of 40 m3/s (1,411.6 ft3/s) from the River Teno and up to a maximum volume of 599,7 million cubic meters (21,163.4 millions ft3) per year, considering a reserved water for the Convento Viejo Dam that was granted in 1983. Additionally, ENDESA requested in 1970 a water right of eventual type of 11,6 m3/s (409.36 ft3/s) as an average annual discharge from surface water resources from Teno Rive, which was granted in October of 1995 as an average monthly flow to be used in hydroelectric generation at Rapel hydropower plant.

Additionally, in 1975 another convention was established between the Irrigation Directorate and ENDESA, in which it was agreed that the canal would operate when a surplus exists in the Teno River. The flows beyond which a surplus exists were defined and agreed upon in 1975, considering the rate of rational and beneficial use according to the Water Code in force at that moment. The canal operates when the flow in the river is more than the needs of the irrigation canals downstream of the intake; that is, more than aproximately 15 m3/s (529.35 ft3/s). It is important to mention that in the Southern Hemisphere the seasons are opposite to the seasons in the Northern Hermisphere, and for that reason the irrigation period starts in September and ends in April. In Table 1 the flows over which ENDESA can take water from the Teno River are shown.

Table 1. Minimum Flows in Teno River over which ENDESA can divert water in the Teno – Chimbarongo canal since 1975

Month	Flow m3/s
September	10
October	12
November	14
December	16
January	18
February	20
March	22
April	24

In Figure 3 the relationship between the available flows in the Teno River, the diverted flows through the canal and the minimum flows over which the canal can divert water from the River Teno are shown.

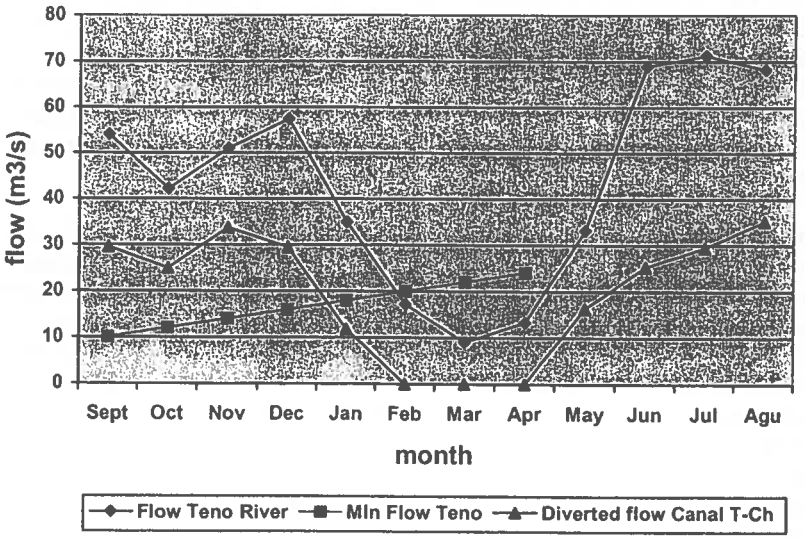


Figure 3. Relationship between the flows in River Teno and flows diverted by the Teno-Chimbarongo Canal.

THE IMPACT OF THE CANAL TENO – CHIMBARONGO

On Irrigation

In the situation without a project; meaning, without the Teno – Chimbarongo Canal and without the Convento Viejo First Step Dam, the available water resources in the Tinguiririca River and Estero Chimbarongo could irrigate, inefficiently, an area of aproximately 120.000 hectares (300,000 acres). Of this surface, 77.000 (192,500 acres) hectares could be supplied with 85% security, using for that purpose the water resources available at the Estero Chimbarongo, Estero Las Toscas and Tinguiririca River; in the meantime the remainder 43.000 hectares (107,500 acres) had only eventual irrigation.

The Convento Viejo First Step Dam has been a key factor in reducing the impact of droughts in the irrigation area served by this dam. This has been particularly remarkable during the dry periods of the years 1996-97 and 1998-99. For this reason the farmers of the Estero Chimbarongo are very interested in the possibility of a bigger dam.

The idea of building a bigger dam has always been considered as a possible alternative. The dam would consist of an increase in the height of the present embankment, thus increasing the capacity of the reservoir. In November 2000 a new study was performed in order to update the studies of the Big Convento Viejo Dam. That analysis recommended a dam with a reservoir of 472 million cubic meters (16,656.88 million ft3) of capacity, which would improve the irrigation of 14.308 hectares (35,770 acres) of existing land and 34.516 hectares (86,290 acres) of a new irrigation area. Considering this, the total impact of the dam would reach an area of 76.254 hectares (190,635 acres).

During the initial 15 years of operation of the canal, there was only one problem detected. The problem was regarding timely information about the operation of the gates for the sediment cleaning operation at the intake to the irrigators in Teno River. This should be done in order to give sufficient time to take measures to protect the intakes of irrigation canals which are close to the diversion structure of the Teno – Chimbarongo Canal and that could be affected by its operation. The cleaning operation is gradual, can take about 10 hours and it is done every 15 days, approximately. This situation is completely solved at present. ENDESA communicates on time the program of sediment cleaning to the irrigators and also the company facilitates the adequate machines to solve problems that can be attributed to the operation of the gates. At present, the irrigators are completely satisfied with the coordination procedure.

On Hydroelectric Generation

The Rapel Hydroelectric Plant has received all the benefits from the transferred resources from the beginning of the operation of the canal in 1975. This is because the Convento Viejo Dam has not been built. When the studies of the canal were done, ENDESA estimated that the investment would be recovered in approximately 7-1/2 years. Considering this, it is reasonable to supposse that this projection has been accomplished and that the additional years of operation have signified additional benefits. It is important to remark that from the point of view of the impact of the canal for ENDESA, the objectives and expectations of this project have produced total satisfaction.

On the Community

On some occasions there have been doubts about possible damages that could be attributed to the canal. Actually, during winter time and rainy years, in spite of the fact that the canal has the intake closed, the registered flows at the discharge to Quebrada Quinta have reached up to 65 m3/s (2,293.85 ft3/s) and more. Under the described circumstances the Estero Chimbarongo has been affected by floods. This has been the reason for claims from the municipalities of Santa Cruz and Chépica. It was demonstrated that the water comes from the collection of waters coming from streams and land through which the canal crosses. To reduce this impact, hydraulic defenses have been built in the Estero Chimbarongo.

On the other hand, in the Estero Chimbarongo the intakes for irrigation are rustic and, in the years with abundant snow melt, the water transported through the canal causes damage to them. Under these circumstances, a decrease in the diverted water has been requested to ENDESA to repair of the intakes. Considering this, the irrigators of the Estero Chimbarongo have the perception that it would have been better to develop a project to improve the irrigation intakes together with the project of the Teno-Chimbarongo Canal. It is important to note that the canal was developed as an isolated project, without considering other elements or factors from the point of view of the river basins involved.

THE EXPERIENCE AND THE FUTURE PROJECTIONS

The Teno – Chimbarongo water transfer Canal is the fundamental work without which there is no possibility to build the Covento Viejo Dam with its consequences of increased irrigation security and irrigation area. At present the irrigators of the Estero Chimbarongo have improved their irrigation security thanks to the present dam of 27 millon of cubic meters (952.83 million ft3) and exists the possibility to increase the capacity of this dam, up to 472 million of cubic meters (16,656.88 ft3), increasing the total impact of the dam up to 76.254 hectares (190,635 acres). Additionally the improvement of the management

capacities of the irrigators of Estero Chimbarongo should be noted, which has been accomplished together with the construction of the dam. At present they are organized as a Vigilance Committee and have an office, secretary and a permanent engineer to perform their tasks. They help to solve the problems of the operation of the system and about 2,800 farmers receive the benefits of this organization. A good indicator of the produced benefits is that at present the irrigators contribute money to pay the operational costs of the dam and give to the Hydraulic Work Directorate the schedule of releases that is of their convenience.

It is also remarkable that the compromises and agreements achieved between the different parties involved have been fully accomplished and respected, in spite of the changes of the characteristics of the parties, from governmental to private, in the case of ENDESA, and more attributions from irrigation to hydraulic works, in the case of the Hydraulic Works Directorate.

To get a vision about the management that has resulted from the construction of this hydraulic transbasin work, the following factors are considered, in the frame of the collected antecedents and the perception resulting from the conversations with the different parties: the legal framework, the transparency in the decision making, the responsibility of the participants and the environment in which the management is developed.

Regarding the legal framework, it is remarkable that the existence of two agreements allow, on one hand, to comply with the Water Code, and on the other hand, to regulate the singular aspects associated to the transbasin work, such as the way in which the studies and investments would be developed; the way the operation and maintenance works would be developed, both in aspects technical and economical; the way in which the resources should be used, before and after the Convento Viejo Dam was built; the way to solve the unforeseen aspects, and other aspects related with the construction and use of the canal. These agreements are in force and are respected by the parties involved.

Also, it is remarkable that all the decisions related to the operation of the canal are communicated to the users, the flows diverted by the canal are registered and it is possible to know them, which gives clarity and transparency to the different parties. In particular, the cleaning operations are known with anticipation and the dates and procedures are respected. This makes a good basis for the existence of confidence between the users, the Hydraulic Works Directorate and ENDESA.

The different parties involved have shown disposition to answer to the problems that occur and that could be attributed to the canal. ENDESA organizes meetings with the irrigators of the Teno River and coordinates with them for the cleaning operations of the intake, and also attends to the requirements of the irrigators of Estero Chimbarongo when it is necessary to modify the diverted flow. Also, the

Hydraulic Works Directorate operates the present dam according to the requirements of the irrigators, which are fully satisfied. The users of Estero Chimbarongo contribute money for the operation, a clear demonstration of interest and confidence in the management of the system.

Finally, the author can verify that the environment among the different involved parties is favorable for the development of conversations to solve problems, configuring a very good situation for the development of management procedures.

In summary, the construction of the transbasin water transfer Canal Teno – Chimbarongo has produced no relevant problems, and the unique problems have been solved through conversation and agreement between the parties. The experience shows that the canal has benefited ENDESA and the irrigators of the Rapel River Basin, and does not represent any damage to the irrigators of the Teno River. On the basis of the satisfaction of the interested parties is a convention that regulates the conditions for the use of the canal.

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