INDEX

2 EXECUTIVE SUMMARY

PURPOSE

The purpose of this study is to define the environmentally important areas (AIA) in each of the rivers and stream subject to flows reduction as a result of the Alto Maipo Hydroelectric Project operation. The critical control and evaluation areas of the AIA zones will also be identified, so as to determine the minimum flow that should go through those zones, the aquatic biota will be the objective of the flow in some cases, in others the human activity, quality of the water or the effects on the landscape. The higher flow among them should be maintained in the zone of environmental interest. In order to comply with those flows, the flow passing through the intake is therefore assessed, taking into account the reloading of the middle basin and the maximum restriction imposed by the AIA.

METHODS

A hydro-environmental characterization of the rivers and streams has been performed to assess the environmentally important zones (AIA). This includes a description of the systems in terms of the biotic components (zoobenthos, phythobenthos, zooplankton, phytoplankton and ictiofauna) and abiotic (morphology of the bed, depth of the flow, runoff speed, substrate type, chemical and physical water quality variables). The anthropic activity and landscape elements are also included.

Once the environmental interest areas are defined, the critical control and assessment segments are identified in each of them, so as to determine the flows required to maintain the uses and services of the rivers and streams. This assessment process is carried out taking into account the requirements of the aquatic biota, by means of habitability curves of the bio-indicator species for the state of the ecosystem as well as the hydrologic and hydraulic characteristics of the rivers and streams. The anthropic and other requirements are assessed in the same manner. Once the flows are determined as a function of the historic flows of the river, a reduction is proposed which will allow maintaining the uses and services of the river, even when lowering those minimum historic flows. This process then allows determining the ecologic flows to fulfill the needs of the biota and anthropic uses, implementing the higher among them to satisfy all the needs.

Finally, once the critical sections and their ecologic flows are determined in various parts of the river bed, the minimum flow to pass through the intakes is determined, so that the ecologic flow will be complied with, thanks to the contribution of the intermediate watershed.

There are also hydrologic requirements defined by the DGA and summarized below:

- Hydrologic evaluation;
- Identification of the environmental components directly related to the water resource;
- Analysis of level variations, produced by the extraction and/or exercise of the requested water use rights;
- Prediction and evaluation of the direct, indirect and associated effects overall and every one of the components identified by the requester, according to the previous point and that can be verified as a consequence of the exercise of the requested water use rights.
- Present and expected régime of the waters.
- Consequence of the exercise of the water use rights, especially the effect of impounding over the water system, should it apply.

Therefore, the report was structured to obtain the hydro-environmental characterization for each of the Maipo, Colorado and Yeso Rivers and the El Morado, Las Placas, Colina and La Engorda streams. The results of the characterization of the study zones are shown for each of them as well as the ecologic flow calculation for the critical sections in each if the environmentally important areas.

A final table delivers the calculations that show the necessary flows that should go through each intake so as to make possible the ecologic flow -both biotic and for anthropic use- in all the environmentally important areas. This is complemented by the calculations of the estimates of ecologic flows using hydrologic methods.

<u>Environmentally important areas (AIA)</u>

The characterization of the study zone consists in the analysis of the hydrologic, morphologic, habitat quality, physic-chemical and biological quality of the rivers and identification of the uses given to them by the local community (transport, fishing, etc.). This characterization allows determining the areas more strongly affected by the reduction of the rivers flows and finally to calculate the ecologic flow for the identified sensitive areas.

The report was structured taking into account the biological, ecologic and anthropic criteria in order to define the ecologic flow. Several international norms were taken into account to calculate the ecologic-biologic flow, however the final determination of this flow was made quantifying the impacts on the habitat availability for the bio-indicator species, as their decrease is associated to the reduction of the flow.

The quantification of the impacts associated to the reduction of the flow in each river or stream segment was based on the calculation of the hydraulic axis in permanent regime, and the result was shown as variation curves for a series of parameters which are runoff descriptors as a function of the flow; this for the zones determined for the calculation of the ecologic flow. These descriptor variables are the average depth of the runoff, speed, width of the free surface, area of the runoff section; the results are shown in terms of percentage variations as compared to the average yearly flow.

The habitat requirements of the fish species present in their juvenile and adult stages were also calculated, from the curves of habitability preference curves, delivering preference indexes from 0 to 1 as a function of the punctual value of the runoff speed and depth. The habitability per area unit in the section was defined, from that index it was possible to identify the variation for the different flows; the changes are expressed in respect to the value associated to the average yearly flow. It should be mentioned that of the two descriptor variables, only the depth of the runoff has practical consequences to determine a minimum flow value because the restriction in terms of speed regulates the maximum values.

The habitat descriptor species defined for this study are:

i) *Oncorhynchus mykiss* (adults and juveniles), this species adequately represent pelagic habits, involving all those that prefer using the bed of the rivers, ii) *Salmo trutta* (adults and juveniles) this species is characteristic of rivers having main river bed currents, especially in zones with more transparent waters and iii) *Trichomycterus areolatus* (adults) and *Oncorhynchus mykiss* (juveniles), these are characteristic of littoral zones.

A bibliographic review was carried out, and also informal interviews were made in the field, so as to determine the maximum or minimum thresholds for the runoff descriptor variables and calculate the ecologic flow according to anthropic criteria; these are: Speed and depth It must be remembered that it is possible that only the depth of runoff may regulate the minimum flows and in the specific case of the rivers, the threshold could be defined by the depth that, as examples, such uses as rafting and canoeing may require. Therefore, to determine flows according to anthropic criteria, this was done using the hydraulic axis results and looking for the river flow that satisfied the determined threshold in each calculation section.

The calculation of the flow passing through the intake was done assuming the reloading of the intermediate watershed with an average yearly flow, as the hydrologic series do not allow the evaluation of reloading based on minimum average flows nor on the 85% probability of surplus.

The cadaster of environmentally important areas identified for each of the rivers is detailed below:

Maipo River

The Maipo River will be affected in the section between the outlet of the Volcán River and the return of the waters at the Las Lajas sector and also partially between the confluences with the Volcán and Yeso rivers.

The issues associated to the evaluation of the ecologic flow in this segment are governed by the biologic and anthropic use of the river issues.

Colorado River

The available antecedents for the Colorado River indicate that the impacts will be associated to a decrease of the flow from the intake and up to the outlet into the Maipo River.

The Colorado River is already intervened in several segments by the operation of the Alfalfal I and Maitenes plants. These operations affect it between the upper segment of the river and the Aucayes Stream.

Yeso River

The available antecedents show that for the segment of the Yeso River comprised between the discharge of the El Yeso Reservoir and the outlet into the Maipo River, its hydrologic régime is conditioned and regulated by the operation of the Reservoir.

The calculation of the ecologic flow according to biologic criteria was evaluated considering that the aquatic ecosystems of the Yeso River are in a permanent anthropic perturbation régime caused by the operation of the El Yeso Reservoir. This historical perturbation régime has determined the present expression of the structure and functioning of the aquatic ecosystem.

Volcán River

As the design of the Project entail to collect the water resources in the upper section of the Volcán River and to return them downstream into the Maipo River below the Colorado in the Las Lajas sector, this means that the definition of the ecologic flow is applied to each segment of the stream and river, between the intakes and the water outlet point.

It should be stressed that the segment between the Volcán Plant intake and the outlet into the Maipo River is affected, as there is no a measure guaranteeing that the operation of that intake will leave a remaining ecologic flow for that segment (environmental liabilities).

In this study it is therefore considered that the calculation of the ecologic flow in this segment should be obtained from the historical conditions recorded in the DGA Volcán fluviometric station at Queltehues.

RESULTS

Ecologic flows in an Environmentally Important Area (AIA) Control Section

The applied method entails the evaluation of the ecologic flow in control sections of Environmentally Important Areas defined by their morphologic, hydraulic, biotic and/or of anthropic use, among other criteria. These AIA control sections require an ecologic flow and a specific environmental water demand to comply with the adequate development of the eco-systemic and anthropic activities these flows are considered rather as an intrinsic property of the evaluated river segment and the Project must safeguard this situation.

The results of the Ecologic Flow calculations for each of the AIA sections under the criterion of minimum average monthly low water and low water flow with 85% surplus probability are shown in tables 2.1 and 2.2 The tables show the sector, the AIA section, the average yearly Q, the minimum monthly average, the Ecologic Q, the percentage of the ecologic Q versus the average yearly Q and the most restrictive criterion to determine the Ecologic Flow.

Table 2.1 Ecologic Flow rate in m^3/s per section (flow based on minimum average monthly low flow)

			HABITABILITY MINIMUM MONTHLY Q PER SECTION					
N°	Sector	Section	Qma	Qmin n	Qecol	Qma %	Criterion 10% decrease of habitat	
1	Colina Stream	AIA Colina-01	3.24	0.89	0.29	9%	Adult *Salmo trutta*	
2	Morado Stream	AIA MOR-01	1.71	0.56	0.53	31%	No Habitat Restriction	Q(0.2m) applied
3	Morado Stream	AIA MOR-02	1.71	0.56	0.56	33%	Qmin low water under 0.2m. Q low water applied	
4	Engorda Stream	AIA ENG-01	0.99	0.32	0.26	26%	Juvenile *Salmo trutta*	
5	Placas Stream	AIA Placas-0	0.47	0.13	0.13	28%	Qmin low water under 0.2m.	Q low water applied
6	Volcán River	AIA PBN11	11.08	4.17	1.49	13%	N/R Habitat Q(0.2m) applied	
7	Volcán River	AIA PBN-18	8.39	1.59	1.49	18%	Adult and juvenile *Salmo trutta*	
8	Maipo River	AIA PBN-07	57.24	25.10	13.49	24%	Juvenile *Salmo trutta*	
9	Maipo River	AIA PBN-06	68.69	30.28	4.40	6%	Juvenile *Salmo trutta*	
10	Maipo River	AIA PBN-22	69.69	31.28	27.00	39%	Juvenile *Salmo trutta*	
11	Maipo River	AIA PBN-23	71.09	32.68	3.60	5%	No Habitat Restriction	Q(0.2m) or Qma5% applied
12	Maipo River	AIA PBN-05	72.01	34.96	4.60	6%	No Habitat Restriction	Q(0.2m) applied
13	Maipo River	AIA Toyo	74.07	37.18	5.10	7%	No Habitat Restriction	Q(0.2m) applied
14	Maipo River	AIA PBN-04	80.53	42.20	35.60	44%	Adult *Salmo trutta*	
15	Maipo River	AIA Lajas	112.01	58.20	5.60	5%	No Habitat Restriction	Q(0.2m) or Qma5% applied
16	Colorado River	AIACOL-2 and I	16.05	2.90	1.49	9%	No Habitat Restriction	Q(0.2m) applied
17	Colorado River	AIA PBN-01	17.55	4.40	2.42	14%	No Habitat Restriction	Q(0.2m) applied
18	Colorado River	AIA PBN-20	28.44	14.09	2.05	7%	No Habitat Restriction	Q(0.2m) applied
19	Yeso River	AIA PBN-09	7.91	5.90	0.74	9%	Juvenile *Salmo trutta*	
20	Yeso River	AIA PBN-15	10.02	8.01	2.09	21%	Juvenile *Salmo trutta*	
21	Yeso River	AIA SEDIM_and	10.59	8.58	0.93	9%	No Habitat Restriction	Q(0.2m) applied
		Intakes						

Table 2.2 Ecologic Flow rate in m^3/s per section (flow based on minimum low flow 85% probability of surplus)

			HABITALITY Q LOW FLOW P85% PER SECTION					
N°	Sector	Section	Qma	Q85%	Qecol	Qma %	Criterion 10% decrease of habitat	
1	Colina Stream	AlA Colina-01	3.24	0.72	0.37	11%	Adult *Salmo trutta*	
2	Morado Stream	AlA MOR-01	1.71	0.44	0.44	26%	Qmin low water under 0.2m.	Q low water applied
3	Morado Stream	AlA MOR-02	1.71	0.44	0.44	26%	Qmin low water under 0.2m.	Q low water applied
4	Engorda Stream	AlA ENG-01	0.99	0.25	0.15	15%	Adult and juvenile *Salmo trutta*	
5	Placas Stream	AlA Placas-0	0.47	0.10	0.10	21%	Qmin low water under 0.2m.	Q low water applied
6	Volcán River	AlA PBN11	11.08	3.10	1.49	13%	No Habitat Restriction	Q(0.2m) applied
7	Volcán River	AlA PBN-18	8.39	0.60	0.42	5%	No Habitat Restriction	Q(0.2m) or Qma5% applied
8	Maipo River	AlA PBN-07	57.24	16.66	13.49	24%	Juvenile *Salmo trutta*	
9	Maipo River	AlA PBN-06	68.69	20.89	5.80	8%	Juvenile *Salmo trutta*	
10	Maipo River	AlA PBN-22	69.69	21.89	3.48	5%	No Habitat Restriction	Q(0.2m) or Qma5% applied
11	Maipo River	AlA PBN-23	71.09	23.29	3.55	5%	No Habitat Restriction	Q(0.2m) or Qma5% applied
12	Maipo River	AlA PBN-05	72.01	23.69	4.20	6%	Adult *Salmo trutta*	
13	Maipo River	AlA Toyo	74.07	24.68	9.80	13%	Juvenile *Salmo trutta*	
14	Maipo River	AlA PBN-04	80.53	26.41	24.30	30%	Juvenile *Salmo trutta*	
15	Maipo River	AlA Lajas	112.01	37.75	5.60	5%	No Habitat Restriction	Q(0.2m) or Qma5% applied
16	Colorado River	AlA COL-2 and I	16.05	0.66	0.66	4%	Qmin low water under 0.2m.	Q low water applied
17	Colorado River	AlA PBN-01	17.55	2.17	2.17	12%	Qmin low water under 0.2m.	Q low water applied
18	Colorado River	AlA PBN-20	28.44	10.94	2.05	7%	No Habitat Restriction	Q(0.2m) applied
19	Yeso River	AIA PBN-09	7.91	0.79	0.46	6%	Adult *Oncorhynchus mykiss*	
20	Yeso River	AlA PBN-15	10.02	2.90	1.97	20%	Adult *Salmo trutta*	
21	Yeso River	AIA SEDIM_Y	10.59	3.47	1.05	10%	Adult *Salmo trutta*	

	Intakes

Flows defined at the intakes

Table 2.3 is the summary of the final results of the flows passing through intakes to comply with the requirements of all the Environmental Important Areas control sections, defined by the Habitat and anthropic uses method.

This calculation of the flow passing through the intakes was made considering all the AIA control sections requirements and the reloading of the middle segment, so that the passing flow should comply with the requirement of each of the downstream segments.

Table 2.3 Ecologic flows passing through the Intakes

Assessment criterion for the flow passing through the intake	**Colina Intake**	**Morado Intake**	**Engorda Intake**	**Las Placas Intake**	**Colorado Alfalfal (LB)***	**Yeso Discharge (LB)***
Hydrologic statistics						
Yearly Q average	3.24	1.71	0.99	0.47	16.05	7.91
Minimum monthly Q average	0.89	0.56	0.32	0.13	2.90	5.90
Low water Q P85%	0.72	0.44	0.25	0.10	0.66	0.79
Hydrologic method						
Q (10% Qma)	0.32	0.17	0.10	0.05	1.60	0.79
Q (50% low water P95%)	0.33	0.20	0.11	0.05	0.09	0.40
Q (Q330)	0.81	0.51	0.29	0.12	1.64	1.98
Q (Q347)	0.73	0.45	0.26	0.10	1.07	0.8
Swiss Laws	0.35	0.26	0.17	0.09	0.46	0.38
Principado of Asturias	0.26	0.19	0.14	0.10	0.37	0.28
New England Regulations	0.41	0.30	0.17	0.06	7.53	1.92
Tennant acceptable condition (10%)	0.32	0.17	0.10	0.05	1.60	0.79
Habitability method						
Q Ecol. Habitat (Minimum monthly Q)	0.29	0.53	0.26	0.13	1.49	0.74
Q Ecol. Habitat (Q low water P85%)	0.37	0.44	0.15	0.10	0.66	0.46
Anthropic uses method						
Q navigation, rafting	0.00	0.00	0.00	0.00	0.00	0.00

* Baseline. Yeso Reservoir and Alfalfal I Plant in Operation.

Volcán River and Upper Volcán Streams Area

A flow rate of 0.44 m^3/s passing through the Morado Stream intake was defined; this is the low flow with an 85% surplus probability. This is equivalent to 26% of the average yearly flow. This value derives from the hydraulic condition of maintaining the present runoff height during the low water period, since this is usually less than 20cm (average height 18cm). The zones situated immediately below the intake are areas of low potential quality in environmental terms.

A flow rate of 0.10 m^3/s passing through the Las Placas Stream intake was defined; this is the low flow with an 85% surplus probability. This is equivalent to 21 % of the average yearly flow. The ecologic flow derives from maintaining the height condition of the present runoff during low water, which is usually below 20 cm (average height 9 cm). On the other hand, the zones situated immediately downstream the intake are areas of low potential quality in environmental terms.

A flow rate of 0.37 m^3/s passing through the Las Placas Stream intake was defined; this flow has potential habitability for adult *Salmo trutta*. This is equivalent to 11 % of the average yearly flow. Besides, this is justified since it complies with the ecologic flow of all the downstream environmental interest areas (biologic and anthropic), of either the Volcán or Maipo rivers. On the other hand, the zone situated immediately downstream the intake are areas of low potential quality in environmental terms.

A flow rate of 0.15 m^3/s passing through the La Engorda Stream intake was defined this flow has potential habitability for adult *Salmo trutta*. This is equivalent to 15% of the average yearly flow. Besides, this is justified since it complies with the ecologic flow of all the downstream environmental interest areas (biologic and anthropic), of either the Volcán or Maipo rivers. On the other hand, the zone situated immediately downstream the intake are areas of low potential quality in environmental terms.

Yeso River

The situation of the Yeso River is that of an intervened river where the hydrologic series is altered by the operation of the El Yeso Reservoir which regulates the flow during the whole years, even leaving it with zero flow during some months. At present it generates an environmental liability which translates into the condition of "dry river" during the year with restrictive habitability condition for the development of aquatic ecosystems. This situation can even become more critical in the future, due to changes in the rules of operation of the Reservoir and/or less water reloading. The above led us to establish as base case the low water condition of an 85% surplus probability, which delivers a value of ecologic flow going through the intake of 0.46 m^3/s and to propose an Integrated Management Plan for the Yeso River ichthyofauna (Chapter 7).

Colorado River

A flow rate of 0.66 m^3/s passing through the Colorado River intake was defined; this is equivalent to the low water flow with an 85% surplus probability. This is equivalent to 4% of the average yearly flow. This flow compiles with the 20cm height of runoff condition. Besides, this is justified since it complies with the ecologic flow of all the downstream environmental interest areas (biologic and anthropic) of either the Volcán or Maipo rivers in the assessment conditions. The whole river was considered as an environmental important area to be evaluated.

Maipo River

Although there are reductions of the flows for the Maipo River, the ecologic flows evaluated for the environmentally important areas in all the critical sections, both biologic and anthropic, are covered by the proposed flows.

Physicochemical quality of the water

The dilution capacity of the rivers could be affected (mainly in the upper segment of the Volcán River) by the changes in the flow mix proportions in the situation with the Project. The evaluation of this impact was made at three confluences: 1) Colina Stream with the Volcán River, 2) Yeso River with the Maipo River, and 3) Colorado River with the Maipo River.

Electric conductivity (as equivalent of the salt concentration) has been used as the parameter to evaluate dilution and a simple mass balance has been applied, using the physicochemical data of Chapter 5 and the average flow and low water flows of the hydrologic series.

The following Table shows the results of the water dilution evaluation, downstream the confluences, in the situation of the Project and low water conditions.

Evaluation table - Water dilution downstream the confluences

Confluence	Conductivity Change
Colina Stream with the Volcán River	12%
Yeso with the Maipo River	4%
Colorado River with the Maipo River	4%

The results show a low impact in the conductivity changes, of the order of 12% for the Volcán River, 4% for the Maipo downstream the Yeso and 4% for the Maipo downstream the Colorado River.

ICHTHYOFAUNA MANAGEMENT PLAN

Considering that at present the Yeso, Volcán and El Colorado rivers are systems with artificially regulated flows and constitute an important environmental liability, and the application of a minimum ecologic flow to maintain the aquatic ecosystems by the implementation of the PHAM it is proposed to apply an comprehensive management plan to the area, to allow the recovery of the rivers or protect some of their main affluents to conserve the ichthyofauna.

3 INTRODUCTION

3.1 BACKGROUND

The Alto Maipo Hydroelectric Project (PHAM) owned by the AES Gener S.A. Company, consists in the construction and operation of two run-of-river plants in hydraulic series, which would have a combined installed power output of 531 MW. The plants will use the waters of the Alto Maipo River watershed as well as the waters of the middle and lower course of the Colorado River in the San José de Maipo Municipality, Metropolitan Region of Santiago.

The first plant, Alfalfal II, will be placed on the southern bank of the Colorado River, downstream the present Alfalfal I plant, and will use the waters of the upper basin of the Volcán River, also incorporating the flows at present released by the El Yeso Reservoir to the river of the same name.

The second plant, Las Lajas, will be placed in the El Sauce sector on the southern bank of the Colorado River and will use the waters coming from the discharge of the Alfalfal I and II plants, also adding the flows of the Colorado River middle watershed.

The operation and construction of these plants requires studying the ecologic flow, as the intakes will alter the natural conditions of the rivers. Therefore, it is necessary to identify the biologic communities present in the river, as well as the natural water ecologic conditions of the river and the minimum hydrodynamic requirements to maintain the habitats and the recorded human activity.

The analysis of the ecologic flow of a river consists in the application of a series of methods defined by the DGA and foreign regulations, so as to obtain a value for the minimum flow that can pass through the rivers. This application of the methods is carried out in zones defined as of ecologic flow, which are considered for this study as the river segments of environmental importance that will be most likely be influenced by the construction and/operation of the hydroelectric plants. The definition of this ecologic flow zone for the Volcán, Yeso, Colorado and Maipo rivers is done by means of a systemic characterization of these water courses, centering on their hydrologic, hydraulic, morphologic, biologic and anthropic classification and characterization.

As each of the methods applied to calculate the ecologic flow delivers a different value, the discrimination of which of them will be defined as the ecologic flow is achieved by the analysis of the variations in the runoff conditions on the river bed in the Project situation and the minimum requirements of the biologic species, mainly the fishes.

The ecologic flow is the minimum value that should circulate in a segment of the river to maintain the aquatic ecosystems. The environmental flow is that which satisfies the eco-systemic use of the goods and services based on the river.

The Project collects the water resources of three sub-sub watersheds belonging to the Maipo River basin: Upper Maipo River sub-basin, which, according to the National Water Bank of the General Waters Directorate is:

- Volcán River Sub-sub basin
- Yeso River Sub-sub basin;
- Colorado River Sub-sub basin, between the Alfalfal Bridge and the Maipo River;
- Upper Maipo River Sub-basin.

The Project collects water resources among some sources of the Volcán, Yeso and Colorado rivers, causing indirect effects upon the Maipo River in the segment between the Volcán River and the Las Lajas Plant outlet point of the waters. The method used to determine the ecologic flow is shown for all of them.

The hydrologic characterization of the rivers was made using the monthly average time flows series obtained from the PHAM Hydrologic Study provided by AES GENER.

The 55 years statistical series was used for the hydrologic characterization of the rivers, and their average seasonal variation; the analysis was centered on the variability of the historical series and its influence on the aquatic ecosystem.

The statistical period used for the Project calculations of all the water courses and for this report is of 55 years, from the 1950/51 to the 2004/05 hydrologic years.

Antecedents of rheophyle systems of the Metropolitan Region.

The Alto Maipo Hydroelectric Project is located in the sector called Cajón del Maipo, belonging to the Upper Basin of the Maipo River. This system is located in the Metropolitan Region, which belongs to the Central Zone of Chile, from the Chacabuco Range (33^0 S.W.) to the Chacao Canal (42^0 S.W.), and from 71^0 06' west longitude to the Pacific Ocean The Maipo basin is located at the northernmost (southernmost??) part of this central zone, which has been named, given its climate and topography characteristics as a sub-humid zone Mixed Régime Torrent Rivers.

Most of the rivers of the region have their sources in the Andes Cordillera, of a very abrupt topography with great heights and peaks above 5,500 masl. The larger water resources to feed the rivers that fall into the Pacific Ocean are within those mountains. These resources correspond to snow precipitations in winter which, joined to the presence of glaciers give rise to the water courses of the zone. This type of feeding, together with the spring and summer high temperatures cause the mixed behavior of the rivers, with two peaks in the monthly distribution histograms. The higher peak belongs rather to the nival behavior with high flows in summer and there is a smaller peak in winter. The torrential character of the rivers is due to their high elevation differences in a short distance.

The Maipo River basin is situated between 33° and 34° south latitude and 69° and 71° 30' west longitude. The Maipo River is born at the foot of the Maipo volcano, from the joining of three rivulets, in the Nacimiento sector, at an elevation of 3,135 masl; it goes north for about 62km down to the confluence with the Volcán River; downstream it receives the waters of the Yeso and Colorado rivers. (Figures 3.1 and 3.2)

The sources of the Volcán River are in the western slopes of the San José volcano and the river runs west for about 34km, down a steep slope. The streams El Morado, Las Placas, Colina and La Engorda flow from the north into the Volcán River and are joined to its southern branch at the Yeseras del Volcán sector (South Volcán).

The Yeso River is formed at the foot of the Los Piuquenes mountain pass, from the confluence of the Yeguas Muertas and Plomo rivers. It has a sharp change to an abrupt slope from its middle section to its outlet into the Maipo River; the El Yeso Reservoir works are located there. The only important affluent to the Yeso River in its lower course is the Manzanito stream, effluent from the Lo Encañado and Negra ponds.

The Colorado River -whose sources are on the western slope of the Cerro Tupungato- falls into the Maipo River about 25km downstream the Yeso river outlet into the Maipo. The Colorado River receives the Azufre and Museo rivers in the upper Cordillera; there it gathers sulfur which causes an abundant turbidity. The most important affluent of the Colorado River is the Olivares River, which collects abundant resources from the Olivares and Juncal Sur glaciers.

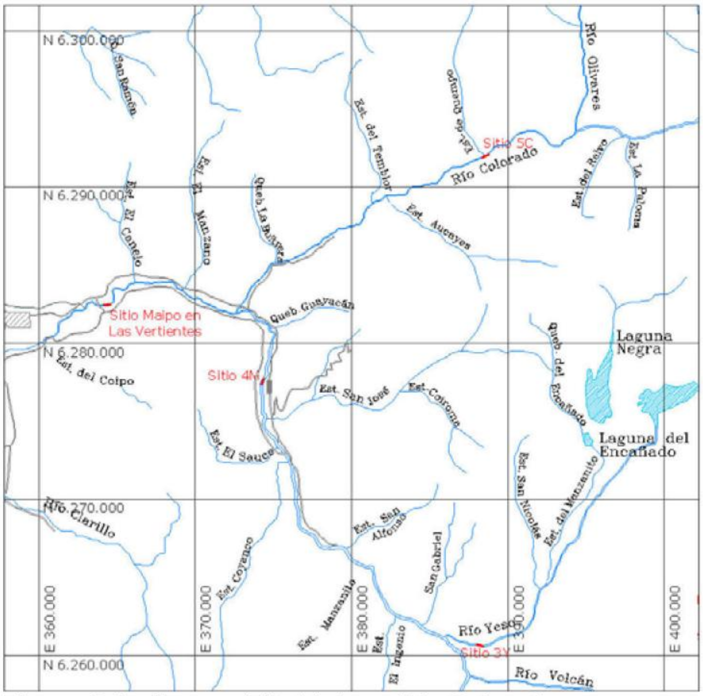


Figura 3.1 Cuenca Río Maipo y Río Colorado

Figure 3.1 Maipo and Colorado rivers Basin

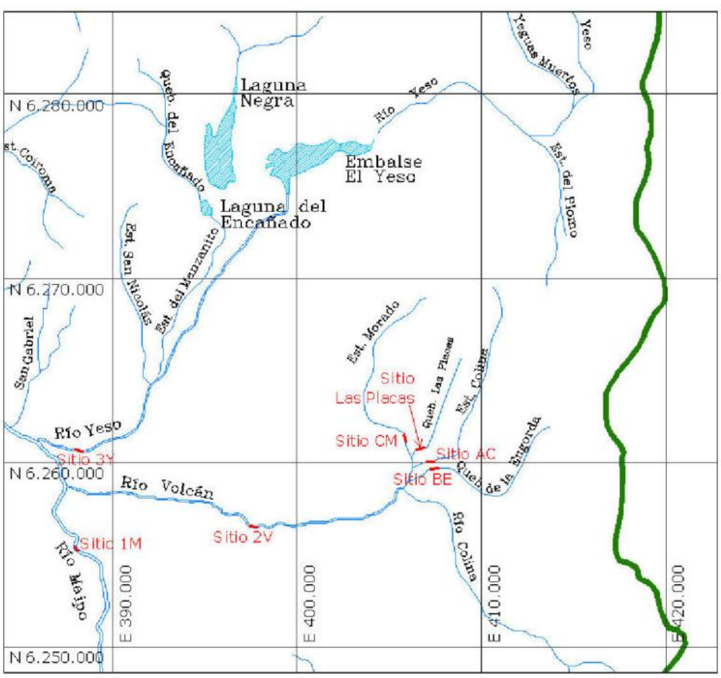


Figure 3.2. Volcán and El Yeso rivers basins.

3.1.1 Climate

The climates found in the Maipo River basin are: mild Mediterranean climate long warm dry season, and high mountain cold climate in the Andes Cordillera.

- Mild Mediterranean climate with long dry season

This climate is found in practically all the middle and low basin of the Maipo River. Its main feature is the presence of a long dry season and a sharply defined winter, with extreme temperatures down to zero degrees. Santiago has a median yearly temperature of 14.5°C, but thermal contrasts are wide. In summer, maximum temperatures climb over 30°C during the day. The median yearly precipitations amounts recorded in the coastal sector of the basin reach amounts of 404 mm/year and temperatures of 14.9° C. There are dryer areas and lower precipitation amounts (300mm/year) in the center of the basin (Quinta Normal Weather Station) due to relief effects. Precipitations increase in higher sectors, reaching average yearly values of 536mm (San José de Maipo) and average yearly temperatures of 14.2°C (Las Melosas).

- High Mountains Cold Climate

The High Mountains Cold Climate is present at the Andes Mountain Rante - above 3,000 masl. This type of climate is characterized by low temperatures and solid precipitations, allowing the accumulation of snow and permanent glaciers on the peaks and creeks of the high Cordillera.

The recorded precipitation values are higher during the summer season, between October and April.

3.1.2 Geology and volcanism

The Maipo River basin geology shows filling by fluvial and fluvioglacial sediments and volcanic ashes, Paleozoic granitic rocks, besides volcanic and Cretacic sedimentary rocks.

The formations found in the basin, which affect water quality are:

Volcanic rocks of the lower and middle Miocene; partly eroded volcanic complexes and volcanic sequences. Lavas, breccia, domes and pyroclastic andesitic-basaltic rocks mainly situated in the Olivares River sector.

• Sedimentary rocks of the Upper Jurassic-lower Cretacic, littoral or platform sedimentary marine sequences of limestones, claystones, calcareous sandstones, sandstones and coquinas mainly situated near the source of the Maipo River.

The area comprised from the sources of the Maipo River to the confluence with the Colorado River is influenced by lavas and carbonated formations. The Olivares River has a slight influence from the andesite in the upper part of its basin. From the Colorado River down to the Colina Stream, we again find lavas and carbonated formations.

The volcanic influence upon the basin is varied, from the point of view of activity. The Tupungato and Marmolejo volcanoes are extinguished, the Tupungatito, San José and Maipo are active. Therefore, there is a large volcanic influence in the zone.

The Tupungatito (5,682 masl and San José (5,856 masl) are strato-volcanoes and the first puffs out permanent fumaroles. The Maipo volcano (5,264 masl) is of the caldera type and it is active; there have not been any eruptions during the past two centuries.

3.1.3 Hydrogeology

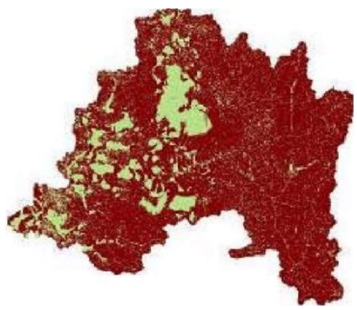
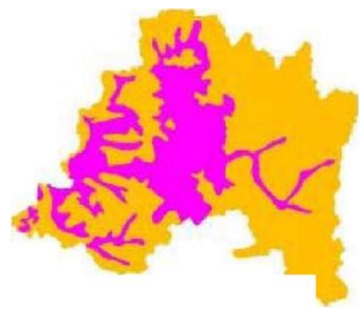
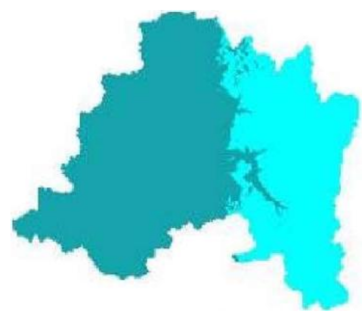
The information concerning the Maipo Basin that can be obtained from the Hydrogeological Map confirms that there is only one aquifer in the cordilleran sector, specifically in the Volcán and Yeso rivers sector. This underground water reservoir, the Santiago aquifer, spreads from the Cordillera down to Talagante, its capacity is of nearly 10,000 million cubic meters, equivalent to 40 El Yeso reservoirs. Following the runoff line of the Maipo River, another aquifer is placed in the Volcán River sector where it joins the Maipo River. There are no aquifers in the remainder of the cordilleran zone.

The climate conditions, added to the topography of the ground, permeability conditions and the precipitation régime, finally determine the structure and functioning of the rivers in the region (CONAMA 2006)[1] Source: CONAMA (2006) Protection and sustainable management of wetlands integrated to the hydrographic basin (31- -22-001/05 Project)

Using as a base the guide prepared by the SAG during 2006: “Concepts and criteria for the environmental evaluation of wetlands” of the CONAMA (2006) study, a classification of the ecotypes found in t6he Metropolitan Region (Source: CONAMA (2006) Protection and sustainable management of wetlands integrated to the hydrographic basin (31- -22-001/05 Project)

[1] *Protection and sustainable management of wetlands integrated to the hydrographic basin (31- -22-001/05 Project)*

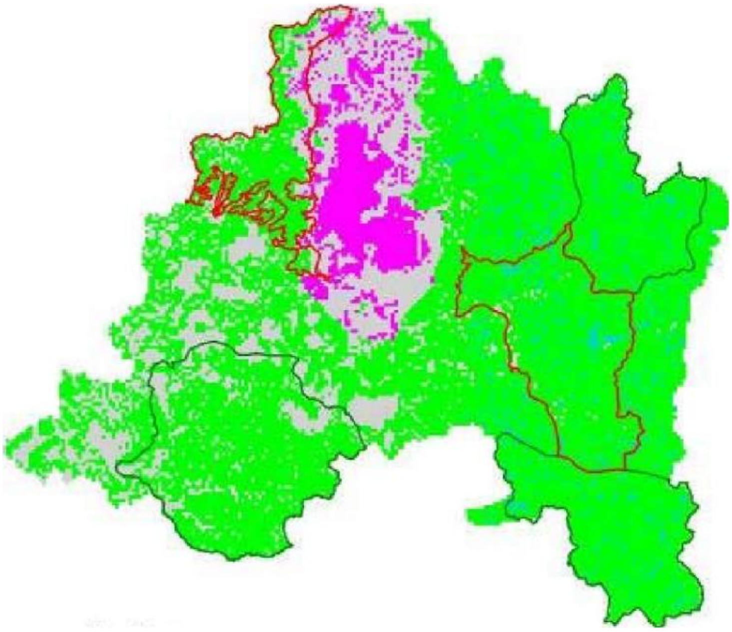
Figure) From this, it can be established that the rivers found in the study area would correspond to the “runoff” and “B infiltration” type.

 Grade	 Permeability
 Aridity	 Frequency

Source: CONAMA (2006) Protection and sustainable management of wetlands integrated to the hydrographic basin (31- 22-001/05 Project).

Figure 3.3. Environmental information used to define the Metropolitan Region ecotypes.

Metropolitan Region Ecotypes



Ecotypes
Runoff
Evaporation
Infiltration A
Without ecotype

Priority site
Wetlands

Source: CONAMA (2006) Protection and sustainable management of wetlands integrated to the hydrographic basin (31- 22-001/05 Project)

Figure 3.4. Ecotypes identified in the Metropolitan Region

3.1.4 Alto Maipo Hydroelectric Project (PHAM)

The purpose of the Project is to generate electric power by the construction and operation of two run-of-river plants in hydraulic series, the Alfalfal II and Las Lajas plant. Together they will generate a maximum output of 531 MW to be delivered to the Central Interconnected Grid (SIC) by means of a transmission system connected to a substation.

GENER

The PHAM will be located south-south east of the city of Santiago, in the San José de Maipo Municipality, Cordillera Province, Metropolitan Region, specifically in the higher basin of the Maipo River (See figure 3.5 “General location of the Project”).

ALTO MAIPO HYDROELECTRIC PROJECT

Source: www.aesgener.cl

Figure 3.5. General location of the Alto Maipo Hydroelectric Project

Insert Figure.

Both plants, Alfalfal II and Las Lajas, will be placed on the basin of the Colorado River, downstream the present Alfalfal I Hydroelectric plant, owned by Gener. The Alfalfal II Plant will mostly use the waters from the upper part of the Volcán and Yeso Rivers, while the Las Lajas Plant will use the waters coming from the Alfalfal II and the existing Alfalfal I plant, added to those from the intakes in the middle watershed of the Colorado River. To do this, the Project envisages the construction of a total of 70km of tunnels; about 60km will belong to the hydraulic tunnels of both plants and the rest are the windows (tunnels) to access the main tunnels and the powerhouse rooms.

3.1.4.1 General Description of the PHAM

The development of the Alto Maipo Hydroelectric Project comprises two plants set in hydraulic series in the upper sector of the Maipo River: Alfalfal II and Las Lajas. The Project entails using the waters from the upper zone of the Volcán and Yeso rivers, the turbinated waters from the Alfalfal Plant and those of the middle watershed of the Colorado River.

Alfalfal II Plant

The Alfalfal II plant has been designed for a flow rate of 27m^3/s, and receives the waters collected from streams in the upper part of the Volcán River, which are led to the Yeso River valley through the El Volcán tunnel. Up to a maximum of 12.8m^3/s is collected from the upper sector of the Volcán River by 4 intakes intercepting the different streams forming the north branch of the Volcán River, which in turn falls into the Maipo River.

The four streams collected are: Engorda, Colina, Las Placas and El Morado. A buried water pipeline will carry the collected flow into the El Volcán tunnel. The collected flows pass through automatic radial sluices and sand traps at the intake sites before entering the Volcán tunnel. The Volcán tunnel receives the waters collected in the upper part of the Volcán River and takes them to the Yeso river valley, where the contribution of the latter is received through a buried pipeline that starts at the Yeso River intake and goes into an intake tank placed at the outlet of the Volcán tunnel, joining both flows.

From the intake tank, the flow is carried to the Alfalfal II tunnel by means of a 13.600m long pressure pipeline, down to the headrace tunnel of the Alfalfal II Plant; until it reaches the upper part of the pressure shaft. The surge shaft is placed slightly above the start of the pressure shaft and the forebay of the plant. The gross head is estimated at 1.146m.

The powerhouse is set in a cavern excavated in the rock mass placed west of the Aucayes stream, in the Colorado River valley. The generation equipment has two four jet 500 rpm Pelton turbines, for a maximum output of 2 x 136 MW.

The discharge tunnel of the Alfalfal II Plant is approximately 2.5km long and delivers its flow to the headrace tunnel of the Las Lajas Plant. The flow generated by the Alfalfal II Plant can be led to the powerhouse room of the Las Lajas Plant or else to its forebay of the latter, placed at on the right bank of the Colorado river, in both cases though the same tunnel as mentioned before.

Las Lajas Plant

The Las Lajas Plant, designed for a flow of 65m^3/s, receives the waters from the Alfalfal and Alfalfal II Plants, besides the contributions of the middle basin of the Colorado River, placed between the intake of the Alfalfal Plant (Colorado and Olivares) and the present intake of the Maitenes Plant. To this is added the contribution of the Aucayes stream.

The Las Lajas Plant considers a forebay, which functions also as regulating reservoir for the Alfalfal II Plant. The waters coming from the Alfalfal Plant go into this forebay, placed on the right bank of the Colorado River by means of works to its evacuation channel.

The waters coming from the existing Channel 1 of the Maitenes plant, are sent by a channel and sand trapped at the works placed on the left bank of the Colorado river; a siphon under the river sends those waters to the Las Lajas forebay.

The adduction to the Las Lajas Plant starts at the loading chamber of the same name, by means of a pressure reinforced concrete duct. This crosses the Colorado River by means of a siphon and joins the Las Lajas tunnel, which runs on pressure runoff. The Las Lajas tunnel receives the contributions of the Alfalfal II discharge tunnel; this tunnel also receives the contribution of the Aucayes stream during its run, it has a surge shaft and ends in a penstock to feed the turbines.

The powerhouse room is placed on the left bank of the Colorado River in a cavern excavated in the rock mass. The generation equipment has two 6 jet Pelton turbines velocity 300 rpm, with a nominal flow of 32.5 m^3/s for each unit and a gross head of 485m.

The discharge tunnel of the Las Lajas Plant sends the water directly into the Maipo River. It is 13.3km long with a 35m^2 horseshoe section and water level runoff.

Water Rights

The Alto Maipo Hydroelectric Project envisages collecting resources at eight different points of the upper basin of the Maipo River. There are no consumptive water rights at each of those points and in most of them there are also ecologic flows established by the General Waters Directorate in the concession of the rights.

Concerning those water courses the following Table 3.1 indicates the basin in question, sub-basin and sub-sub basin, according to the classification establish by the National Waters Bank of the DGA.

Table 3.1

Classification of the sub-basins, according to the National Waters Bank

Water Course	Basin	Sub-basin	Sub-sub basin	BNA Code
Colina Stream	Maipo River	Upper Maipo River	Volcán River	05702
La Engorda stream	Maipo River	Upper Maipo River	Volcán River	05702
Las Placas Creek	Maipo River	Upper Maipo River	Volcán River	05702
El Morado Canyon	Maipo River	Upper Maipo River	Volcán River	05702
Yeso River	Maipo River	Upper Maipo River	Yeso River	05703
Colorado River	Maipo River	Upper Maipo River	Colorado River between Olivares and Maipo rivers	05707
Aucayes Stream	Maipo River	Upper Maipo River	Colorado River between Olivares and Maipo rivers	05707

Source: Environmental Impact study (EIA) Alto Maipo Hydroelectric Project (PHAM) 3119-0000-MA-INF-004_Rev.0 May, 2008 Chapter 2 2.2-12

The design flows of the Plants must be supplied by the total or partial sum of the design flows of each of their intakes.

The flow intake points are:

Alfalfal II Plant

Cajón Del Morado
Cajón La Engorda,
Colina Stream,
Las Placas Creek
Yeso River
Las Lajas Plant
Alfalfal discharge channel

Colorado River at the Maitenes intake Channel 2 of the Maitenes Plant

La Engorda intake

The La Engorda intake is a high mountains or Tyrolean type intake, placed at an elevation of 2,520masl of the stream and designed to collect a flow of 2.1m^3/s.

Colina Intake

The Colina stream intake is a lateral type headrace, considering the construction of a frontal barrier to the runoff, 15m wide and approximately 2.5m above the bottom of the bed. Its base is placed at an elevation of 2,516masl on that stream and is designed for a flow of 6.0m^3/s.

Las Placas Intake

The Las Placas intake is an high mountains or Tyrolean type headrace, placed at an elevation of 2,513.5masl of the stream and designed to collect a flow of 1m^3/s.

El Morado headrace

The El Morado stream intake is a lateral type headrace, entailing the construction of a frontal barrier to the runoff, 12 m wide and approximately 2.5m above the bottom of the bed. Its base is placed at an elevation of 2,511masl in that stream and is designed for a flow of 3.7 m^3/s.

El Yeso intake

The works are placed 700m downstream the El Yeso reservoir, and their purpose is to collect the contribution of the Yeso River and carry it to the Alfalfal II Plant system. This entails the construction of a perpendicular 17m long and approximately 2.5m high barrier to the runoff in respect to the bottom of the river bed, its base at an approximate elevation of 2,500masl. The design flow is 15.0m^3/s.

Maitenes Plant intake

This intake is named after the Maitenes hydroelectric plant, since it belongs to it and is set on the Colorado River. The headrace was built in 1923 and b in 1989 after the 1987 mudslide. This is a fixed transversal barrier to the Colorado River bed placed immediately upstream of the Alfalfal discharge. The headrace itself is a lateral intake with seven movable intake openings and two automatic radial sluices. It feeds the Maitenes 1 Channel on the left bank of the Colorado River. Since the nominal capacity of the headrace and the Maitenes channel is over 10 m^3/s, both structures will be used by the Alto Maipo Project to feed the Las Lajas Plant forebay, by the transfer of 10m^3/s from Channel 1.

Channel 2 of the Maitenes Plant

At present, this channel carries up to 2m^3/s of the Aucayes stream waters from the existing intake down to the Maitenes Plant forebay. These waters will be used by connecting that channel to the Las Lajas headrace tunnel by means of a vertical shaft about 150m deep.

Those waters will be used as that channel will be connected to the Las Lajas headrace tunnel by a vertical shaft about 150m deep.

Table 3.2

Characteristics and description of the Headraces Works

Intake	Collection system	Design Flow m^3/s	Ecologic Flow m3/s	Location UTM	
Engorda	High mountain intake	2.1	0.2	6.259.798	407.256
Colina	Lateral intake	6.0	0.3	6.260.082	407.156
Las Placas	High mountain intake	1.0	0.14	6.260.714	406.642
El Morado	Lateral intake	3.7	0.24	6.261.259	405.759
El Yeso	Lateral intake	15	0.20	6.274.117	399.669
Maitenes	Existing Channel 1	10	0.30	6.292.504	389.069
Alfalfal	Existing discharge channel	30	0.00	6.292.675	389.107
Aucayes	Channel 2 - existing	2.0	0.00	6.287.958	384.009

Source: Environmental Impact study (EIA) Alto Maipo Hydroelectric Project (PHAM) 3119-0000-MA-INF-004_Rev.0 May, 2008 Chapter 2 2.2-12
May 2008. Chapter 2.2.2.-19

3.1.5 Ecologic flows

The ecologic flow is defined in the Norms and Procedures Handbook of the DGA 8DGA, 2002) as the minimum flow that a river must have to maintain the present aquatic ecosystems, preserving the quality of the water.

According to this definition, it is evident that there is a wide range of flows that are ecological for a specific river, depending on how the present ecosystems are defined (Baeza y García del Jalón, 1997). Therefore, maximum and minimum extremes can be defined within this range of flows. In the most frequent cases, where water is considered as a scarce resource, the minimum value is especially taken into account. But there might be cases where it is necessary to empty a reservoir very quickly (due to the danger of flooding, the need for hydroelectric production or transfer of water) and in those cases the maximum values for the circulating flow must be fixed, so as to maintain the stability of the habitats and biologic components of the aquatic ecosystem.

Numerous methods have been developed to determine the ecologic flows[2] of the aquatic ecosystems. The hydrologic or statistical methods are the simplest, they determine the

[2] *a) The ecologic flow allows "maintaining the minimum population number necessary to ensure the survival of the species that make up the existing aquatic ecosystems" (Garcia de Jalon et al, 1993).*
b) "is the average historical flow sufficient to sustain the native aquatic organisms during the whole year" (New England flows program).
"c) "is the minimum flow that must be let through the dam to maintain the biogenic capacity of the river and ensure that no irreversible changes will occur in the ecosystem" (CONAMA)

minimum ecologic flow by the study of flow data. An example of the statistical method is to define the minimum flow as 10% of the average yearly flow, The most coherent criterion would be that which links the habitat requirements of the fluvial species to the variations of the flow characteristics as a function of the circulating flows (Baeza y García del Jalón, 1997). Several authors have used methods based on this criterion, among them Tennant (1976), who analyzes qualitatively the fish habitat as a function of the hydrology of the watershed; White (1976) who develops an hydraulic analysis between the circulating flows and the wet perimeter of the water course, supposing a growing relationship between this and the biogenic capacity of the river. Finally, Stalnaker (1979) and Bovee (1982), developed the IFIM method (Instream Flows Incremental Methodology) based on the quantitative relationships between the circulating flows and the physical and hydraulic parameters that determine the biological habitat.

The IFIM/PHABSIM method consists in quantifying the changes that may take place in the habitat availability of a fluvial system as a function of the changes in the flow of the system 1995). Therefore, an appropriate method becomes available to both determine the effects that may take place with a determine flow regime on the resources of interest of a fluvial system as to evaluate the diverse possible flow options so as to optimize them, taking into account the different uses that may exists concurrently for the water of the system in question. The IFIM/PHABSIM system is often used to forecast the effects that a proposed hydroelectric plant may have on the availability of habitats so as to calculate the flow value of the necessary discharge to satisfy the needs of the aquatic resources present in the segment situated downstream of the dam. In a large number of cases, it has been found that to implant a controlled flow regime for the discharge may result in benefits for the aquatic life species.

However, this method shows three important restrictions: i) the hydraulic modeling component of the IFIM/PHABSIM model is able to predict exactly the changes occurring in the elevation and velocities of the current within a range of 2.5 times the value of the maximum measured flow and 40% less than the minimum measured flow, values considered as acceptable as normal limits for data extrapolation purposes. It is especially useful to study rivers with sub critical hydrodynamic conditions, However, most of the reservoirs built in our country are placed in areas with strong slopes and torrent type systems, where there are often rapids, generating supercritical conditions which strongly restrict their implementation; ii) one of the most critical steps to be carried out when using the IFIM/PHABSIM model is to determine which would the species be and their respective development stages, for a model to reflect exactly the changes that may be produced in the habitat. It will be necessary to know first the requirements as regards the habitat characteristics that must be present to satisfy the need of each species or activity of interest. Therefore it is necessary to define precisely in what circumstances it is feasible to apply the IFIM/PHABSIM method, considering that in our country there is a scant or rather inexistent primary information to provide for the required habitats analysis and iii) the method does not consider changes in water quality, such as alochtonous organic matter.

This method is widely used in the United States and Europe. Gore and Nestlé (1900) have prepared a critical analysis of the method, pointing out the research lines required for its development and improvement, Souchon (1983) proposed an adaptation to French rivers and Gustard (1987) to those of the United Kingdom.

3.2 OBJECTIVES

3.2.1 General objective

Determine the ecologic flow that must be considered by the Alto Maipo Hydroelectric Project in its construction and operation stages.

3.2.2 Specific objectives

- Characterize the availability of water resources in the main water courses of the Volcán river and its streams, the Yeso, Colorado and Maipo between the confluence with Volcán and down to Las Lajas.
- Carry out a hydro-environmental characterization of the Volcán river and its streams, of the Yeso, Colorado and Maipo between the confluence with El Volcán and Las Lajas, taking into account To this effect the biological requirements such as the distribution, abundance and diversity of fish species and macro-benthic and their habitat as well as the anthropic use of the water courses and banks for recreational purposes.

- Determine the zones affected by hydrological flows or which could be strongly affected as an effect of the changes of flows or the runoff pattern as a production of the construction and operation of the PHAM
- Determine the critical or sensitive segments or sections of the Volcán River and its streams, the rivers Yeso, Colorado and Maipo between the confluence with El Volcán and Las Lajas that are characteristic in terms of the environmental attributes that it should be important to preserve.
- Estimation of the environmental water demand in the critical or sensitive points as defined, by the use of methods adjusted to the characteristics of the environmental element that it is intended to protect.

3.3 SCOPES

The following relevant concepts for this study are defined as follows:

Ecologic flow zone: Zone of the river of environmental importance that will be influenced by the constructions and/or operation of the hydroelectric plants,

Environmentally important areas (AIA): Areas of ecologic relevance which will be affected by the construction or operation of the PHAM (ex. Aquatic flora and fauna) and or anthropic relevance for the local community (ex. Rafting bays, recreation zones, intakes, etc.).

Ecologic flow: According to the definition of the DGA in its Norms and Procedures Handbook ((DGA, 2002) it is the minimum flow that a river should keep to maintain its ecosystems preserving water quality. This definition applies to the ecologic flow zone.

Flow through the intake: Minimum flow that should be delivered by the hydro electrical plants at the restitution point to satisfy both the ecologic flow and the anthropic requirements. It is calculated as the ecologic or anthropic flow of the downstream segment, less the average minimum monthly flow of the historical series, contributed by the intermediate basin between the ecologic flow zone or sensitive points of an anthropic character, and the dam.

These concepts have been defined due to the singularities of the area in terms of human intervention on its water courses, and as the PHAM uses existing infrastructure (intakes, Aucayes, Maitenes, etc.).

3.4 BIBLIOGRAPHIC DATA

3.4.1 Expected effects of the operation of hydroelectric plants upon rheophyle systems.

Fluvial communities have evolved subjected to specific types of flow regimes, therefore, their biological cycles and ecologic requirements are adapted to the seasonal variations proper to that regime. Likewise, they are adapted to tolerate minimum flows during a more or less long drought and can even tolerate exiguous flows during one or several days, these obviously cannot be maintained during long periods, to which the biota is not adapted. However, the role of the physical, chemical and biotic factors in the aquatic ecosystems structures is not well defined (Power et al, 1988; Rosenberg et al, 1997). When physical characteristics change too fast and with unexpected frequency, the ecosystem may never reach a stable balance (Jansson et al, 2000) Generally speaking, the communities that establish themselves near the reservoirs are made up by tolerant and/or temporary resident species, while communities are more natural downstream, because conditions improve, tributaries and underground water exchanges bring the river back to a regime nearer to the natural one (Ward y Stanford, 1989; Curry et al, 1994).

Therefore, regulated discharges are often pointed out as responsible for the loss of biological diversity and habitat (Jansson, 2002). Although most of the responses to flow regulation are site-specific, the general patterns of large scale effects downstream of the reservoirs are being monitored over the world (Dynesius y Nilsson, 1994; Nilsson et al, 1997; Rosenberg et al, 1997, 2000).

Table 3.3 summarizes the expected effects in different components of the aquatic community that could be caused by changes in the runoff velocity of the water, temperature and oxygenation, ascribed to the conditions generated by the operation of a plant.

Table 3.3 Expected effects of the changes in the physical and chemical characteristics of the rivers upon the biota.

Taxonomic group	Velocity	Depth (desiccation)	Temperature	Oxygenation	References
(Phythobenthos)	Heightened velocity causes an increase in nutrient quantity An increase of velocity causes the dragging of strips of phythobenthos adhering to the rocky surfaces	High tolerance to desiccation, however this tolerance varies between the different taxonomic groups	Decrease of biomass and richness.		Potts & Whitton (1979) Casco & Toja (2003) Biggs & Close (1989)
Phytoplankton			Tendency to increase due to lowering of temperature.		Jacobsen et al, 1997
Zoobenthos	High velocities produce re-suspension of solids from sediments, hindering feeding and breathing	Great zoobenthos mortality rates have been found in drought or desiccation conditions	Diversity decreases as temperature falls.		Golladay et al (2002)
Bryophytes	High velocities can cause re-suspension of solids, this leads to light diminution for aquatic plants.	Some species able to withstand up to 6 hours desiccation periods have been reported.			Sinzar-Sekulié (2005) Davies-Colley et al (1992)
Macrophytes	Inverse ratio between Macrophytes mass and water velocity. The abundance of most species				Riggs & Biggs (2003) Chambers et al (1991) Henriques (1987)

	diminishes above velocities of 0.4 m/s. It has been reported that there would not be Macrophytes development at a critical velocity of 0.8 m/s				
Fishes	Fishes can tolerate velocities between 0.1 and 0.25 m/s during their first development stages. They can tolerate velocities above 0.5 m/s once they reach a larger size (40-50mm)	A quick lowering of the water level could cause the death of the fry . Level changes affect the reproductive behavior, or spawning. Loss of spawning and refuge habitats	Temperatures near 25°C can be lethal for some dish species A relationship between lower temperatures and lesser abundance of species has been observed.	An increase in gas concentration can cause the death of migrating individuals, as it generates similar conditions at the bottom and surface.	Heggenes & Traaen (1988) Vismara et al. (2001) Bardonner et al. (2006) Lezard & Hayes (2003)

3.4.1.1 Ecologic flows versus fish habitat requirements

Fishes are frequently used as bio-indicators to establish the river flow requirements, as they are top predators at the higher levels of trophic networks. Fishes that inhabit rheophyle-type rivers as is the case of the Volcán, Yeso, Colorado and Maipo rivers, are exposed to extreme conditions arising from wide flow variations and steep slopes; these factors originate natural perturbations such as flooding.

The perturbations affect the structure and functioning of the rivers, and depending from their behavior they can belong to two types: i) pressure, where the process is present for a long period of type and ii) pulse, where there is an unique event. Within this last type we find catastrophic perturbations, event of short duration and high intensity. Depending on their origin, perturbations can be natural or derived from the human activity, although the effects that they generate are usually similar, their properties differ fundamentally. The natural type perturbations (flooding) modify the rivers, but those processes are part of the dynamic of the systems. To the contrary the anthropic perturbations are processes or materials frequently “unknown” by the systems, and therefore their effects can vary, but in most cases they are of the negative kind (contamination, massive mortality of plants or animals).

The ecologic functioning of the rivers is mainly regulated by factors such as the flow, climate conditions and nutrients, among others. However, not all factors are of the same hierarchy (importance) as to their role as regulating factors.[3] The Figure shows the hierarchy of factors that regulate the rivers, from this it is seen that the physical factors are the most important, to flow with chemical factors and finally the biological factors. We can give an example of this: we can add a very large amount of nutrients to a river without any changes in its trophic condition due because the times of residence (water renewal) are very low.

This means that we must affirm the need to use this hierarchy wherever we study rivers aquatic ecosystems, especially when determining the ecologic flow. We must link the hierarchy to the specific requirements of the fishes, with special notice of the intrinsic properties of the river. (Figure 3.6).

[3] *Contreras et al. (2006). Concepts and criteria for the environmental evaluation of wetlands. SAG. Chile,*

Therefore, coherence must be kept between fish distribution and abundance and the properties of the rivers (Figure 3.6)

The critical variables to maintain species in the rivers were defined from the information available in the literature – using fishes as indicators of the environmental requirements of the aquatic species (similar to the criterion used by the DGA and CONAMA to establish the ecologic flows). These are: Height, runoff and runoff velocity (García de Jalón et al, 1993)[4]. The variable ranges that it is necessary to maintain downstream the intake point of the hydro electrical plant, as required by aquatic organisms and especially the fishes were established using two criteria: i) ranges measured in the Volcán, Yeso and Colorado rivers and their streams and ii) an eco-physiological analysis to establish the fishes threshold as regards the height of runoff and velocity fluctuations.

It is important to note that the scientific information available in our country to analyze the environmental requirements of native fish species is practically non-existent (habitability curves) and it was necessary to use studies carried out abroad to prepare this analysis.

Figures 3.7, 3.8 and 3.9, from Garcia de Jalón et al (1993)4, detail the habitat requirements of the trout. The minimum depth requirements are a height of 10cm and 30cm for 50% of the cases (Figure 3.7). The maximum velocity values (90 %) are not above 1 m/s, in favorable conditions for the development of the trout. The Figure ¿??? Describes the velocity requirements for different development stages of the trout, where it can be seen that the early development stages have greater limitations concerning runoff velocities. These values correspond to average conditions that control fish habitats.

Figures 3.4 and 3.5 show the tolerance ranges of salmonid fishes living in rheophyle environments, considering different development phase. Generally speaking we can establish that maximum velocities do not rise above 2 m/s and optimum velocities are not above 1 m/s.

In our country, the only available data concerning the habitat requirements of fishes and other aquatic organisms are found in a study carried out by the Centro EULA (2000, Figure 3.10 and Figure)

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[4] *GARCIA DE JALON, D., M. MAYO, F. HERVELLA. E. BARCELO & T. FERNANDEZ. (1993). Management Principles and Techniques for Continental Waters Fishing Editions Mundi-Prensa, Madrid 247 pp.*

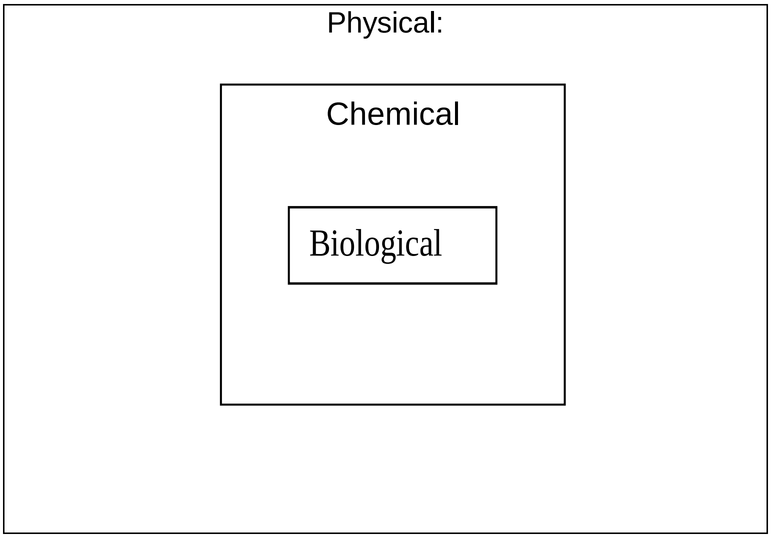
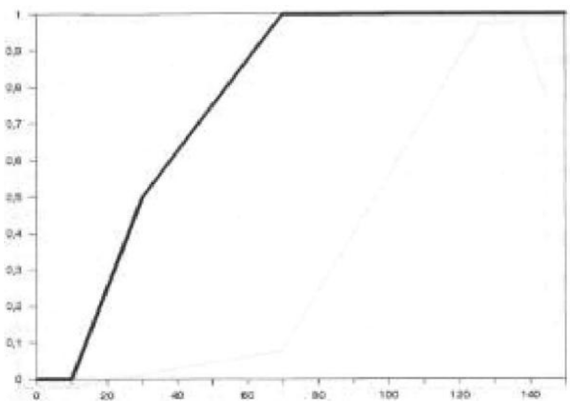
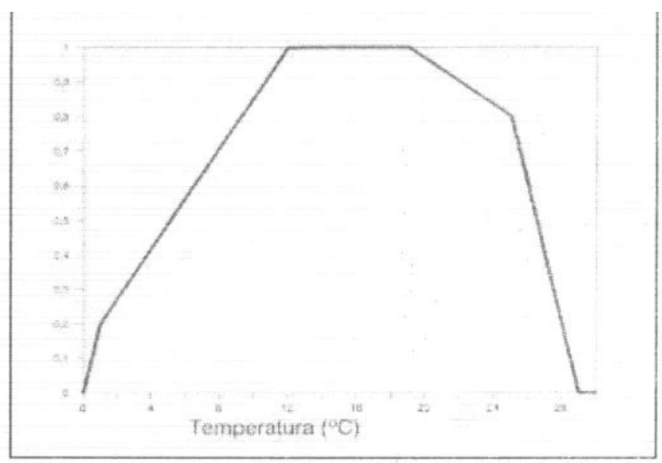


Figure 3.6. Hierarchical distribution of the factors controlling rhytronic-type Rivers.

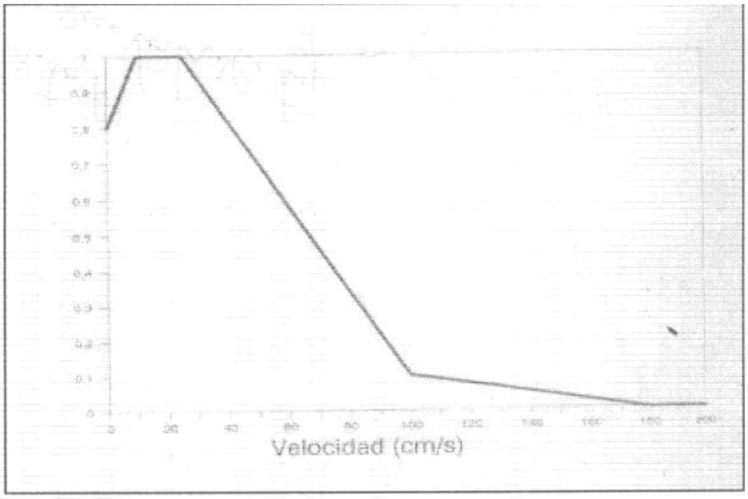


Depth (cm)



Temperature °C

Figure 3.7. Trout habitat requirements



Velocity (m/s.)

Figure 3.8. Trout habitat requirements (velocity)

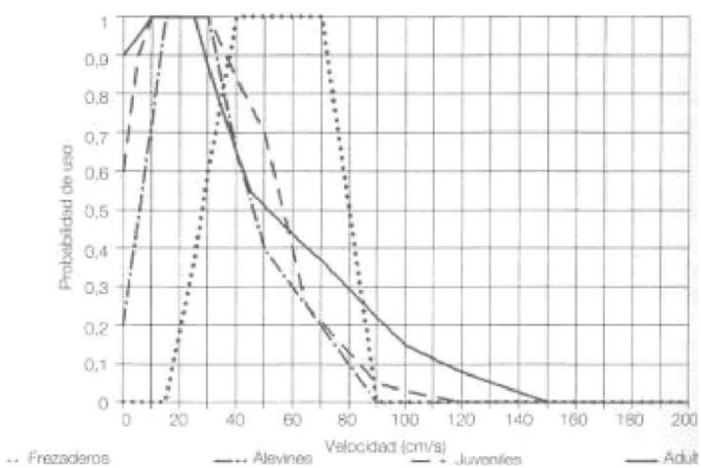


Figure 3.9. Trout habitat requirements (velocity) for different development phases.

Table 3.4 Velocity values as upper limit for salmonids (m/s)

SPECIES	SPAWNING	FRY	JUVENILE	ADULT
Atlantic Salmon[5]	1.00	1.00	1.00	-
Brown trout	1.19	0.88	1.07	1.83
Rainbow Trout	0.94	0.90	1.06	1.06
Chinook Salmon[6]	1.31	10.76	0.91	11.52

Table 3.5 Preferred current velocity for salmonids (m/s).

SPECIES	SPAWNING	FRY	JUVENILE	ADULT
Atlantic Salmon	0,60-0,80	0,10-0,30	0,10-0,40	
Brown trout[7]	0,21-0,52	0,09	0,15	0,15
Rainbow Trout	0,49-0,91	0,00	0,00-0,15	0,15-0,61
Chinook Salmon[8]	0,46-0,73	0,06-0,09	0,12-0,21	0,83

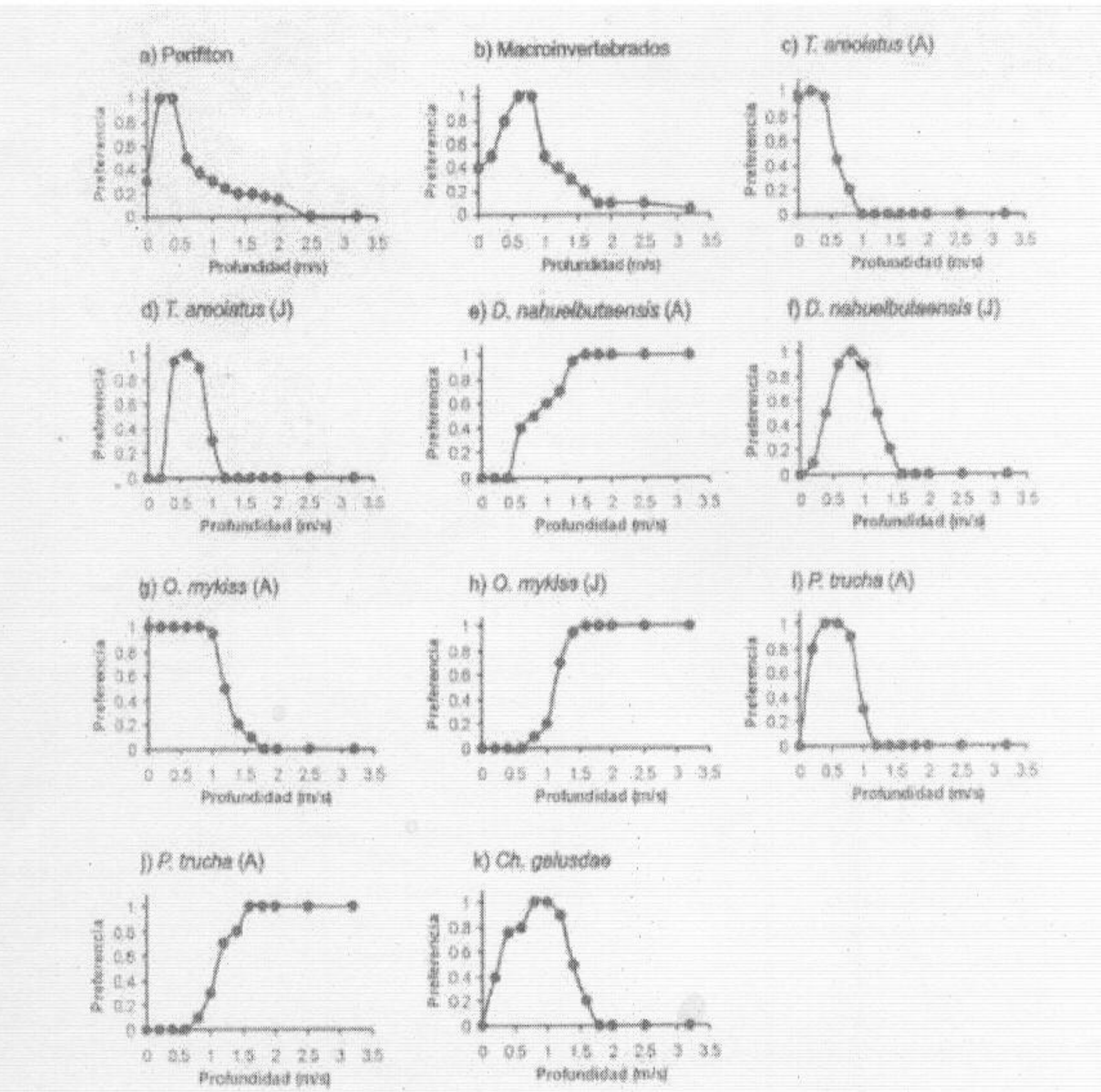
5 *Stanley, J.G. y J.G. Trial. 1995. Habitat Suitability Index Models: Nonmigratory Freshwater Lile Stages 01 Atlantic Salmon. Biological Science Report 3. U.S. Department 01 the Interior, National Biological Service. Washington, D.C..*

6 *Raleigh, R.F .. W.J. Miller y P.e. Nelson. 1986a. Habitat Suitability Index Models and Instream Flow Suitability Curves: Chinook Salmon. U.S. Fish Wildl. Servo Biol. Rep. 82(10.122).64 pages*

7 *Raleigh, R.F .. L.D. Zuckerman y P.e. Nelson. 1986b. Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout, Revised. U.S. Fish Wildl. Servo Biol. Rep. 82(10.122)0.65 pages [Editado inicialmente con en N°: FWS/OBS-82/10.71, September 19841*

8 *Raleigh, R.F .. W.J. Miller y P.e. Nelson. 1986a. Habitat Suitability Index Models and Instream Flow Suitability Curves: Chinook Salmon. U.S. Fish Wildl. Servo Biol. Rep. 82(10.122).64 pages*

c)



d)

Figure 3.10. Habitat depth requirements for different species (EULA, 2000). (A) and (J) refer to adult and juvenile stages of the fish species.

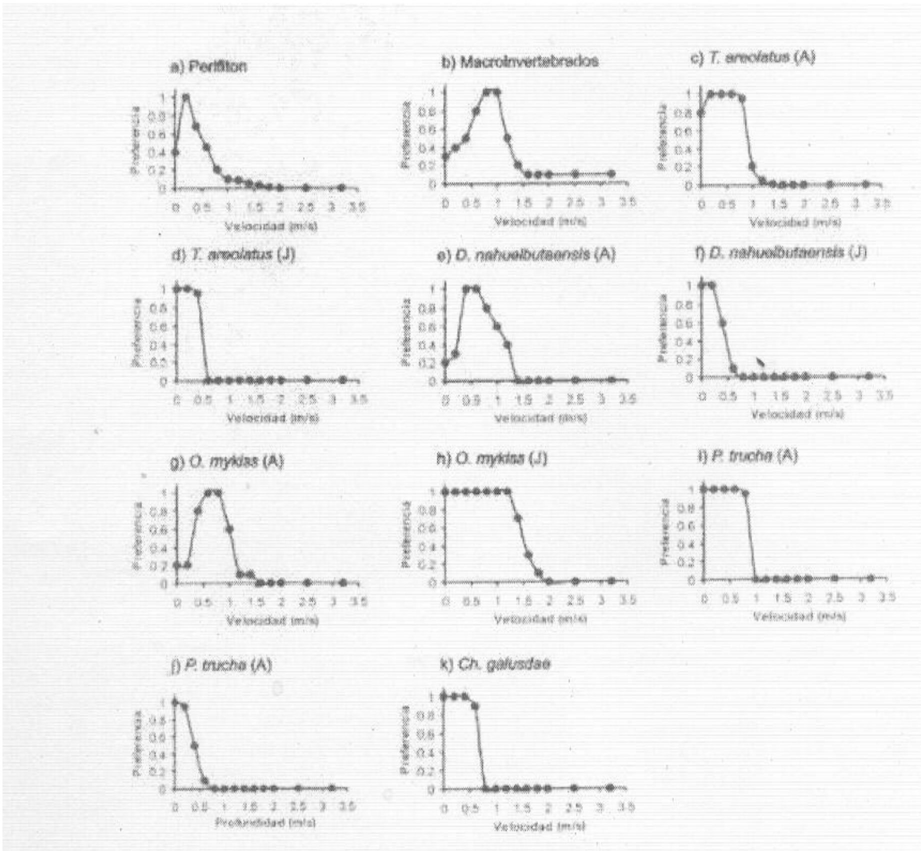


Figure 13. Habitat preference curves for the current velocity (m/s) variable of the species studied with PHABSIM a) perfiton; b) benthic Macroinvertebrate; c) Adult Trichomycterus areolatus; d) juvenile T. areolatus; e) Adult Diplomystes nahuelbutaensis; f) Juvenile D. nahuelbutaensis; g) Adult Oncorhynchus mykiss; h) Juvenile 0. mykiss; i)Adult Porcichthys trucha; j) Juvenile P trucha; k) Adult and juvenile Ch, galusciae,
Figure 3.11. Habitat velocity requirements for different species (EULA, 2000). (A) and (J) refer to adult and juvenile stages of the fish species.

3.4.1.2 Ecologic flows versus aquatic plants requirements

An analysis of the aquatic plants was included as this component does not have the capacity to move as does aquatic fauna. Therefore, the vascular aquatic flora sustainability depends from its resistance and resilience capacities to withstand flow regime variations.

The revision separates the most general aspects of aquatic plants biology (Biomass, Establishment) from the specific (exposure, temperature and radiation) which deepen the analysis of the ecologic processes and physiologic mechanisms that are fundaments of the described pattern hypotheses.

3.4.1.3 Aquatic Plants Environment and Biology

Aquatic plants vary in anatomy, physiology, characteristics and life history, and capacity to tolerate environmental stress (abiotic and biotic) Comparative studies of environmental effects on the biomass, refers to results in Elodea canadensis, Potamogeton nodosus, (P. americanus) and Vallisneria americana, where increments were recorded with more light and temperature (up to 28°C at least). However, the changes in biomass and other parameters are influenced by the interactions between light and temperature. For example The density of the stems was directly related to the production of biomass in the species, but as a contrast to this, the light and temperature caused divergent responses in the length of the stems, which would diminish with an increase in radiation but increase with a rise in temperature. The extension of the morphology variation differs among species, suggesting that Light and temperature would interact in the Macrophytes, affecting lower distribution limits in depth and duration of the seasonal growth. Temperature would probably cause a greater effect in the distribution of aquatic plants (the different responses to temperature would be species-specific) due to differences, basically, in the histories or life cycles (Baker et al, 1982).

These environmental effects in the biology of aquatic plants were complemented i with a study made in Japan about the life cycle of E. densa. The biomass reaches its maximum in august and December-January in a bi-modal growth curve attributed to two type of plants (winter and summer). Optimum high temperatures in the culture (20.rC) and photosynthesis (35°C) similar to those of C4 plants were recorded for the relative summer growth rate, Finally, the photosynthesis/temperature curves would suggest that E. densa would be able to adapt seasonally to the changes of temperature in its natural environment (Haramoto & Ikusima 1988).

Several Works on physical factors (current velocity, temperature) chemical (pH, conductivity, dissolved oxygen, nutrient contents of the water and sediments) and biological (Wells & Clayton 1991; Feijoó et al, 1996; Kahara & Vermaat 2003) will be discussed as fundamental in the responses to changes in the environment and on the biology of aquatic plants, specifically in each context in which they were published (exposure, temperature and radiation). The importance of aspects such as reproduction, survival, dispersion and competition is emphasized in the specificity of the strategies and characteristics of the life histories. It was considered at that time that the knowledge of the reproduction, dispersion and competition in aquatic plants was still fragmentary, especially from a quantitative point of view, as well as the theoretical and practical applications (Barrat-Segretain 1996).

At this time the productivity models in Macrophytes have allowed to develop hypotheses about the mechanisms involved in the growth of the plants and predict responses to changes in the quality regimes of the waters. The environmental factors considered as affecting the plants for these models were light availability, temperature, velocity of the water as well as concentrations of phosphorus, nitrogen and inorganic carbon (Carr et al, 1997).

3.4.2 Environmental effects and Biology (Ecophysiology) of aquatic plants

Some articles describe, in a general manner, the changes in abundance patterns and presence of this species, and suggest the environmental factors that would affect the biology of aquatic plants. In France, the colonization of a water reservoir and invasion by this species, the uprooting in winter by water flooding and massive formation of ice, as well as warm temperatures in spring (favoring the development of cianobacteria with detriment of Macrophytes) probably explain significant “declines" in colonization (Dutartre et al, 1999). This work suggests that monitoring competition between cianobacteria and aquatic plants could lead to determine the causes of the dominance of the one in respect to the other. However, environmental factors that have been related to the establishment and growth aquatic plants points out in New Zealand lakes that the changes in water clearness (Wells & Clayton 1991) and suspended solids (Tanner et al, 1993) as well as the light attenuation coefficient of the Itaipu reservoir in Brazil-Paraguay (Bini & Thomaz 2005) as the greater “predictor” for those organisms.

In aquatic plants, the physiological significance of changes in the radiation level would be directly related to photosynthesis rates. A seasonal study found that during1998, the highest photosynthesis rates that were found in May (between 6.1 to 10.0 mg 02/g DW/h) correspond to periods in which the PAR radiation under water is highest, between 900 and 1.130 I-lmol/m2/s (Pezzato & Monteiro Camargo 2004). E. nejas, which has low light requirements (Tavechio & Thomaz 2003) suggest that this characteristic of the genus would allow its growing in waters of high turbidity- This limnological relationship to water and sediments resulted in more photosynthesis when phosphorus and total CO2 were available to the plant (besides heightened light). In spite that this is an evident response, when comparing the Hydrilla verticillata, Potamogeton schweinfurthii and P. lucens Macrophytes and the effect on the alkalinity of bicarbonate (HC03-) as substrate in the performance of photosynthesis, showed that at a higher concentration (2.0 meq L-1 HC03-). Responses described for photosynthesis and respiration of Elodea nuttallii to changes in environmental pH conditions (pH 5-9), 02 (31-625 I-lM) and dissolved inorganic carbon (0.15-24 mM) show that increments in the concentration of O2 and reduced availability of CO2 result in a diminution of photosynthesis and increase of respiration.

This is due in part to the effects on the CO2compensation point due to the O2 concentration (6.0 I-lM a 62.5 I-lM 02, 16.3 I-lM to 313 I-lM 02 and 54.6 I-lM to 500 I-lM 02) showing and suggesting that when the water conditions change there would be effects not only on photosynthesis due to environmental changes on the light, CO2 or pH (Jones et al, 2000).

3.4.2.1 Effects of exposure to air and low flow in aquatic plants

In spite of the importance of radiation rates for Macrophytes, both at the individual and community level (Bienzer et al, 2006; Sant-Jenzen et al, 2007) the relevance of factors such as temperature, inorganic carbon and other nutrients is being understood only now. One of these is related to the environment in which many aquatic plant species grow, in sunny water courses (no shadow) of little depth (wetlands) in the transition between water and land (Sand-Jensen & Frost-Christensen 1999). The depth differences in the level at which plants grow has effects not only on their growth and morphology but are also related to the light level, to processes of the establishment of plantlets (Clevering et al, 1996). Some tolerance to water-logging processes (Blanch et al, 1999) and effects of the depth, duration and frequency in the establishment and communities of terrestrial plants (Casanova & Brock 2000) are comparative examples of the impact that hydrologic changes would have in the biomass, richness and structure or composition of aquatic Macrophytes (Maltchik et al, 2007). In the rivers, these changes in the distribution of the species are usually observed as related to changes in environmental conditions and useful comparison between ensembles becomes difficult due to limitation in the restricted distribution of the species (Demars & Harper 2005).

In this sense, the influence of the amplitude of the cyclic fluctuations of the water level on growth can be summarized in a study carried out in emergent Macrophytes (Cyperus vaginatus, Phragmites australis, Triglochin procerum and Typha domingensis in a controlled experiment of 14 days in which the amplitude of water fluctuation was from constant (control) at ±15, ±30 and ±45cm, with an initial depth of 60cm and different depths of the sediment (20, 40 and 60cm). The biomass responses to fluctuation is different in T. domingensis with a decrease (52%) at the ±45cm amplitude. By contrast it is higher for P. australis at ±30cm. The biomass of C. vaginatus increases with elevation but does not respond to amplitude, whereas T. procerum does not respond to amplitude or elevation. These responses could be explained by the capacity of the alter to carry out photosynthesis under water; in vaginatus due to the effect of water-logging to obtain atmospheric carbon by its photosynthetic "canopy". According to (Degan et al, 2007) another factor would restrict growth in T. domingensis y P. australis: one of these could be the effect of the depth of the water in rhizome dynamics, relating to anchoring and also hypoxia (Sharma et al. 2008).

Finally, evaluations of the resistance to CO_2 for its diffusion from the water to the chloroplast carried out in submerged "amphibian" plants, show that for the same species the cuticle-foliar membrane resistance is always lower in leaves under water (Frost-Christensen & Floto 2007). This is explained by a gas "film" on the foliar surface, which increases the ´CO_2 absorption and photosynthesis during the day, allowing gas exchange through stomata and so evading the resistance to diffusion of the cuticle (Colmer & Pedersen 2008). It is not known of these processes and gas exchange mechanisms would be affected by a direct exposure to air in E. densa.

3.4.2.2 Ecologic and photosynthetic effects of exposure to air

The impact that the changes in the level of the flow could have in the biology and specifically in the photosynthesis of aquatic plants is not known, nor the direct effects due to desiccation of the tissues, gas exchange and photo-inhibition. However, these aspects would affect significantly the assimilation capacity of this species, described as C4 (Browse et al, 1977). Photosynthesis in aquatic species probably arose as a response to dissolved CO_2 limitations (of 7600 species C4 only a dozen are aquatic). Therefore this carbon extraction capacity – which would reflect the extent in which the plants use HC03- or C4 acids for photosynthesis – is not a common attribute of submerged Macrophytes. Light saturated photosynthesis is common in marine macro algae and is frequently saturated by inorganic carbon at the natural concentration, but rarely in fresh water (wetlands). When carbon is not limited (high carbon, low Light) the high carbon extraction and affinity is suppressed. Therefore in Macrophytes an efficient photosynthesis capacity reduces the effects of the imbalance of the required resources (Madsen & Sand-Jensen 1991) which would be critical in conditions of changes in the exposure of the plants.

On the other hand an excess of light, which is photo-inhibition by light stress is possibly another explanation for the decrease of those plant populations. In this case the plant could suffer irreversible damages at the level of the photo system proteins of the chloroplasts, caused by higher radiation. In this type of stress the growth conditions (nutrients, etc) together with other environment factors (toxic, salinity, Eric) could affect photosynthesis in a complementary or synergic manner. This condition would occur with low flow and exposure of the plant to direct sunlight.

3.4.3 Flow regulation criteria for different uses

Water is one of the most employed natural resources given its importance for the development of Man and the maintenance of the ecosystem. Use is a concept related to the benefit obtained from objects.

In hydrology terms, it applies as a synonym for use, consumption or demand, therefore the water needs vary among users, the water uses determine the amount employed. Figure 3.12 details the uses of water, which can be separated into consumptive and non-consumptive. Consumptive use is that in which there are water volume losses, due to characteristics of the process; this is determined by the differences in volume between the determined quantities which are extracted less what is discharged. A non-consumptive use is that in which there is no loss of water, as the quantity that enters is the same or approximately the same that ends the process (Castelán, 2003).

The social importance of water is based on tangible and intangible and symbolic values which prevent treating it as solely an economic asset, since it entails aspects as availability, fair access, satisfaction of basic needs, and preservation of the cultural and religious heritage as well as ecologically adequate practices (Postel, 1994). For analysis purposes, the non-consumptive and nonproductive uses examined are the recreational and environmental uses.

Table 3.6 details the non-consumptive uses of the rivers associated to anthropic needs, the depth and velocity of runoff criteria to maintain those activities are indicated.

Figure 3.12. Consumptive and non-consumptive uses of the water.

<table>
<tr><td colspan="5">Water Uses</td></tr>
<tr><td colspan="5">Consumptive
Non-consumptive</td></tr>
<tr><td rowspan="2">- Domestic and Municipal
- Agriculture and livestock
- Industry and Mining
- Thermal energy production</td><td colspan="2" rowspan="2">Recreation</td><td>Human needs</td><td>Ecologic and Environmental needs</td></tr>
<tr><td>Residues acceptance</td><td>Environmental use</td></tr>
<tr><td>Productive uses</td><td>With direct contact</td><td>Without direct contact</td><td rowspan="2">Water masses or water courses to receive residues</td><td rowspan="2">Aquatic life conservation
Use as flora and fauna refuges
Natural Reserve</td></tr>
<tr><td>Energy, water courses or water masses as production sources
Transportation</td><td>Swimming,
Kayaking,
Canoeing
Sailing
Fishing
Spas
Motor boats
Sailing boats
Resorts
Beaches</td><td>Photography.
Walks,
Ship travel
Landscape, flora and fauna observation,
Cascades and waterfalls observation
Camping and picnic</td></tr>
</table>

Gener		

Table 3.6 Water courses depth and height thresholds for different uses.

Human uses	Critical values (minimum))	Maximum)	Bibliography
	Depth (m)	Velocity (m/s.)	
Kayak/ canoe/ rafting	P_{min}: 0.1 – 0.2A P_{min}: 0.6B•C P_{min}: 0.2[D]	V_{max}: 4.5[u]	
Rowing/fording	P_{max}: 1.2[u]	V max: 1.8[u]	
Fishing/fording	P_{max}: 1.2[u]	V max: 1.8[u]	A. Gordon and col. (2004) ~2004) : Rood and Tymensen (2001 : C: Rood and col. (2003) (2003) D: Mosley (1983)
Swimming	P_{mn}: 0.8[u]	v.: 1.0[u]	
Snorkeling	P_{mn}: 0.3[u]	v.: 2.0[u]	
Walks	P_{max}: 1.2[u]	V max: 1.8[u]	
Fishing (boat)	P_{min}: 0.3[u]	v.: 3.0[u]	
Rowboat	P_{min}: 0.5[u]	v.: 1.5[u]	
Sailing boat	P_{min}: 0.8[u]	v.: 0.5[u]	
Motor boat (low power)	P_{min}: 0.6u	v.: 3.0[u]	
Motor boat (high power)	P_{min}: 1.5[u]	V_{max}: 4.5[u]	
Jet boating	P_{min}: 0.1 u	V_{max}: 4.5[u]	

4 METHODS

4.1 METHODOLOGICAL STRUCTURE

The methods to calculate the ecological flow of the Plants of the Alto Maipo Hydroelectrical Project (PHAM) are based of the requirements established by the DGA in the Handbook for the Administration of Water Resources (DGA 2002) regarding the calculation of ecologic flow and environmental water demand. The requirements established by the governmental authority are summarized as follows:

- Hydrologic evaluation;
- Identification of the environmental components directly related to the water resource;
- Analysis of level variations, produced by the extraction and/or exercise of the requested water use rights;
- Prediction and evaluation of the direct, indirect and associated effects over all and every one of the components identified by the requester, according to the previous point and that can be verified as a consequence of the exercise of the requested water use rights.
- Present and expected regime of the waters.
- Consequence of the exercise of the water use rights, especially the effect of impounding over the water system, should it apply.

Based on these requirements, this report is separated into two relevant sections: The description of the study zone and the calculation of the ecologic flow; the evaluation of different aspects related with the construction and operation of the PHAM.

The hydrologic data was supplied by AES GENER and come from the hydrologic studies submitted in the Project EIA.

The Description of the study zone consists in a global study of the hydrological, morphological, hydraulic, habitat quality, physicochemical quality of the water In order to determine the sensitive zones and areas or ecologic (biologic) flow zones where the ecologic flow calculation will be carried out. The identification of these ecologic (biologic) flow zones is based on criteria related to the water ecology of the rivers.

The analysis of the antropic criteria is added, concerning the uses given to the rivers which will be intervened by the PHAM by the local human community and which will be affected by changes in the hydrologic regime. To this effect and besides the ecologic flow areas included in the description of the study zone, the areas called "sensitive areas of antropic character" will also be included and their flow requirements calculated so that the uses of the rivers made by the local community at present should not be significantly affected.

Therefore, the calculation of the total ecologic flow or environmental water demand is carried for the areas identified in the description of the river, both of ecologic and antropic character, generically known as environmental important areas (AIA). The calculation of the ecologic (biologic) flow according to ecologic criteria is carried out in this report taking into account several national and international norms. On the other hand, the calculation of the ecologic flow according to antropic criteria is carried out using criteria obtained in the field, taking into account the uses that the local community gives to the rivers, as well as data obtained from the literature. The minimum passing flow to take place at the PHAM intakes is established from the values of the ecologic flows, both biologic, antropic and others, so that the ecologic flow requirements in the sensitive points (sections or areas) should be satisfied.

Briefly, the following methods have been used to determine the total ecologic flow or environmental demand in the Volcán, Yeso, Colorado, Maipo rivers and the El Morado, Colina, and La Engorda streams:

a) To characterize the rivers and streams affected by a reduction of the flows by the PHAM both as to morphology and hydraulics, from each of the intakes to the point of return of the waters at the Las Lajas sector of the Maipo River. To this end a helicopter over flight was carried out, and a land journey along the rivers to zone the rivers and streams as a function of their conditions, placement of the intake works to the point of return of the waters, in terms of the composition and abundance of aquatic organisms.

b) Spatial definition of the areas of environmental importance (AIA), morphology and hydraulics (segments with rapids, pools, littoral platforms).

c) Characterize hydro-biologically the rivers and streams from the area to which an ecologic (biologic) flow will be applied, by means of a comprehensive analysis of the hydrologic, morphologic, hydraulic and hydrodynamic information. The criteria used for the definition of the AIA are the presence of species with conservation problems, according to what is established in the CONAF Red Book, and the species classification carried out by the CONAMA (www.conama.cl) as well as the existence of favorable habitats for the maintenance of juveniles and/or reproduction of the aquatic species. Concerning the AIA of an antropic nature, a survey of the antropic uses of the river is carried out, sport fishing, recreational uses, landscape issues, sports uses, among others.

d) Determination of the ecologic flows for the AIA using hydrologic methods.

e) Determination of the ecologic flow for the AIA using hydro-biologic methods, by means of numeric simulation modeling of the habitats. This entails coupling the physical conditions to the requirements of the biological indicators and/or minimum condition indicators for the antropic uses.

4.1.1. Study Area

The Project collects water resources from three sub-sub basins belonging to the Maipo river basin, Upper Maipo River Sub-basin, which are:

- Volcán River Sub-sub basin
  Direct effects: Colina, Engorda, Las Placas and El Morado streams.
  Indirect effects: Volcán River

- Yeso River Sub-sub basin;
  Direct effects: Yeso River, between the discharge of the El Yeso Reservoir and the Maipo River.

- Colorado River Sub-sub basin, between the Alfalfal Bridge and the Maipo River; Direct effects: Colorado River, between the El Alfalfal discharge and the Maipo River.

- Maipo River Basin
  Indirect effects: Segment from the outlet of the Volcán River to the outlet point at Las Lajas.

The Project collects water resources among some sources of the Volcán, Yeso and Colorado rivers, causing indirect effects upon the Maipo River in the segment between the Volcán River and the Las Lajas Plant outlet point of the waters. The method used to determine the ecologic flow is shown for all of them.

The study area is defined between the intakes of each river and stream and the final discharge point of the Project at the Las Lajas sector of the Maipo River.

4.1.2 Field survey

Several field inspection campaigns were carried out during August to identify and validate the sensitive areas of the whole area of service of the Project. Information was obtained from the community, in terms of learning as much as possible about the antropic uses of the waters of the area. Given the climate conditions, these campaigns were very difficult in the upper part of the Volcán River. This was completed by helicopter over flight, filming and photographs obtained by means of specially designed equipment for the purpose, besides high resolution Quickbird photographs.

4.1.3 Sampling campaigns

To complement the available information, specially needed in the zones of interest, an additional sampling campaign was carried out complementing the information available in the environmental impact study of the Project. The sampling was carried out with helicopter support, between August 11 and 13, 2008, and included samples of chemical quality, biologic components and physico-chemical parameters. Later on, 19 samples for physico-chemical parameters were collected in situ, and also a sampling for oils, greases and total fixed and volatile hydrocarbons.

4.1.4 Sampling sites

The location and description of the sampling sites are shown in Tables 4.1, 4.2 and 4.3 and Figures 4.1 a) and 4.1 b).

Table 4.1 Sampling Locations CEA, August, 2008

Stations	East	North	River	Sector	Date
Station 1	388715	6291888	Colorado River	Under the Alfalfal Bridge	11-08-08
Station 2	383391	6289221	Colorado River	Before Maitenes Plant and Aucayes Stream	11-08-08
Station 3	382535	6288499	Colorado River	Aucayes Stream, almost outfall Colorado (under the bridge)	11-08-08
Station 4	380443	6287213	Colorado River	Below Maitenes Plant	11-08-08
Station 5	373089	6282313	Colorado River	Below Pine Forest, almost at outfall	11-08-08
Station 6	368066	6283634	Maipo River	Before Las Lajas discharge downstream Colorado outfall	11-08-08
Station 7	367.812	6.283.701	Maipo River	After Las Lajas discharge downstream Colorado outfall	12-08-08
Station 8	372.982	6.281.800	Maipo River	Before Colorado River outfall	12-08-08
Station 9	374.337	6.278.201	Maipo River	Next to San José de Maipo town	12-08-08
Station 10	375.469	6.272.719	Maipo River	Downstream El Toyo Bridge	12-08-08
Station 11	386.099	6.260.865	Yeso River	Arriving at the outfall into the Maipo	12-08-08
Station 12	388.095	6.260.211	Yeso River	Lower bed of the river	12-08-08
Station 13	391.479	6.262.346	Yeso River	Middle bed of the river	12-08-08
Station 14	399.177	6.273.297	Yeso River	Higher bed, under Yeso dam wall	12-08-08
Station 15	406184	6259459	Colina Stream	Arriving to confluence with El Morado	12-08-08
Station 16	406160	6259449	Morado Stream	Arriving to confluence with Colina	12-08-08
Station 17	407094	6259480	North La Engorda stream	Middle segment intake sector	12-08-08

Station 18	407128	6259453	South La Engorda stream	Middle segment intake sector	12-08-08
Station 19	407011	6257784	South Volcán River	Upstream from the bridge, where the river widens	12-08-08
Station 20	404256	6257108	Volcán River	Where the river has a small pond, upstream from Lo Valdes	12-08-08
Station 21	402.461	6.256.625	Volcán River	Volcán River zone	13-08-08
Station 22	400.383	6.256.505	Volcán River	Las Amarillas sector	13-08-08
Station 23	388.013	6.254.786	Maipo River	Las Melosas sector	13-08-08

*Datum WGS84

Table 4.2 Location of the samplings – CEA, September 2008
IN SITU CONDUCTIVITY VERIFICATION

Sampling point	River	Sector	East	North	**Date**
PHAMC-1	South Volcán River	Point 1	406996	6257778	23-09-2008
PHAMC-2	Volcán	Point 2	407055	6257763	23-09-2008
PHAMC-3	Volcán	Point 3	407134	6257724	23-09-2008
PHAMC-4	Volcán	Point 4	407221	6257761	23-09-2008
PHAMC-5	Volcán	Point 5	406923	6257786	23-09-2008
PHAMC-6	El Morado Creek	Point 1	405535	6261106	23-09-2008
PHAMC-7	Volcán	Point 2	405555	6261013	23-09-2008
PHAMC-8	Volcán	Point 1 (Volcán, before Las Amarillas)	400761	6256595	23-09-2008
PHAMC-9	Las Amarillas Stream	Point 2	400471	6256662 7	23-09-2008
PHAMC-10	Volcán River	Baños Morales Bridge	401505	6256571	23-09-2008
PHAMC-11	Morales Stream	Morales Stream, outfall into El Volcán	401470	6256603	23-09-2008
PHAMC-12	Volcán	Downstream Baños of Baños Morales Bridge	401436	6256562	23-09-2008
PHAMC-13	Volcán	El Volcán Bridge	387962	6258307	23-09-2008
PHAMC-14	El Yeso	El Yeso middle zone	387964	6260232	23-09-2008
PHAMC-15	El Yeso	Upstream Yeso Bridge	386199	6260850	23-09-2008
PHAMC-16	Maipo River	Upstream Jaboncillo Bridge	381238	6265475	23-09-2008
PHAMC-17	Maipo River	Upstream Toyo Bridge	375907	6272397	23-09-2008
PHAMC-18	Colorado	Upstream Colorado Bridge (Wood)	373065	6282318	23-09-2008
PHAMC-19	Maipo River	Las Lajas	368040	6283616	23-09-2008

*Datum WGS84

Table 4.3 Sampling Locations CEA, August, 2008

Location Sampling for Oils, Greases and Hydrocarbons					
Point	East	North	River	Location description	Sampling date
PH-1	405956	6251715	Upper Volcán Streams	El Morado, Las Placas, Colina and La Engorda group of streams	13-10-2008
PH-2	406674	6257757	South Volcán	Upstream South Volcán river bridge	13-10-2008
PH-3	403200	6256725	Volcán	Lo Valdés	13-10-2008
PH-4	399298	6256444	Volcán	Upstream El Volcán intake	13-10-2008
PH-5	392995	6257726	Volcán	Upstream El Volcán village	13-10-2008
PH-6	387959	6258294	Volcán	El Volcán Bridge	13-10-2008
PH-7	387231	6258120	Maipo	Maipo River	13-10-2008
PH-8	387967	6254736	Maipo	Maipo river, Sonambula bridge	13-10-2008

PH-9	387029	6259381	Maipo	Maipo River, below confluence with El Volcán	13-10-2008
PH-10	399327	6273328	Yeso	Upper Yeso River	14-10-2008
PH-11	398076	6272925	Yeso	Upper Yeso River 2	14-10-2008
PH-12	391849	6263805	Yeso	Yeso River, downstream Laguna Negra	14-10-2008
PH-13	398467	6260272	Yeso	Yeso Rover, upstream Yesera	14-10-2008
PH-14	386146	6260854	Yeso	Yeso River, San Gabriel Bridge	14-10-2008
PH-15	382012	6262802	Maipo	San Gabriel	14-10-2008
PH-16	381010	6265470	Maipo	El Ingenio	14-10-2008
PH-17	375897	6272394	Maipo	El Toyo	14-10-2008
PH-18	374349	6278209	Maipo	San José	14-10-2008
PH-19	388721	6291818	Colorado	Colorado River, Central Bridge	14-10-2008
PH-20	388197	6291492	Colorado	Colorado Rover, Upstream Maitenes	14-10-2008
PH-21	382539	6288521	Aucayes	Aucayes Stream	14-10-2008
PH-22	380473	6287209	Colorado	Colorado River, Downstream Maitenes	14-10-2008
PH-23	373090	6282325	Colorado	Colorado River, Upstream Maipo River	14-10-2008
PH-24	368028	6283633	Maipo	Las Lajas	14-10-2008
PH-25	372226	6281519	Maipo	Maipo River, downstream Colorado	14-10-2008
PH-26	372961	6281781	Maipo	Maipo River, upstream Colorado	14-10-2008

*Datum WGS84

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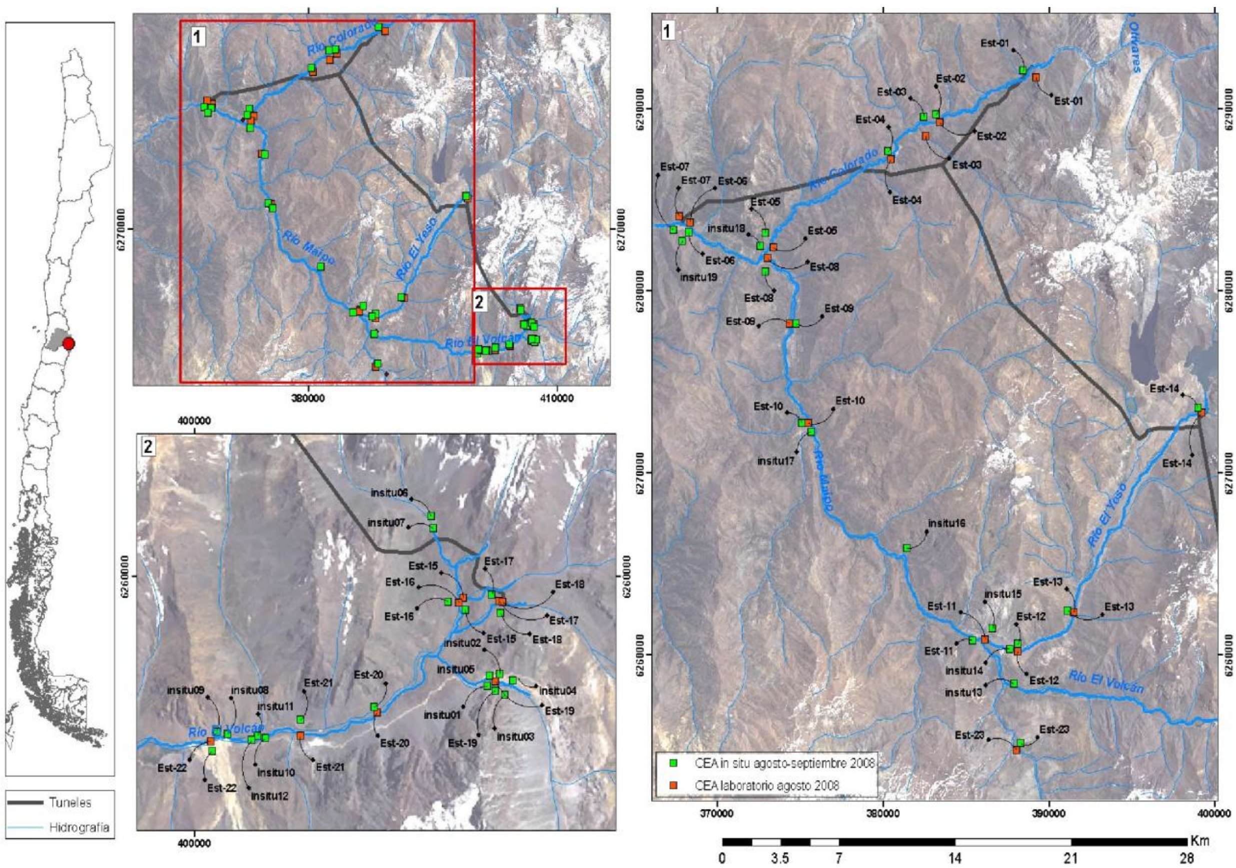


Figure 4.1a Location of Limnologic and water quality sampling stations. CEA, August / September, 2008

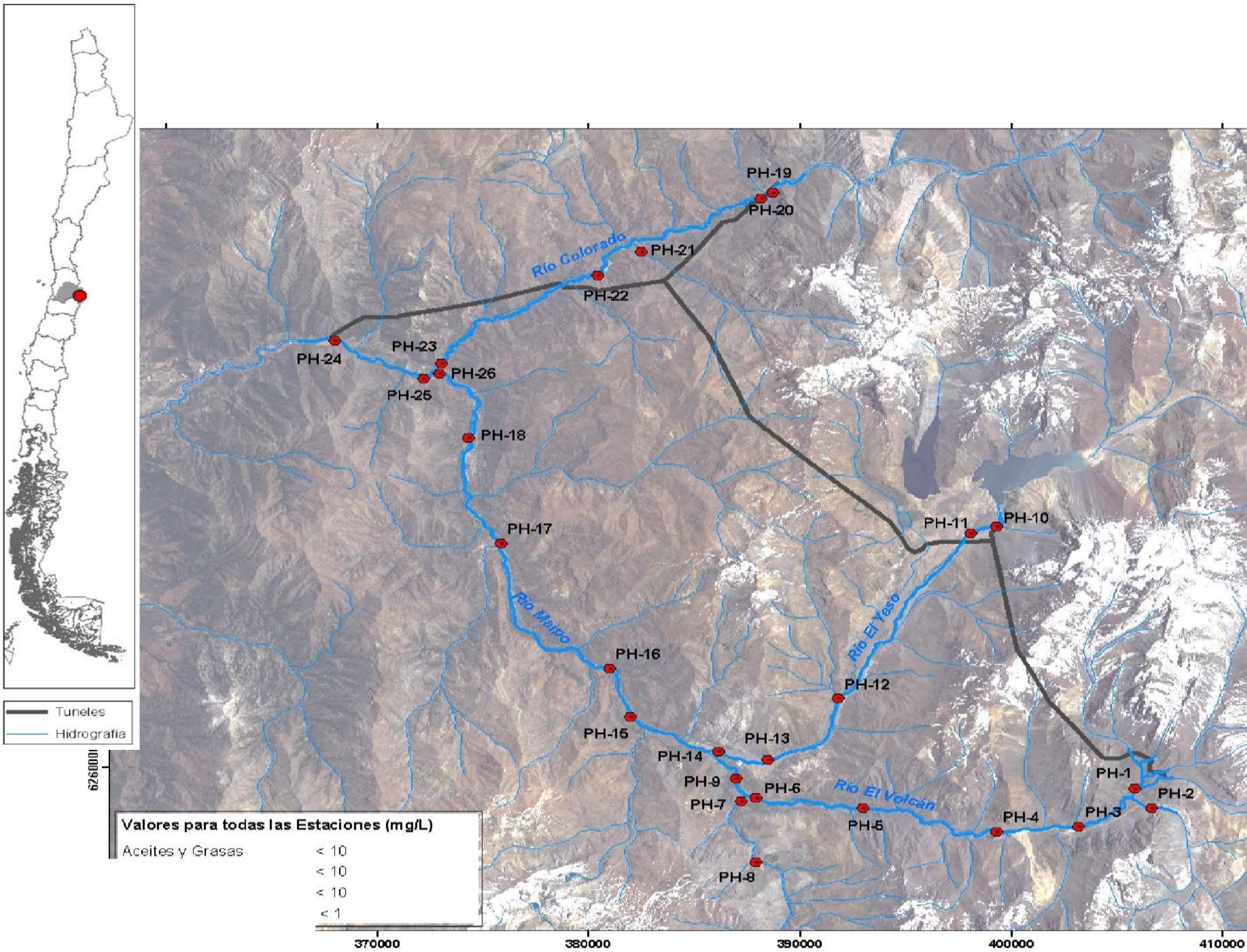


Figure 4.1b Location of hydrocarbons, oils and grease sampling stations **CEA, October 2008**

4.2 Hydro-environmental characterization and identification of environmental important areas (AIA)

In order to determine the environmentally important areas in the area of study it is necessary to have the hydro-environmental characterization, which includes a description of the systems in terms of the biotic components (zoobenthos, phythobenthos, zooplankton, phytoplankton and fishes) and the abiotic components (runoff velocity, temperature, substrate type and the physical and chemical variables of the water quality). The antropic elements are also incorporated.
In this characterization it is necessary to describe the system physically, including hydrologic, morphologic and hydraulic antecedents. The physical characterization of the system must include the hydrologic information and the topo-bathymetric information of the rivers and their longitudinal profiles, description of the granulometry and geomorphologic characteristics. This information was employed to identify sites and zones of specifically high value, in terms of their diversity or of the presence of species in the conservation category and also includes zones that are of intrinsic value, due to their habitability potential.

4.2.1 Hydrologic characterization

4.2.1.1 Information sources

The available hydrologic antecedents are:

- Final Basic Studies – Hydrology – Objective 3 Report - September 2007
- Water Balance of the Maipo River Watershed – Final Report CONIC-BF Ingenieros Civiles Consultores Ltda. February 2008
- Hydrological Statistics Environmental Impact Study, Alto Maipo Hydroelectric Project. Arcadis Geotécnica
- Hydrologic statistics Maitenes Headrace intake operation AES GENER

4.2.1.2 Hydrologic characterization points

Table 4.4 shows the fluviometric stations (F-01 to F-07) with the average monthly flows series for the lower zones of the Volcán, Yeso, Maipo and Colorado rivers. In addition, previous studies had prepared the hydrologic statistics of a series of points of interest (P-01 to P-13), as well as those of the Alto Volcán streams, shown in Tables 4.5 and 4.6.

Table 4.4Hydrology statistics at Fluviometric Stations

N°	Hydrology statistics at Fluviometric Stations	East UTM*	North UTM*
F-01	Maipo River at El Mansion	372023	6281962
F-02	Maipo River at San Alfonso	379639	6266811
F-03	Colorado River before Maipo confluence	373148	6282685
F-04	Colorado River before Olivares confluence	394633	6293757
F-05	Olivares River before Colorado confluence	394398	6294001
F-06	Volcán River at Queltehues	388100	6258689
F-07	Maipo River at Las Melosas	389339	6253999

*Datum WGS84
Source: Water Balance of the Maipo River Watershed – Final Report CONIC-BF.

Table 4.5 Hydrology Statistics at Sections of Interest

N°	Hydrology Statistics at Interest Sections	East UTM*	North UTM*
P-01	Maipo at discharge of the Queltehues Plant	387332	6258320
P-02	Maipo at confluence with the Volcán River	387350	6259060
P-03	Maipo at confluence with the Yeso River	385939	6261274
P-04	Maipo at AES Genre headrace (75 m^3/s) (File ND-1302-27)	376225	6272150
P-05	Maipo at discharge of Las Lajas Plant	368082	6284050
P-06	Colorado at discharge of Maitenes Plant	382550	6289520
P-07	Yeso at Reservoir discharge	399588	6274547
P-08	Yeso at confluence with Cortaderas stream	394555	6267607
P-09	Volcán at AES GENER headrace (12.7 m^3/s) (File ND-1302-11 b).	405800	6258700
P-10	Volcán at AES GENER restitution(13.1 m^3/s) (File ND-1302-11a)	399500	6256800
P-11	Yeso at confluence with the Maipo River	385939	6261274
P-12	Colorado at Alfalfal Plant discharge	389079	6292541
P-13	Volcán at AES GENER headrace (13.1 m^3/s) (File ND-1302-11a)	403200	6257000

*Datum WGS84

Source: Water Balance of the Maipo River Watershed – Final Report CONIC-BF.

Table 4.5 Hydrology Statistics at Sections of Interest

N°	Hydrology Statistics at Interest Sections	East UTM*	North UTM*
1	Colina stream (projected intake)	406978	6259761
2	Colina stream (projected intake)	405565	6260912
3	La Engorda stream (projected intake)	407264	6259431
4	Las Placas stream (projected intake)	406577	6260462

*Datum WGS84

Source: Final Basic Studies – Hydrology – Milestone 3 Report (Cade-Idepe, Poch and Norconsult)

4.2.1.3 Source method

Reloading estimates

The values of the intermediate reloading between each of the points with hydrologic statistics were obtained from the water balance of the Maipo River watershed (See Table 4.7). This was done using the natural regime flow at the level of average yearly flows.

According to field measurements, there is additional reloading in the zones below the El Yeso reservoir, which would correspond to filtration from it. This situation was measured at one time when the reservoir was not discharging water (Source Flow gauging by AES GENER submitted in the EIA Annex 10 – Ecologic Flow). This would correspond to constant contributions during the year, as they depend on the hydraulic load represented by the reservoir and the permeability of the grounds. Measurements gave 126 l/s downstream from the reservoir, 386 l/s in front of the administration buildings, 498 l/s two kilometers down from the administration and 650 l/s next to Cortaderas.

Table 4.7 Average intermediate reloading per segment. Names correspond to the fluviometric stations (F) and synthetic (P) of the CONIC-BF Water Balance study

Segment	Distance (km)	Average yearly reloading (m^3)	Outputs ($m^3/s/km$)
Colorado River			
F05+F04 --> P12	1.00	0.76	0.76
P12 --> P06	8.80	1.72	0.20
P06 --> F03	14.00	3.18	0.23
El Yeso River			
P07 --> P08	9.30	1.36	0.15
P08 --> P11	12.90	1.57	0.12
Volcán River			
P09 --> P13	3.60	0.54	0.15
P13 --> P10	4.00	2.21	0.55
P10 --> F06	14.30	2.24	0.16
Maipo River			
F07 --> P01	1.00	0.57	0.57
PO 1 +F06 --> P02	0.70	0.05	0.07
P02+P11 --> P03	3.00	0.23	0.08
P03 --> F02	9.00	3.56	0.40
F02 --> P04	7.80	1.56	0.20
P04 --> F01	13.80	6.96	0.50
F01 --> P05	5.00	0.60	0.12

Source: Own preparation based on average median yearly flows of the River Maipo Water Balance Final Report CONIC-BF.

Baseline Hydrologic Statistics

The present situation of the Baseline must be considered for the Ecologic Flow estimate that is the operation of 3 projects for the sector. The following will be taken into account for the analysis:

- Operation of the El Yeso Reservoir
- Operation of the Alfalfal I Plant and of the Maitenes Plant
- Operation of the Volcán Plant.

Operation of the El Yeso Reservoir

The use of the El Yeso Reservoir has evolved since it started operations in 1967. Therefore, the historical series must be analyzed for the Baseline to be represented by the use of El Yeso as reservoir to regulate potable water. The historical series since 1978 conforms to that condition. The following Table shows the details of the use of the reservoir.

Table 4.8 Evolution of the uses of the El Yeso Reservoir-

Period	Use of the Reservoir	Reservoir Operations
1967-1978	Multiple use, improve irrigation safety and potable water supply	Irrigation Department - MOP
1978-1993	Preferment Potable Water use	Agreement EMOS and Irrigation Department - MOP
1993 -date	Exclusive Potable Water Use	EMOS. From 2000 on: Aguas Andinas.

Source: Final Basic Studies – Hydrology – Milestone 3 Report (Cade-Idepe, Poch and Norconsult)

Figure 4.1 shows the historical series of the median monthly flows of the reservoir discharge, separated in the three periods reflecting the main uses given to the reservoir.

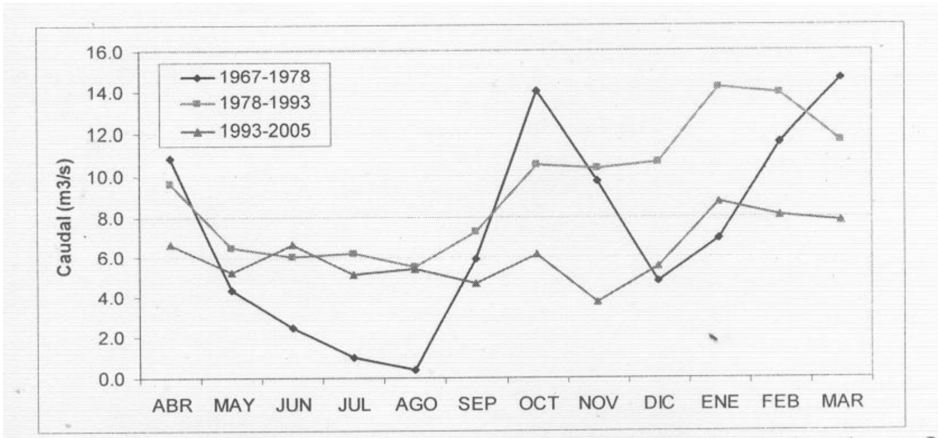


Figure 4.1. Table 4.8 Evolution of the uses of the El Yeso Reservoir - Source: Own preparation on the basis of the El Yeso Reservoir Historical Series.

Zero flow discharges were found in some months of the historical series, as shown in Figure 4.2. To estimate the ecologic flow, those months have been removed from the statistics, that is to say, only the positive flow months are considered in the estimate. Conceptually, it is understood that the ecologic flow can apply only during the period that the reservoir (operated by third parties in this case) is discharging water.

Period of the statistics with low water flow, zero flow:

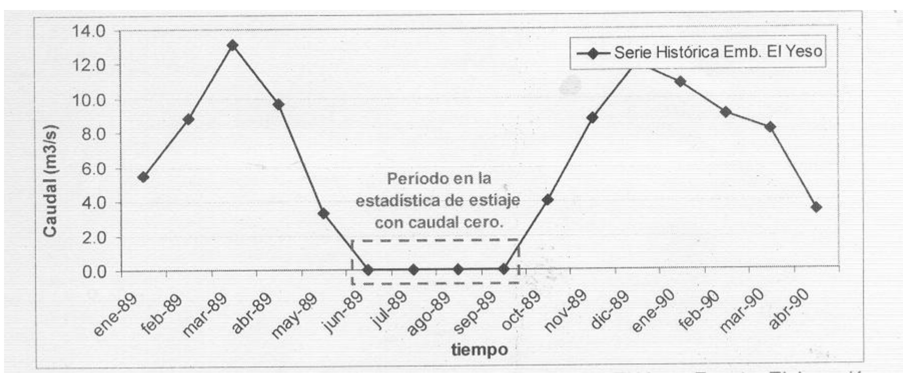


Figure 4.2 Hydrologic statistics of the El Yeso Reservoir Discharge. Source: Own preparation on the basis of the Historical Series of the El Yeso Reservoir.

The statistics of the months with non-null flow show that the reservoir has a minimum monthly flow during August, while the minimum of the empiric 85% surplus probability has been displaced to November and December, given the regulation capacity of the reservoir. The ecologic flow will be estimated in each case for the month of lower flow discharged from the reservoir (Figure 4.3).

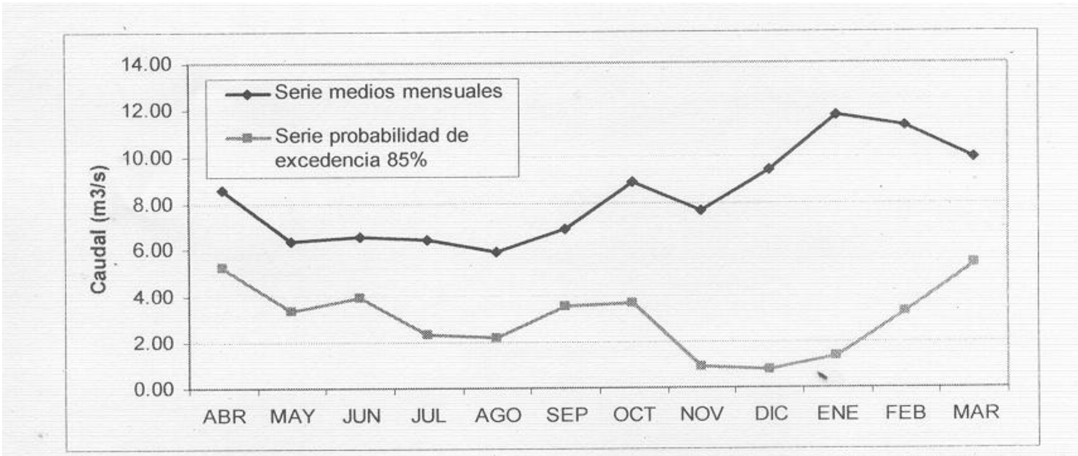


Figure 4.3: Series of average flows and empiric 85% surplus probability. Source: Own preparation on the basis of the Historical Series of the El Yeso Reservoir.

<u>Operation of the Alfalfal I Plant and of the Maitenes Plant</u>

In the Colorado River, the Baseline must take into account the operation of the Alfalfal I and Maitenes Plants. In this case the Maitenes Plant collects water from a point very close to the Alfalfal I discharge (collects 10m^3/s as a maximum), and affects a segment of the river downstream from the intake, which has zero flow during some months.

Similarly to what happens at the El Yeso reservoir, the statistic only shows the non-null months so as to estimate the ecologic flow during the times when the river carries water. (Figure 4.4)

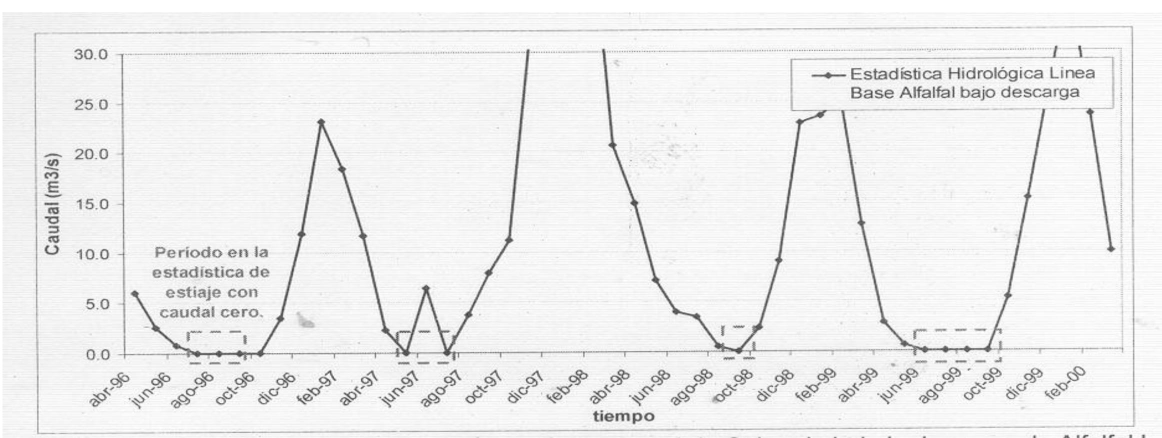


Figure 4.4: Baseline hydrologic statistics for the Colorado River below the Alfalfal I discharge, corresponding to the P-12 Station. Source: AES GENER on the basis of a natural regime flow (CONIC Water Balance) less the flow collected for the Maitenes Plant.

Operation of the Volcán Plant.

The Baseline situation for this segment below the intake is considered taking as analysis information the recorded statistics of the Volcán River DGA Station at Queltehues.

4.2.1 Hydrologic characterization

4.2.2.1 Photographs, films

Quickbird panchromatic satellite images with 0.6m pixel resolution and multispectral imaging with 2.4m resolution. The images cover a surface of 299.0 Km^2, distributed as shown in Figure 4.5.

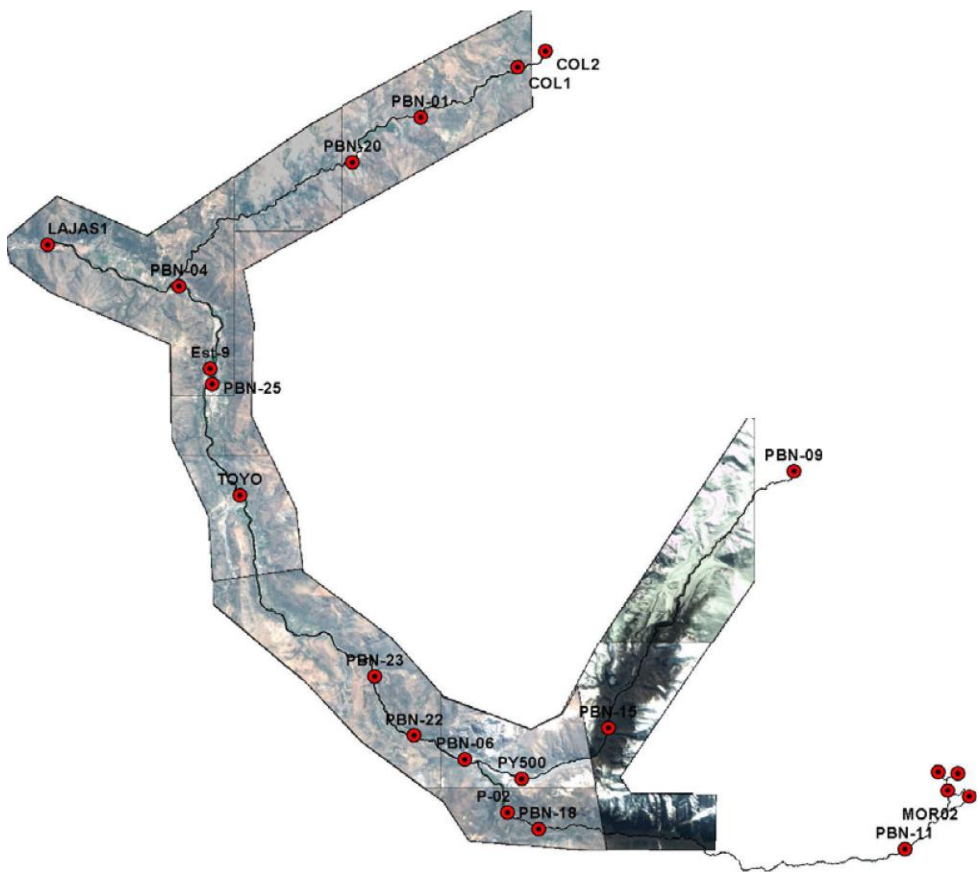


Figure 4.5: Coverage by high resolution Quickbird satellite photographs used for the study.

Furthermore, there is a set of photographs and videos taken during a helicopter over flight covering the Maipo and Volcán rivers and the streams of Upper Volcán zones. These records were obtained with cameras and special accessories installed under the helicopter. **Figure 4.6** shows the over flight route recorded by the GPS navigator.

Figure 4.6: GPS route (red line) of the over flight covering the Maipo River, Volcán River and Upper Volcán streams.

4.2.2.2

Cartographic information (DEM)

The following topographic and topographic bases are available for the development of the study.

- AES GENER aero photogrammetric topographic, 1:1000 scale, made during 2007 by the Geoexploraciones S.A. Company.
- DEMs (Digital Elevation Model) corresponding NASA SRTM mission of 3 arc.seg. (Approx. grid 90m) corresponding to ground elevations obtained from satellite sensors **(Figures 4.7 and 4.8)**, Allowing to obtain longitudinal profiles of the ground grades, useful to characterize the types of runoff and borderline conditions of the model.

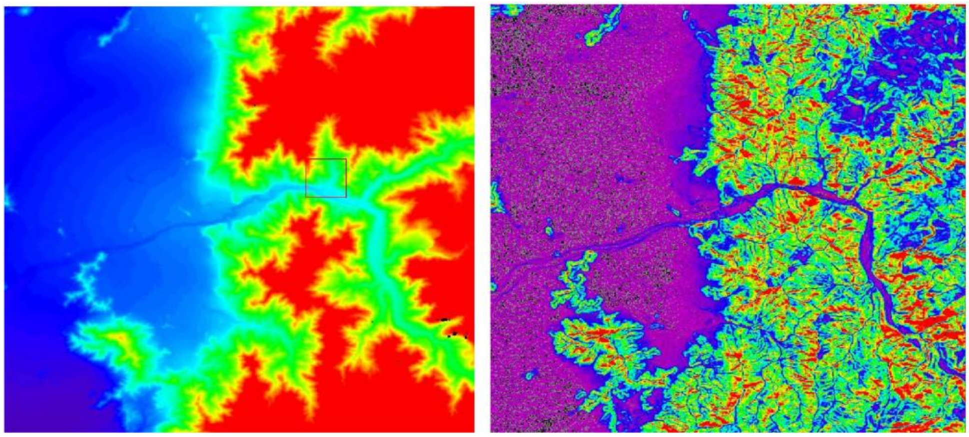


Figure 4.7: *Left:* NASA-SRTM Topography based on altitude. *Right:* Topography based on ground grade values. The sector shown is the Maipo River at the confluence of the Colorado River.

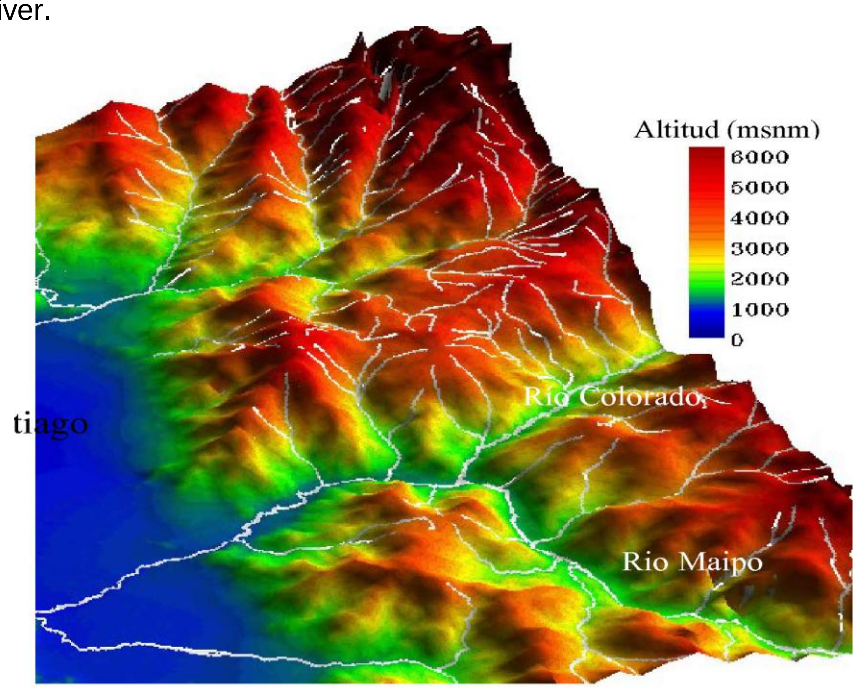


Figure 4.8: NASA-SRTM topographic base, Maipo River sector, Colorado River confluence.

4.2.2.3

Topo-bathymetric profiles

This study has considered to complement the topo-bathymetric information of the previous stages and incorporated 25 new profiles of the Maipo, Volcán, Yeso and Colorado rivers as well as 5 new profiles for the Upper Volcán streams. This information is detailed below:

- Special topobathymetric profiles carried out during September 2008 for the complement and calculation of the hydraulic axis. This survey contains 25 transversal profiles distributed over the Volcán, Yeso, Colorado and Maipo rivers **(Figure** 4.9).
- Special topobathymetric profiles carried out during October 2008, in five transversal sections of the Colina, Morado and Engorda streams.
- Topo-bathymetric profiles carried out for the sedimentological study of the University of Chile, Corresponding to the sectors of the lower El Yeso, Maipo at Las Melosas and Volcán River downstream from the intake.
- Topo-bathymetric profiles of the AES GENER Project in the headrace and restitution zones of Alfalfal and Las Lajas, respectively. Topo-bathymetric profile at the Toyo Bridge.

Table 4.9 below details each of the profiles, name, sector and UTM coordinates.

Table 4.9 Topo-bathymetric profiles available for this study.

AES GENER Project profiles

Profile	East	North	Sector
TOYO	375621	6272644	Maipo River
COLI	387600	6291400	Colorado River
COL2	388798	6292099	Colorado River
LAJAS1	367300	6283630	Maipo River
LAJAS2	368307	6283573	Maipo River

Special topo-bathymetric Alto Volcán streams

Profile	East	North	Sector
COLINA 01	406911	6259727	Colina Stream
COLINA 02	405818	6258570	Colina Stream
ENG01	407088	6259442	La Engorda stream
MORO 1	405728	6260520	Morado Stream
MOR02	406150	6259713	Morado Stream

Special topo-bathymetric, Volcán, Yeso, Colorado and Maipo rivers

Profile	East	North	Sector
PBN-01	383389	6289221	Colorado River
PBN-02	377603	6285805	Colorado River
PBN-03	373057	6282324	Colorado River
PBN-04	372982	6281798	Maipo River
PBN-05	379348	6266608	Maipo River
PBN-06	385319	6261066	Maipo River
PBN-07	387069	6258662	Maipo River
PBN-08	394958	6268862	Yeso River
PBN-09	399504	6273697	Yeso River
PBN-10	405283	6258038	Volcán River
PBN-11	404293	6257120	Volcán River
PBN-12	400045	6256460	Volcán River
PBN-13	396562	6270946	Yeso River
PBN-14	393425	6266446	Yeso River
PBN-15	391500	6262449	Yeso River
PBN-16	395214	6257571	Volcán River
PBN-17	391757	6257875	Volcán River
PBN-18	388505	6257996	Volcán River
PBN-19	386265	6290914	Colorado River
PBN-20	380449	6287261	Colorado River
PBN-21	374936	6284719	Colorado River
PBN-22	383110	6262118	Maipo River
PBN-23	381412	6264714	Maipo River

Lower Yeso Sedimentologic study

Profile	East	North	Sector
PY0	388246	6260374	Yeso River
PY100	388160	6260324	Yeso River
PY150	388116	6260303	Yeso River
PY200	388070	6260281	Yeso River
PY250	388022	6260266	Yeso River
PY300	387974	6260251	Yeso River
PY350	387925	6260246	Yeso River
PY400	387875	6260247	Yeso River
PY450	387825	6260243	Yeso River
PY50	388204	6260348	Yeso River
PY500	387775	6260239	Yeso River

Sedimentologic study Volcán below intake

Profile	East	North	Sector
PV0	397681	6256317	Volcán River
PV100	397602	6256254	Volcán River
PV150	397558	6256228	Volcán River
PV200	397521	6256199	Volcán River
PV250	397473	6256184	Volcán River
PV300	397423	6256176	Volcán River
PV350	397374	6256167	Volcán River
PV400	397324	6256170	Volcán River
PV450	397274	6256175	Volcán River
PV50	397644	6256283	Volcán River
PV500	397224	6256180	Volcán River

Sedimentologic study Maipo Melosas

Profile	East	North	Sector
PM0	388076	6254805	Maipo River
PM100	388020	6254768	Maipo River
PM150	387974	6254744	Maipo River
PM200	387933	6254716	Maipo River
PM250	387885	6254701	Maipo River
PM300	387835	6254696	Maipo River
PM350	387785	6254698	Maipo River
PM50	388047	6254781	Maipo River

PBN-24	376456	6268557	Maipo River
PBN-25	374416	6277531	Maipo River

*Datum WGS84

Figure 4.9. Topo-bathymetric profiles Survey in the Upper Volcán Sector.

In order to obtain results at an adequate geometric scale, comparisons have been made between the topo-bathymetric profiles surveyed and the transversal sections obtained from aero-photogrammetric topography. A runoff area has been estimated for each of the sections, which must be adjusted to the restituted profiles (as trapezoidal cuts) so as to generate representative runoff conditions in the HEC-RAS model. The comparison of the profiles and the calibration of the runoff area of the main channel that must be adjusted can be valued in the following Figures 4.10, 4.11 and 4.12.

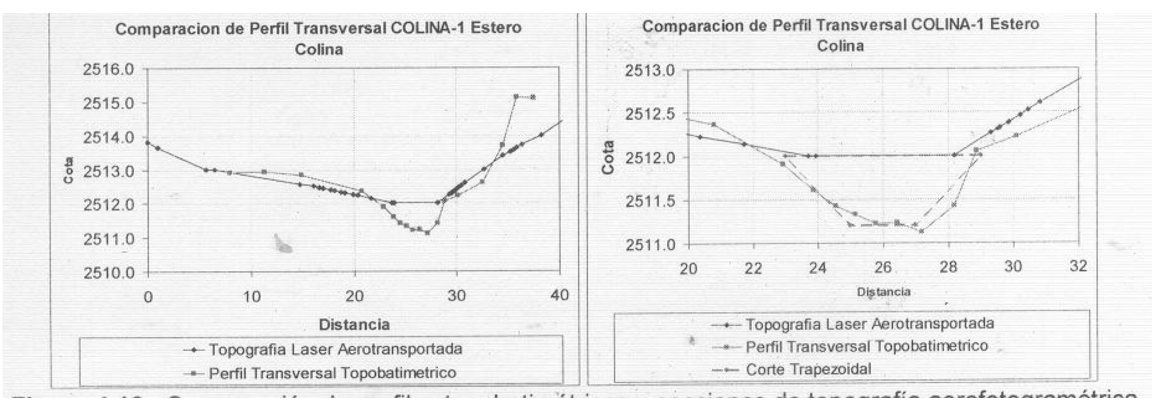


Figure 4.10. Comparison between the topo-bathymetric profiles and aero-photogrammetric topography for the Colina stream COLINA 01.

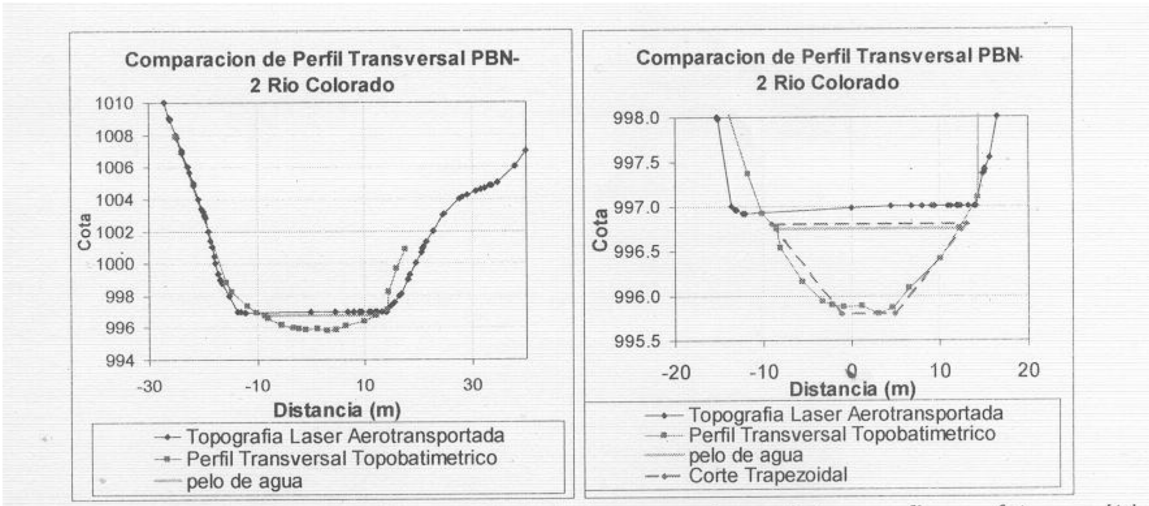


Figure 4.11: Comparison between the topo-bathymetric profiles and aerophotogrammetric topography for the Colorado River at PBN-02.

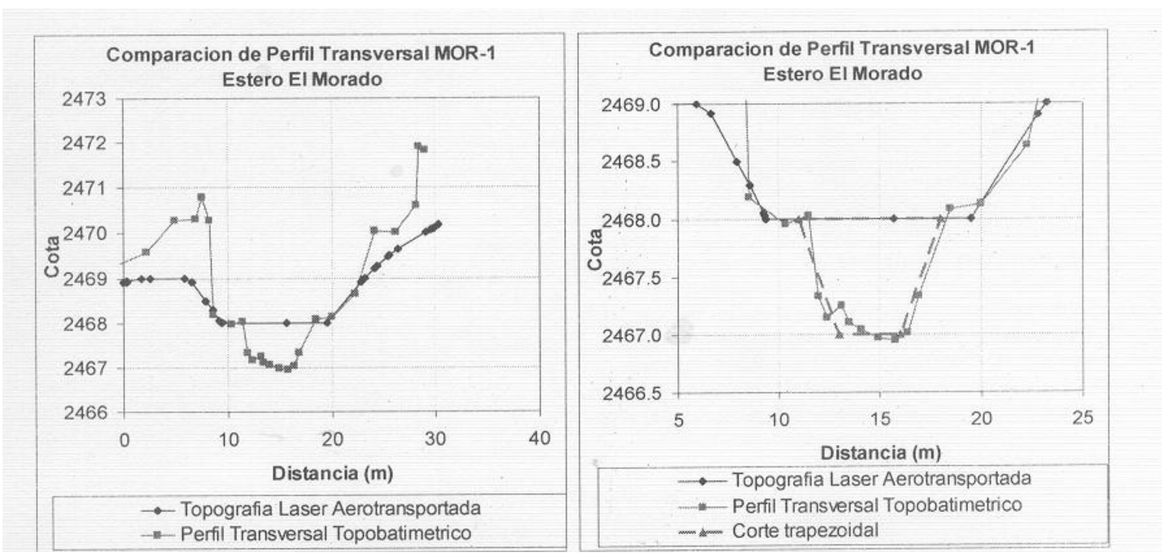
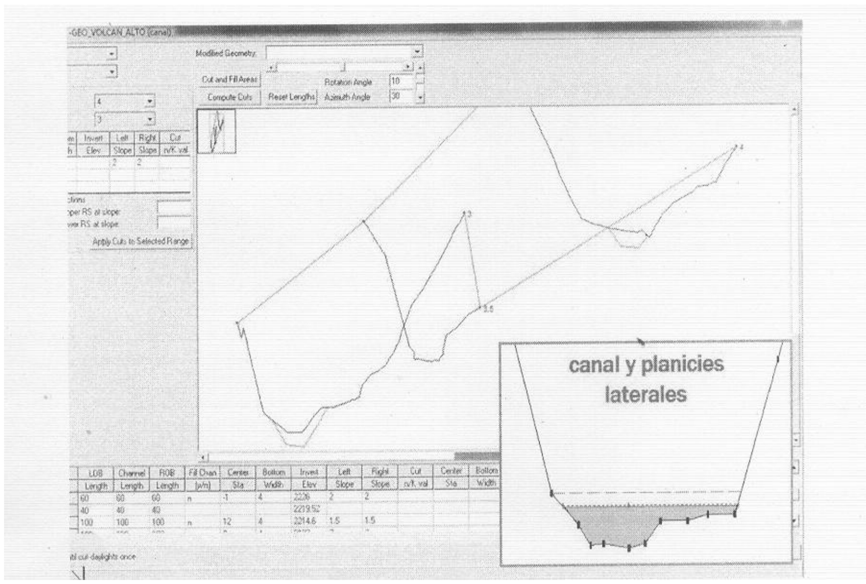


Figure 4.12: Comparison between the topo-bathymetric profiles and aerophotogrammetric topography of the Colina stream COLINA 01.

Figure 4.13 shows the HEC-RAS program module, where a trapezoidal section cut is applied to correct the restituted topography. The upstream and downstream sections are from the restituted topography, while the ones in the middle correspond to a topo-bathymetric survey. The red line shows the correction of the trapezoidal cut

Figure 4.13. Comparison of topo-bathymetric profiles and aero-photogrammetric topography sections.



4.2.2.4 Sedimentometric data and rugosity coefficients.

The Manning numbers for several segments of the rivers studied at present can be found in the Sedimentologic Study of the Maipo River carried out by the Civil Engineering Department of the University of Chile. These values were calculated according to the Cowan method and are shown in **Table 4.10.**

The n0 parameter is the Basic Manning coefficient, depending from the roughness or rugosity of the bed bottom and can be determined starting from the Stickler number and a characteristic diameter of the shield, d.

The characteristic diameter was determined from the granulometry curves of several cuts excavated in the river beds.

Table 4.10 Characteristic granulometry diameter, Cowan method parameters and calculation of the Manning coefficient (n)

Site	d (mm)	n0	n1	n2	n3	n4	m	n
1 M Maipo River at Las Melosas	253	0.03	0.01	0.005	0	0	1	0.045
2V El Volcán River	274	0.032	0.01	0.005	0	0	1	0.047
3Y El Yeso River	202	0.029	0.01	0.005	0.01	0	1	0.054
4M Maipo River at San José	152	0.028	0.01	0.01	0.005	0	1	0.053
5C Colorado River	172	0.028	0.01	0.01	0	0	1	0.048
Maipo at Las Vertientes	53	0.023	0.01	0	0	0	1	0.033
AC Colina Stream	102	0.026	0.01	0.005	0.01	0	1	0.051
BE La Engorda stream	172	0.028	0.01	0.01	0.01	0	1	0.058
CM El Morado Canyon	56	0.023	0.005	0.005	0	0	1.15	0.038
Las Placas Creek	108	0.026	0.008	0.007	0.007	0	1.05	0.05

Source: Sedimentologic study of the Maipo River. Civil Engineering Dept. Universidad de Chile.

4.2.2.5

Calculation of hydraulic axes.

The main objective of this chapter is the determination of the hydraulic axes of the Colorado, Volcán, El Yeso, Maipo rivers and of the Colina, Morado, La Engorda and Las Placas streams situated in the upper zone of the Volcán River.

The HEC-RAS model (Hydrologic Engineering Centers River Analysis System) has been used to resolve the hydraulic axis of the rivers and streams. The following are among its main characteristics:

- Application to rivers and channels having sub-critical, supercritical or mixed régimes;
- One-dimensional model for the calculation of the hydraulic axis;
- The basic focus is to solve the one-dimensional energy equation, considering friction (Manning) contractions/expansions and obstructions by typical river elements, i.e. a bridge.

HEC-RAS employs a one-dimensional focus derived from Bernoulli's fluid energy equation, to calculate the runoff height in gradually varied flows. An iterative calculation is done, starting from a point of known characteristics and advancing as a function of the loss of energy estimation.

For example, in a sub critical flow the downstream section is known due to the imposed hydraulic control, therefore the upstream adjacent section will have an equivalent energy, less the frictional/singular loss of energy of the segment. Then, successively the resolution is carried upstream, until the channel segment is completed.

$$Y_2 + Z_2 + \frac{a_2 V_2^2}{g} = Y_1 + Z_1 + \frac{a_1 V_1^2}{g} + h_e$$

Where $Y_{1.}, Y_2$: depth of the water in the transversal section; Z_1, Z_2 : Elevation of the bottom of the channel; V_1, V_2: Average velocities of the flow; a_1, a_2: Coefficients; g: gravitational acceleration, h_e energy loss.

When the flow reaches the critical height, the energy equation is not considered applicable, since it is use when the flow is gradually varied. In cases when the change goes from sub critical to supercritical flows or vice versa, the flow varies rapidly. In the HEC-RAS model case, the balance of forces equation is applied derived from the second law of Newton applied to a fluid section between two sections 1 and 2.

$$P_2 - P_1 + W_x - F_f = Q \cdot \rho \cdot \Delta V_x$$

Where P: Hydraulic pressure in points 1 y 2; Wx :Force due to the weight of the water in the x direction; F1 Force due to the losses by friction from 2 to 1; Q: Flow; p of the water; ρ Water density; ΔVx : velocity variation from 2 to 1 in the x direction.

Figure 4.14 is a sketch of a mixed hydraulic regime, where the entry flow is sub critical (torrent) and passes to a sub critical regime by means of a hydraulic ledge. The situation described in this example is typical of Chilean rivers, which are found in zones where middle/soft grades are intercepted by strong grades, or with bathymetric that conditions a supercritical regime (narrowing or natural tiers). The mixed regime is specifically considered the most adequate method to solve the hydraulic axis of the rivers and streams of this study.

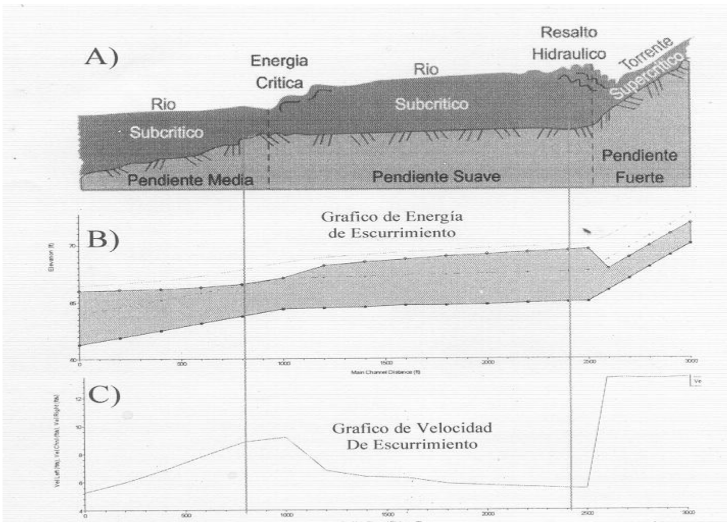


Figure 4.14: A) Sketch of mixed supercritical and sub critical runoff regime. B) Graph of the runoff energy solved by HECRASS: the red line shows the critical energy and the green line the total energy. C) HEC-RAS graph of the average runoff velocity.

Five hydraulic models have been developed from the available data and their characteristics are shown below:

- Maipo River: 38km
- Colorado River: 24km
- Volcán River: 20.5km
- Yeso River: 23km
- Upper Volcán River (Sub-basin with the Colina, El Morado, Engorda and Las Placas streams).

The normal runoff height border condition has been imposed on the models, both upstream and downstream (requirement of the mixed regime modulation). Table 4.11 below shows the grades used to determine that condition.

Table 4.11 Grades to set the HEC-RAS model border conditions.

River	Upstream grades	Downstream grades
Colina	3%	1.60%
Morado	12%	2.60%
Placas	17.90%	3.10%
Engorda	4.40%	29.30%
Volcán	2.50%	1.40%
Yeso	6.20%	2.60%
Colorado	3.20%	2.00%
Maipo	2.20%	0.90%

Source: NASA-SRTM Topographic base

A flow gauging series were carried out in the Colina stream before its confluence with the Volcán River in February 1990 and February 1991 (Source (AES-GENER flow gauging). The velocity and depth were measured point to point of the transverse section in each flow gauging. The median depth was estimated based on that information, and then the maximum depth (based on a trapezoidal section) and this was associated to the measured flow. The result is a discharge curve which can be compared directly with the HEC-RAS model output. Figure 4.15 below shows the adjustment of the curve to the discharge curve built with the data of the available flow gauging.

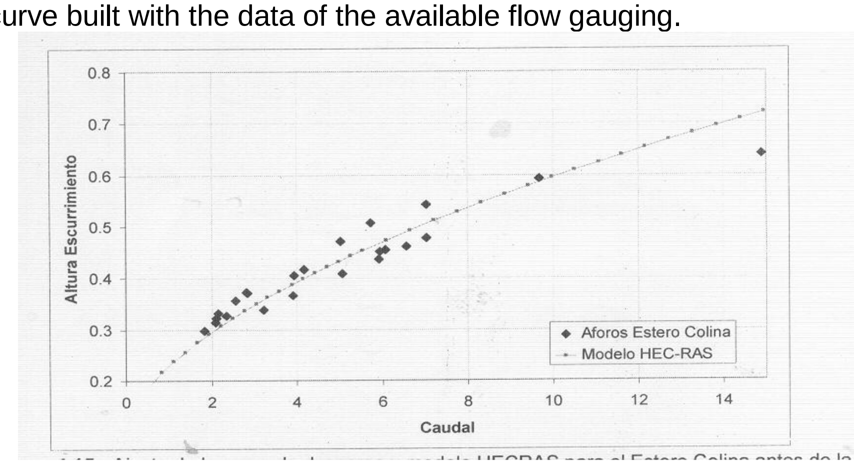


Figure 4.15. Adjustment of the discharge curve and HEC-RAS model for the Colina Stream before the confluence with the Volcán River. Source: Own preparation on the basis of the 1990-1991 flow gauging carried out by AES GENER.

It should be pointed out that the preliminary results of the model showed that the transversal section of the restored topography showed a much larger width of the bed than the true one, therefore the discharge curves were not well represented.

The calibration of the runoff areas and the later correction of the geometric section (trapezoidal channel cut) allowed reaching a satisfactory adjustment of the discharge curve.

Among the remaining segments, there are two topo-bathymetric profiles near fluviometric stations, where it was possible to carry out comparisons of the discharge curves with the HEC-RAS model. The adjustments for the following sections are shown below:

- Colorado River before the confluence with the Maipo River (Figure 4.16).
- Maipo River at San Alfonso /Figure 4.17).
-

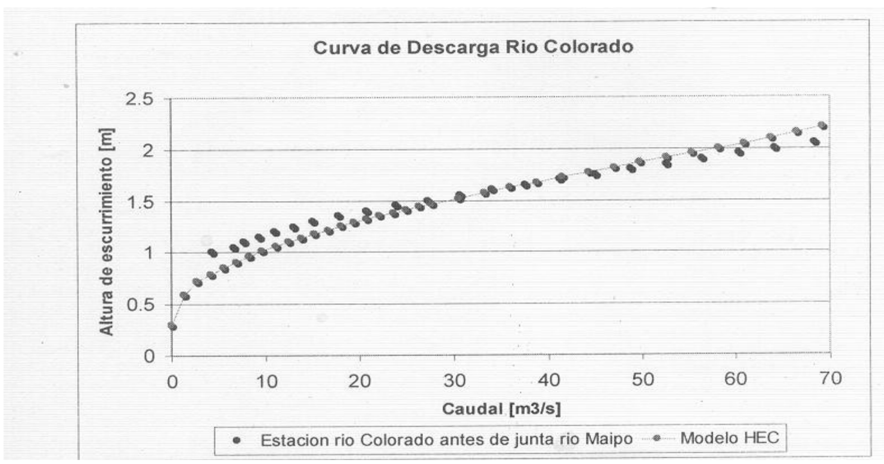
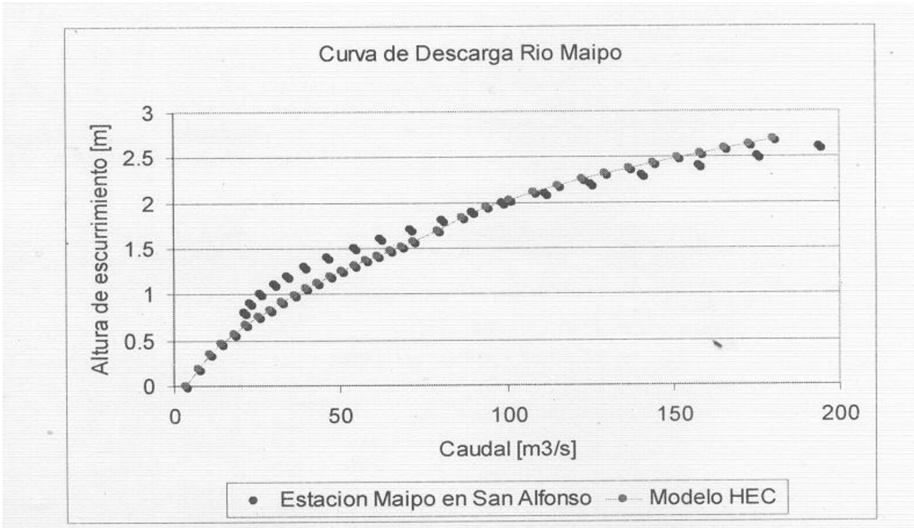


Figure 4.16: Adjustment between the DGA discharge curve and the HEC-RAS model for the Colorado River before its confluence with the Maipo River.



4.17: Adjustment of the DGA discharge curve and HEC-RAS model for the Maipo River at San Alfonso.

4.2.3 Morphological characterization

Morphological characterization refers to the definition of the geometric characterization of the river bed and its relationship with river hydraulics.

The morphological characteristics of the study zone are defined considering the morphological classification of alluvial riverbeds of Montgomery & Buffington (1997), and the degree of connectivity between habitat and water quality.

It should be pointed out that these morphologic types are closely related with the habitat conditions, as the physical differences reflect on the different environmental conditions as the oxygenation of the rivers and the velocity of the current.

This morphological classification establishes riverbeds of the following types:

- **Cascade-type morphology**. This type is characterized by steep grades of the grounds, relatively straight segments, and rough substrates of the rocky type which obstruct the runoff forming white water zones and to be confined in rocky terrain and with scant fine sediments deposits in its banks. From the point of view of solids transports, this is a zone of high energy, high transport and undermining. From the point of view of fish habitats, this region has high turbulence and obstacles level, which impedes their longitudinal migratory processes, specifically their upstream movement upon the water course.

- **Regions with straight channels and sequences of rapids and pools.** These regions shows an important variability of the runoff conditions on the longitudinal axis, originating high velocity sectors (rapids, downstream from critical runoff sections) and zones of low velocity upstream of the critical zone (pools).

Although this type of fluvial bed shows supercritical runoff zones, as the cascade morphology, there are no white water zones. This is explained because white waters are related to the relative roughness, that is o say the relationship between the height of the runoff and the size of the sediments rather than with the type of runoff. From the point of view of the fish's habitat, the rapids-pools morphology allows favorable habitat conditions in the slower zone, although the rapids hydraulics conditions are I significant for the longitudinal migration of the fishes.

- **Braided river.** This type of runoff is generated by the decrease in the terrain grade, favoring lateral development and the existence of more than one water course channel. The braided or anastomosed channels are <u>characteristic of water courses which have large flow and sediments load variations.</u> In their low water level episodes, the flow of the current is confined to the channels, separated by sediment bars. These bars are formed during the lowering period of the river, when sediments accumulate around some obstruction or the remains of an old bar. The whole valley is frequently subjected to undermining during the flood period, the current creates new channels in the bottom sediments and the channels are finally filled and begin to develop in width Besides, due to the rosin processes of the banks of the channels, the temporal variability in the shape of the channel is wide, resulting that the braiding of the river varies in shape during the year. From the hydraulics point of view the regime in these zones is sub critical (river), characterized by low velocities and high runoff heights. There braided regions are very important for fishes, as the high transversal variability of the runoff conditions allows the coexistence of varied habitats.
- **Meanders current morphology.** This type of current that develops meanders is usually those with low grades, with moderate sediments loads and moderate fluctuations of the discharge. The current velocity is higher along the thalweg and so is the transport of sediments, especially that of thicker materials. The most active sediments transport takes place when the river is at flood and at the same time stronger erosion takes place at the undermined bank. The meanders bars develop when flooding abates, in the interior zones of the meanders. In a meander bar there is

a reduction of the size of the grains from the base to the top, as well as a decrease in the magnitude of the sedimentary structures, from the large scale crossed stratification down to small ripples with intertwined sheets. Sedimentation takes place over the whole structure of the bar and as the bends of the meanders grow, the sand bars widen due to a lateral accretion process.

- **Flat bed:** Runoff conditioned by a flat bed, of thick gravel and paving. Not many perturbations are found on the free surface, due to the presence of rocks.

To record this, there are:

- Filmmaking and aerial photographs of the zones immediately downstream from the intakes of the Project to the return zone. Procedure used to support of the definition of the ecologic and antropic AIAs.
- High resolution QuickBird photographs to support the AIA definition.
- Field checking of the different zones.

The different zones of the Maipo, Colorado, Yeso, Volcán rivers and their streams El Morado, Las Placas, Colina and La Engorda are identified and described according to this morphologic classification. The types of runoff are analyzed (sub or super critical) hydraulic control zones and type of channel (braided, straight or meanders). This data is later on linked to the biological, physico-chemical and antropic uses information so as to define the environmentally sensitive zones defined as Environmentally Important Areas.

4.2.1 Characterization of the physico-chemical properties of the water

The physico-chemical characterization of the physico-chemical quality of the waters of the Volcán, Yeso, Colorado, Maipo rivers and the El Morado, Las Placas, Colina and La Engorda streams is found in Chapter 5, section 5.3.5.2 Water Quality of the EIA. That report contains a detailed analysis of the physical, chemical and biological quality of the waters of the rivers in different sampling stations, considering the main water courses and tributaries.

To characterize the water quality in the study area, data gathered for the EIA complementing the study of the “Diagnostic and classification of the water courses and bodies according to quality objectives for the Maipo River Basin”, carried Out in July 2004 by the DGA, containing data from three field campaigns, additional information to that of the EIA is added in this study, so as to carry out sampling in the water courses of interest for the evaluation of the ecologic flow.

It is furthermore complemented by the analysis of oils, greases and hydrocarbons in 26 sampling points. An integral analysis of the baseline information and of the data obtained is given in this report so as to determine the impacts, if any, due to changes in flow regimes.

Samples to measure water quality parameters were collected in the sectors of the Volcán, Yeso, Colorado, Maipo rivers and the El Morado, Las Placas, Colina and La Engorda streams.

4.2.4.1 Sampling method

The sampling and preservation of the samples procedure was carried out according to Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF, 1995). The sampling containers were supplied by the CEA [1] [1]environmental laboratory (taking care of the type of assay and the corresponding clearing procedure (APHA-AWWA-WEF, 1995).

The physico-chemical parameters, temperature, pH, conductivity and dissolved oxygen were measured in situ with a telemetric WTW Multiline F/SET 3 gage. The samples were obtained on the surface. Duplicate water samples were collected in high density polyethylene flasks of 1l capacity, directly from the water courses. A 50% of each sample was filtered at once for analysis, using a membrane filter 0,45 μm pore size (Millipore HAWP filter). Part of the filtered samples was packed together with the others not yet filtered in insolated thermal boxes and transported to the laboratory in Santiago for their chemical analysis. Whitton type bottles were used for the 0805 measurements. Glass filters, 0.8μm, were used for the chlorophyll measurements; these were transported at low temperature.

4.2.4.2 Analytical methods.

The methods used to monitor the water quality of the rivers and streams of the Alto Maipo Project are based on the scopes of the environmental studies and protocols that the National Environmental Commission proposes in the document "Environmental Characterization Methods" (CONAMA, 1996 and according to APHA, AWWA, WEF (1995), Standard Methods for the Examination of Water and Wastewater.

Parameters measured *in situ*

Specific conductivity (at 25°C, μS/cm): Measured with a telemetric WTW Multiline F/SET 3 gauge, precision 0.01.

[1] *INN certified laboratory*

- Hydrogen ion concentration (pH): The pH was measured with a telemetric WTW Multiline F/SET 3 gage, precision 0.01.
- Dissolved oxygen (mg/l): Measured with a telemetric WTW Multiline F/SET 3 gage, precision 0.01.
- Temperature (°C): Measured with a telemetric WTW Multiline F/SET 3 gage, precision 0.01.

Physical parameters

- True color (Pt-Co): measured photo-metrically according to APHA, AWWA & WEF (1995).
- Solid filterable residues (mg/l): Determined according to the gravimetric method APHA, AWWA & WEF (1995).
- Sedimentable solids (mg/l): Determined according to the gravimetric method APHA, AWWA & WEF (1995).
- Total dissolved solids (mg/l): The total dissolved solids were determined according to APHA, AWWA & WEF (1995), (2540-C).
- Total suspended solids (mg/l): The total suspended solids were determined according to APHA, AWWA & WEF (1995), (2540-D)
- Turbidity (NTU): The turbidity determination was done using the nephelometric method, according to APHA, AWWA & WEF (1995).

Biological parameters

- Chlorophyll 'a' (μg/l): Measured according to the protocol indicated in APHA, AWWA & WEF (1995). Met. 10200-H.
- Total and faecal coliforms (NMP/100 mi): The chromomeric substrate test was employed, according to APHA, AWWA & WEF (1995).
- Biochemical oxygen demand (DB05, mg/l): Measured following the protocol indicated in APHA, AWWA & WEF (1995).

Nutrients

- Ammonia (NH3 mg/l): Determined according to the electrometric method APHA, AWWA & WEF (1995).
- Orthophosphate phosphate (P-P04, μg/l): Determined by the photometric method according to APHA, AWWA & WEF (1995). Met. 4500 P E.

- Total phosphorus (P-total, μg/l): Determined by the photometric method according to APHA, AWWA & WEF (1995). Met. 4500 P E.
- Nitrate nitrogen (N-N03, μg/l): Determined by the photometric method according to APHA, AWWA & WEF (1995). Met. 4500 N03 B.
- Nitrite nitrogen (N-N02, μg/l): Determined by the photometric method according to APHA, AWWA & WEF (1995). Met. 4500 N02 A
- Ammonia nitrogen (N-N03, μg/l): Determined by the photometric method according to APHA, AWWA & WEF (1995). Met. 4500 F.
- Total organic nitrogen (N-N03, μg/l): Determined by the photometric method according to APHA, AWWA & WEF (1995). Met. 4500 F, with prior digestion.

Major elements

- Macro elements (mg/l): The cationic macro elements were determined according to APHA, AWWA & WEF (1995). 3120 A. The determinations or carbonates and bicarbonates were done using volumetric methods (APHA, AWWA & WEF (1995). The chloride analysis was done by the argentometric method, according to APHA, AWWA & WEF (1995). 4500-CI - B). The sulphate analysis was done by the turbid-metric method, according to APHA, AWWA & WEF (1995).

Trace elements

- Trace elements (μg/L): The determination of As, Ba, B, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Ag, Pb, Se, V and Zn, was done by inductively coupled plasma optical emission spectroscopy (ICP/OES). Elements such as Al, Cr+6 by atomic absorption spectroscopy and Hg by atomic absorption with hydride generation.
- Cyanide (mg/l): The molecular absorption spectroscopy method was employed, according to APHA, AWWA & WEF (1995).

Other parameters

- Total alkalinity (mg/l): The titrimetic method was employed according to APHA, AWWA & WEF (1995).
- Phenol compounds (mg/l): The molecular absorption spectroscopy method was employed, according to APHA, AWWA & WEF (1995).
- Chemical oxygen demand (DQO, mg/l): The closed reflux colorimetric method was employed, according to APHA, AWWA & WEF (1995).

- Detergents (mg/l): The molecular absorption spectroscopy method was employed, according to APHA, AWWA & WEF (1995).
- Fluorine (F, mg/l): Determined according to the electrometric method APHA, AWWA & WEF (1995).
- Fluoride (F-, mg/l): Determined by the photometric method according to APHA, AWWA & WEF (1995). Met. 4500-F- D.
- Sodium percentage (%): Calculated estimation, using the values obtained for Na, K, Ca, Mg according to Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005. Method 3120 B.

The analysis techniques of the physico-chemical parameters have detection and quantification values limits, defined as follows:

Detection limit of the method (LD): This is the minimum concentration of a compound that can be detected in a specific kind of sample (true matrix), which is examined following all the phases of the full method. This minimum concentration produces a detectable signal of defined reliability.

Quantification limit of the method (LC): This is the minimum concentration of a compound that can be quantified in a specific type of sample (true matrix), which is examined following all the phases of the full method. This minimum concentration produces a quantifiable signal of defined reliability.

An additional sampling for the analysis of Hydrocarbons, Oils and Greases was carried out.

- Oils and Greases Standard Methods Ed.21 (2005) Method 5520-B Gravimetric)
- Total Hydrocarbons: Standard Methods Ed.21 (2005) Method 5520-F Hydrocarbons
- Fixed Hydrocarbons: NCh 2313/7 Gravimetric
- Volatile Hydrocarbons: NCh 2313/7 Of 1997 Gas Chromatography

4.2.5 Biologic Characterization

The biological characterization of the Volcán, Yeso, Colorado, Maipo rivers and the El Morado, Las Placas, Colina and La Engorda streams is found in Chapter 5, Biotic Environment, Aquatic Flora and Fauna of the EIA and is complemented in this study by sampling focused on a better description of the sensitive areas and a comprehensive analysis of the information was carried out.

4.2.5.1 Analysis methods

Phytoplankton:

Two random replicates were obtained at each sampling site using the profilometer proposed by Davies & Gee (1993). Aliquots of the phythobenthos samples (diatomea) were extracted in the laboratory and cleaned using the oxidation method (APHA 1995). They were fixed on permanent preparations and examined with a light microscope (Carl Zeiss, model Axioskop 2) for the identification of the species and counting (Wetzel & Likens 1991). The identification of the diatomea and other groups was done using the keys of Rivera (1983), Krammer & Lange-Bertalot (1986, 1991), Simonsen (1987), Parra et al. Bardonner et al. (2000) and Lange-Bertalot (2001). (Phythobenthos)

Duplicate samples were collected using a 60μm grid mesh drag net with an 18cm diameter mouth opening; once obtained they were preserved in a Lugol solution. They were analyzed in the laboratory using a Light microscope (Carl Zeiss, model Axioskop 2). Diatomea using permanent preparations and other microalgae groups (clorificeae, cianoficeae among others) in fresh preparations. A Sedgewick-Rafter (APHA 1995, Stevenson & Bahls 1999) counting device was used to quantify the other groups. Only live individuals were considered for this analysis (with chloroplasts). For all groups, the filtered volume was estimated by multiplying the area of the net by the velocity of the water and the sampling time (2 minutes) The number of individuals in the simple divided by the filtered volume allows estimating the density as cell/L. In the chamber this will be quantified by means of transects and a volume of 1 ml, the number of counted transects is a function of the precision desired and the number of units (cells, colonies or filaments) per transect. Therefore, the plankton number in the S-R chamber is calculated as follows:

$$\frac{N^o\ cel}{mL} = \frac{1000mm^3\ C}{L \cdot D \cdot W \cdot S}.$$

Where:

C= number of organisms counted

L = total length of the chamber (50mm) length of the transect (2.3mm)

D = Depth of the chamber (1mm)

W = Width of the chamber (20mm)

S= number of counted transects

Finally, the number of cells per milliliter is divided by a correction factor adjusted to the dilution or concentration of the sample.

The identification of the diatomea and other groups was done using the keys of Rivera (1983), Krammer & Lange-Bertalot (1986, 1991), Simonsen (1987), Parra et al. (1982, 1983), Prescott (1970), Pereira & Parra 1984, Round et al. (1996), Rumrich et al (2000) and Lange-Bertalot (2001).

Zoobenthos

The estimation of the macrozoobenthos was done by means of direct counting per group of organisms. Three random simples were collected using a Surber net of 0.09m^2 with mesh of 250μm. The samples were analyzed quantitatively. The method used was to analyze the simples under a Zeiss Stemi 2000-C lens separating all the organisms, classifying and counting them. The identification of the organisms was based on the work of Bertrand (1995), Lopretto & Tell (1995) and Merrit & Cummins (1996).

Zooplankton

The zooplankton community of the area studied was characterized by the collection of duplicate samples at each station, by means of a drag net having a 60μm mesh and 12cm opening. The samples were fixed in 10% formalin for their later analysis by Light microscopy, classifying and counting all organisms (Wetzel & Likens, 1991). The classification of the zooplankton organisms was done according to Araya & Zuñiga (1985) and Pennak (1989). Since the samples were taken in rheophyle, running water systems, the zooplankton collection also included zoobenthos organisms that drifted in, mainly aquatic insect larvae, which were also included in the total counting of organisms.

Fishes

To study the composition and abundance of the Ictic community of the Volcán, Yeso, Colorado, Maipo rivers and the El Morado, Las Placas, Colina and La Engorda streams, Fishes were collected to recognize the fish species present in the study zone and their spatial distribution. The electric fishing technique was used to this end, in one of the banks of the rivers, with a portable Honda electric fishing tackle and nets, collecting all the individuals in a 100m^2 area, approximately.

All the fishes collected were identified and measured in situ as to total length (L T) and total weight (PT)

The survey included the 23 stations defined in the critical areas identification stage.

4.2.5.2

Statistical analysis.

The order method employed to represent graphically the similitude between sampling sites was a non-metric dimensional scaling (Nonmetric MultiDimensional Scaling nMDS-PRIMER v.6.0). The nDMS is an ordering technique that shows the relationships between populations using a small number of dimensions (Lessa, 1990). When the interpopulation variation is a function of distance only, the graph of the first two dimensions produces a grouping pattern similar to a geographic map of the populations (Jackman and Wake 1994). This technique does not assume linearity between proximities and distances; it establishes a monotonous growing relationship between them (Shepard ,1962; Kruskal 1964) and is effective for the study of biological communities (Cune and Grace 2001). The "stress" value is the regression adjustment measure (measure of the deviation of a linear relationship between the distance of the original data matrix and the distance in the ordered space). The stress values that appear in each one of the ordering indicate the degree of reliability of the similitude representation between the simples and their original space (multidimensional) to the reduced space (NMDS-2 dimensions), Stress values < 0.05 show a good representation of the data in the graph. A < 0.1 stress indicates a good representation. If the stress is > 0.2 the graph is not reliable. If the stress is over 0.3, we can consider that the distribution of the points is almost random (Kruskal ,1964).

The association index used for this analysis was the Bray-Curtis Similitude Index which is appropriate for the abundance of species data and allows balancing the contribution of the more or less abundant species (Clarke and Warwick, 2001). The Euclidian distance was used for the physical and chemical variables, in agreement with continuous distribution data (Clarke and Warwick, 2001).

The significance of the differences between sampling sites and campaigns was evaluated using the non parametric analysis of similarities ANOSIM- PRIMER 6.0 test. The ANOSIM is a multivariate statistic test, analogous to the variance analysis (ANOVA) which obtains significance levels by means of general randomization (Clarke, 1993; Clarke and Warwick, 2001). This technique is based on the similitude range between the sites or the times of the sampling (rB), the similitude range among the simples of each site or the time of the sampling (rW) and the total number of simples taken into account (n). It compares pairs of "sample groups" (sampling times or sites) and adds significance values to the comparisons. In this case, a global statistic - R - (analogous to F in ANOVA) To determine if there are statistically significant difference among all the groups, this can vary between -1 and 1.

A 5% error interval was accepted for all the multivariate and non-parametric tests, therefore the interpretation of the statistic results was as follows: $p \geq 0.05$: Non-significant $p < 0,05$ Significant.

4.2.6 Characterization of the antropic uses

The antropic uses were characterized according to the following points of view:

Identified from the cadastre and informal interviews:

- Rafting
- Kayaking
- Sports fishing

Another use evaluated from an antropic point of view is what refers to the changes in the landscape as the flow decreases; this is evaluated in the sections where the greatest loss of beach area occurs in the rivers and streams (intakes).

4.3 Identification of Environmentally Important Areas (AIA):

The environmentally important areas were classified as ecologic and antropic, and when evaluated together they determined the Environmental Water Demand (Total Ecologic Flow) of the Volcán, Yeso, Colorado, Maipo rivers and the El Morado, Las Placas, Colina and La Engorda streams.

4.3.1 Ecologic AIAs

The ecologic AIAa are identified by a process which uses several kinds of interrelated information.

The AIAs of ecologic importance were identified from the baseline described in chapter 5.4. Biotic Environment, Aquatic Flora and Fauna of the EIA. Using as criterion the areas with greater richness and abundance of aquatic species, presence of species with conservation problems and the existence of favorable habitats. This was validated by field visits, the use of aerial photographs as well as the morphological and grades analyses.

4.3.2 Antropic AIAs

The AIAs of antropic importance were identified by means of a cadastre carried out at the rivers during August 2008, where the following uses were identified:

- Rafting: Use of the Maipo River, from the Yeso outlet down to the Parque Los Héroes sector of San José de Maipo using rafts operated by several tourism companies.
- Kayaking: Use of the Maipo River, from the Yeso outlet down to the Parque Los Héroes sector of San José de Maipo by sportsmen and tourism operators.
- Fishing: On areas of the Yeso, Colorado and Maipo rivers, having |border fishing potential. This activity was identified spatially by a survey of the river and the support of information provided by residents of the sector.

Bathymetric profiles of the transversal section of each of the AIA were provided by GENER.

4.4 Environmental water demand estimation methods.

The following is a description of each of the methods recommended by the DGA for the calculation of the estimated ecologic flow.

The DGA recommends criteria for the estimation of ecologic flows, in order to decide on the water rights requests, and these criteria are mentioned in the document "*Norms and procedures for the Administration of Resources*" (DGA, 2002). These are as follows:

Q_{EC01} = 10 % OF THE AVERAGE YEARLY FLOW (on the basis of the average monthly flows);

Q_{EC02} = 50 % OF THE MINIMUM LOW WATER FLOW OF THE YEAR 95% (on the basis of the average monthly flows);

Q_{EC03} = Q_{330} (average daily flow which is exceeded 330 days of the year);

Q_{EC04} = Q_{347} (average daily flow which is exceeded 347 days of the year.

Should the average daily flow data not be available, the Q_{347} and Q_{330} flows are homologous to the average monthly flows with 95% and 90% surplus probabilities, respectively.

It is also pointed out that the total ecologic flow to be respected is as follows:

Total ecologic Q = ecologic Q + Environmental Water Demand.

4.4.2 Swiss, French Asturias and Basque regulations.

Ecologic flows have been determined in some European countries using hydrologic methods as those detailed below:

Swiss regulations establishing the conservation of a minimum qualitative and quantitative flow:

- The minimum qualitative flow considers the quality of the surface water (taking into account the residual water poured into them at present and in the future), the conservation of the atypical biotopes[2] and biocenoses[3] and the safeguarding of recreational spaces whose aesthetic and environmental character depends on the water.
- The minimum quantitative flow is of 50l/seg at least. Starting from that quantity, the flows are defined as a function of 0347, and a minimum depth of 20cm must be maintained to allow the migration of the fishes, if the flow is over 50l/s.

The ecologic flows defined by Swiss federal laws as function of O_{347} are those shown in Table 4.12 The Swiss law proposes the use of the eco (a) formula so as to simplify the calculation of the 0347 value. This equation is used when there are no average daily flow data, but there is information about the average yearly flow.

$$Q_{347} = \frac{a_o Q_{ma}}{10} \tag{a}$$

Where a is a coefficient that can have the values of 0.5; 1; 1.5 and 1.8, without specifying in what case each of them is used. *Qma* is the average yearly flow.

The value of a, such as that Q_{347} is similar to the value obtained from the historical series of average monthly flows is employed in this report.

The General Public Works Directorate of the Basque country estimated in 1980 a permanent circulation flow in regulated water courses consisting in 10% of the natural net yearly contributions to the water course, that is 10% of the average yearly flow, this criterion is included in those recommended by the DGA.

The waters laws of France establish that the ecologic flow must be a tenth of the average inter-years flow, evaluated with data of a minimum period of 5 years, and for modules over 80 m^3/s this can be extended up to 20% of the module.

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[2] *Site or physical sector occupied by a community*
[3] *Biologic community or group of species that inhabit a specific area*

Table 4.12 Ecologic flows defined by Swiss regulations.

Type of water course	*Q347* *[l/s]*	Ecologic flow *[l/s]*
Non fishing waters	[O - 1000]	0.35Q347
Fishing waters	[O -60]	50
	[60 -160]	50+0.8(Q347 - 50)
	160	130
	[160 - 500]	130+0.44(Q347 -160)
	500	280
	[500 - 2500]	280 + 0.31 (Q347 - 500)
	2500	900
	[2500 - 10000]	900+0.2131(Q347 - 2500)
	10000	2500
	[10000 - 60000]	2500 + 0.15(Q347 -10000)
	60000	10000

The Principate of Asturias applies the Swiss regulations, with special interest in the migration and fostering of the production of the salmonids *(Salmo trutta* and *Salmo salar).* Modifying the Swiss regulations, the criterion adopted by the Principate of Asturias defines as ecologic flow the highest value obtained according to the four following equations, expressed in l/s;

$$Qec = 50$$

$$Qec = \frac{15Q_{347}}{(\ln Q_{347})^2}$$

$$Qec = 0{,}35Q_{347}$$

$$Qec = 0{,}25Q_{347} + 75$$

The Q347 is calculated according to equation (a) should there be no data about the daily average flows.

The Hydrographic Confederation of the North of Spain considers that equation (e) gives higher values than equations (c) and (d) and for this reason apply it in the rivers where Q_{347} < 750 l/s. To the contrary equation (d) is applied in basins where the Q_{347} > 750 l/s.

4.4.3 New England regulations

The method used in New England was developed by the US Fish and Wildlife Service in 1981 and calculated the ecologic flow starting from a representative value of the contribution to the flow by basin surface unit. This representative value was stated as the median for the month of August as hydrologic conditions are critical for the State of New England during this month. This value is 0.5 $ft^3/s/mi^2$; or 0.005467 $m^3/s/km^2$. in the international units system.

4.4.4 Montana or Tennant Method

The Montana Method was Developer by Tennant in the United States, to be used in the long term planning of the piscicultures of that country. Tennant used a series of personal observations made in Montana and the Middle west, to characterize water courses according to the variations of the trout habitat quality, depending on the flows of the water courses, The methods consists in the determination of the minimum flow expressed as a percentage of the average yearly flow that supports the habitat quality for the fishes.

Since the method Developer is based on personal observations of the author, he considers that the habitat quality classification is made according to the professional judgment of the observer.

It is applied to river segments as a function of the median monthly flows of the water courses, as indicated in table 4.13.

Table 4.13 Percentage of the median yearly natural flow as a function of the quantification of habitat quality.

Qualification of Habitat Health	Recommended flow regime	
	Fall Winter [% del Qma]	Spring - Summer [% del Qma]
Abundant or maximum	200	
Optimum range	60 - 100	
outstanding	40	60
Excellent	30	50
Good	20	40
Sufficient or passable	10	30
Minimum or poor	10	10
Severe degradation	< 10	

4.4.5 Wet perimeter method

This method consists in building a graph with the wet perimeter data versus the flow running through each section. In this way, the point where the curve slope changes as the sought for flow is chosen. This inflexion point represents the flow above which the variation of the wet perimeter begins to diminish. That is to say, the narrowest transversal section or critical section as a habitat index for the rest of the current, as it is assumed that the minimum flow obtained in the critical section also satisfies the minimum needs of production, feeding, spawning, etc., guaranteeing the protection of the minimum habitat necessary to preserve the quality of the ecosystem.

This method is usually employed in wide sections, of little depth and relatively regular as the shape of the river bed affects the results. Results have not been satisfactory when applying this method to the Alto Maipo rivers, as the runoffs show a histogram with torrential flooding that can use the lateral plains on a yearly frequency. The graphs are shown in **ANNEX E.** In general, no inflexion points associated to lateral development are identified within the range of the analyzed flows (range of 100% Q yearly average down to 5% Q yearly average). This is morphologically represented in that the main channel of the water course has the transport capacity of a flow of the order of the yearly average flow, and that the lateral plains do not represent an appropriate microhabitat for the development of the biota.

Figure 4.18 shows two typical sections. 1) Upstream, a typical mountain section, of high grades and 2) downstream a low grade section, with a main channel and lateral development zones.

The level variation is reflected differently in the variation of the wet perimeter in each case. In the first section (upstream) inflection points are not observed for flows under the average yearly flow, while in the second, there are cuts in the Wet Perimeter/Flow curve.

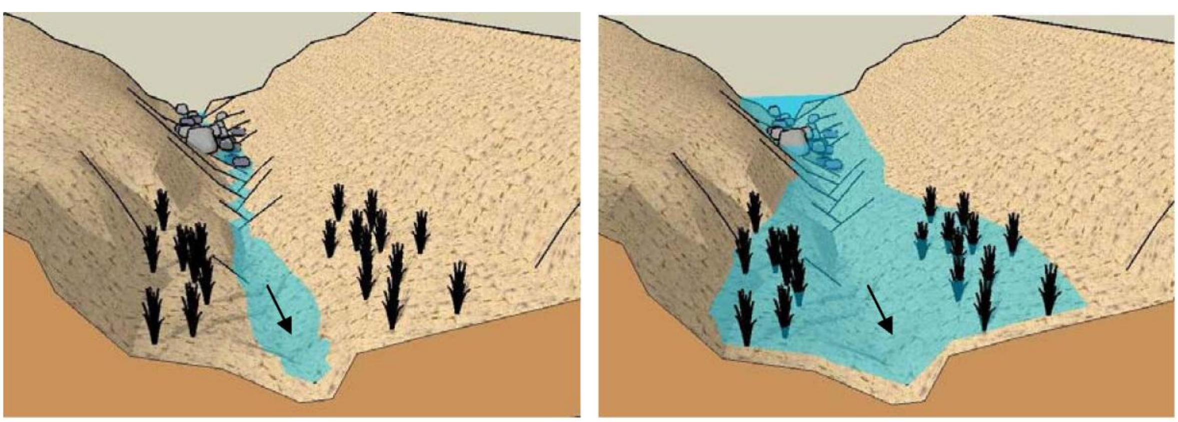

Figure 4.18. Sketch of the level increase and occupation of the flood plains.

4.4.6 Habitat simulation methods

The habitat simulation consists in coupling the runoff conditions, as the velocity, depth and substrate type, with the specific requirements of the biologic species studied. This quantification is done starting from the calculation of an index for the different flows analyzed. In this way it is possible to obtain the value of this index for the different flows and quantify the decrease in habitat quality due to the effects of flow decrease.

- Simulation of fish habitat

The quantification of the impacts on the available habitability, associated to flow variation was done based on the calculation of the hydraulic axis in permanent regime for a range of flows of the HEC-RAS model. The modeling results are the average depth of runoff, the average velocity, and width of the free surface, area of the runoff sections, wet perimeter and Froude number.

The habitat simulation model combines the results of the physical conditions of the river with the Preference Curves of some bio indicator species (fishes that require a specific range of velocity or depth). By weighing the factors and in function of the flow a habitat index is generated for each sector.

A computer code has been implemented in the MATLAB program, based on the (Physical Habitat Simulation System) method; this processes the hydraulic axes and delivers the necessary results to be interpolated in the preference curves.

The average values per section delivered by the HEC-RAS program were first translated into punctual runoff height and velocity. The local runoff height is directly determined as the calculation between the elevation of the free surface and the elevation at the bottom of the sections, while runoff velocity is assumed to be proportional to local depth and the proportional coefficient is defined by the total flow of the section.

These punctual runoff velocity and depth were interpolated into a regular grid and finally the habitability index is calculated for each point of the grid. The further calculation is the composite habitability index, consisting in the evaluation of the simultaneous condition of occurrence of the preference of a species for determined physical conditions, which is to multiply the habitat preferences of velocity, the depth and substrate preference, as shown in Figure 4.19.

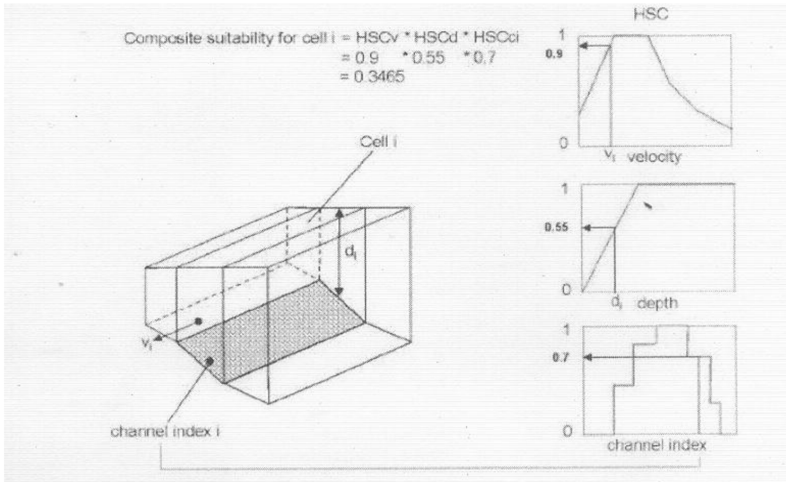

Figure 4.19. Sketch of the composite habitability index based on velocity, depth and substrate. Source: Figure obtained from "PHABSIM for Windows" USGS, November 2001.

River maps in 2 or 3 dimensions are obtained as results, where the color assigned to each pixel indicates the calculated value of the habitability index as shown in the following Figure 4.20:

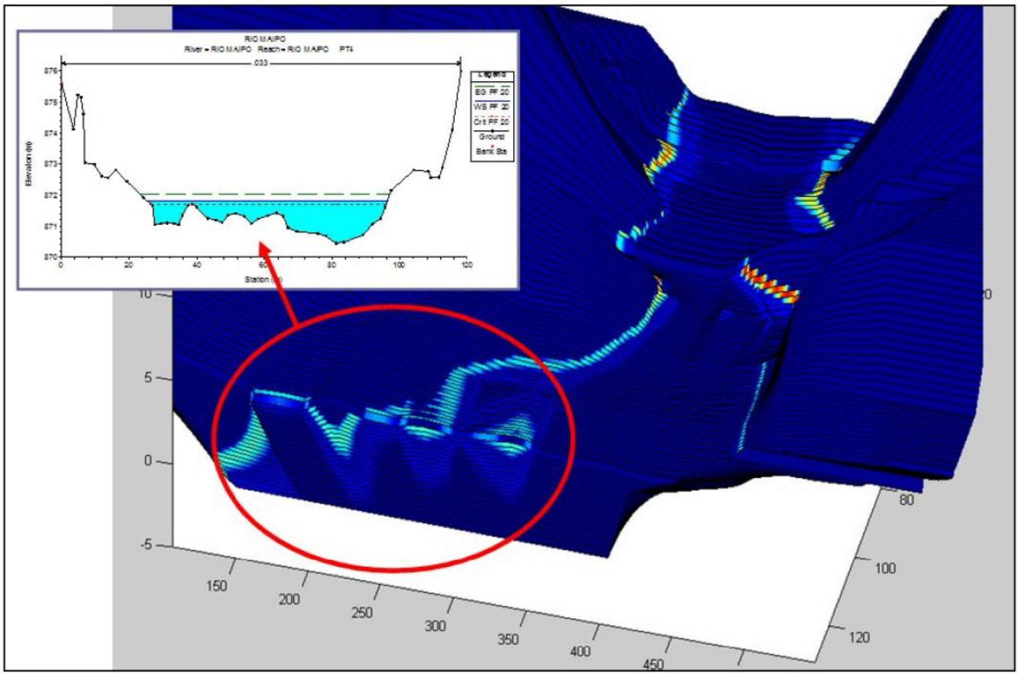

Figure 4.20. Result of the Habitat modeling for the Maipo River, considering the preference curves of brown trout (*Salmo trutta).* The topobathymetric profile of the section is also shown. He MATLAB model has 131 longitudinal sections and the river bed is partitioned into a lateral grid of 20cm.

The habitat sum in each transversal section delivers a General Habitat (example Figure 4.21) which simulates the general conditions of the river to safeguard a species in particular. This study contains an analysis for each of the transversal sections of the Environmentally Important Areas (AIA).

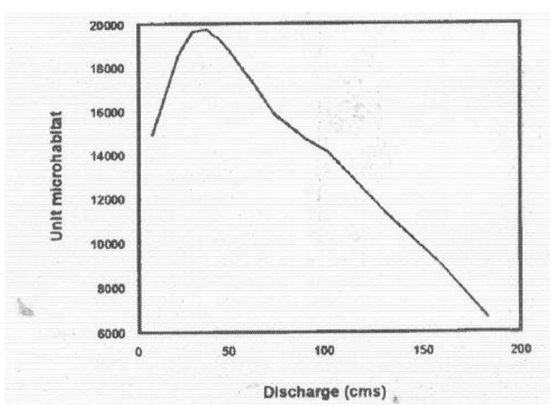

Figure 4.21. Example of the final IFIM result: Microhabitat v/s flow Curve. Source: Figure obtained from "PHABSIM for Windows" USGS, November 2001.

The habitat requirements of the fish species present in their juvenile and adult stages were also calculated, from the curves of habitability preference curves, delivering preference indexes from 0 to 1 as a function of the punctual value of the runoff speed and depth.

:

- *Salmo trutta* (juvenile and adult)
- *Oncorhynchus mykiss* (juvenile and adult)
- *Trichomycterus areolatus* (juvenile and adult)

The species used as bio indicators are based on field survey results and specific bibliographic research for each river or stream (for example *Oncorhynchus mykiss* and *Trichomycterus areolatus* are reported for the Colorado River).
The sources for these figures are shown below in figures 4.22, 4.23 and 4.24; the detailed graphs for each species (age, velocity and depth) are found in the annex.

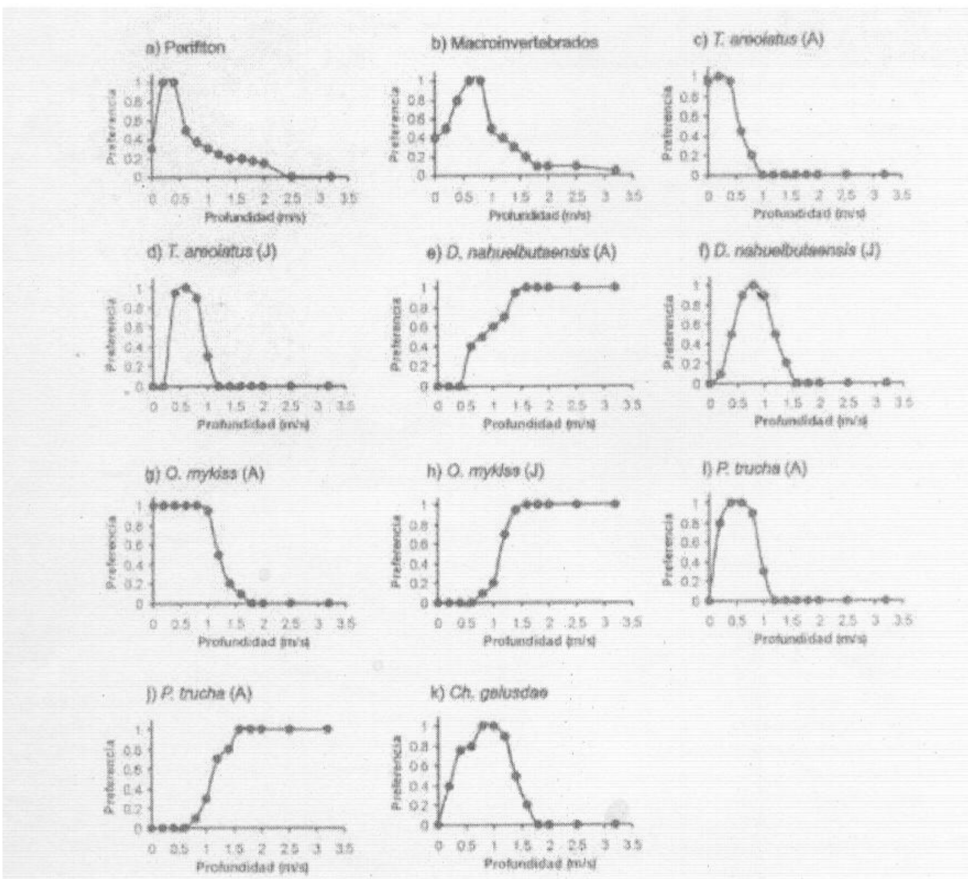

Figure 4.22: Habitat depth requirements for different species (EULA, 2000). (A) and (J) refer to adult and juvenile stages of the fish species.

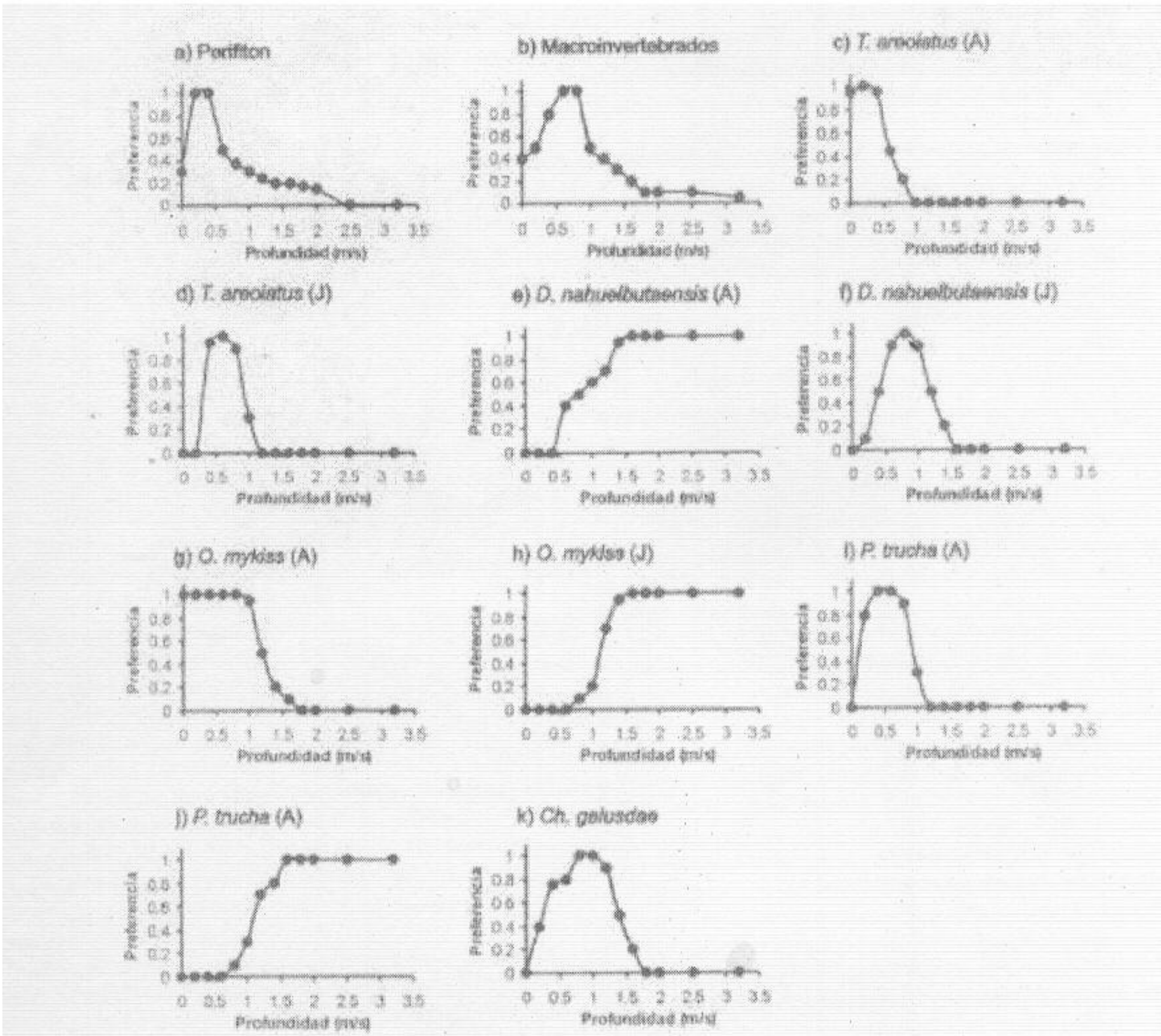

Figure 13. Habitat preference curves for the current velocity (m/s) variable of the species studied with PHABSIM a) perfiton; b) benthic Macroinvertebrate; c) Adult Trichomycterus areolatus; d) juvenile *T. areolatus*; e) Adult *Diplomystes nahuelbutaensis*; f) Juvenile *D. nahuelbutaensis;* g) Adult *Oncorhynchus mykiss*; h) Juvenile *0. mykiss*; i)Adult *Porcichthys trucha*; j) Juvenile *P trucha*; k) Adult and juvenile *Ch, galusciae.*

Figure 4.23: Habitat velocity requirements for different species (EULA, 2000). (A) and (J) refer to adult and juvenile stages of the fish species.

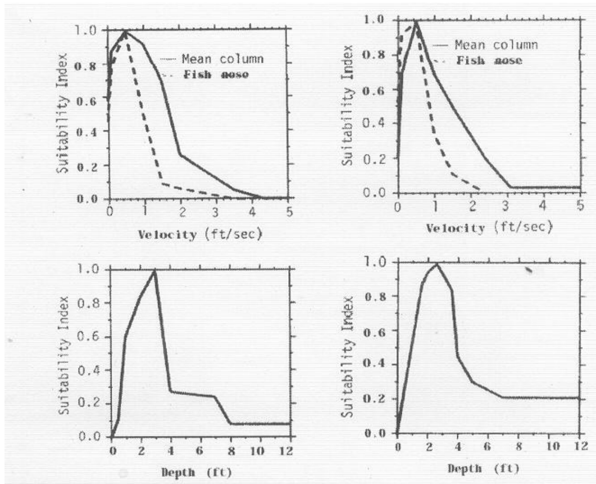

Figure 4.24: Velocity and Depth Habitability Curves for Brown Trout *(Salmo Trutta).* Left; juvenile. Right: adult. Source: Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout. U.S. Fish and Wildlife Service. September, 1986.

- General description of habitat conditions

The runoff heights that allow quantifying the impacts associated to the flow decrease are related to the longitudinal migratory processes along the rivers. The criterion adopted by the DGA and explicit in the Swiss regulations is that the runoff height cannot fall below 20cm. Therefore it is considered that if the minimum runoff depth is below that limit, longitudinal migratory processes will be affected by the diminution of the flow.

4.5. Criteria for the AIA Ecologic Flow evaluation

4.5.1 Areas of ecological importance

The habitat requirements of the fishes were analyzed, as they are used as bio indicators for the habitat requirements of all the aquatic organisms. This because their habitability curves are more restrictive than those of the macro benthos and Macroinvertebrate.

A graph of Habitability v/s Flow has been built for each of the control sections of the Environmentally Important Areas /AIA) so as to evaluate and quantify the habitability changes for the bio indicator species used for each river of stream.

Each of the control sections of the Environmental Important Areas (AIA) Was subjected to the following rigorous evaluation criteria:

- The low water, that is the average minimum monthly flow or low water with 85% probability of surplus, is the basal evaluation condition.
- A habitat diminution of not more than 10% upon the basic low water condition is considered.
- The ecologic flow value is adopted for each river section, determined with the most restrictive species curve, as the others will be covered by those requirements.

If the habitability condition increases should the flow be less, it is understood that the habitability curve is not restrictive. The hydraulic criterion is applied in such cases:

- Maintain a runoff height of 20cm as a minimum to maintain the longitudinal continuity of the river.
- Should the natural runoff height (or baseline) already be less than 20cm, the low water flow is maintained as ecologic flow.

The analysis is shown graphically in Figure 4.25, The habitability curve of the Brown Trout has been taken as example. The habitability value is estimated at the low water condition, then a 10% decrease in habitability is considered and finally the curve is again cut to estimate the resulting flow, which will be the Ecologic Flow to be adopted.

This analysis for each section is done for each species in their respective juvenile and adult ages. The habitability result is multiplied by the width of the cell to deliver an absolute value of habitat quantity. In this way, values are comparable for different water courses. The resulting unit from a profile is Habitability (per meter). However, if it is considered that the profile represent a determined length of river, the unit is Habitability (x square meter).

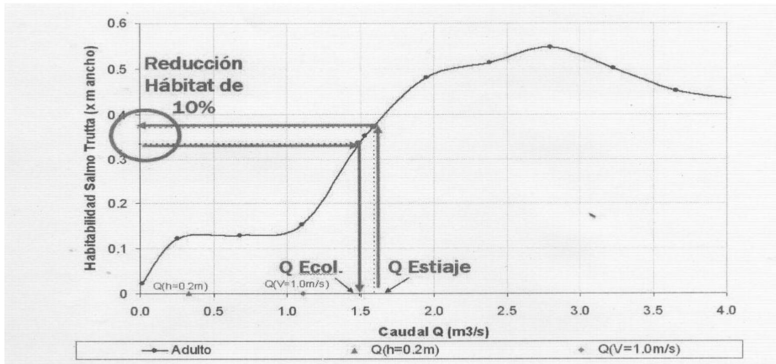

Figure 4.25. Graph of the method for the estimation of the Ecologic Flow, accepting a diminution of the habitat of 10% upon the low water base condition.

4.5.2 Areas of antropic importance

The main non-consumptive uses associated to antropic activities in the rivers And those corresponding to the present and potential uses of the Maipo, Colorado, Yeso and Volcán Rivers and the El Morado, Las Placas, Colina and La Engorda streams were selected. The thresholds limiting the activities for each of them were identified in the literature, in terms of the depth and velocity of water runoff (Table 4.14).

Table 3.6 Water courses depth and height thresholds for different uses.

Antropic uses	Critical values (minimum))	Maximum)	Bibliography
	Depth (m)	Velocity (m/s.)	
Kayak/ canoe/ rafting	P_{min}: 0.1 – 0.2A P_{min}: 0.6B•C P_{min}: 0.2^{D}	$V_{máx}$: 4.5^{u}	A. Gordon and col. (2004) ~2004) : Rood and Tymensen (2001 : C: Rood and col. (2003) (2003) D: Mosley (1983)
Rowing/fording	$P_{máx}$: 1.2^{u}	V max: 1.8^{u}	
Fishing/fording	$P_{máx}$: 1.2^{u}	V max: 1.8^{u}	
Swimming	P_{min}: 0.8^{u}	v.: 1.0^{u}	
Snorkeling	P_{min}: 0.3^{u}	v.: 2.0^{u}	
Walks	$P_{máx}$: 1.2^{u}	V max: 1.8^{u}	
Fishing (boat)	P_{min}: 0.3^{u}	v.: 3.0^{u}	
Rowboat	P_{min}: 0.5^{u}	v.: 1.5^{u}	
Sailing boat	P_{min}: 0.8^{u}	v.: 0.5^{u}	
Motor boat (low power)	P_{min}: 0.6u	v.: 3.0^{u}	
Motor boat (high power)	P_{min}: 1.5^{u}	$V_{máx}$: 4.5^{u}	
Jet boating	P_{min}: 0.1 u	$V_{máx}$: 4.5^{u}	

Local residents who navigate on the Maipo River were interviewed at the same time, to determine the requirements and periods of river use.

5 ALTO MAIPO PROJECT RERSULTS OF RIVERS AND STREAMS HYDROBIOLOGICAL CHARACTERIZATION

5.1 MAIPO RIVER AREA

5.1.1 MAIPO MORPHOLOGICAL CHARCATERISTICS

The slope of the Maipo river between the discharge point in Las Lajas and upstream Volcán river is shown in Figure 5.1.1), with a variation ratio of 0.9 to 2.2 %. It has two different characteristics zones, in the upper part (34 and 38 Km) of this tranche mainly morphologies of waterfall type, with very encased sectors and strong currents, and its lower part (0 to 34 Km.) smoother slopes with predominance of morphologies of flat river bed and braided river types, this from the outlet of the Yeso river up to Las Lajas.

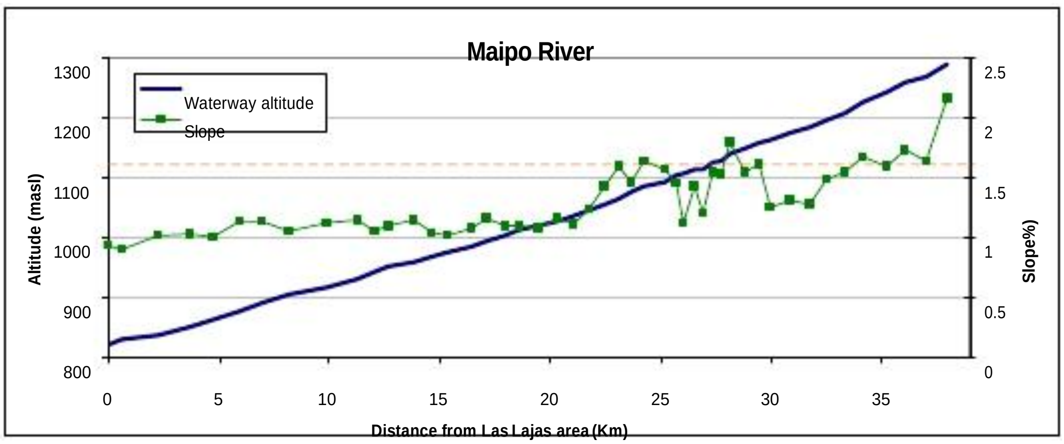

Figure 5.1.1 Longitudinal profile Maipo River (Between Las Lajas and upstream the Volcán River outlet)

The tranche between the outlet of the Volcán river up to the outlet of Yeso river, presents a morphology with rapids and waterfalls with scarce development of banks and beaches, therefore from minor to lower environmental importance. The Maipo river tranche between Yeso river and Las Lajas presents morphology of flat river bed and braided river which generates appropriate conditions for development of flora and aquatic fauna along the whole tranche.

5.1.2 MAIPO RIVER PHYSICAL-CHEMICAL QUALITY CHARACTERISTICS

For the Maipo river study, it was considered the subdivision of it in three tranches, mainly determined by the influence that the confluence might have with diverse feeders which discharge its waters. The first tranche defined give an account of the natural conditions of the Maipo river (from spring up to confluence with Volcán river), the second of the modifications of the properties due to the Volcán river waters (from confluence with Volcán river up to the confluence with Colorado river), and the final tranche, which is influenced by the entry of waters from Colorado river (from the confluence with Colorado river downstream).

5.1.2.1 From Maipo river spring up to the confluence with Volcán river.

The pH values obtained show the sector classified as moderately alkaline (Hounslow, 1995), with an average value of 8.1 units, and range of homogeneous variation which varies between 8.4 units maximum (winter 2008) and a minimum of 8 units, found in the four seasons of the year 2004.The mean average pH value obtained complies with the environmental standard (5.5 - 9.0 units; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987), which indicates that the resource has aptitude for irrigation and aquatic life (Table 5.1).

The electrical conductivity found in the upper sector of Maipo river, delivers an average value of 1087 uS/cm, with a variation range between 599 and 1608 uS/cm, (winter 2008 and autumn 2004, correspondingly). The values corresponding to electrical conductivity in this sector do not comply with the maximum values stipulated for water which generally detrimental effects are not observed on crops (≤750 uS/cm; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987) therefore the system does not have irrigation aptitude (Table 5.1).

With regards the dissolved oxygen parameter measured in the aquatic system, the average value was 9.9 mg/L, such value is above the minimum stipulated in the environmental standard (5.0 mg/L; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987) therefore the water resource has conditions for irrigation and aquatic life. The limit values found were 9.8 mg/L in summer 2004 and 10.1 mg/L in winter 2008 (Table 5.1). A relation between temperature and dissolved oxygen is recognized again, finding the highest values in winter mainly due to the inversely proportional ratio between them.

In the case of macro elements, represented by sulphates, the average value obtained is 224 mg/L (table 5.1), these values varied inconsistently between 97 mg/L (winter 2008) and 356 mg/L (autumn 2004).Yet, the average value recorded is under the maximum stipulated by the current environmental standard (250 mg/L; Official Chilean Standard 1.333, Note 78, INN-Chile,1987), complying with the requirements of irrigation water use.

Finally, for the measured parameter of total dissolved solids, it was registered only one value in the analysed area, which was obtained in the last measure done (winter 2008), with a value of 398 mg/L, which is within the standard values of the Chilean regulation 1.333 Note 78, 1987. Thus with regards this this parameter, the water resource in the area has irrigation aptitude.

5.1.2.2 From Volcán river confluence area up to confluence with Colorado river

The intermediate area of the Maipo river between the confluence with Volcán and Colorado rivers, presented homogeneous pH values between 8.3 and 8.4 units (both taken in winter 2008), with an average value of 8.4 units. These values show that the water resource is classified as moderate alkaline (Hounslow, 1995). The average value determined by the area of study is within the ratio demanded by the environmental standard (5.5 - 9.0 units; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987) therefore the water resource in both sectors has conditions for irrigation and aquatic life.

For electrical conductivity, the area presents an average of 1437 uS/cm, the highest value was found within the studied areas, with specific values varying between 1246 and 1603 uS/cm, both obtained in winter campaign 2008.This can be mainly because of the contribution by the Volcán river, which brings a high amount of total dissolved solids and high values of electrical conductivity. The average value does not comply with the maximum levels stipulated for water were damaging effects are not observed (≤750 uS/cm; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987) for irrigation use, having a classification as water that can have perjudicial effects in sensitive crops.

In the case of dissolved oxygen, homogeneous values could be found between samples, with an average value of 10.7 mg/L and a variation ratio varying between 10.7 and 10.8 mg/L, both values obtained in the winter campaign 2008, which show a favourable condition for biotic aquatic development. With regards the minimum values of dissolved oxygen demanded by the standard, the studied tranche complies with the value demanded in the environmental legislation (5.0 mg/L; Official Chilean Standard 1.333, Note 78, INN.Chile, 1987), which shows that the resource has aptitude for irrigation and aquatic life.

The sulphate values taken in the studied area, show a mean value of the measures of 246 mg/L, with a minimum value of 245 mg/L and a maximum value of 248 mg/L, both taken in winter 2008.The low ratio of dispersion of the data is mainly due to the low number of samples taken in this area for this parameter. This average value is under the environmental standard (250 mg/L; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987), complying with the requirements for irrigation water use.

In the case of total dissolved solids, values between 945 mg/L and 1056 mg/L were found, both values were obtained in winter 2008, and an with average value of 987 mg/L. This value is increased mainly due to the contribution of waters from the Volcán river, with contributions higher than the recorded in the first sector studied in the Maipo river. This average value does not comply with the maximum value of the environmental standard (500 mg/L), therefore its use, with regards this parameter, is not suitable for irrigation.

5.1.2.3 From Colorado River confluence downstream

The last area in study shows homogeneous pH values between them, with a variation ratio registered between 8.0 units in summer and autumn 2004 and 8.4 units obtained in spring 2006, with an average 8.2 units, value whereby the water resource in this tranche is classified as moderately alkaline (Hounslow 1995). This average value is in the ratio demanded by the environmental standard (5.5 - 9.0 units; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987), which shows that both systems presented physical-chemical conditions for irrigation use and aquatic life.

In the case of electrical conductivity, the average value of the specific samples registered was 1194 uS/cm, which were within the ratio given by 838 uS/cm (summer 2004) as minimum value, and 1439 uS/cm (winter 2008) as maximum value. There is a low decrease in the sector regarding the tranche immediately previous to the area of the study, therefore waters of the Colorado river would contribute to decrease the electrical conductivity values, with a dilution phenomenon or by a salt precipitation process due to an increase of the ionic force.These values were higher to the maximum values demanded by the environmental standard (≤750 uS/cm; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987), so that the water resource of the analysed sector is not suitable for irrigation use.

The dissolved oxygen showed favourable conditions for development of aquatic life with an average value of 10.7 mg/L , an a minimum value 9.5 mg/L registered in spring 2006 campaign, and a maximum of 11.9 mg/L in winter 2008. These values were similar to the previously analysed tranche, therefore the Colorado river does not affect the aerobic condition typical of Maipo river. With regards the minimum values of dissolved oxygen demanded by the standard, the studied tranche complies with the standard value of the environmental legislation (5.0 mg/L; Official Chilean Standard 1.333, Note 78, INN.Chile, 1987), which shows that the resource has aptitude for irrigation and aquatic life.

For the sulphate parameter, the values found in the diverse samples varied between 59 and 361 mg/L, found in the samples from spring 2006 and autumn 2004, correspondingly. The mean value calculated between all the registered measures is 241 mg/L, value within the maximum limit permitted by the current environmental standard of 250 mg/L (Official Chilean Standard 1.333, Note 78, INN-Chile, 1987).

The total dissolved solids reveal a mean value of 776 mg/L, a minimum value of 631 mg/L obtained in spring 2006 and a maximum value of 881 mg/L registered in winter 2008.These values are slightly lower to those registered in the immediately previous to the area studied, confirming the dilution factor which adds the entry of waters from Colorado river towards the Maipo river waterway. The mean value calculated for this parameter is above the maximum regulated in the environmental regulation (500 mg/L; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987).

Table 5.1 Physical-chemical characteristics of the influence area of PHAM

Area	Parameter	unit	Min.	Aver.	Max.	Ch.Std. 1.333 Irrigation		Ch.Std. 1.333 Aquatic Life		Ch.Std. 1.333 Leisure and Aesthetic		Secondary standard preliminary plan for the environmental quality protection of the Maipo river basin		Clasiffication as per CONAMA (1)
						Limit Value	Complies with	Limit Value	Complies with	Limit Value	Complies with	Limit Value	Complies with	
El Morado Stream	CE	µS/cm	730	931	987	≤ 750**	x	-	-	-	-	-	-	Type 2
	O_2	mg/L	8.7	10.2	11.7	-	-	5,0*	√	-	-	-	-	Type of Exception
	pH	unit	8.4	8.5	8.7	5,5-9,0	√	6,0-9,0	√	8.3	x	-	-	Type of Exception
	SO_4^{-2}	mg/L	83	250	417	250	√	-	-	-	-	-	-	Type 2
	STD	mg/L	610	618	626	500	x	-	-	-	-	-	-	Type 2
	Faecal coliforms	NMP/100mL	-	1	-	1000	√			1000	√	-	-	Type of Exception
	Total coliforms	NMP/100mL	-	2	-	-	-	-	-	-	-	-	-	Type of Exception
Las Placas River	CE	µS/cm	-	-	-	≤ 750	-	-	-	-	-	-	-	-
	O_2	mg/L	-	-	-	-	-	5,0*	-	-	-	-	-	-
	pH	unit	-	-	-	5,5-9,0	-	6,0-9,0	-	8.3	-	-	-	-
	SO_4^{-2}	mg/L	-	-	-	250	-	-	-	-	-	-	-	-
	STD	mg/L	-	-	-	500	-	-	-	-	-	-	-	-
	Faecal coliforms	NMP/100mL	-	-	-	1000	-		-	1000	-	-	-	-
	Total coliforms	NMP/100mL	-	-	-	-	-	-	-	-	-	-	-	-
Colina Stream	CE	µS/cm	325	703	1290	≤ 750**	√	-	-	-	-	195	x	Type 1
	O_2	mg/L	7.5	9.4	11.7	-	-	5,0*	√	-	-	8.9	√	Type of Exception
	pH	unit	8.4	8.5	8.5	5,5-9,0	√	6,0-9,0	√	8.3	x	6,5-8,1	x	Type of Exception
	SO_4^{-2}	mg/L	142	149	155	250	√	-		-		26	x	Type 1
	STD	mg/L	299	653	1212	500	x	-		-		-	-	Type 2
	Faecal coliforms	NMP/100mL	-	1	-	1000	√			1000	√	1.000	√	Type of Exception
	Total coliforms	NMP/100mL	-	7	-	-	-	-	-	-	-	2.000	√	Type of Exception
Engorda Stream	CE	µS/cm	624	788	1002	≤ 750**	x	-	-	-	-	-	-	Type 2
	O_2	mg/L	7.9	8.9	9.7	-	-	5,0*	√	-	-	-	-	Type of Exception
	pH	unit	6.7	7.2	8.6	5,5-9,0	√	6,0-9,0	√	8.3	√	-	-	Type of Exception
	SO_4^{-2}	mg/L	77	206	332	250	√	-		-		-	-	Type 2
	STD	mg/L	530	662	779	500	x	-		-		-	-	Type 2
	Faecal coliforms	NMP/100mL	1	1	1	1000	√			1000	√	-	-	Type of Exception
	Total coliforms	NMP/100mL	1	1	1	-	-	-	-	-	-	-	-	Type of Exception
Volcán River	CE	µS/cm	794.3	1374	1670	≤ 750**	x	-	-	-	-	1245	x	Type 2
	O_2	mg/L	8.5	10.4	11.7	-		5,0*	√	-		9.0	√	Type of Exception
	pH	unit	7.7	8.2	8.4	5,5-9,0	√	6,0-9,0	√	8.3	√	6,5-8,1	x	Type of Exception
	SO_4^{-2}	mg/L	110	307	635	250	x	-		-		330	√	Type 2
	STD	mg/L	902	983	1091	500	x	-		-		-	-	Type 2
	Faecal coliforms	NMP/100mL	1	1.2	2	1000	√			1000	√	100	√	Type of Exception
	Total coliforms	NMP/100mL	10	19	28	-	-	-	-	-	-	200	√	Type of Exception
Maipo River before confluence with Volcán River	CE	µS/cm	599	1087	1608	≤ 750**	x	-	-	-	-	1574	√	Type 2
	O_2	mg/L	9.8	9.9	10.1	-	-	5,0*	-	-	-	9.9	√	Type of Exception
	pH	unit	8	8.1	8.4	5,5-9,0	√	6,0-9,0	√	8.3	√	6,5-8,5	√	Type of Exception
	SO_4^{-2}	mg/L	91	224	355.8	250	√	-		-		356	√	Type 2
	STD	mg/L	-	398	-	500	√	-		-		-	-	Type of Exception
	Faecal coliforms	NMP/100mL	-	6	-	1000	√			1000	√	1.000	√	Type of Exception
	Total coliforms	NMP/100mL	-	78	-	-	-	-	-	-	-	2.000	√	Type of Exception
El Yeso River	CE	µS/cm	325	832	1086	≤ 750**	x	-	-	-	-	1066	√	Type 2
	O_2	mg/L	8.6	10.1	11	-	-	5,0*	√	-	-	10	√	Type of Exception
	pH	unit	7.8	8.4	10	5,5-9,0	√	6,0-9,0	√	8.3	x	6,5-8,3	x	Type of Exception
	SO_4^{-2}	mg/L	105.5	286	370	250	x	-		-		304	√	Type 2
	STD	mg/L	589	700	834	500	x	-		-		-	-	Type 2
	Faecal coliforms	NMP/100mL	1	1	1	1000	√			1000	√	100	√	Type of Exception
	Total coliforms	NMP/100mL	1	19	46	-	-	-	-	-	-	200	√	Type of Exception
Colorado River	CE	µS/cm	682	967	1159	≤ 750**	x	-	-	-	-	1152	√	Type 2
	O_2	mg/L	9.3	11.1	12.2	-	-	5,0*	√	-	-	11	√	Type of Exception
	pH	unit	7.8	8.3	8.5	5,5-9,0	√	6,0-9,0	√	8.3	√	6,5-8,0	x	Type of Exception
	SO_4^{-2}	mg/L	8	221	360.5	250	√	-		-		361	√	Type 2
	STD	mg/L	132	605	792	500	x	-		-		-	-	Type 2
	Faecal coliforms	NMP/100mL	2	70	304	1000	√			1000	√	1.000	√	Type 1
	Total coliforms	NMP/100mL	65	227	437	-	-	-	-	-	-	2.000	√	Type 1
Maipo River from confluence with Volcán River up to confluence with Colorado River	CE	µS/cm	1246.3	1437	1603	≤ 750**	x	-	-	-	-	1382	x	Type 2
	O_2	mg/L	10.7	10.7	10.8	-	-	5,0*	√	-	-	10.4	√	Type of Exception
	pH	unit	8.3	8.4	8.4	5,5-9,0	√	6,0-9,0	√	8.3	x	6,5-8,1	x	Type of Exception
	SO_4^{-2}	mg/L	245	246	248	250	√	-		-		361	√	Type 2
	STD	mg/L	945.2443694	987	1056	500	x	-		-		-	-	Type 2
	Faecal coliforms	NMP/100mL	80	240	333	1000	√			1000	√	1.000	√	Type 1
	Total coliforms	NMP/100mL	317	716	1414	-	-	-	-	-	-	2.000	√	Type 1
Maipo River from confluence with Colorado River downstream	CE	µS/cm	837.8	1194	1439	≤ 750**	x	-	-	-	-	1333	√	Type 2
	O_2	mg/L	9.5	10.7	11.91	-	-	5,0*	√	-	-	9.4	√	Type of Exception
	pH	unit	8.0	8.2	8.4	5,5-9,0	√	6,0-9,0	√	8.3	√	6,5-8,1	x	Type of Exception
	SO_4^{-2}	mg/L	59	241	361.2	250	√	-		-		355	√	Type 2
	STD	mg/L	631	776	881	500	x	-		-		-	-	Type 2
	Faecal coliforms	NMP/100mL	12	178	345	1000	√			1000	√	1.000	√	Type 1
	Total coliforms	NMP/100mL	649	1191	1733	-	-	-	-	-	-	2.000	√	Type 1

**Water that usually detrimental effects are not seen

* Minimum value as requirement to comply with the standard

(1) CONAMA guideline for the establishment of secondary standards of environmental quality on continental waters; Type 1=Very good quality; Type 2=Good quality; Type 3=Regular quality.

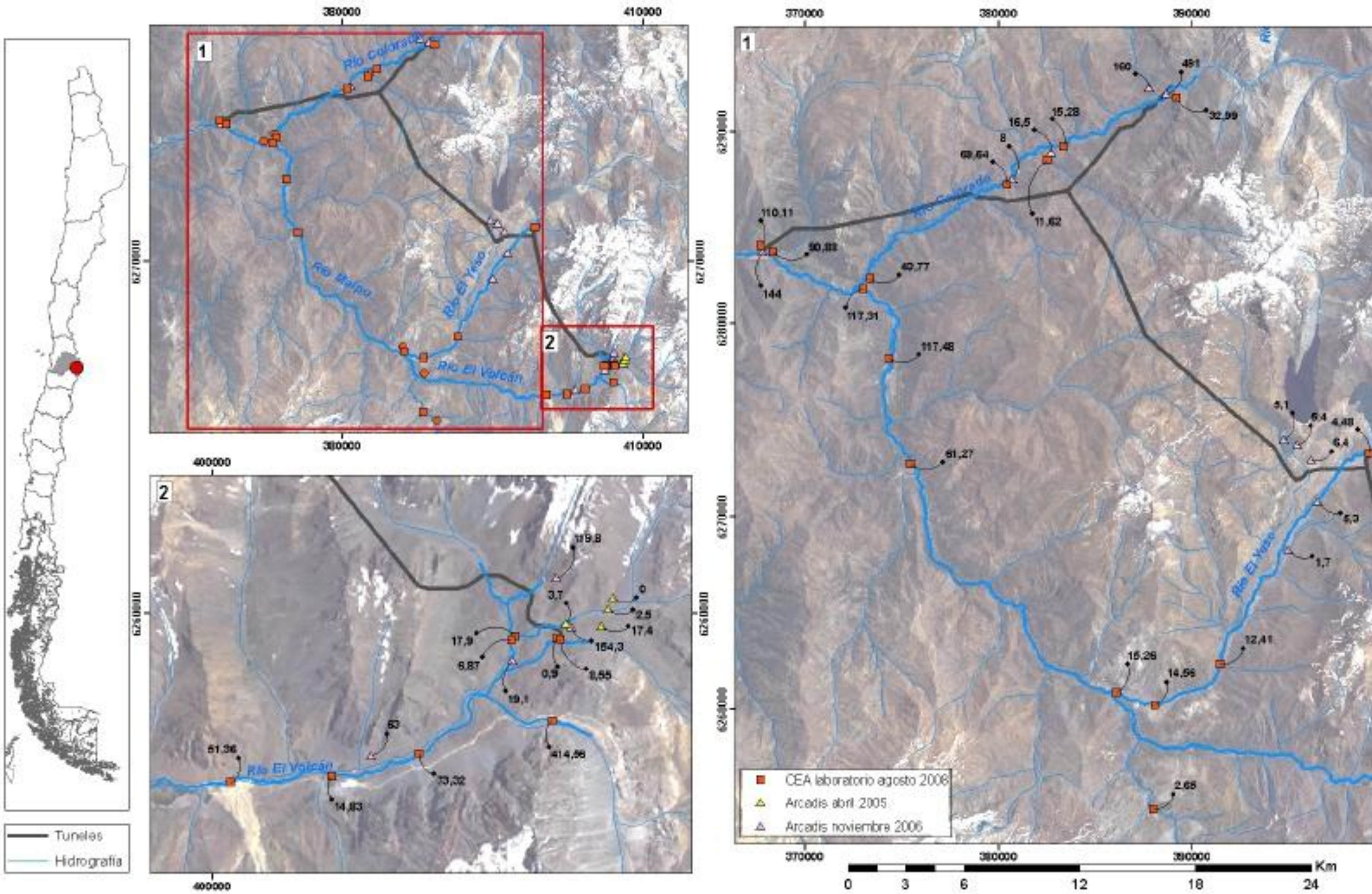

Figure 5.1.2.1 Total Suspended Solids (STS)

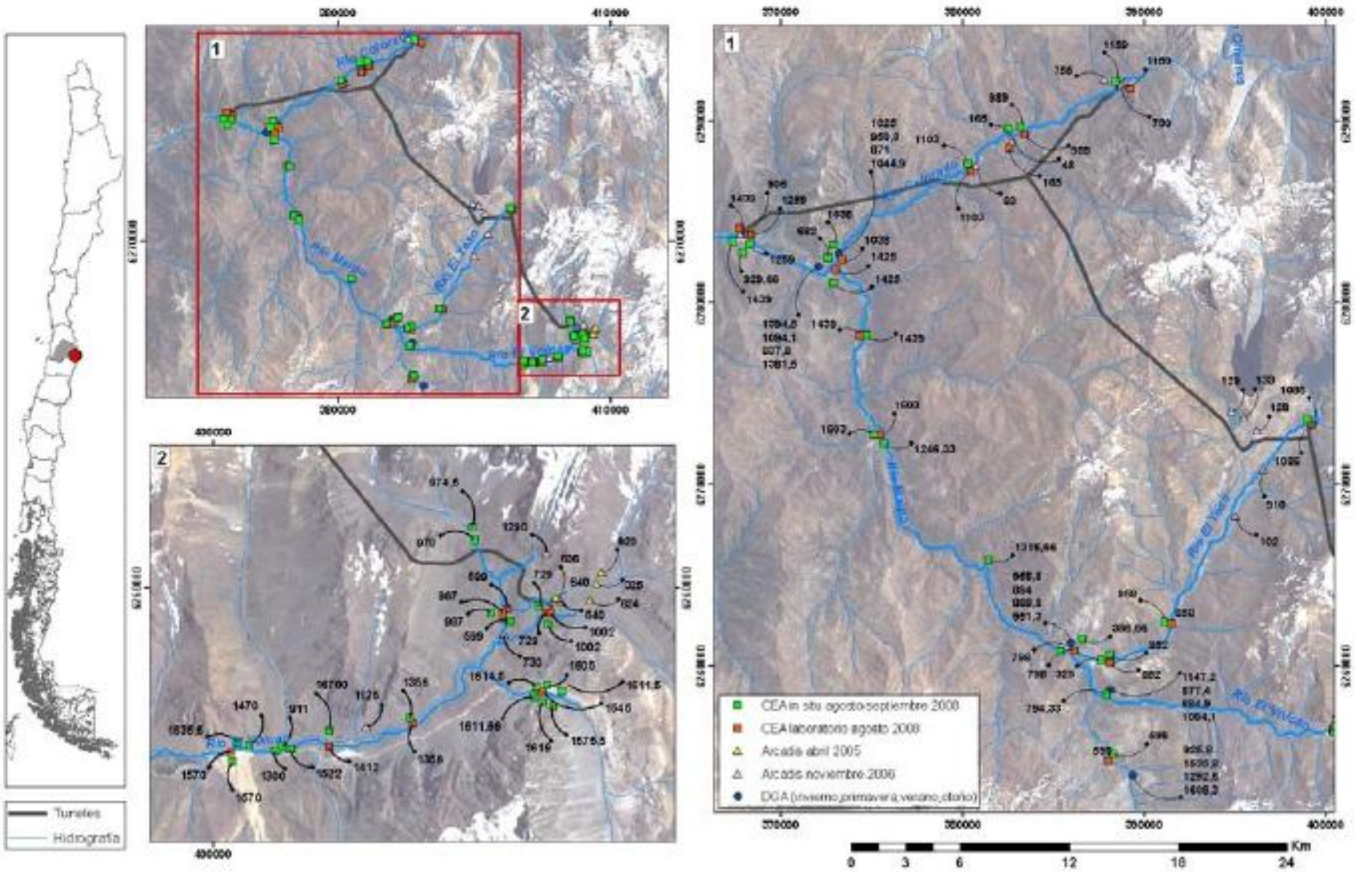

Figure 5.1.2.2 Conductivity (uS/cm)

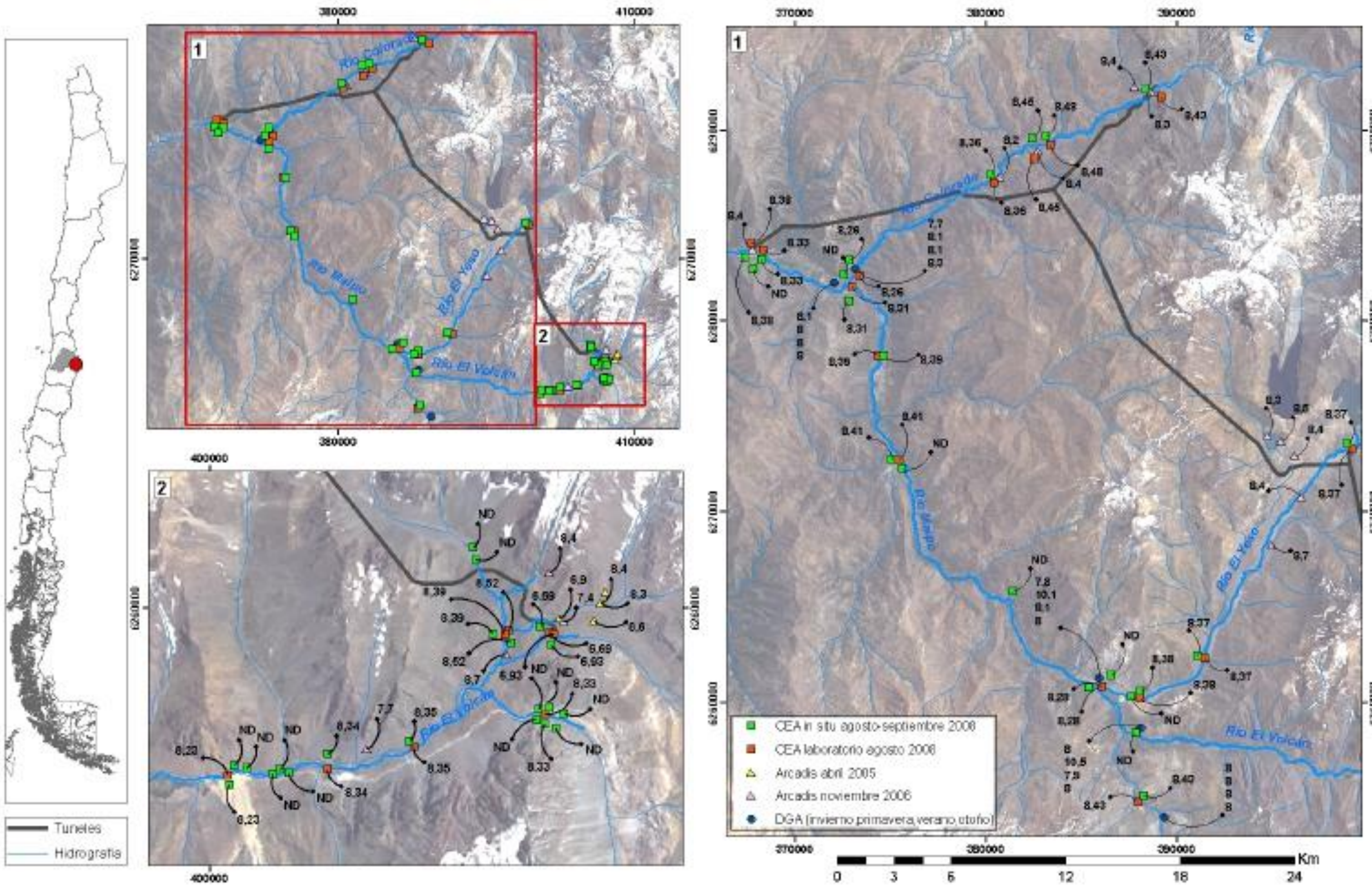

Figure 5.1.2.3 pH

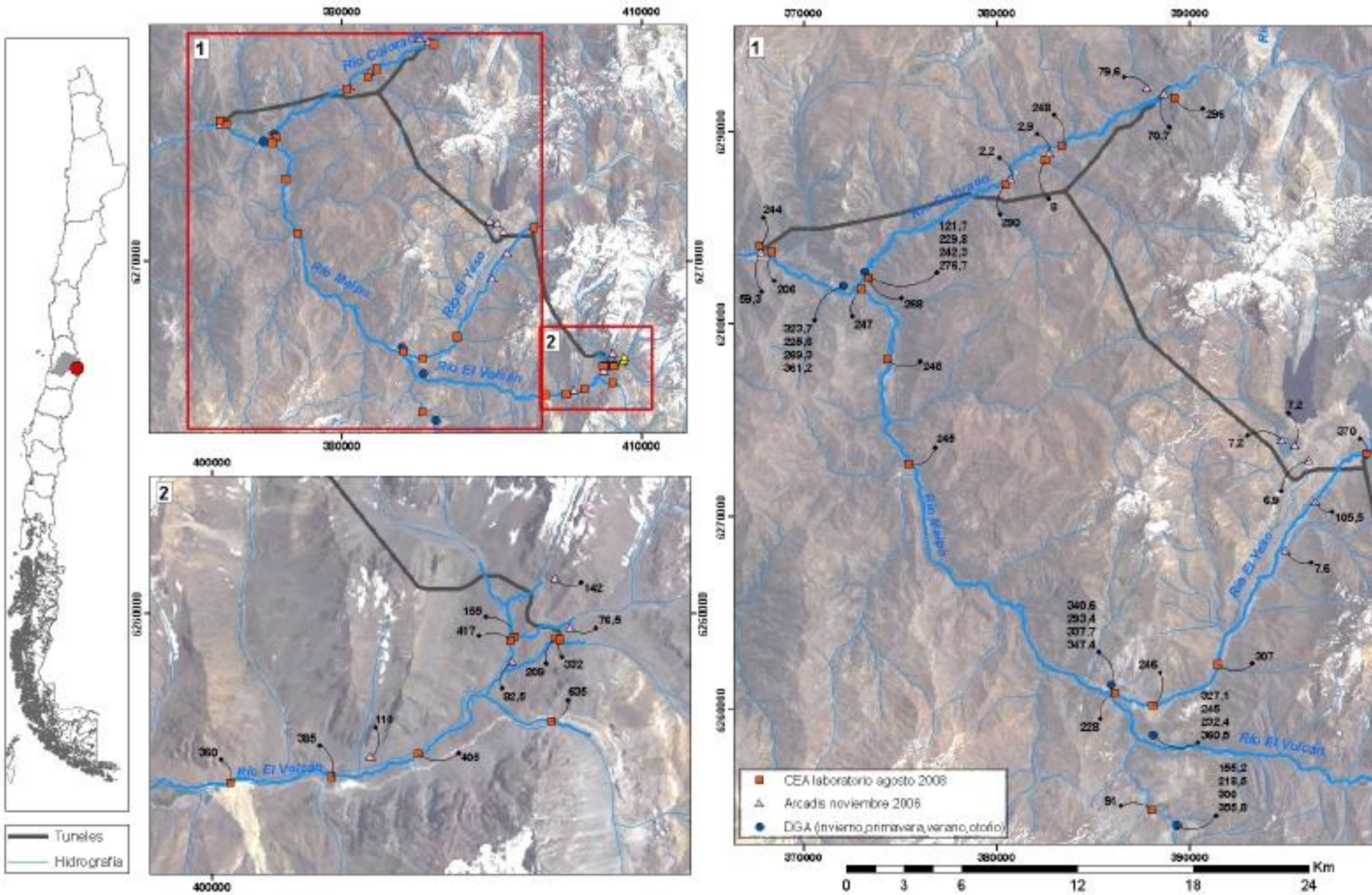

Figure 5.1.2.4 Sulphates mg/L

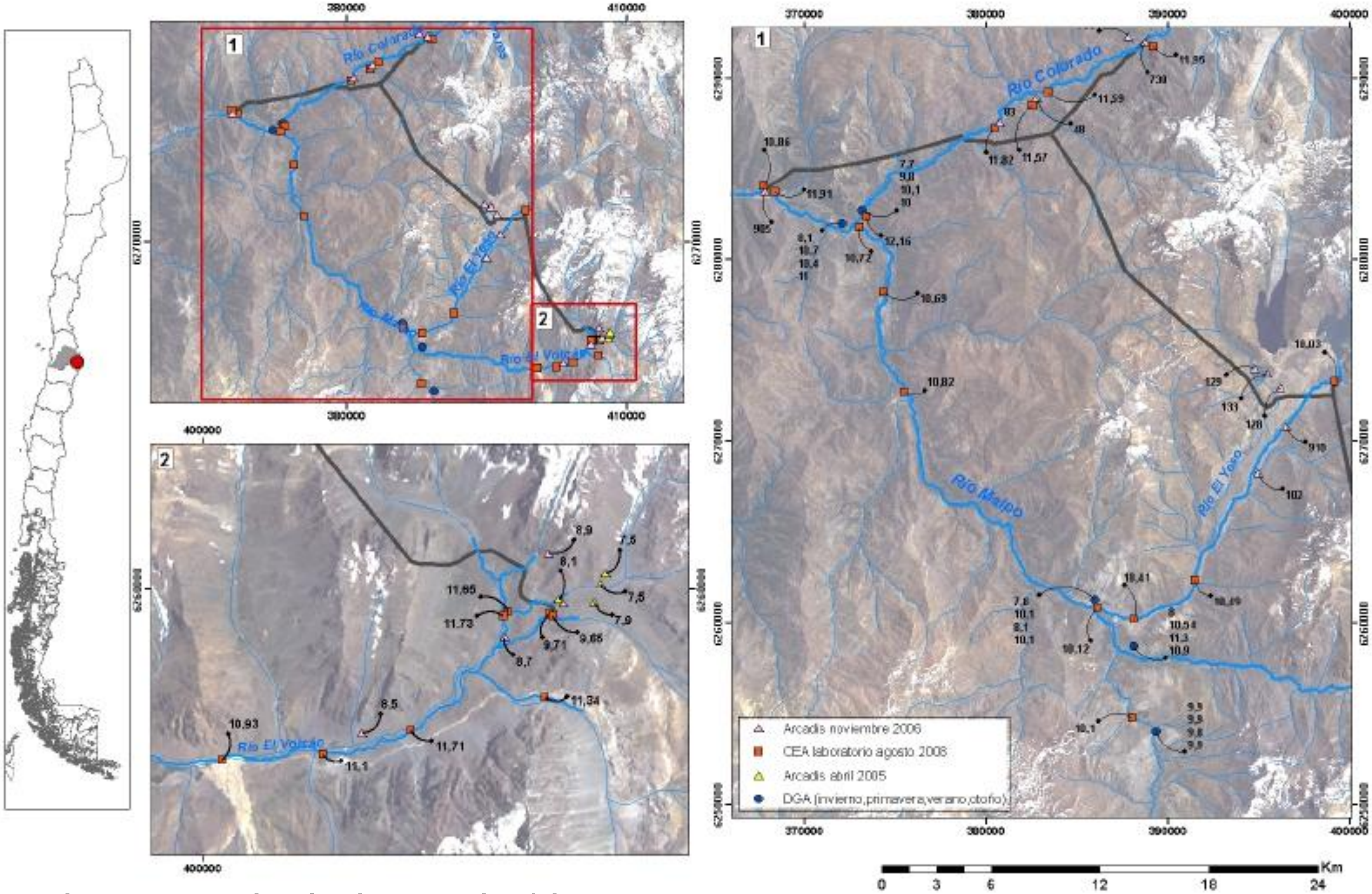

Figure 5.1.2.5 Dissolved oxygen (mg/L)

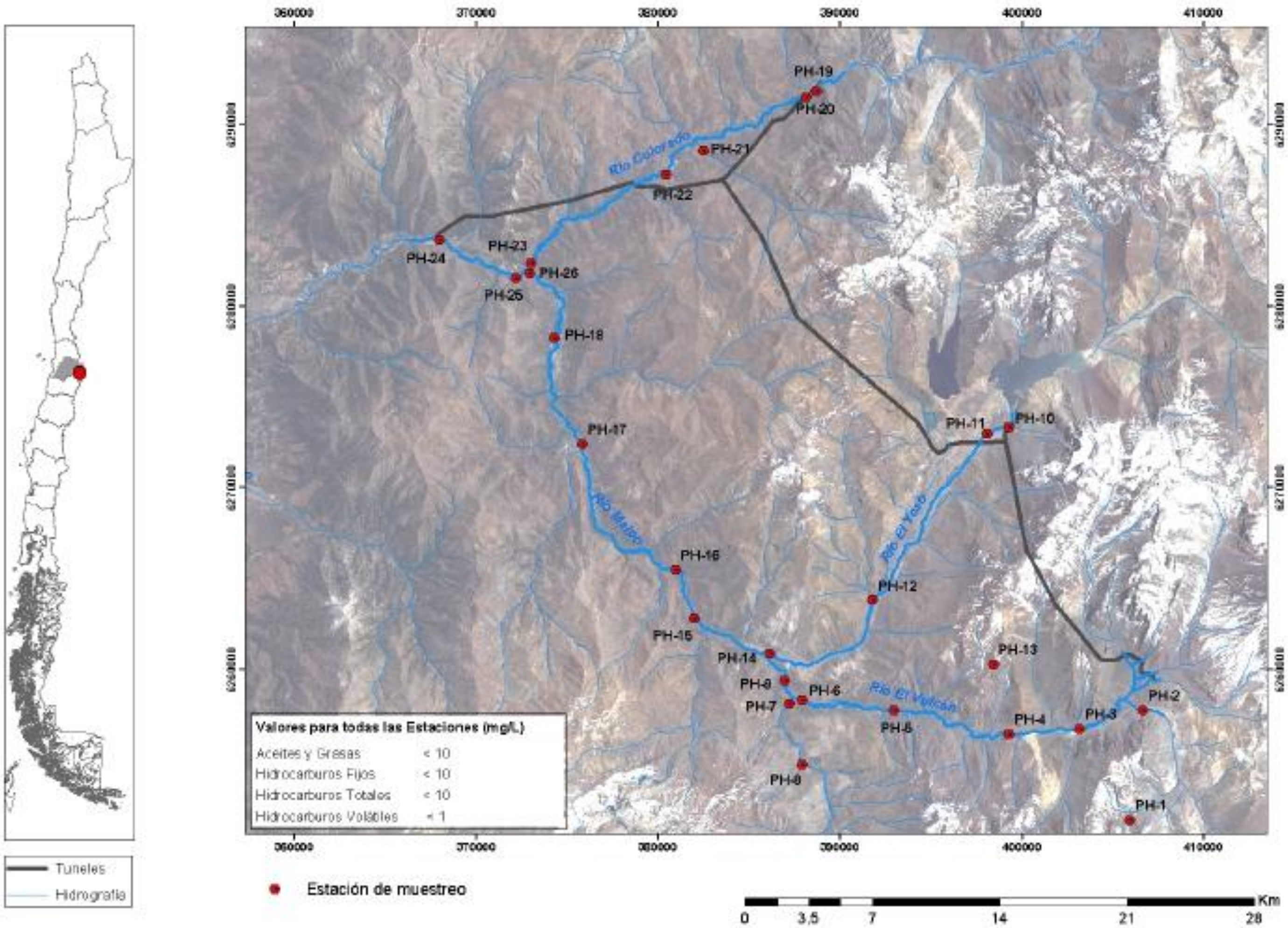

Figure 5.1.2.6 Total Hydrocarbon, Fixed, Volatiles, Fats and Oils

5.1.3 BIOLOGICAL CHARCATERISTICS MAIPO

5.1.3.1 Phytobenthos

Diversity

In the Maipo river area, 16 phytobenthic diatomaceous species were detected, presenting an average of richness of five species. The species richness per sampling station varied between one species at station 10 (downstream El Toyo bridge) and 10 species at station 23 (Las Melosas Sector, Figure 5.1.3.1a). With regards Shannon's diversity, a lower diversity was observed in station 10 with 0.00 bits, while station 23 presented the greatest diversity with 2.86 bits (Figure 5.1.3.1b and Table 5.1.3.1).

Abundance

With regards the total abundance, this parameter presented an average of 1.477 cel/mm 2 in the sector, with extreme values between 77 and 5.260 cel/mm2 in stations 8 and 6 (before Las Lajas discharge, downstream Colorado outlet) respectably (Figure 5.1.3.2). The relative abundance illustrated in the theme map showed variabilities in the dominances, being relevant in Maipo river the *Cymbella helvetica, Diatoma moniliformis, Navicula gregaria, Nitzschia dissipata* and *Reimeria sinuata* (Figure 5.1.3.3).

Community Analysis

The community analysis done through MDS (non metric multidimensional scaling) at a cut level of 50%, did not show similarities between the monitored stations (Figure 5.1.4.1).

5.1.3.2 Phytoplankton

Diversity

In the Maipo river area, 32 phytoplankton micro algae were detected, presenting an average of richness of 10 species. The species richness per sampling station varied between three species at station 23 (Las Melosas area) and 20 species in station 6 (before Las Lajas discharge, downstream Colorado outlet, Figure 5.1.3.5a). With regards Shannon's diversity, a lower diversity was observed in station 23 with 1.13 bits, while station 6 presented the greatest diversity with 3.47 bits (Figure 5.1.3.5b and Table 5.1.3.2).

Abundance

With regards the total abundance, this parameter presented an average of 119 cel/L in the sector, with extreme values between 12 and 347 cel/L in stations 7 (before Las Lajas discharge, downstream Colorado outlet) and 6 respectably (Figure 5.1.3.6). The relative abundance illustrated in the theme map showed variability in the dominances, being relevant in Maipo river the *Achnanthidium minutissimum*, *Navicula viridula*, *Fragilaria capucina* var. *vaucheriae* and *Diatoma moniliformis* (Figure 5.1.3.7).

Community Analysis

The community analysis done through MDS (non metric multidimensional scaling) at a cut level of 50%, did not show similarities between the monitored stations (Figure 5.1.4.2).

5.1.3.3 Zoobenthos
Diversity

As it is observed in Table 5.1.3.3 and Figure 5.1.3.9a, the richness of the species per station is still poor, where the minimum registered corresponded to stations 8 (before the outlet of Colorado river) and station 23 (Las Melosas area) both with taxon 1, and the maximum at station 10 (downstream El Toyo bridge) with taxa 4. In terms of Shannon's diversity (Table 5.1.3.3 and Figure 5.1.3.9b), in this sector the maximum registered at station 6 (before Las Lajas outlet) with 0.91 bits and minimum of 0.41 bits for station 7 (after Las Lajas discharge, downstream the Colorado river outlet).

Abundance

Differences of abundance were seen between stations and mainly downstream Alfalfal bridge area and Las Melosas sector. The average value of this parameter was 122 ind/m2 ± 120, the maximum value registered was at station 7 (after Las Lajas discharge, downstream the Colorado river outlet), with 328 ind/m2 and the minimum was seen in two stations, 6 (before Las Lajas discharge) and 23 (Las Melosas area), with 17 ind/m2 respectively (Table 5.1.3.3 y Figure 5.1.3.10).

In relation to the dominant taxa (relative abundance) per station, the ones obtaining the greatest percentage representation (above 10%) with regards the total individuals collected in the different assessed sectors, in Figure 5.1.3.11 is seen with more details the dominance of the taxa in each of the sampling stations. It is observed that the group with greatest dominance, as well as the other three sectors Volcán, Yeso and Colorado, corresponded to the dipterous nature dominating the orthocladiinae under-family, with percentages varying between 81% and 100%. At station 6 (before Las Lajas discharge), the ephemeropterous nature with *Andesiops* sp. was registered with 33%.

Community Analysis

The multidimensional scaling (MDS) carried out in the sampling stations, using total abundance (Ind/m2), showed in this opportunity, the formation of three conglomerates mainly given by the diversity and abundance found in such stations. The first conglomerate is formed at station 7 (after Las Lajas discharge, downstream the Colorado river outlet) and 10 (downstream El Toyo bridge) where the Orthocladiinae under-family is predominant, the second one at station 8 (before the Colorado river outlet) and 9 (San José town side) with dominance of dipterous nature and the last one with station 6 (before Las Lajas discharge) and 23 (Las Melosas sector) with similar taxa as ephemeropterous and dipterous. (Figure 5.1.4.3). For this seasonal campaign, the similarities between each one of the stations was only higher to 50% for the formed conglomerates.

5.1.3.4 Zooplankton

Diversity

The taxonomic richness of the present zooplankton in the Maipo river area was the lowest compared to the other three sectors assessed, registering four taxa. The average value of the taxonomic richness for this sector was only of two taxa. The maximum taxonomic richness corresponded to three taxa and it was registered at stations 6 and 7 (downstream the Colorado river outlet) and at stations 8 (before the Colorado river outlet). Station 10 presented a value of two taxa, while at stations 9 and 23, registered the minimum value with presence of only one taxon (Figure 5.1.3.13a and Table 5.1.3.4).

For the Maipo river area, Shannon's diversity index (H') presented an average value of 0.8 bits. The maximum diversity was registered at stations 7 and 8 with 1.4 bits, while the minimum value of 0.9 bits was presented at station 10. Stations with only one taxon presented a diversity value of 0.0 bits (Figure 5.1.3.13b).

Abundance

The abundance values registered in this sector were the lowest compared to the other analysed sectors. The average value reached was 4,2 ind/m3. The maximum abundance registered was present at station 6 reaching a value of 8,5 ind/m3 and the minimum value was found at station 9 where it was registered 0,3 ind/m3 (Figure 5.1.3.14).

The most abundant group in the Maipo river sector was insects, with only one representative which corresponded to a Chironomidae and an abundance value equal to 12,1 ind/m3. Besides, this taxa was present in five of six stations corresponding to this sector. The taxonomic groups following in terms of importance were the nematode and oligochaeta with a total of 5,6 ind/m3 y 5,5 ind/m3, respectively.

In Figure 5.1.3.15, it is observed a great dominance of the insects group in most of the stations, being the most important in stations 9 and 23, where it reaches 100% of representativeness. In stations 7 and 10 the dominance is marked by the oligochaeta taxa.

CommunityAnalysis

In Figure 5.1.4.4, which shows the analysis of similarities between the stations belonging to the Maipo river area, obtained through the multidimensional scaling (MDS) method, is possible to identify a group with similar percentages over 50% which was part of stations 6 and 8. Stations 6 and 8 show a similar zooplankton composition, as well as the total abundance values, which will justify its grouping.

5.1.3.5 Ichthyofauna
Diversity

The ichthyofauna collection in the Maipo river area described the most diverse ichthyofauna between the sectors, since the total of species of the whole assessed area described three fish species, the native: *Trichomycterus areolatus* (Small catfish) and the introduced: *Salmo trutta* (brown Trout) and *Oncorhynchus mykiss* (rainbow Trout). As it has been already described, the T. areolatus species presented a conservation category corresponding to "Vulnerable" in the area of study, while the introduced species do not present a conservation category in Chile because this qualification has been only developed for native species (Campos et al.1998, CONAMA 2008). On the other hand, at worldwide scale, none of the species, both native and introduced ones, are included in the red list of threatened species by IUCN at worldwide level (www.iucn.org).

In the area, a ratio of values was described between absence and two fish species, the minimum described at stations 7 and 23 and the maximum at stations 8, 9 and 10 (Figure 5.1.3.17).

Abundance

For the Maipo river area, the fish caught reached a total of 11 fish specimens, being the *T. areolatus and O. mykiss* the most abundant ones, both presented five specimens, so each one represents a 45.5% of the total ichthyofauna in the area, the 9% left (1 specimen) corresponded to *S. trutta*. Between stations there were two which presented zero collection, stations 7 and 23, while there were three stations with a maximum collection of two specimens, stations 8, 9 and 10 (Figure 5.1.3.18). In terms of relative abundance of the species in the stations, as is shown in Figure 3 (Theme Map) illustrates station 6 as the only station where absolute dominance in terms of abundance is described by some specimens, in this case *T. areolatus* with a relative abundance of 100%. On the other hand, the remaining stations with presence of fish, co-dominance was observed in fish abundance for each one of them, at station 8 with 50% for S. trutta and O. mykiss species, and at stations 9 and 10 with relative abundance over 30% for *T. areolatus* and *O. mykiss* species.

Community Analysis

The non-metric multidimensional scaling (MDS) analysis identified only one group of stations with similarity percentages over 50% (Figure 5.1.4.5), which corresponds to stations 6, 9 and 10 which were mainly determined by the presence of T. areolatus in an elevated proportion of these stations (Figure 5.1.3.19). The remaining station with fish presence, station 8, was separated from the rest of the stations with a lower similarity at 50% due to this station was the only one in the sector which included S. trutta as one of the most abundant species.The rest of the stations without fish presence, do not contribute the spatial variability of the stations because of the ichthyofauna and therefore, they were not included in the similarity analysis. The stress coefficient of the MDS was 0.0 showing that at one level, the planning is excellent.

Condition and sexual reason factors

Table 5.1.3.5 summarizes the morphometry analysis of fish in terms of their total length, total weight and gutting, as well as the condition factors (K and K gutting), sex and gonadal development of the caught specimens. Table 5.1.3.6, summarizes the average condition factors (K) of the species per station and within the assessed sectors, describing the sexual reason of the specimens per sector. As this last table describes, for the Maipo river area, the average condition factor of *T. areolatus* showed a relatively wide value, with a K = 4.31 minimum at station 9 and a maximum K = 8.95 at station 2, with differences that, nevertheless, were not statistically significant (Kruskal-Wallis: H (2, 5) =3,600, p = 0,17). For the total sector of the condition factor of *T. areolatus* reached an average value of K = 6.66 which corresponds to the "thinnest" species of the area. Whereas the *S. trutta,* the only specimen caught at station 8 showed a condition factor of K = 9.60. On the other hand, in *O. Mykiss*, the condition factor showed a relatively narrow range of values with a minimum of K = 10.64 at station 8 and a maximum of K = 12.19 at station 10. Although, these last differences could not be statistically assessed because only at station 10, the average condition factor was estimated based on more than one specimen. The average condition factor for the total sector was K = 11.75, which characterizes it as the "strongest" species of the sector.

With regards the sexual reason of the species in the area, none of them had a number expression in this index (Table 5.1.3.6), because in *T. areolatus* all the specimens caught that could be analysed with regards its sex were undetermined juveniles (IND) (Table 5.1.3.5), while *S. trutta* and *O. Mykiss,* sex of the specimens in one of the analysed specimens could be determined, in both cases was only a male one (Table 5.1.3.6).

Diet Analysis

The detail of the items included on the fish diet of the area is summarized in Table 5.1.3.7, while in Figure 5.1.3.20 the relevant items of the fish diet are summarized (>5%). In the Maipo river sector, as it can be see in Table 5.1.3.6 and Figure 5.1.3.20, the diet of the specimens was mainly made of native origin material typical of the aquatic system, constituting 100% of the diet in the case for *T. areolatus* and *S. trutta* and a 90.2% in the case of *O. mykiss*. As it is observed in Figure 5.1.3.20, the main feed item of the diet of all species was the *Chironomidae dipterous*, specially in the case of *T. areolatus* where this item represented 100% of the diet, while in the rest of the species it represented more than 50%. In *S. trutta* and *O. mykiss* were also important in the diet the *Hydropsychidae trichopterous*, which represented more than 20% of the diet of these species in the Maipo area.

5.1.3.6 Conclusions

The phytobenthos of the Maipo river were characterized by the variability in the dominances, standing out the species *Cymbella helvetica, Diatoma moniliformis, Navicula gregaria, Nitzschia dissipata* and *Reimeria sinuata*. Within the river, important was the Las Melosas area where it was observed with the greatest richness and diversity, before Las Lajas discharge, downstream Colorado outlet with the greatest abundance. On the other hand, similarities with regards the species composition and total abundance was not observed in the area. In relation to the historical background, it presented the greatest richness with regards the observed in the upper part of the Maipo basin.

The phytobenthos of the Maipo river were characterized by presenting differences in the dominances, standing out the species *Achnanthidium minutissimum, Navicula viridula, Fragilaria capucina var. vaucheriae and Diatoma moniliformis.* Within the river, important was the zone before Las Lajas discharge, downstream Colorado outlet where was observed the greatest richness, diversity and abundance. On the other hand, similarities with regards the species composition and total abundance for the monitored stations were not observed in the area. Historical background for planktonic micro-algae in the upper part of the Maipo basin were not observed.

The biological parameters assessed for zoobenthos of the Maipo river area registered the lowest values compared to the other three analysed sectors. Its taxonomic richness, diversity and abundance obtained very poor values, especially at station 8 (before the Colorado river outlet) and station 23 (Las Melosas area). The richness found corresponded to station 10 (downstream El Toyo bridge) and the highest abundance at station 7 (after the Las Lajas discharge, downstream the Colorado river outlet). In terms of the community analysis, three groups were obtained, the first one is comprised by station 7 (after Las Lajas discharge, downstream the Colorado river outlet) and 10 (downstream El Toyo bridge), the second group stations 9 (San José de Maipo town side) and 8 (before the Colorado river outlet), and the third group with stations 6 and 23, its similarities are based in the presence of the *orthocladiinae* under-family and other *dipterous*, at greater or lower degree of abundance. These taxonomic groups have been described in different tasks (JICA, 2003, López 2004 and CEA 2008).

The community parameters assessed for zooplankton of the Maipo river area, presented the lowest values compared to the other three assessed sectors. Thus, the taxonomic richness, the total abundance and the diversity registered in this sector presented decreased values, especially at stations 9 and 23. The first of them is located near San José de Maipo town and the second one in Las Melosas area before the junction with Volcán river. Stations 6 and 8 presented the highest values of abundance and richness thus, presented more similarity with regards other stations of this sector. In this sector the most abundant and representative group was the *Chironomidae*, which was present in 5 of the 6 assessed stations.The *oligochaeta* and *nematode* taxa followed in terms of importance.

The ichthyofauna of the Maipo river area was described as the most diverse of the area, where three species of fish were described, the native: *Trichomycterus areolatus* and the introduced: *Salmo trutta* and *Oncorhynchus mykiss*.The native species was the only one with problems of conservation in the area, with "Vulnerable" category.

The *T. areolatus* and *O. mykiss* species were the most abundant in the whole sector, standing out the *T. areolatus* especially at station 6 where dominated 100% of the relative abundance.

S. trutta was the least conspicuous species of the sector, which was only detected at station 8, which determined that this station was the most different in terms of its composition of species and the community analysis. The ichthic richness and the abundance of the fish out of all the stations was low, at stations 8, 9 and 10 presenting a maximum of two species and at station10 with a maximum of 5 caught specimens.

The analysis of the condition factor (K) described the *T. areolatus* species as the "thinnest" of the area and the *O. mykiss* as the "strongest". In *T. areolatus*, the only species where it was able to compare the K between stations, relevant differences for the fish in it could not be described.

The sex analysis of the specimens was poorly informed, because most of the specimens that were able to be analysed were undetermined immature individuals, describing only the presence of one male specimen in the case of *S. trutta* and *O. mykiss* species, therefore the sexual reason did not present a number value in any of the species of the area. The fish diet was mainly based on the native items or typical from the aquatic ecosystem, within those, were specially highlighted the *Chironomidae dipterous* with a 100% of the diet in *T. areolatus*, and more than 50% of the *S. trutta* and *O.mykiss* diet.

For the under basin of the Maipo river, the previous background studies (Table 5.1.3.9 and 5.1.3.10) do not provide information about the presence of any additional species in the area with regards this study, this because in the case of the study of Duarte et al. (1971), the presence of *T. areolatus* and *S. trutta* was detected, while in the EIA (2007) fish species in the area were not detected, which could have been determined at some degree because this study only assessed one station.

5.1.4 MAIPO RIVER ANTHROPIC USES CHARACTERISTICS

The following uses were identified:

- **Rafting:** It corresponds to the use of the Maipo river from the Yeso outlet up to the San José de Maipo area, Los Héroes Park sector, through rafts operated by several tourist companies.

- **Kayak**: It corresponds to the use of the Maipo river from the Yeso outlet up to the San José de Maipo area, Los Héroes Park sector, through rafts operated by sports people and tourist operators.

- **Fishing:** It corresponds to areas of the Maipo river where potentially fishing on the banks of the river can be done. This activity was identified spatially through a round of the rivers and with the support of information provided by people from the area.

5.2 COLORADO RIVER AREA

5.2.1 COLORADO RIVER MORPHOLOGICAL CHARCATERISTICS

The Colorado river slope between the Maipo river outlet and Maitenes intake is shown in Figure 5.2.1, with a variation ratio of 1.1 to 3.3%, with a light drop towards the outlet. The river has strong currents, with a morphology predominance of flat river bed type, this is from Maitenes intake up to the Maipo river outlet. It has isolates tranches, but along its whole extension with morphology of breaded type, which generates favourable conditions for development of flora and aquatic fauna along the whole tranche, from the Maitenes intake to the Maipo outlet.

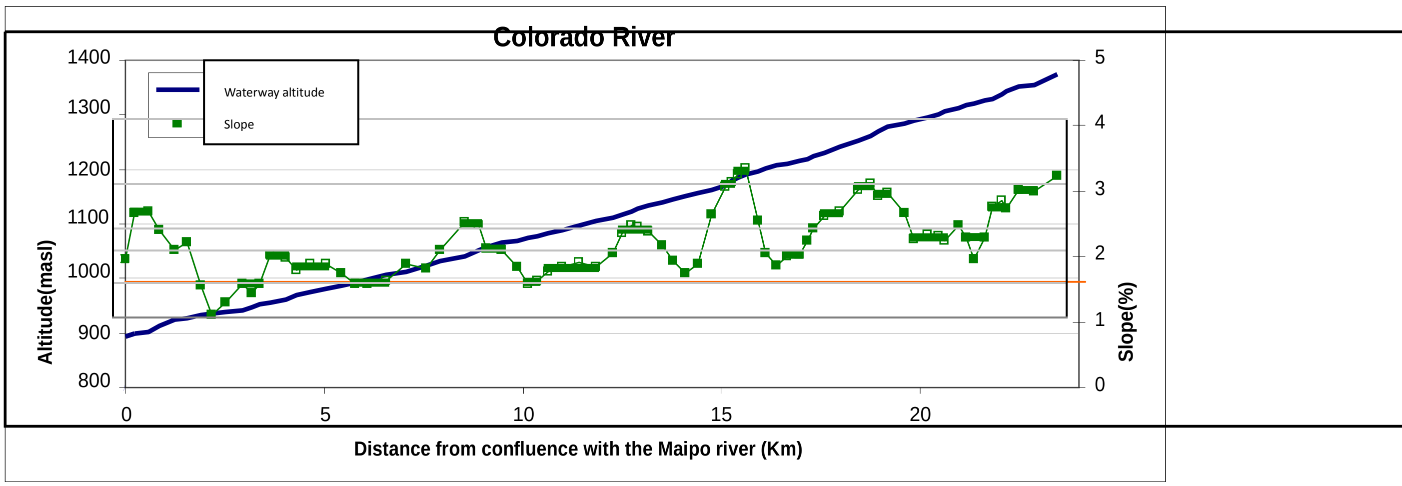

Figure 5.2.1 Colorado river longitudinal profile (between the Maipo outlet and Maitenes intake).

5.2.2 COLORADO RIVER PHYSICAL-CHEMICAL CHARACTERISTICS

The area of study considered measures just for the Coloradoriver at full extension, from its source up to its confluence with Maipo river. The Colorado river presented a mean pH value equal to 8.3 units (Table 5.1), recording the lowest value in spring 2004 with 7.80 units and the maximum in winter 2008 with a value of 8.5 units. These average values are within the ratio demanded by the environmental standard (5.5 - 9.0 units; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987), which shows that the resource has conditions for irrigation use and aquatic life. Besides, these values classified the water resource as moderate alkaline (Hounslow, 1995).

The values obtained for the electrical conductivity parameter, gave a result a mean value of 967 uS/cm, showing dissimilar values along the run-off, which are within the ratio of 682 uS/cm and 1159 uS/cm, both obtained in winter 2008 (Table 5.1). The maximum value is in the part near the source, is mainly because of areas of greater slopes and entrainment of material due to the erosive effect of the waterway. The average value of conductivity for the Colorado river does not comply with the standard value for such parameter (≤, 750 uS/cm; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987), whereby the waters of the Colorado river does not naturally have conditions for irrigation, classifying itself as water that might have damaging effects on sensitive crops.

For dissolved oxygen, the average value calculated along the Colorado river was 11.1 mg/L, the highest mean value registered for the Maipo river basin with regards this parameter. The minimum value of 9.3 mg/L was obtained in spring 2006 and the maximum 12.2 mg/L obtained in the current winter campaign 2008. These features show a high availability of dissolved oxygen in the water and as consequence favourable conditions for the development of aquatic biota. The detected values along the Colorado river comply with the minimum value arranged in the environmental standard (5.0 mg/L; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987) showing that the resource has conditions for irrigation and development of aquatic life (Table 5.1).

The sulphate concentration along the river body produced values from 8 mg/L, recorded in winter 2008 up to 361 mg/L registered in autumn 2004, providing an average value of 221 mg/L, which is within the maximum limit regulated in the current environmental legislation (250 mg/L; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987), whereby the resource has conditions for its use in irrigation (Table 5.1).

The total dissolved solids show a dissimilar behaviour along the sampled sector, it can be noticed a ratio between 132 and 792 mg/L (winter 2008 and spring 2006, correspondingly). It is worth to mention that the maximum value was obtained upstream the sector, which would explain that this value would be the strong entrainment of particulate material mainly due to its glacial river origin and to the erosive action of the waterway. The mean value for the studied parameter is 605 mg/L, which is out of the maximum limits of the standard (500 mg/L), therefore the resource is not suitable for its use in irrigation (Table 5.1).

5.2.3 C COLORADO RIVER BIOLOGICAL CHARCATERISTICS

5.2.3.1 Phytobenthos

Diversity

In the Colorado river area, eight phytobenthic diatomaceous species were detected. The species richness per sampling station varied between 0 species in most of the stations and seven species in station 3 (Aucayes stream, almost at the Colorado outlet). The richness average was of two species in the studied area. Stations 1,4 and 5 presented absence of species (Figure 5.1.3.1a). With regards Shannon's diversity, only two stations presented quantifying values, while station 3 presented the greatest diversity with 2.00 bits (Figure 5.1.3.1b).

Abundance

With regards the total abundance, this parameter presented an average of 287 cel/mm2 in the sector, with extreme values between 0 and 5.260 cel/mm2 in stations 1, 4, 5 and 1.309 cel/mm2 in station 3. Most of the monitored stations presented 0 cel/mm2 (Figure 5.1.3.2). The relative abundance illustrated in the theme map, showed differences in the dominances only at the stations that presented diatomaceous, being of relevance the Colorado river Cymbella helvetica and Mayamaea atomus (Figure 5.1.3.3).

Community Analysis

The community analysis done through MDS (non metric multidimensional scaling) at a cut level of 50%, did not show similarities between the monitored stations (Figure 5.2.4.1).

5.2.3.2 Phytoplankton

Diversity

In the Colorado river area, 30 phytoplanktic micro algae species were detected. The species richness per sampling station varied between five species in station 3 (Aucayes stream, almost at the Colorado river outlet) and 19 species in station 1 (downstream Alfalfal bridge). The average richness was 12 species in the area of study (Figure 5.1.3.5a). With regards Shannon's diversity, only two stations presented quantifying values, while station 3 presented the greatest diversity with 2.00 bits (Figure 5.1.3.5b).

Abundance

With regards the total abundance, this parameter presented an average of 284 cel/L in the sector, with extreme values between 97 and 732 cel/L in stations 4 (under Maitenes Power Plant) and 1 respectably (Figure 5.1.3.6). The relative abundance illustrated in the theme map showed differences in the dominances, being relevant in Colorado river *Cymbella helvetica*, *Achnanthidium minutissimum*, *Encyonema minutum* and *Diatoma moniliformis* (Figure 5.1.3.7).

Community Analysis

The community analysis done through MDS (non metric multidimensional scaling) at a cut level of 50%, showed similarities between stations 2 and 5 in composition and abundance (Figure 5.2.4.2).

5.2.3.3 Zoobenthos

Diversity

As it is observed in Table 5.1.3.3 and Figure 5.1.3.9a, the richness of the species per station was low, where the minimum registered corresponded to stations 3 (Aucayes stream) and station 4 (under Maitenes Power Plant) both with one taxon, and the maximum at station 1 (downstream Alfalfal bridge) with six taxa. In terms of Shannon's diversity (Figure 5.1.3.9b), the maximum in this sector was registered at station 2 (before Maitenes Power Plant and Aucayes station) with 1.63 bits and the minimum was 0.81 bits for station 5 (under the Pine tree forest).

Abundance

As it is observed in Table 5.1.3.3 and Figure 5.1.3.10, there are differences of abundance between the stations and mainly between downstream the Alfalfal bridge and under the Pine tree forest. The average value of this parameter was 281 ind/m2 ± 491, the maximum value registered downstream the Alfalfal bridge, station 1 with 1.144 ind/m2 and the minimum was logged in Aucayes stream, station 3 with 5, 6 ind/m2.

In relation to the dominant taxa (relative abundances) per station, the taxa obtained the greatest ratio representation (over 10%) with regards the total amount of individuals collected in the Colorado river areas, as it is shown in Figure 5.1.3.11, where it can be seen in details the taxa dominance in each one of the sampling stations. It is observed that the dipterous nature with the Orthocladiinae under-family which is the group of greatest dominance (90%-100%) followed by station 3 Aucayes stream with the trichopterous nature registering a 100% value, and in a lower degree the annelids (10%) at station 2 before Maitenes Power Plant.

Community Analysis

When the multidimensional scaling (MDS) is done for the sampling stations, in this sector as well as the other areas (Yeso), the stations show a sectorizing, all different between them (Figure 5.2.4.3). What is reflected when making a cut level of 50% where there are no similarities at diversity level and abundance between each one of the assessed stations.

5.2.3.4 Zooplankton

Diversity

The taxonomic richness registered in the sector corresponding to Colorado River reached a total of 10 taxa; six of them belonged to the insect group. The greatest number of taxa registered, were seven, in stations 1 and 3, while the minimum richness was registered in stations 4 and 5, and corresponded to four taxa (Figure 5.1.3.13a).

Shannon's diversity (H) index calculated for the stations from the Colorado River area showed relatively high values, with regards the other assessed sectors, with an average of 2.0 bits. Station 3, corresponding to Aucayes stream, registered the highest Shannon's diversity value, with a value reaching 2.4 bits, while in station 4, located under the Los Maitenes Power Plant, a minimum of 1.6 bits was observed (Figure 5.1.3.13b).

Abundance

The total abundance values of zooplankton registered in the stations corresponding to Colorado river sector were relatively lower than the registered in sectors previously described (Volcán river and Yeso), reaching an average of 12,9 ind/m^3. The station which presented the greatest abundance of zooplankton was station 3 reaching 29.8 ind/m^3. On the other hand the lowest abundance was registered at station 4, where a total of 5.8 ind/m was found^3 (Figure 5.1.3.14).

The most abundant group in Colorado River area was insects, mainly represented by the *Chironomidae dipterous* with a total of 23, 9 ind/m^3, which was also present in all stations corresponding to this sector. The nematode group was the second group in terms of abundance with 8, 5 ind/m^3.

The insects group was the dominant in all stations of this area, as it can be seen in Figure 5.1.3.2 (Theme map), reaching 79.7% at station 3. The second important group in terms of dominance was the *nematode* reaching 25.9% at station 2

Community Analysis

The analysis of similarities between the stations belonging to the Colorado river area, obtained through the multidimensional scaling (MDS) method, it produced a group with similar percentages over 50% which was part of stations 1,2,3,4 and 5. The similarities between grouped stations was mainly determined by two factors, the first of them is attributable to the similarity in zooplankton composition between these four stations. With regards this point, is possible to see in Figure 5.2.4.4 which within the group is nearer to stations 1 and 2 and on the other hand stations 4 and 5, which would show a greater similarity in the composition of those pairs of stations. The second factor would be related to zooplankton abundance values, which arrange those four stations aside from station 3 which is the one clearly representing higher values of abundance within the Colorado river area.

5.2.3.5 Ichthyofauna

Diversity

For Colorado river area, ichthyofauna was poor, because was detected only one species of fish, the native *Trichomycterus areolatus* (Small Catfish) which was described only at station 4 (Figure 5.1.3.17). It is worth to mention, that according to Campos et al. 1998 and CONAMA 2008 this species is in a conservation category corresponding to "Vulnerable" in the Metropolitan region, where the area of study is carried out.

Abundance

The ichthyofauna prospecting on the Colorado river area turn out into the caught of a total of three specimens of fish, all *T. areolatus* at station 4 (Figure 5.1.3.18), which describes this species as dominant with 100% of abundance for the station and the total of the sector (Figure 5.1.3.19).

Community Analysis

Given the poor nature of the ichthic assembly in the sector, was not necessary to carry out the similarity analysis of the stations by the non-metric multidimensional scaling (MDS) method, to make a difference in stations for their ichthic composition. Station 4, was the only one with fish presence, it made a difference from the others stations of the sector that did not have ichthyofauna.

Condition and sexual reason factors

Table 5.1.3.5 summarizes the morphometry analysis of fish in terms of their total length, total weight and gutting, as well as the condition factors (K and K gutting), sex and gonadal development of the caught specimens. On the other hand, the condition factors summary of the fish species per station within the assessed sectors summarised in Table 5.1.3.6, which also describes the average of the condition factor for the total sector and the sexual reason of the specimens in the sector. As this last table describes, for the Colorado river sector, the average condition factor of T.areolatus, the only species of the sector, was K = 7.89, which describes it as a relatively "thin" species.

In the Colorado river area, all the caught specimens of *T. areolatus* that could be analysed with regards its sex were undetermined juveniles (IND) (Table 5.1.3.5), therefore a sexual reason for this species of the sector could not be determined.

Diet Analysis

The detail of the items included on the fish diet of the area is summarized in Table 5.1.3.7, while in Figure 5.1.3.20 the relevant items are summarized (>5%) of the fish diet. In the Colorado river area, as it is seen in Table 5.1.3.7 and Figure 5.1.3.20, the diet of the only species present in the area, *T. areolatus*, was constituted by only two diet items, the most important one with relative abundance of 92.2% of the diet was the *Chironomidae dipterous* which corresponded to an native item, or from the aquatic ecosystem, while the second one with 7.8% was the *Formicidae hymenoptera*, an *allochtonous* item typical from the surrounding terrestrial means.

5.2.3.6 Conclusions

The registered phytobenthos in Colorado river was characterized by the main dominance of *Cymbella helvetica* and *Matamaea atomus*. Similarities with regards the species composition and total abundance were not observed in the sector. In terms of the historical background, it presented a total intermediate richness with regards the observed in the upper part of the Maipo basin.

The phytoplankton community of the Colorado river was characterized by presenting differences in the dominances, standing out the species *Cymbella helvetice, Achnanthidium minutissimum, Encyonema minutum and and Diatoma moniliformis.* Within river, importat was the downstream the Alfalfal bridge zone where it was observed the greatest richness and abundance. On the other hand, similarities with regards the compositions of the species and total abundance for the stations located before the Maitenes Power Plant and Aucayes stream were observed, also under the pine tree forest almost at the outlet.

The Colorado river sector presented a taxonomic richness of zoobenthos similar to the Yeso river area, nevertheless the abundance registered obtained the maximum and minimum value between the three analysed sectors. The diversity index (H') reached in this sector a maximum value at station 2 before the

Maitenes Power Plant and Aucayes station, and the minimum was for station 5 under the Pine tree forest almost at the outlet. It is still the most abundant insects group, the dipterous nature being the most representative of the sector, especially by the *Chironomidae* family and the *orthocladiinae* under-family, the third in terms of importance corresponds to the trichopterous with the *Parasericostomatidae sp.* species which is intolerant to organic contamination. This natures had already been registered in this sector (JICA, 2003 and Arcadis, 2008).

The zooplankton of the Colorado river area presented a taxonomic richness similar to the Yeso river and Volcán areas, although the abundance registered was lower to the average of the two sectors already described. Shannon's diversity index (H') reached a higher average value between the three assessed sectors. The insects group was the most abundant and representative of the sectors, specially by the presence of the *Chironomidae dipterous*. The second group of importance corresponded to the *Nematode*.

Station 1 (downstream the Alfalfal bridge) and 3 (Aucayes stream) presented the higher values of the assessed community parameters, while station 4 presented the minimum values. According to the community analysis is possible to find similarities between stations 1, 2, 4 and 5, all belonging to the main course of the Colorado river. Station 3 is left aside of this group because it presents a composition relatively different to the one found in other stations, possible due to differences attributable to its waters coming from Aucayes Stream, before its outlet into the Colorado river.

In the Colorado river area, ichthyofauna was poor, it was only detected at station 4 three specimens of the native species Trichomycterus areolatus, which has a conservation category corresponding to "Vulnerable" in the area of study.

For the under basin of the Colorado river, the previous studies background (Table 5.1.3.10 does not contribute with information on the presence of fish in the case of Duarte et al. (1971) study because this sector was not assessed in this study, while in EIA (Arcadis, 2008) was detected, besides the *T. areolatus*, the introduced species *O. mykiss*, although this last one only at Aucayes stream.

5.2.4 COLORADO RIVERANTHROPIC USES CHARACTERISTICS

The following uses were identified:

Neither sports nor leisure anthropic uses of the Colorado river were identified.

.5.3 YESO RIVER SECTOR

5.3.1 YESO RIVER MORPHOLOGICAL CHARCATERISTICS

The Yeso river slope between the Maipo river outlet and Maitenes in take at the foot of the EL Yeso reservoir wall is shown in Figure 5.3.1, with a variation range of 2.59 and over 10%.The river has strong currents, with morphological predominance of the flat river bed and torrent type, it presents isolated tranches, but along this whole extension with local morphologies of breaded type which generates favourable conditions for the development of flora and aquatic fauna along the whole tranche of the river.

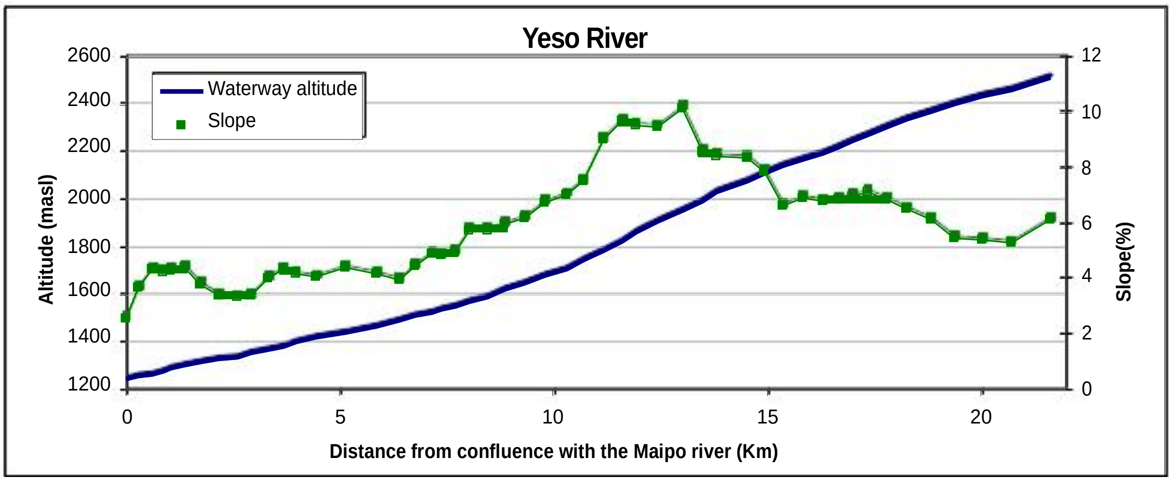

Figure 5.3.1 Yeso river Longitudinal profile (between the Maipo rirver outlet and the intake at the foot of El Yeso reservoir wall)

The tranche between the outlet of the Volcán river up to the outlet of Yeso river, presents a morphology with rapids and waterfalls with scarce development of banks and beaches, therefore from minor to lower environmental importance. The Maipo river tranche between Yeso river and Las Lajas presents morphology of flat river bed and braided river which generates appropriate conditions for development of flora and aquatic fauna along the whole tranche.

5.3.2 MAIPO RIVER PHYSICAL-CHEMICAL QUALITY CHARACTERISTICS

For this sector, the analysis was carried out a long the whole longitudinal tranche, from its source up to its confluence with Maipo river. In this sector, the pH produced an average value of 8.4 units, registering its minimum value in winter campaign 2004 and a maximum value of 10 units in spring campaign 2004 (Table 5.1). According to the average value obtained the water resource is classified as moderate alkaline (Hounslow, 1995). The pH values detected in El Yeso river area is in the ratio demanded by the environmental standard (5.5 - 9.0 units; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987), which shows that the resource has conditions for irrigation use and aquatic life.

Regarding its electrical conductivity, the minimum value was registered in the on-site winter campaign 2008 (325 uS/cm) and likewise for the maximum value, which was registered near the source with an equal value to 1086 uS/cm. The average value of all the measures done in El Yeso river provided a value of 832 uS/cm. This mean value does not represents high conditions for irrigation, because it might present detrimental effects fro sensitive crops (≤ ,750 uS/cm; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987).

The mean value found for oxygen was 10.1 mg/L, finding as maximum value in winter campaign 2004 a value of 11 mg/L. On the other hand the minimum value was found in summer campaign 2004 with 8.6 mg/L (Table 5.1). The maximum values in winter season are explained due to the decrease of temperatures, therefore make the oxygen dilution to increase in the waterway, adding a re-oxygenation suffered by the strong slope and the typical morphology of the place. The values found, comply with the minimum estimated values in the Chilean Environmental Standard 1.333, Note 78, where the value for this parameter id 5.0 mg/L.

The sulphate concentrations vary between 106 mg/L for spring 2006 and 370 mg/L in winter 2008; producing an average of 286 mg/L, superior value to the standard (250 mg/L; Official Chilean Standard, 1.333, Note 78, INN, Chile, 1987). Naturally, therefore, this water resource does not comply with the conditions to be used as irrigation water (Table 5.1).

The values for total dissolved solids provide an average value of 700 mg/L, and a variation ratio between 589 mg/L and 834 mg/L, in winter 2008 and spring 2006, respectively (Table 5.1). The total concentration of solids dissolved was greater than the maximum value demanded by the environmental standard (500 mg/L), which indicates that the resource does not have aptitude for irrigation according to this parameter (Official Chilean Standard 1.333, Note 78, INN-Chile, 1987).

5.3.3 YESO RIVER BIOLOGICAL CHARCATERISTIC

5.3.3.1 Phytobenthos

Diversity

In the Yeso river area, nine *phytobenthic diatomaceous* species were detected, presenting an average of richness of three species. The species richness per sampling station varied between one species in station 14 (upper waterway, under the El Yeso reservoir wall) and six species at station 13 (mean waterway, Figure 1a). With regards Shannon's diversity, a lower diversity was observed in station 14 with 0 bits, while, in station 11 (reaching the Maipo river outlet) presented the greatest diversity with 1.00 bits (Figure 5.1.3.5b).

Abundance

With regards the total abundance, this parameter presented an average of 1.810 cel/mm2 in the sector, with extreme values between 19 and 3.752 cel/mm2 in stations 11 and 13 respectably (Figure 5.1.3.2). The relative abundance illustrated in the theme map showed variability in the dominances, being relevant in Yeso river *Achnanthidium minutissimum*, *Cyclotella stelligera, Encyonema minutum and Fragilaria spp.* (Figure 5.1.3.3).

Community Analysis

The community analysis done through MDS (non metric multidimensional scaling) at a cut level of 50%, did not show similarities between the monitored stations (Figure 5.3.4.1).

5.3.3.2 Phytoplankton

Diversity

In the Yeso river area, 20 phytoplankton micro algae species were detected, presenting an average of richness of seven species. The species richness per sampling station varied between four species in station 14 (upper waterway, under the El Yeso reservoir wall) and ten species at station 11 (reaching the Maipo river outlet, Figure 5.1.3.5a). With regards Shannon's diversity, a lower diversity was observed in station 14 with 1.66 bits, while, in station 11 presented the greatest diversity with 2.40 bits (Figure 5.1.3.5b).

Abundance

With regards the total abundance, this parameter presented an average of 42 cel/L in the sector, with extreme values between 27 and 73 cel/L in stations 13 (mean waterway of the river) and 14 respectably (Figure 5.1.3.6). The relative abundance illustrated in the theme map showed two dominant species, *Achnanthidium minutissimum* and *Diatoma moniliformis* (Figure 5.1.3.7).

Community Analysis

The community analysis done through MDS (non metric multidimensional scaling) at a cut level of 50%, showed similarities between stations 11 and 14 in composition and abundance (Figure 5.3.4.2).

5.3.3.3 Zoobenthos

Diversity

As it is observed in Table 5.1.3.3 and Figure 5.1.3.9a, the richness of the species per station was still low, where the minimum registered corresponded to stations 11 (Maipo outlet) with two taxa, and the maximum at station 13 (mean waterway of the river) with six taxa. In terms of Shannon's diversity (Table 5.1.3.3and Figure 5.1.3.9b), the maximum in this sector was registered at station 13 with 1.85 bits and the minimum was 0.81 bits for station 11.

Abundance

Differences of abundance were seen between stations and mainly between the lower, mean and upper waterway of the river. The average value of this parameter was 76.4 ind/m2 ± 44.1, the maximum value registered in mean waterway, station 13 with 133 ind/m2 and the minimum was recognized in the upper waterway under the wall of the reservoir Yeso, station 14 with 39 ind/m2 (Figure 5.1.3.10).

In relation to the dominant taxa (relative abundance) per station, the ones obtaining a greatest percentage representation (above 10%) with regards the total individuals caught in the different sectors of the waterway, are shown in the theme map 5.1.3.11, were is seen with more details the dominance of the taxa in each of the sampling stations. It is observed that the group of greater dominance, as well as in Volcán river area, corresponded to the dipterous nature, these vary from station to station, for instance, at station 11 in the Maipo river outlet, the *Arthericidae* family predominates with 75%, station 13 in mean waterway of the river the *Orthocladiinae* under-family with 54% and at station 14 in upper waterway, the *Chironomidae* family was registered with 43%. While at station 12 (lower waterway) the *ephemeropterous* nature with the *Meridialaris chiloeensis* species was registered with 56%.

Community Analysis

In this opportunity, the multidimensional scaling (MDS) performed in the sampling stations, does not show groups in this opportunity but an elevated sectorization, due to all the assessed stations in the Yeso river sector does not present taxonomic similarities mainly given by a greater or lower diversity found in such stations (Figure 5.3.4.3). For this sector, at a cut level of 50%, there are no similarities between each one of the assessed stations.

5.3.3.4 Zooplankton

Diversity

The Yeso river area registered a total richness of eight taxa, being the insects group the most represented with three taxa. The taxonomic richness for this sector presented quite homogeneous values (Figure 5.1.3.13a; Table 5.1.3.4), finding the minimum value at station 13 with five taxa, while the maximum with six taxa was registered in the other three stations corresponding to this sector (stations 11, 12 and 14). The average of taxonomic richness in the Yeso river sector was six taxa.

The average of Shannon's diversity index (H') registered in the Yeso river sector reached a value of 1.7 bits, varying in a ratio of 2.2 bits in station 11 to 1.0 bits at station 14 (Figure 5.1.3.13b).

Abundance

The zooplankton abundance reached an average value of 28.1 ind/m^3 in the Yeso river area. The average value reached was 48,0 ind/m^3. at station 14, which is under the El Yeso reservoir wall, while the lowest abundance registered was 8.8 ind/m^3 at station 13, which is at mean waterway of the Yeso river (Figure 5.1.3.14).

The most abundant group found in the Yeso river area was Cladocera, mainly represented by the *Ceriodaphnia dubia* species reached an abundance of 69, 3 ind/m^3. The second most abundant group was the insects, within which the Chironomidae mainly stand out with12, 2 ind/m^3.

In Figure 5.1.3.15 it is observed the clear dominance that the cladocera group presented in all the stations from Yeso River, reaching a maximum of 78.9% at station 14. In most of the stations the insects and oligochaeta groups followed in terms of representativeness. At stations 11 and 14, oligochaeta was presented as the second dominant group with 28.3% and 15.5%, respectively. The insects group was the second in terms of importance at stations 12 and 13 with values of 30.2% and 15.0%, respectively.

Community Analysis

The analysis of similarities between the stations belonging to the Yeso river area, obtained through the multidimensional scaling (MDS) method, produced two groups of similar percentages over 50% (Figure 5.3.4.4). The first of them was comprised of stations 11 and 13, while the second one was part of stations 12 and 14. Similarities between grouped stations was determined both for the composition of the zooplankton community as well as the abundance values reported for this sector. Stations 12 and 14 are the ones which registered the greatest abundance values for the Yeso river area, the first of them is located in lower waterway of the river and the second one is in the upper waterway under the El Yeso reservoir wall.

5.3.3.5 Ichthyofauna

Diversity

For the Yeso river area, ichthyofauna was poor, because it was detected only one species of fish, the introduced *Salmo trutta* (Brown trout) which was described in all stations of the area (Figure 5.1.3.17). This species does not represent a conservation category in Chile because this qualification has been only developed for native species (Campos et al. 1998, CONAMA 2008). On the other hand, at worldwide scale, this species was not included in the red list of species threatened by the IUCN at worldwide level (www.iucn.org).

Abundance

A total of 31 specimens of S. trutta were caught in the sector, which were distributed en the stations with a ratio between a minimum of 1 specimen at station 14 and maximum of 15 specimens at station 13 (Figure 5.1.3.18). Given the exclusive presence of *S. trutta* in the sector and each one of the stations, this was the dominant species with a relative abundance of 100% in them (Figure 5.1.3.19).

Community Analysis

Given the poor nature of the ichthic assembly in the sector, was not necessary to carry out the similarity analysis of the stations by the non-metric multidimensional scaling (MDS) method, to make a difference in stations for their ichthic composition. The distinction level in this case is given at fish abundance level at stations, where stations 11 and 13 stand out due to its elevated values of abundance, over 10 specimens which contrasts with the low values at stations 12 and 14 with less than 5 specimens.

Condition and sexual reason factors

Table 5.1.3.6 summarizes the morphometry analysis of fish in terms of their total length, total weight and gutting, as well as the condition factors (K and K gutting), sex and gonadal development of the caught specimens. On the other hand, the summary of the condition factors of the fish species per station within the assessed sectors are summarised in Table 5.1.3.6, which also describes the average of the condition factor for the total sector and the sexual reason of the specimens in the sector. As this last table describes, the average condition factors of *S. trutta* in the stations showed a relatively wide variation, which was determined by the maximum value described at station 14, a K = 13.28, which, although, could be little representative being based only on 1 specimen caught in that station. For the rest of the stations the value ratio was narrow, between a K = 11.21 at station 11 and a K = 11.94 at station 12, describing a variation that was not statistically significant (Kruskal-Wallis: H (3, 31) = 2,805, p = 0,42). The average condition factor for the total sector was K = 11.39, characterizing this specie as "strong" within the species of the area of study.

In the Yeso river area, contrary to other sectors, most of the caught specimens that could be analysed with regards its sex were able to be determined, finding a high proportion of males with regards females (Table 1), which produced a sexual reason (N° Males/N° Females) with an elevated value of 6.0 (Table 2).

Diet Analysis

For S. trutta, the detail of the items included on the fish diet of the area is summarized in Table 5.1.3.7, while in Figure 5 the relevant items (>5%) of the fish diet is summarized. The Yeso river area, as it can be seen in Table 5.1.3.7 and Figure 4, the *S. trutta* diet was wide and mainly based on native origin material or typical from the aquatic ecosystem, reaching 99.4% of representativeness. As it is observed in Figure 5.1.3.20, *S.trutta* included a total of four significant items, three of them were relative abundance in the diet over 10%, these were the *Chironomidae dipterous*, the *Hydrobiosidae trichopterous* (26.7%) and the *Hydropsychiadea trichopterous* (18.8%).

5.3.3.6 Conclusions

The phytobenthos present in Yeso river was characterized by having variable dominances in the sector, standing out the *Achnanthidium minutissimum*, *Cyclotella stelligera, Encyonema minutum* and *Fragilaria spp*. species. Within the importance river was the mean waterway zone, were it was observed the greatest richness and abundance, while the greatest diversity was reported in the area near the outlet towards the Maipo river. On the other hand, similarities with regards the species composition and total abundance was not observed in the area. In terms of the historical background, it presented a low total richness with regards the observed in the upper part of the Maipo basin.

The phytoplankton of the Yeso river was characterized by presenting two dominant species, standing out the *Achnanthidium minutissimum and Diatoma moniliformis species.* Within the river, important was the zone reaching the Maipo river outlet where it was observed the greatest richness and diversity, while the greatest abundance was observed in the upper waterway, under the El Yeso reservoir wall. On the other hand, similarities with regards the compositions of the species and total abundance for the stations located in the Maipo river outlet and upper waterway, under the El Yeso reservoir wall. Historical background for planktonic micro-algae in the upper part of the Maipo basin were not observed.

In the Yeso river area, the benthic macro-invertebrates collection was poor in terms of species and little abundance with regards the amount of individuals collected compared to other sectors, this because only 10 taxa were detected in the four assessed stations, being able to have effects on the taxa richness when is under the reservoir wall. All the assessed stations of the Yeso river, registered some species of dipterous nature, although stations 11 and 14 specially stand out because of its greater relative abundances (%) with the athericidae and chironomidae families. The lowest richness corresponded to station 11 located at the outlet of the Maipo river and the highest in mean waterway of the river station 13, the same happens with the total abundance. All the stations belonging to the Yeso river area, showed similar zoobenthic communities in terms of its composition. The dominant species registered corresponded to the dipterous nature, athericidae family, chironomidae, orthocladiinae and is followed by the Meridialaris chilooensis species. These natures were detected in previous studies (Arcadis, 2008).

Regarding the zooplankton of the area corresponding to the Yeso river, it showed great homogeneity in terms of specific richness, with a relatively high average value of six taxa. The total abundance registered its highest values at stations 12 and 14. Station 12 is located in the low waterway under the Yeso river, on the contrary, station 14 is located in the upper waterway, under the El Yeso reservoir wall. On the other hand, station 13 is in the mean waterway of the river, which registered the lowest values for the area, both for its taxonomic richness and for total abundance. Generally, the average values for the biological parameters registered in the Yeso river area, were quite similar to those obtained in the Volcán river. All the stations belonging to the Yeso river area, showed similar zooplankton communities in terms of its composition. For this sector, the dominant species was the *Ceriodaphnia dubia* belonging to the Cladocera group, followed by the *Chironomidae* representative of the insects group. *Ceriodaphia dubia* had been previously detected in Lo Encañado Small Lake, near the Yeso river area (Arcadis, 2008).

In the Yeso river area, the ichthyofauna was poor in species but relatively abundant in terms of the amount of specimens collected compared to other sectors, this because only the introduced species *S. trutta* was detected, although with 31 specimens in the area. It is worth to mention that this species neither has the conservation category assigned in Chile nor at worldwide level. All the assessed stations of the Yeso river, registered some *S. trutta* specimens, although stations 11 and 13 specially stand out because of its greater abundance of fish (over 10 specimens).

The average condition factors (K) of the *S. trutta* specimens between stations showed a non relevant variation among them, with an average of K for the sector defining the *S. trutta* as one of the strongest species in the assessed area. The sexual reason for the caught *S. trutta* specimens showed an unbalance on favour of males in the populations of the sector.

The S. trutta diet was relatively wide and included items mainly of native origin (or typical from the aquatic ecosystem). Between these last ones, the *Chironomidae dipterous, Hydrobiosidae trichopterous* and *Hydropsychidae* stand out with relative abundances over 10% of the diet.

For the under basin of the Yeso river, the previous studies background (Table 5.1.3.10 does not contribute with information on the presence of additional fish (Arcadis, 2008), but it does in the case study of Duarte et al. (1971), which found in this sub-basin, besides *S. trutta*, the *O. mykiss* species.

5.3.4 YESO RIVER ANTHROPIC USES CHARACTERISTICS

The following uses were identified:

It was only identified the sport fishing as leisure anthropic use of the Yeso river waters.

5.4 VOLCÁN RIVER AND STREAMS AREAS

5.4.1 VOLCÁN RIVER AND STREAMS MORPHOLOGICAL CHARACTERISTICS

The Volcán river slope between the Maipo outlet and its intersection with Colina stream is shown in Figure 5.3.1a, with a variation ratio of 2.59 and over 10%. The river has strong currents, with morphological predominance of the flat river bed and torrent type, it presents isolated tranches, but along this whole extension with local morphologies of breaded type which generates favourable conditions for the development of flora and aquatic fauna along the whole tranche of the river.

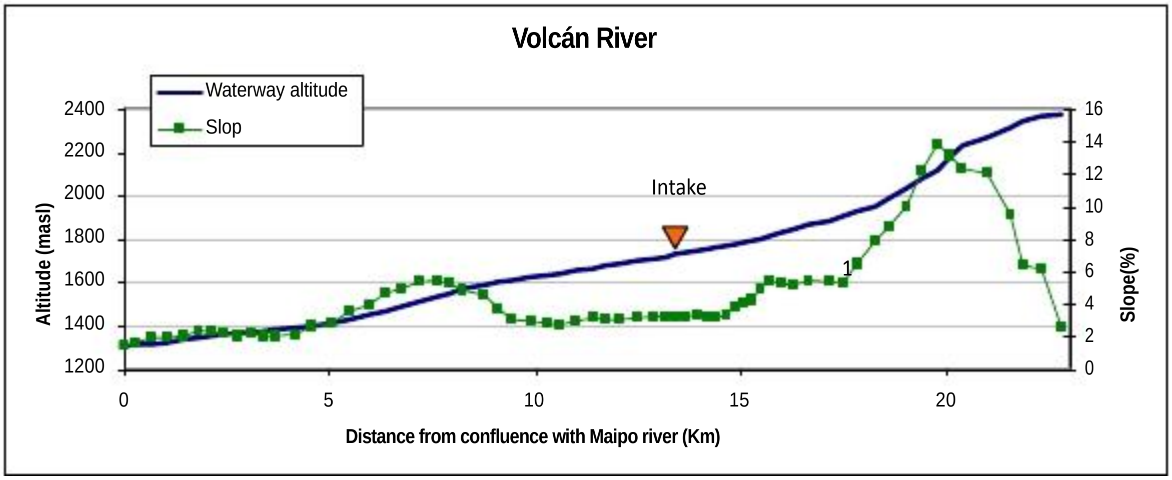

Figure 5.4.1a Volcán river longitudinal profile (Between the outlet in Maipo river and the intersection with Colina stream)

The tranche between the outlet of Volcán river in Maipo river and the area of the Volcán town (0 to 4.5 Km) presents a slope minor to 2.5% with flat river bed morphology and breaded river sectors which generate conditions suitable for the development of flora and aquatic fauna. From this point and up to the intersection with Colina stream, it presents a flat river bed morphology with rapids and waterfalls of scarce development of banks and beaches, therefore of minor to low environmental importance, except from upstream tranche of Lo Valdés area where a small tranche of the river is developed with breaded river morphology and low slope which generate suitable conditions for development of flora and aquatic fauna.

The El Morado, Las Placas, Colina and La Engorda streams present a morphology of rapids and waterfalls,and pools given its high slope which is over 30% and reaches up to 50% in some cases. These morphological conditions makes them with scarce habitability conditions for development of flora and aquatic fauna (Figures 5.4.1a, 5.4.1b, 5.4.1c, 5.4.1d y 5.4.1e)

In the case of El Morado stream, and just as it can be appreciated in Figure 5.4.1b two zones of low slope are observed which coincide with the development of a flat river bed morphology and partially of a breaded river in a alluvium zone.

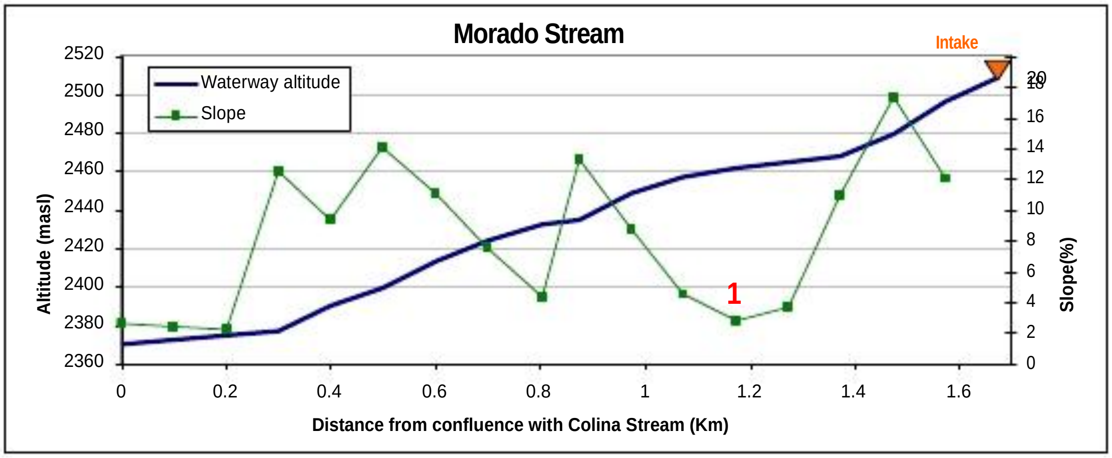

Figure 5.4.1b El Morado Stream longitudinal profile (Between the outlet in the Colina stream and the El Morado intake)

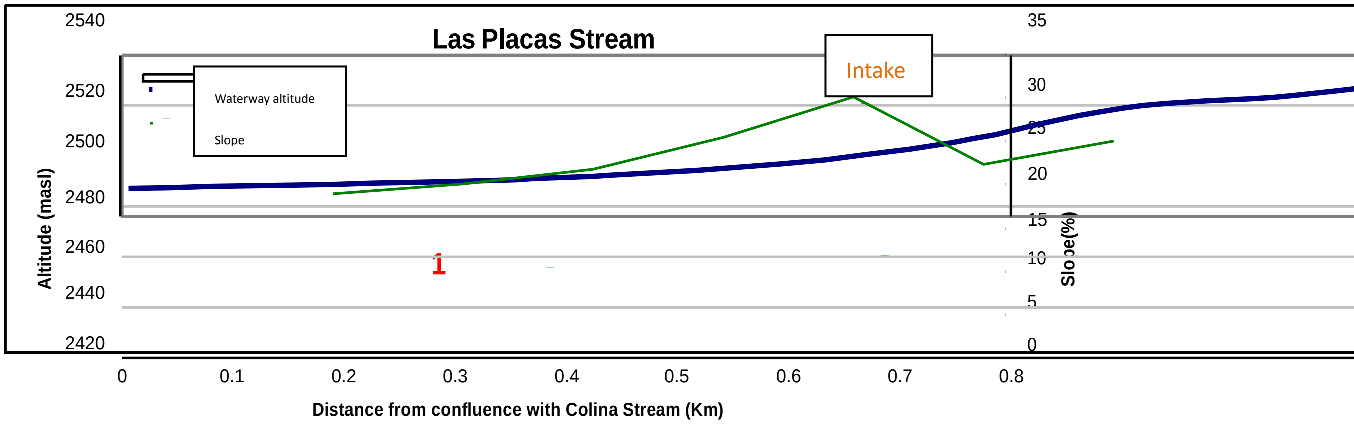

Figura 5.4.1c Las Placas Stream longitudinal profile (Between the outlet in the Morado stream and Las Placas intake)

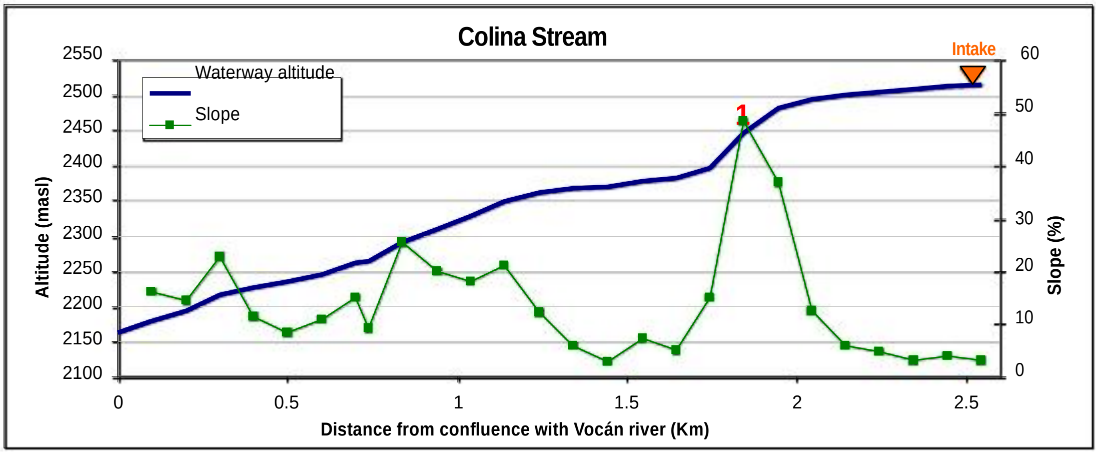

Figure 5.4.1d Colina Stream longitudinal profile (Between the outlet in Volcán river and Colina outlet)

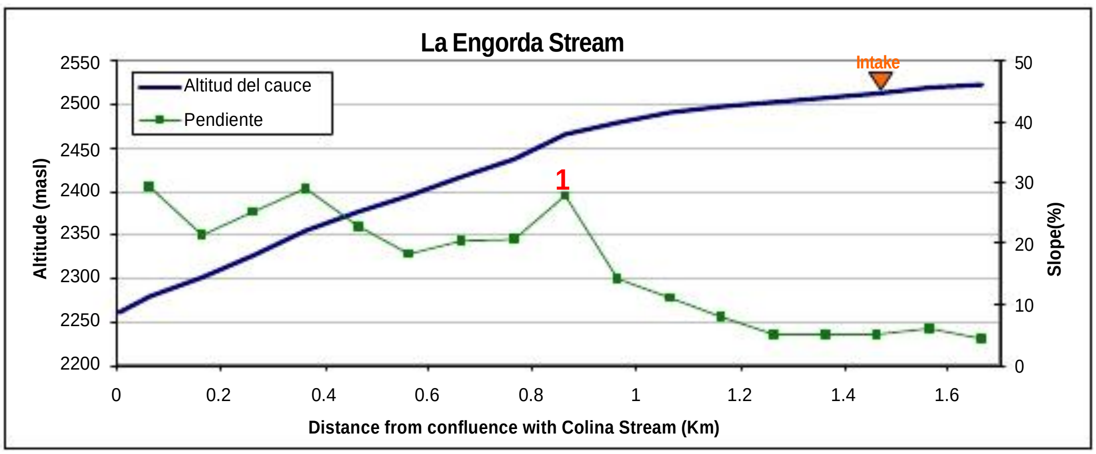

Figure 5.4.1e La Engorda Stream longitudinal profile (Between the outlet in the Colina stream and La Engorda intake)

5.4.2 VOLCÁN RIVER AND STREAMS PHYSICAL-CHEMICAL QUALITY CHARACTERISTICS

The Volcán river analysis area is considered together with its four tributary streams (El Morado, Las Placas, Colina and Engorda streams). The pH in the Volcán river area, varied between 7.2 and 8.5 units (Table 5.1). The average value was found in El Morado stream classified as moderate alkaline, while the minimum value was found in Engorda stream, classified as neutral (Hounslow, 1995). From the found values in the Volcán river area and the river subsystems, all are in the ratio demanded by the environmental standard (5.5 - 9.0 units; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987), which indicates that the resource has aptitude for irrigation and aquatic life.

For electrical conductivity, the maximum average value was located in Volcán river with a value of 1.374 uS/cm, followed by El Morado stream (931 uS/cm), Engorda (788 uS/cm) and finally Colina stream with 703 uS/cm (table 5.1). According to the obtained values, only Colina stream complies with the current environmental standard for irrigation water (≤,750 uS/cm; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987), whereby in natural conditions the values established by the standard for the rest of the rivers do not comply with.

The dissolved Oxygen values showed an average maximum value in Volcán River with 10.4 mg/L and a minimum value in Engorda stream equal to 8.9 mg/L (Table 5.1). The maximum values are registered for all the sampling, in winter stations; this is mainly because of the inverse relation that there is between dissolved oxygen and temperature, where, the higher the temperature, the lower the gas dissolution in waters, and also a high re-oxygenation due to the mountain run-off present in these waterways. For Volcán River and all of its tributary streams, the values obtained in terms of this parameter comply with the Official Chilean Standard 1.333/78, on irrigation and aquatic life for dissolved oxygen, showing values over the minimum stipulated (5.0 mg/L).

With regards the sulphate measured in a water column for the Volcán river area, a minimum average value in Colina stream (149 mg/L) and a maximum average value for Volcán river (307 mg/L) is seen. Generally, the sulphate values obtained are within the limits determined by the Official Chilean Standard 1.333/78, for the use of water resource as irrigation functions, but not the Volcán river waters which naturally exceed the maximum values permitted in it (250 mg/L; Official Chilean Standard, 1.333, Note 78, INN-Chile, 1987) (table 5.1).

Finally, the total dissolved solids registry in different campaigns showed values relatively homogeneous between the river bodies in the area (El Morado 618 mg/L, Colina 653 mg/L, Engorda 662 mg/L), by exception of the maximum average value found in Volcán river with a value of 983 mg/L, mainly due to its source from glaciers located in the upper mountain, which in its thawing process drags big amounts of sediments. With the obtained average values, the resource does not have aptitude for irrigation with regards this parameter (500 mg/L; Official Chilean Standard 1.333, Note 78, INN-Chile, 1987).

5.4.2 VOLCÁN RIVER AND STREAMS BIOLOGICAL CHARACTERISTICS

5.4.2.1 Phytobenthos

Diversity

In the Volcán river area, seven phytobenthic diatomaceous species were detected, presenting an average of richness of three species. The species richness per sampling station varied between two species in station 22 (Las Amarillas area) and six species at station 21 (in Lo Valdés, Volcán river zone, Figure 5.1.3.1a). With regards Shannon's diversity, a lower diversity was observed in station 22 with 0.85 bits, while, station 21 presented the greatest diversity with 1.73 bits (Figure 5.1.3.1b).

Abundance

With regards the total abundance, this parameter presented an average of 248 cel/mm2 in the sector, with extreme values between 48 and 647 cel/mm2 at stations 19 (upstream the bridge) and 21 respectably (Figure 5.1.3.1 and Figure 5.1.3.2). The relative abundance illustrated in the theme map showed one dominant species, *Achnanthidium minutissimum* (Figure 5.1.3.3). At Station 19, the codominance with *Fragilaria capucina var. vaucheriae.*

Community Analysis

The community analysis done through the MDS (non metric multidimensional scaling) at a cut level of 50% did not show similarities between the monitored stations (Figure 5.1.3.4), so every station would be considered as a particular entity in terms of phytobenthos community.

5.4.2.2 Phytoplankton

Diversity

In the Volcán river area, 22 phytoplankton micro algae were detected, presenting an average of richness of six species. The species richness per sampling station varied between two species in station 21 (Volcán river zone) and 10 species in station 20 (upstream Lo Valdés zone, Figure 5.1.3.5a). With regards Shannon's diversity, a lower diversity was observed in station 21 with 1.00 bits, while, in station 17 (La Engorda North stream) presented the greatest diversity with 2.57 bits (Figure 5.1.3.5b).

Abundance

With regards the total abundance, this parameter presented an average of 39 cel/L in the sector, with extreme values between 3 and 81 cel/L in stations 18 (La Engorda South stream) and 20 respectably (Table 5.1.3.2 and Figure 5.1.3.6). The a relative abundance illustrated in the theme map showed variabilities in the dominances. Between the species the *Fragilaria pinnata*, *Spirogyra spp., Synedra moniliformis, Encyonema minutum* and *Nitzschia fonticola* stand out (Figure 5.1.3.7).

Community Analysis

The community analysis done through MDS (non metric multidimensional scaling) at a cut level of 50%, did not show similarities between the monitored stations (Figure 5.3.3.8).

5.4.2.3 Zoobenthos

Diversity

As it is observed in Table 5.1.3.3 and Figure 5.1.3.9a, the richness of species per station was low, where the minimum registered corresponded to station 20 with four taxa, and the maximum at station 21 with nine taxa, being this value the maximum value reached out of all the assessed stations in the area of study. In terms of Shannon's diversity (Table 5.1.3.3 and Figure 5.1.3.9b), the maximum in this sector was registered at station 22 with 1.29 bits and the minimum was 0.97 for station 20.

Abundance

Differences of abundance were seen between stations and mainly between the Volcán river waterway and Las Amarillas sector. The average value of this parameter was 461.1 ind/m2 ± 467.1, the maximum registered value was in Volcán river, station 21 with 1000 ind/m2 and the minimum was recognized at Las Amarillas sector, station 22 with 172 ind/m2. (Table 5.1.3.3 and Figure 5.1.3.10).

In relation to the dominant taxa (relative abundances) per station, the taxa that obtained the greatest percentage representation (above 10%) with regards the total individuals collected in the Volcán river sector and streams, is shown in the theme map Figure 5.1.3.11 (Annex x), were is seen with more details the dominance of the taxon in each of the stations of sampling. It is observed that the group with greatest dominance varies from station to station, for instance, at station 20 upstream Lo Valdés, station 21 in the Volcán river zone and station 22 (Las Amarillas area), dominance almost exclusive of the Dipterous type with the Orthocladiinae under-family with 82%, 80% and 71% respectively.

Community Analysis

The multidimensional scaling (MDS) carried out in the sampling stations, using total abundance (Ind/m2), showed in this group, campaigns and a sectorization due to stations 20 (upstream

Lo Valdés) and 22 (Las Amarillas sector) present taxonomic similarities, such similarities are given by the presence, in most part of it, of the dipterous nature (Figure 5.1.3.12). While at station 21 (Volcán River) made a clear difference from the other two sectors because of greater diversity, situation given exclusively by the big abundance of chironomids, simulids and ephemeropterous found. For this seasonal campaign, the similarities between each one of the stations was only higher to 50% for upstream Lo Valdés area and Las Amarillas sector.

5.4.2.4 Zooplankton

Diversity

The Volcán river area presented a total richness of 10 taxa, within which the insects group was the most represented with four taxa. The greatest richness was eight taxa at station 20 where the river forms a small pool upstream Lo Valdés, while the lower number of taxa was registered at stations 18 (south La Engorda stream) and 19 (south Volcán river) with a total of two taxa, (Figure 6.2.4.1a; Table 5.1.3.4). The average value of taxonomic richness presented in this sector reached five taxa.

Shannon's diversity index (H') showed an average value for the Volcán river area of 1.5 bits. The highest value registered was 1.2 bits and it was presented at station 20, while the minimum value reached only 0.6 bits at station 19 (Figure 5.1.3.13b and Table 5.1.3.4)

Abundance

The total zooplankton abundance in the Volcán river area showed relatively high values with an average of 29.2 ind/m^3. The greatest abundance of the sector was at station 20 with a value of 83.9 ind/m3 and the minimum abundance was registered at station 18 with a total of 1, 8 ind/m^3 (Figure 5.1.3.14).

The most abundant group in Volcán river area was insects, mainly represented by the Chironomidae dipterous with a total of 68, 7 ind/m^3, which was also present in all stations corresponding to this sector. Canthocamptidae, from the Copeda group, was the second in terms of abundance with 48, 8 ind/m^3. In Figure 5.1.3.15 it is observed the important dominance the insects group presented in all the stations corresponding to Volcán river area, reaching a maximum of 86.7% of representativeness at station 19. The Copeda group reached its maximum of 36.8% at station 17, where was also registered the third group of importance, Oligochaeta with 27.4%.

Community Analysis

The analysis of similarities between the stations obtained through the multidimensional scaling (MDS) method, produced a group with similar percentages over 50% which was part of stations 17, 21 and 22 (Figure 5.1.3.16). Station 17 is located in North La Engorda Stream, in the mean tranche of the intake sector, the 21 and 22 are located in the main course of Volcán river. Similarities between grouped stations were mainly determined by the composition of the zooplankton community, in which the copepoda, insects and oligochaeta taxonomic groups were found. (Table X).

5.4.2.5 Ichthyofauna

The Volcán river area was the poorest in ichthyofauna in the assessed areas, because non of its eight assessed stations in this campaign of study detected the presence of ichthyofauna (Figures 5.1.3.17 and 5.1.3.18 and 5.1.3.19).

5.4.2.6 Conclusions

The registered phytobenthos in Volcán river was characterized by the main dominance of *Achnanthidium minutissimum*. Within the river of importance, the Volcán river area observed the greatest richness, abundance and diversity. On the other hand, similarities with regards the species composition and total abundance was not observed in the area. In relation to the historical background the total abundance obtained in this study presents an intermediate value with regards the observed in Volcán (25 species Table 5.1.3.8) (Jica & CEA 2003, Arcadis 2008 and CEA 2008).

On the other hand, the Volcán river was characterized by presenting variability in the phytoplankton dominances where species like *Fragilaria pinnata, Spirogyra spp., Synedra ulna, Gomphonema olivaceum, Surirella minuta, Diatoma moniliformis, Encyonema minutum* and *Nitzschia fonticola* stand out. Within the river, import was the upstream Lo Valdés zone where the greatest richness and abundance was observed, while the greatest diversity was observed in North La Engorda stream. On the other hand, similarities with regards the species composition and total abundance was not observed in the area. Historical background for planktonic micro-algae in the upper part of the Maipo basin were not observed.

According to the results of zoobenthos obtained, the Volcán river area is one of the richest in terms of taxonomic richness and abundance of zoobenthos between the assessed sectors. At station 21, in the Volcán river zone, appears as the one having the best conditions for the settlement of benthic communities, because it shows the highest value of taxonomic richness and the second in total abundance and diversity index. On the other hand, station 20, located upstream Lo Valdés was the one which showed the lowest community parameters value analysed.

With regards the composition and dominance, the most representative zoobenthic group and abundant of the area corresponded to the dipterous nature with the orthocladiinae under-family. In the found literature for the area JICA, 2003, Arcadis, 2008 and CEA 2008 also detected this nature (Table 5.1.3.9). According to the community analysis, two groups with similarities were found, the first one between stations 22 (Las Amarillas sector) and 20 (upstream Lo Valdés) mainly given by the presence of trichopterous and dipterous, and the second one corresponded to station 21 (Volcán river area) due to its greatest diversity.

According to the exposed results, it is possible to describe the El Volcán river area as one of the richest in terms of taxonomy and zooplankton abundance between the sectors considered in this analysis. Station 20 appears as the one with the best conditions for zooplankton proliferation, since it shows the highest values of taxonomic richness, total abundance and Shannon's diversity index. This station is located in a zone where the Volcán river forms a small pool, which encourages the zooplanktic growth. On the other hand, stations 18 and 19 were the ones with the lowest values for the community parameters analysed, both stations are in the upper tranche of the Volcán river area. Station 18 is located in the South La Engorda stream, in the mean tranche of the intake area and station 19 corresponds to South Volcán river. The remaining stations have a similar zooplankton composition and intermediate community parameters between the stations which presented the extreme values. Regarding composition and dominance of the zooplanktic groups present, the Chironomidae taxon was found, belonging to the insect group which was the most abundant and representative of the sector.

The Volcán river area did not present ichthyofauna. Likewise, this area did not present background about fish presence in the analysis of previous information available for the sector (Table 5.1.3.10).

5.4.4 VOLCÁN RIVER AND STREAMS ANTHROPIC USES CHARACTERISTICS

Leisure anthropic uses were not identified in the waters of the Volcán river and its streams.

5.5 ALTO MAIPO HYDROELECTRIC PROJECT ENVIRONMENTAL INTEREST AREAS (AIA)

5.5.1 BIOLOGICAL AIA

5.5.1.1 MAIPO RIVER BIOLOGIC AIA

Given the hydrobiological characteristics present in the Maipo river which point out the presence of ichthyofauna and favorable conditions tranches for biota, it have been identified two areas of biological environmental interest, one between the outlet of Volcán river and the area called Romeral, and the second one between the outlet of Yeso river and Las Lajas. The tranche between Romeral area and the outlet of Yeso river presented characteristics of torrent and scarce development of beaches and high speeds, these conditions strongly limit the development of aquatic organisms due to the effort of cut which such run-off generates avoiding the establishment of flora and aquatic fauna (Figure 5.5.1.1).

In the most favorable sectors, due to the presence of beaches and important biota (fish as indicators), it has been defined critical control sections and assessment for such areas, in some cases some have been defined by expert criterion.

These correspond to the following sampling stations:

Critical sections for Maipo River

Section	Station	Argument
PBN-07	without	Expert criterion
Toyo	St. 10	Fish
PBN-04	St. 8	Fish
Las Lajas 2	St. 6	Fish

5.5.1.2 COLORADO RIVER BIOLOGIC AIA

Given the hydrobiological characteristics presents in the Colorado river which point out the presence of ichthyofauna in almost all the tranche between the Maitenes intake and the Maipo river outlet and the presence of zones of breaded river (discontinuous) with beaches almost along the whole tranche, the whole tranche of the river was defined (Figure 5.5.1.2) as a biologic environmental important area and the following critical control sections and assessment were defined:

Critical sections for Colorado River

Section	Station	Argument
COL-2	St. 1	Expert criterion
PBN-01	St. 2	Fish
PBN-20	St. 4	Fish

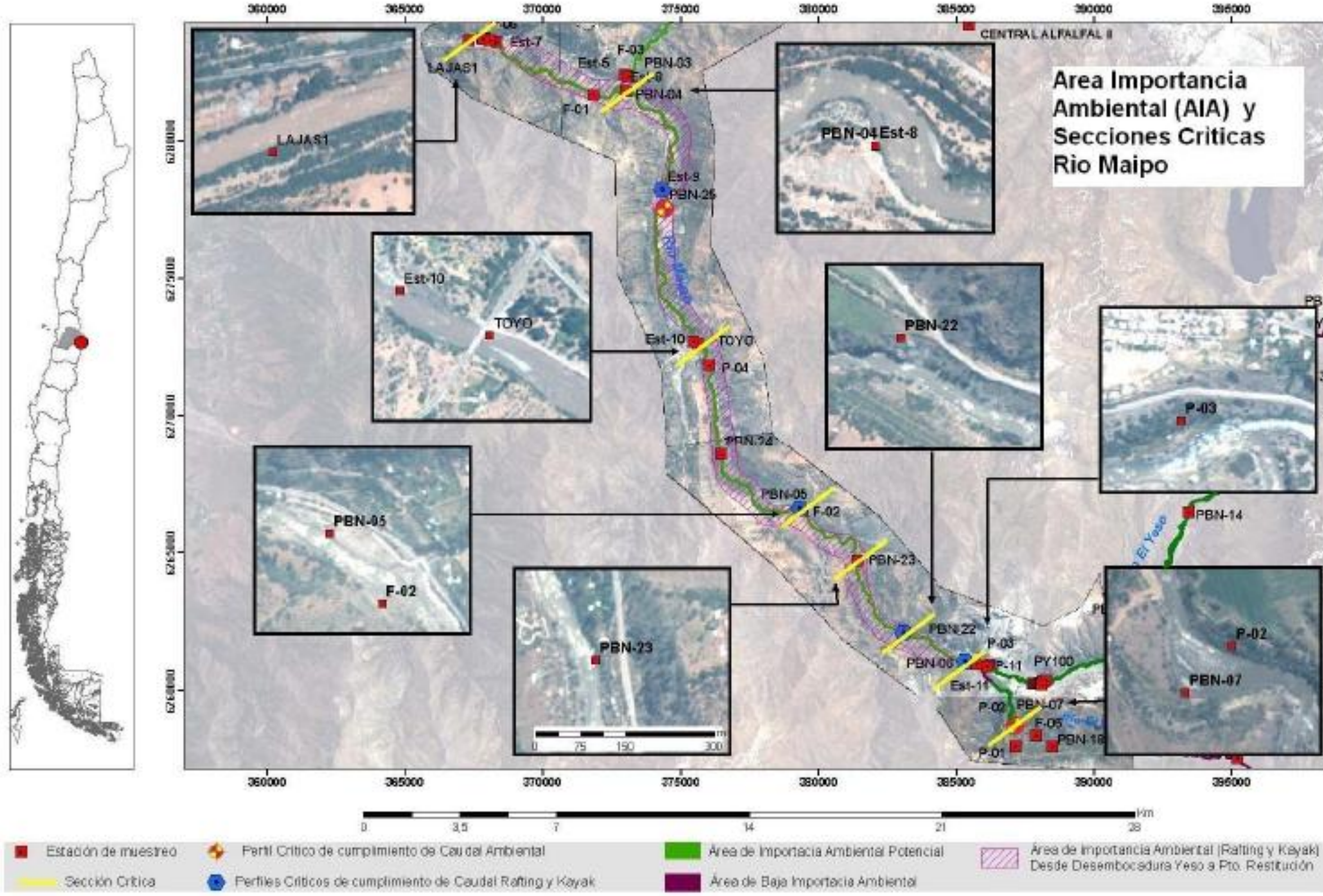

Figure 5.5.1.1 Maipo River Environmental Importance Area (AIA) and Critical Sections

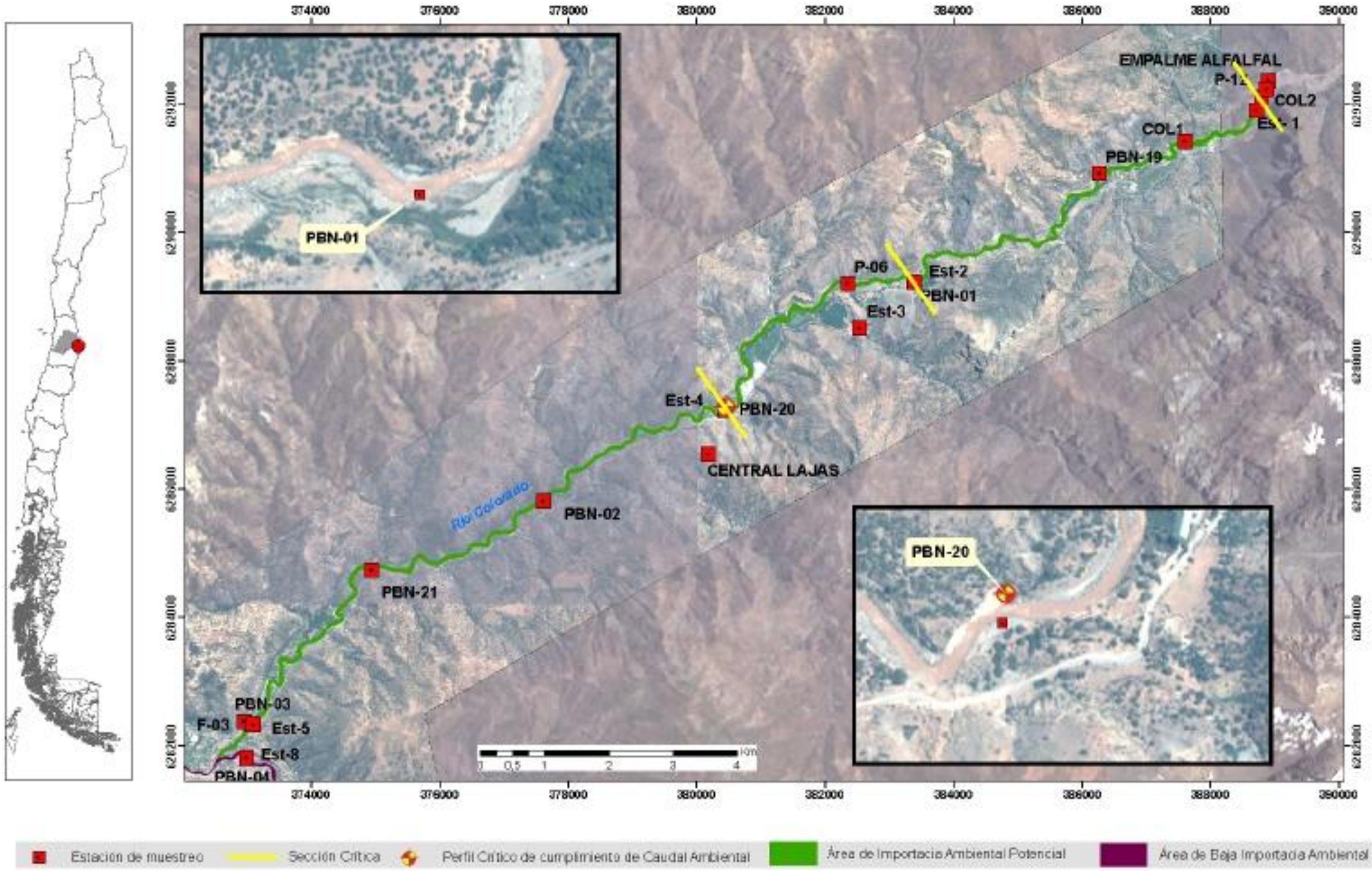

Figure 5.5.1.2 Colorado River Environmental Importance Area (AIA) and Critical Sections

Area Importancia Ambiental (AIA) y Secciones Criticas Rio Yeso
Rio El Yeso
CAPTACION YESO
P-07
PBN-09
Est-14
PBN-13
PBN-08
P-06
PBN-14
PBN-23
PBN-15
Est-13
PBN-22
PBN-06
P-03
P-11
Est-11
PYO
Est-12
Estación de muestreo
Sección Critica
Perfil Critico de cumplimiento de Caudal Ambiental
Área de Importacia Ambiental Potencial
Área de Baja Importacia Ambiental

Figure 5.5.1.3 Yeso River Environmental Importance Area (AIA) and Critical Sections

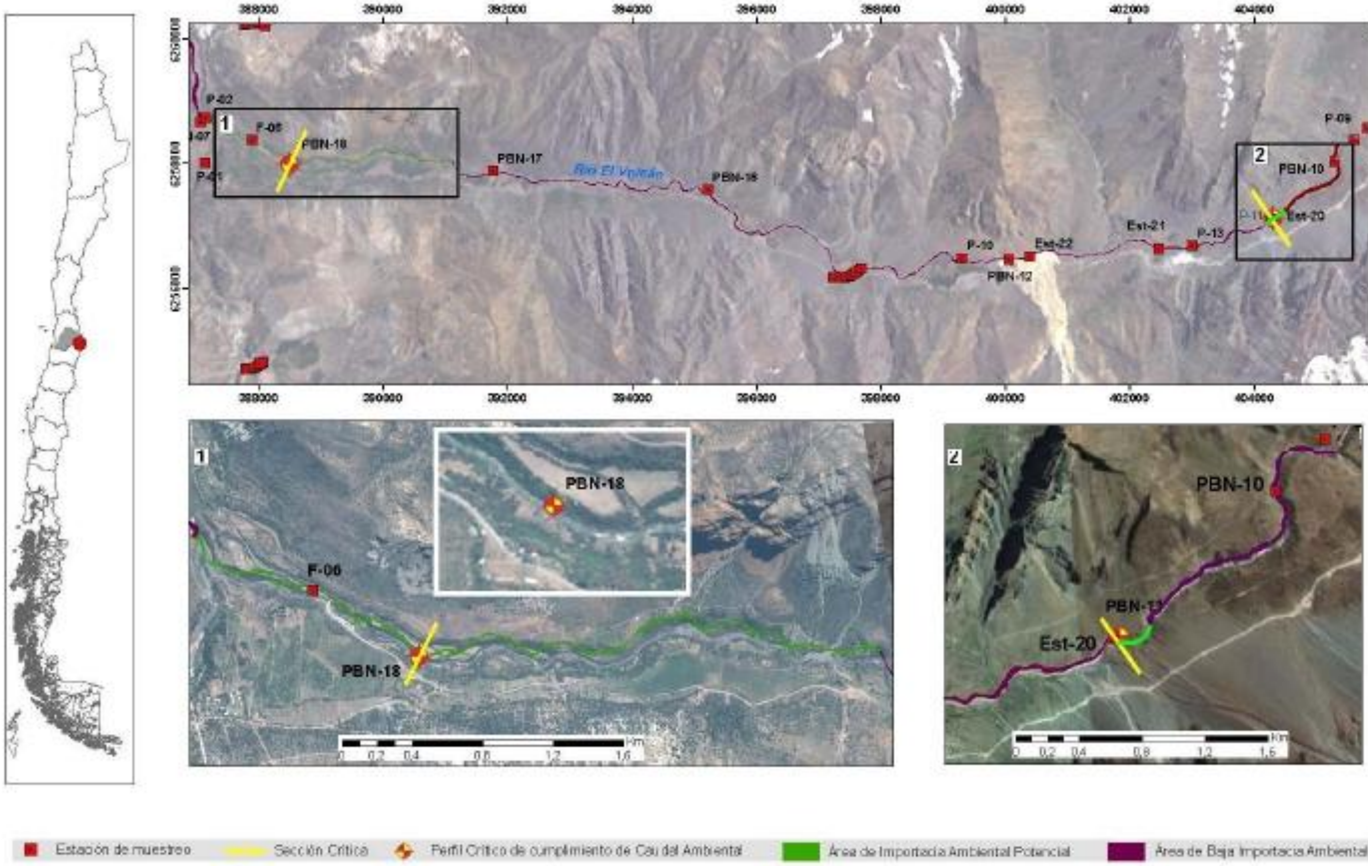

Figure 5.5.1.4a Volcán River Environmental Importance Area (AIA) and Critical Sections

Figure 5.5.1.4b Volcán River Environmental Importance Area (AIA) and Critical Sections

5.5.1.3 YESO RIVER BIOLOGIC AIA

Given the hydrobiological characteristics presents in the Yeso river which point out the presence of ichthyofauna in all the tranche between the intake at the foot of the El Yeso reservoir wall and the outlet in the Maipo river and the presence of zones of breaded river (discontinuous) with beaches almost along the whole tranche, the whole tranche of the river was defined (Figure 5.5.1.3) as a biologic environmental important area and the following critical control sections and assessment were defined:

Critical sections for Yeso River

Section	Station	Argument
PBN-09	St. 14	Fish
PBN-15	St. 13	Fish
SEDIM	St. 12	Fish

5.5.1.4 VOLCÁN RIVER AND STREAMS BIOLOGIC RIVER AIA

In the Volcán River and its streams ichthyofauna has not been detected, nevertheless, there are zones with morphological characteristics suitable for a good habitability of the flora and aquatic fauna, reason why, areas of potential environmental importance have been defined. In the case of El Morado stream which has two small areas (Figure 5.5.1.4b) have been considered and which it has been defined a critical section and two zones on Volcán River (Figure 5.5.1.4a) with a critical section each one of them.

Critical sections for Volcán River and Streams

Section	Station	Argument
MOR-01	without	Morphology/exp.
Colina-01	without	Morphology/exp.
ENG-01	without	Morphology/exp.
Placas-01	without	Morphology/exp.
PBN-11	St. 20	Morphology/exp.
PBN-18	without	Morphology/exp.

5.5.2 ANTHROPIC USES AIA

5.5.2.1 MAIPO RIVER ANTHOPIC AIA

The Maipo river tranche was in-field assessed, which is used for Kayak and Rafting activities, the anthropic environmental importance area was defined between the Yeso river outlet and San José de Maipo (Los Héroes Park area). In this area, 5 critical sections to control and assess the minimum flow required for such activities were defined. These are (Figure 5.5.1.1):

Critical anthropic sections for Maipo River

Section	Station	Argument
PBN-06	without	Morphology
PBN-22	without	Morphology
PBN-23	without	Morphology
PBN-05	without	Morphology
El Toyo	without	Morphology

5.5.2.2 COLORADO RIVER ANTHROPIC AIA

Anthropic uses of the course waters of the Colorado river area not declared.

5.5.2.3 YESO RIVER ANTHOPIC AIA

Yeso river reports sports fishing in some periods of the year, given that in this river the biologic ecological flow is assessed to guarantee the presence of fish, the same area and defined sections are used to obtain the biological ecological flow.

5.5.2.4 VOLCÁN RIVER AND STREAMS ANTHOPIC AIA

Anthropic use of the water course of the Volcán river and streams are not declared.

6 ENVIRONMENTAL FLOW ESTIMATION RESULTS

6.1 ENVIRONMENTAL FLOW ESTIMATION BY HYDROLOGIC METHODS

Table 6.1 shows Environmental Flow results by hydrologic methods for the Areas of Environmental Interest and/or the head stations of each river under study. The assessed methodologies were the following, as it is stated in the requirements established by the DGA in the Standards and Procedures Manual for Hydric Resources Management (DGA, 2002):

- EnvQ1: 10% of the Annual Average Flow
- EnvQ2: 50% of the low water level flow in a year with a 95% exceedance probability
- EnvQ3: Q330 Flow exceeded 330 days in one year (homologated by a F of P90% based on a monthly average statistic)
- EnvQ3: Q347 Flow exceeded 347 days in one year (homologated by a F of P95% based on a monthly average statistic)

Additionally, there have been international methodologies considered for this assessment, such as the following legislations and methods:

- Environmental Flow according to Swiss Laws
- Environmental Flow according to the Principality of Asturias Laws
- Environmental Flow according to New England's Laws
- Environmental Flow according to Tennant Method (F10%) for an acceptable condition

Table 6.1: Environmental Flow Results with hydrologic methods

Point	10% Q Annual_Aveat	50% Qmin_mon (95%)	Q330	Q347	Swiss Laws	Principality of Asturias	New England Laws	Tennant (10%) Acceptable
ALTO VOLCÁN								
Colina-01 AEI	0.32	0.33	0.81	0.73	0.35	0.26	0.41	0.32
MOR-01 AEI	0.17	0.20	0.51	0.45	0.26	0.19	0.30	0.17
ENG-01 AEI	0.10	0.11	0.29	0.26	0.17	0.14	0.17	0.10
Placas-01 AEI	0.05	0.05	0.12	0.10	0.09	0.10	0.06	0.05
VOLCÁN								
P-09 Hydrologic Station	1.08	1.31	3.40	3.02	1.01	1.06	2.06	1.08
MAIPO								
PBN-07 AEI	5.72	7.38	20.28	16.99	3.55	5.95	11.10	5.72
COLORADO								
COL-2 AEI	1.60	0.09	1.64	1.07	0.46	0.37	7.53	1.60
YESO								
PBN-09 AEI	0.79	0.40	1.98	0.81	0.38	0.28	1.92	0.79

The advantages of applying these methods are that the assessment can be carried out without many calculation complexities, since they are based entirely on hydrological statistics, without considering other variables such as the shape of the hydrograph, the physical variables or hydrobiological processes associated to the river.

In some cases the availability of hydrological information must be considered. In this case, for flows Q330 and Q347, there are not daily hydrological statistics available. The approximation carried out based on the monthly average statistics (homologation of Q330 at P90%, and Q347 at P95%) provides higher values than there would be expected for a daily statistic, due to the fact of taking average values.

6.2 RESULTS OF THE ENVIRONMENTAL FLOW ESTIMATION WITH THE HABITABILITY AND ANTHROPIC USES METHOD

6.2.1 ENVIRONMENTAL FLOW HABITABILITY METHOD

This section provides the results of the Environmental Flow estimation with the Habitability Method for the control sections of the Areas of Environmental Importance (AEI) and the flows passing through the intake in order to meet those requirements.

- **Maipo River**

In Maipo river, the Environmental Flow was assessed in 8 sections: PBN-7, PBN-6, PBN-22, PBN-23, PBN-5, El Toyo, PBN-4 and Las Lajas. **Figures 6.1, 6.2 and 6.3** show the geometry and some habitability results for the brown trout (Adult *Salmo trutta*) and the rainbow trout (*Adult Oncorhynchus mykiss*).

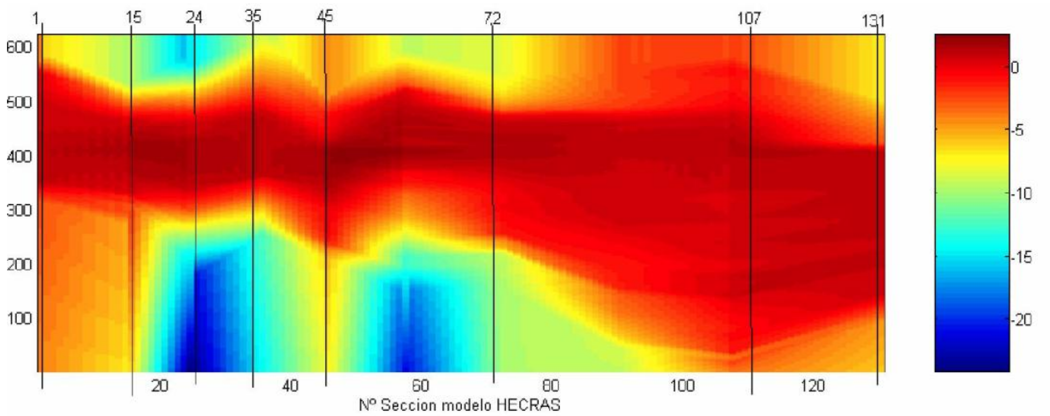

Figure 6.1: HECRAS interpolated geometry for Maipo river, based on topobatimetric sections. The color scale represents the Runoff height variable (negative values in dry land). The position of sections 1,15,24,35,45,72,107 and 131 that correspond to the position of some EIA control sections (which are PBN-7, PBN-6, PBN-22, PBN-23, PBN-5, Toyo, PBN-4 and Las Lajas, respectively) is shown. Upstream (left) and Downstream (right) chart. The longitudinal scale is 38 km (131 profiles of approximately 300 m) and the transversal scale is 120 m (600 points with a space of 20 cm each).

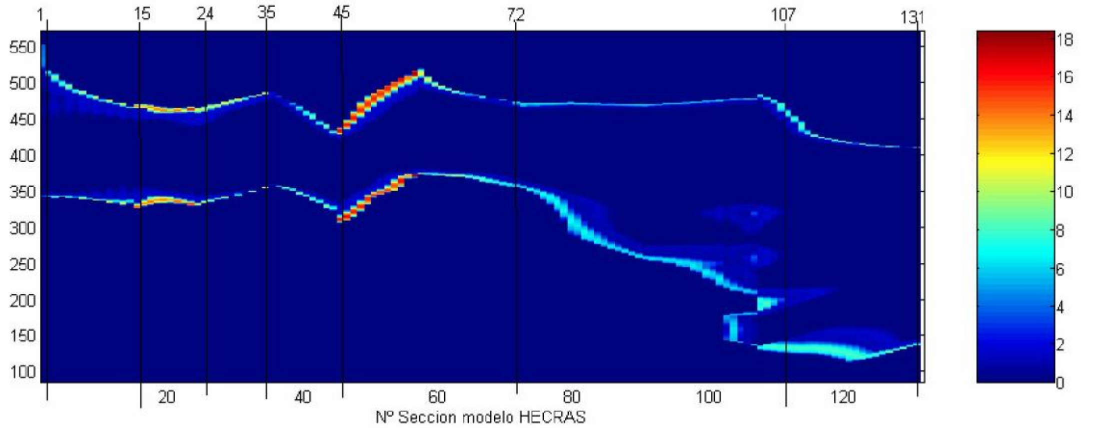

Figure 6.2: Brown trout habitability (Adult *Salmo trutta*) for Maipo river (average annual Q). The color scale represents the habitability variable (x m2). The position of sections 1, 15, 24, 35, 45, 72, 107 and 131 that correspond to the position of some EIA control sections (which are PBN-7, PBN-6, PBN-22, PBN-23, PBN-5, Toyo, PBN-4 and Las Lajas, respectively) is shown. Upstream (left) and Downstream (right) chart. The longitudinal scale is 38 km (131 profiles of approximately 300 m) and the transversal scale is 90 m (450 points with a space of 20 cm each).

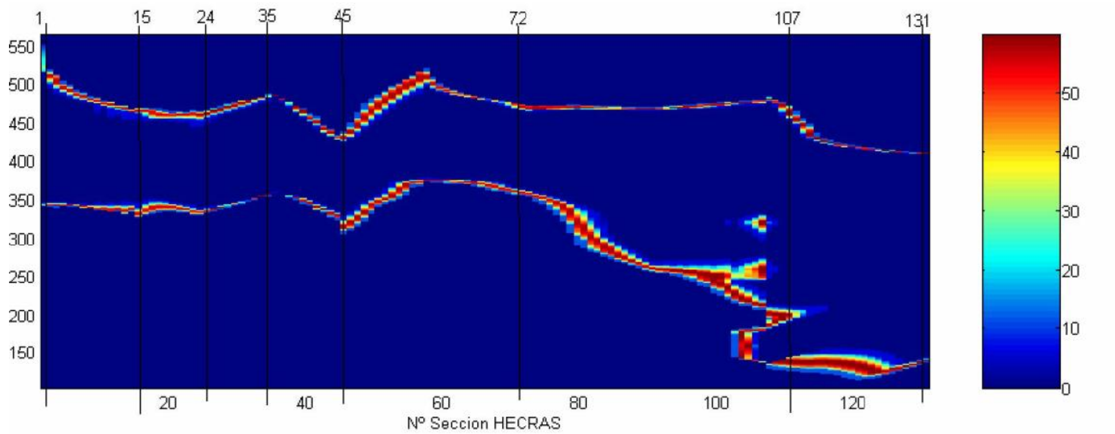

Figure 6.3: Rainbow trout habitability (*Adult Oncorhynchus* mykiss) for Maipo river (annual average Q). The color scale represents the habitability variable (x m2). The position of sections 1, 15, 24, 35, 45, 72,107 and 131 that correspond to the position of some EIA's control sections (which are PBN-7, PBN-6, PBN-22, PBN-23, PBN-5, Toyo, PBN-4 and Las Lajas, respectively) is shown. Upstream (left) and Downstream (right) chart. The longitudinal scale is 38 km (131 profiles of approximately 300m) and the transversal scale is 90 m (450 points with a space of 20 cm each).

The following five **Figures (6.4a-e)** show the habitability variation of the brown trout (*Adult salmo trutta*) in Maipo river according to a series of 100%, 75%, 50%, 25% and 10% flows of the annual average.

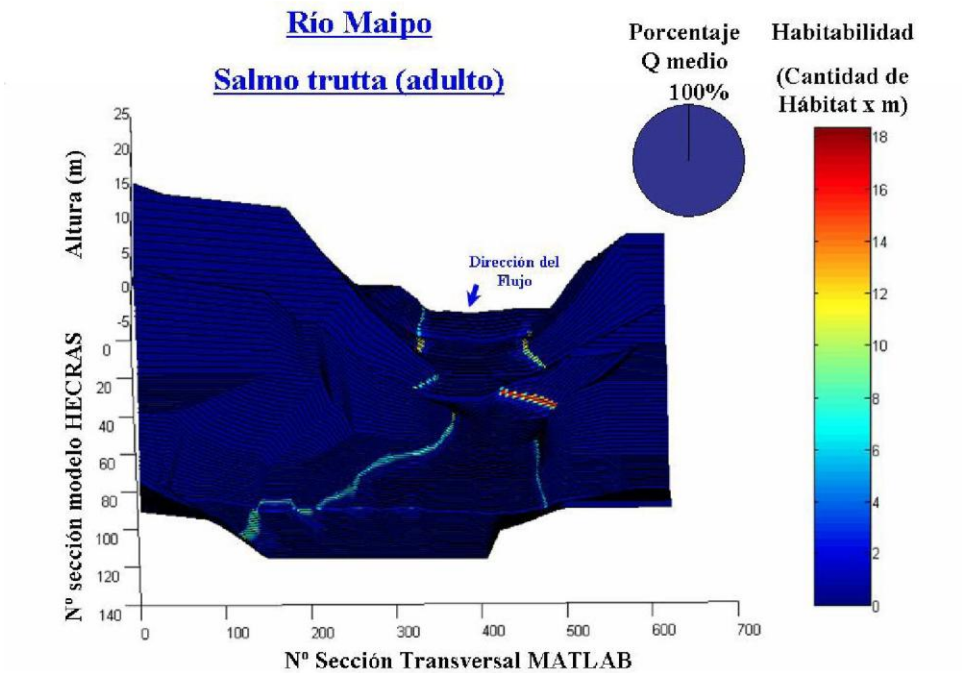

Figure 6.4a: Habitability of the brown trout (Adult *Salmo trutta*) in Maipo river according to a series of 100% flows. The longitudinal scale is 38 km (131 profiles of approximately 300m) and the transversal scale is 140 m (700 points with a space of 20 cm each).

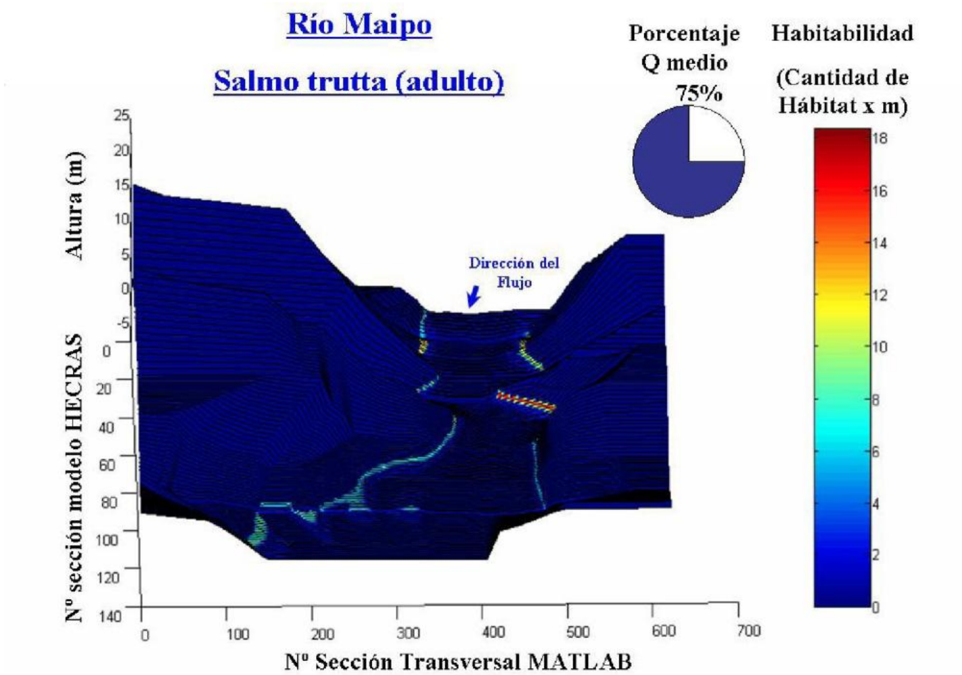

Figure 6.4b: Habitability of the brown trout (Adult *Salmo trutta*) in Maipo river according to a series of 75% flows. The longitudinal scale is 38 km (131 profiles of approximately 300m) and the transversal scale is 140 m (700 points with a space of 20 cm each).

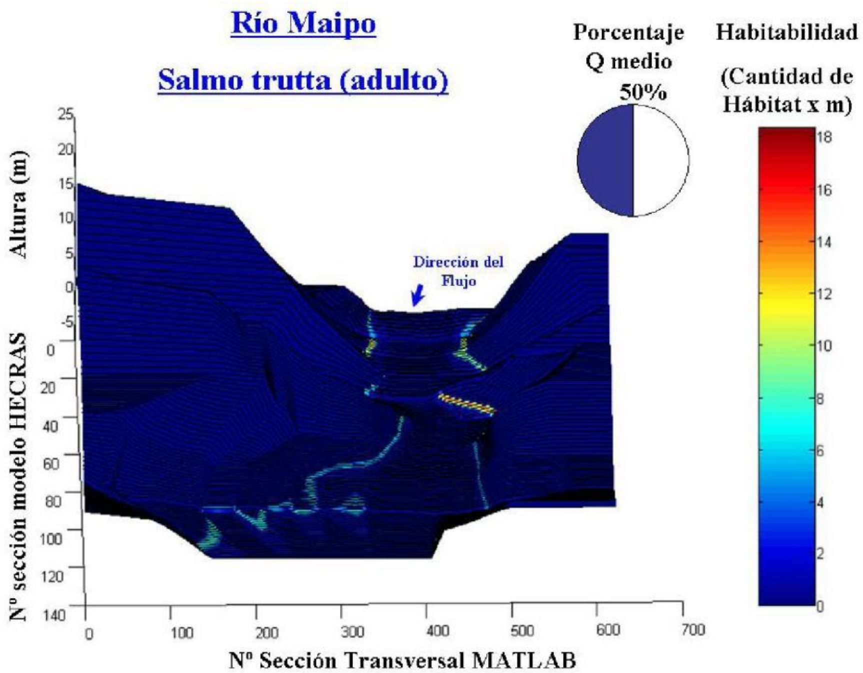

Figure 6.4c: Habitability of the brown trout (Adult *Salmo trutta*) in Maipo river according to a series of 50% flows. The longitudinal scale is 38 km (131 profiles of approximately 300m) and the transversal scale is 140 m (700 points with a space of 20 cm each).

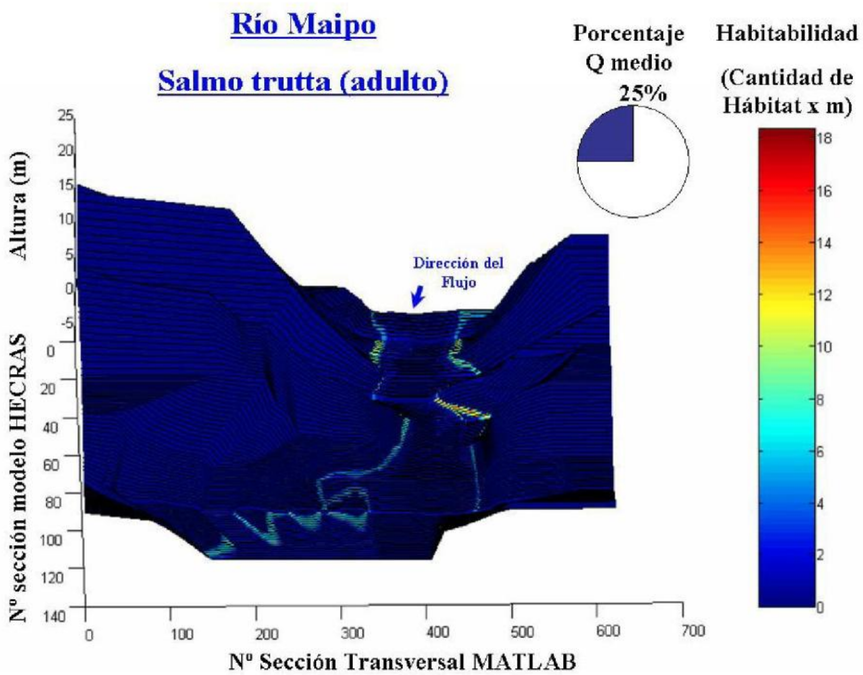

Figure 6.4d: Habitability of the brown trout (Adult *Salmo trutta*) in Maipo river according to a series of 25% flows. The longitudinal scale is 38 km (131 profiles of approximately 300m) and the transversal scale is 140 m (700 points with a space of 20 cm each).

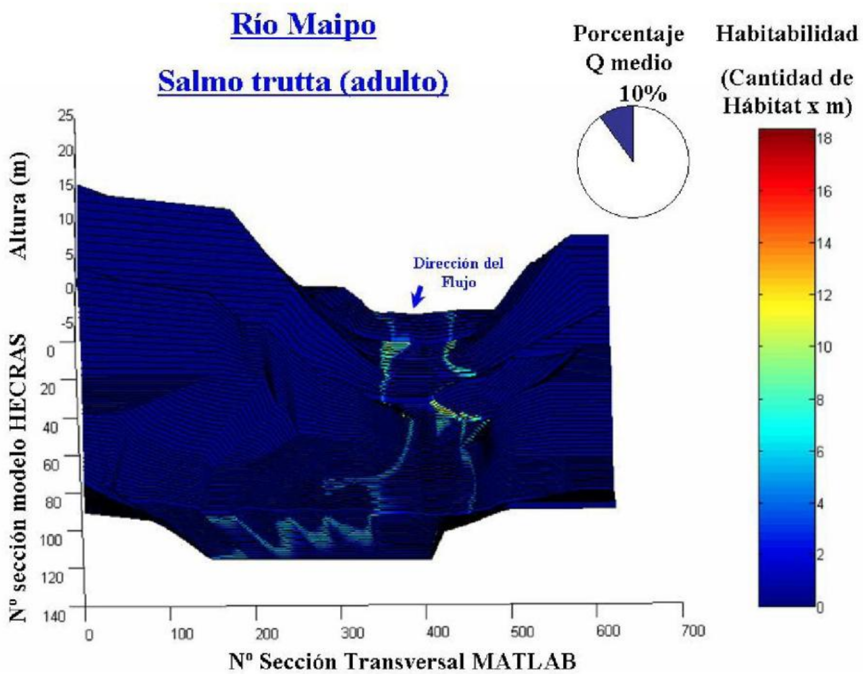

Figure 6.4e: Habitability of the brown trout (Adult *Salmo trutta*) in Maipo river according to a series of 10% flows. The longitudinal scale is 38 km (131 profiles of approximately 300m) and the transversal scale is 140 m (700 points with a space of 20 cm each).

- **Colorado River**

In Colorado River the Environmental Flow was assessed in 3 sections: COL-,2 PBN-01 and PBN-20. **Figures 6.5 and 6.6** show the geometry and some habitability results for the rainbow trout (*Adult Oncorhynchus mykiss*).

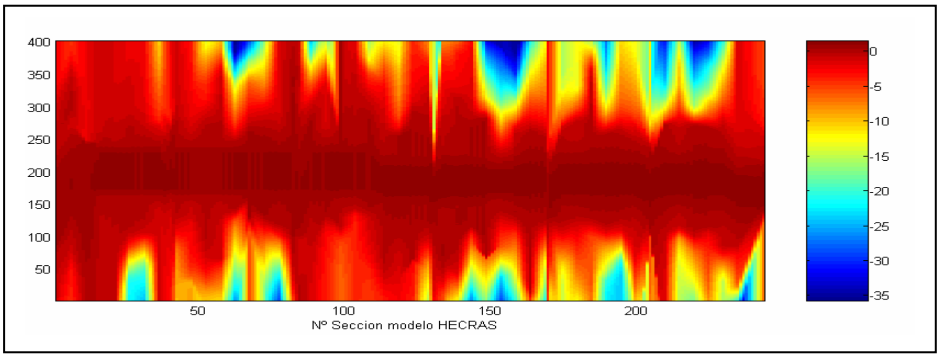

Figure 6.5: HECRAS interpolated geometry for Colorado river, based on topobatimetric and aerophotogrametric topography sections. The color scale represents the Runoff height variable (negative values in dry land). Upstream (left) and Downstream (right) chart. The longitudinal scale is 24 km (244 profiles of approximately 100m) and the transversal scale is 80 m (400 points with a space of 20 cm each).

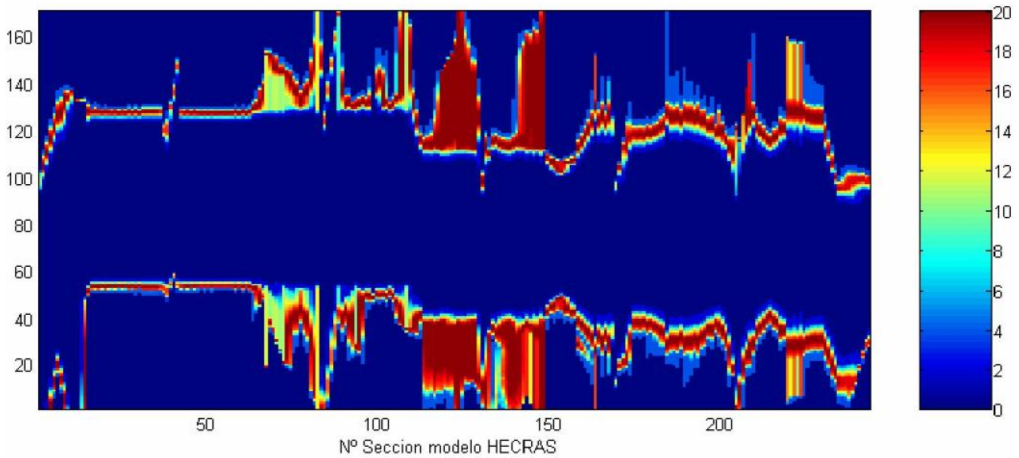

Figure 6.6: Rainbow trout habitability (*Adult Oncorhynchus* mykiss) for Colorado river (annual average Q). The color scale represents the habitability variable (x m2). Upstream (left) and Downstream (right) chart. The longitudinal scale is 24 km (244 profiles of approximately 100m) and the transversal scale of 32 m (160 points with a space of 20 cm each).

- **Yeso River**

In Yeso river the Environmental Flow was assessed in 3 sections: PBN-09, PBN-15 and a sedimentologic study profile. Fi**gures 6.7 and 6.8** show the geometry and some habitability results for the brown trout (*Adult Salmo* trutta).

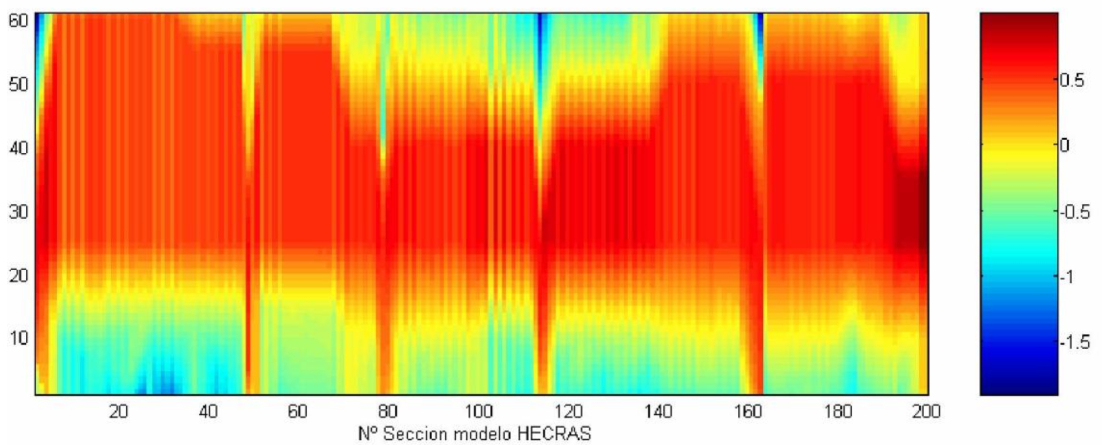

Figure 6.7: HECRAS interpolated geometry for Colorado river, based on topobatimetric and aerophotogrametric topography sections. The color scale represents the Runoff height variable (negative values in dry land). Upstream (left) and Downstream (right) chart. The longitudinal scale is 23 km (238 profiles of approximately 100m) and the transversal scale is 12 m (60 points with a space of 20 cm).

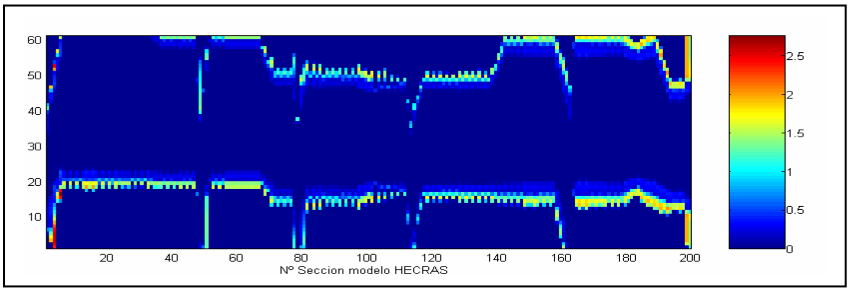

Figure 6.8: Brown trout habitability (Adult *Salmo trutta*) for Yeso river (average annual Q). The color scale represents the habitability variable (x m2). Upstream (left) and Downstream (right) chart. The longitudinal scale is 23 km (238 profiles of approximately 100m) and the transversal scale is 12 m (60 points with a space of 20 cm each).

- **Volcán River**

In Volcán river the Environmental Flow was assessed in 2 sections: PBN-11 and PBN-18. **Figures 6.9 and 6.10** show the geometry *and some habitability results for the brown trout (*Adult Salmo trutta).

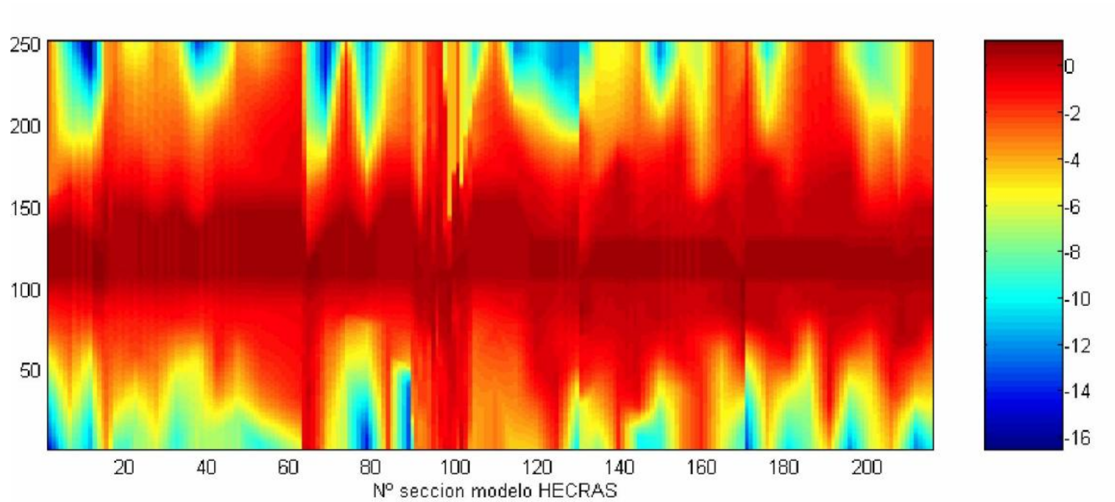

Figure 6.9: HECRAS interpolated geometry for Volcán river, based on topobatimetric and aerophotogrametric topography sections. The color scale represents the Runoff height variable (negative values in dry land). Upstream (left) and Downstream (right) chart. The longitudinal scale is 20.5 km (216 profiles of approximately 100m) and the transversal scale is 50 m (250 points with a space of 20 cm).

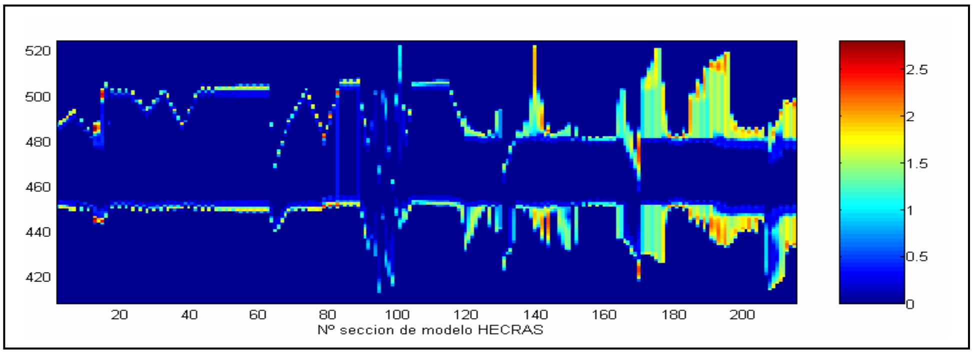

Figure 6.10: Brown trout habitability (Adult *Salmo trutta*) for Volcán river (average annual Q). The color scale represents the habitability variable (x m2). Upstream (left) and Downstream (right) chart. The longitudinal scale is 20.5 km (216 profiles of approximately 100 m) and the transversal scale is 20 m (100 points with a space of 20 cm each).

- **Colina Stream** In Colina Stream the Environmental Flow was assessed in 1 section: COLINA-01. Fi**gures 6.11 and 6.12** show the geometry *and some habitability results for the brown trout (*Adult Salmo trutta).

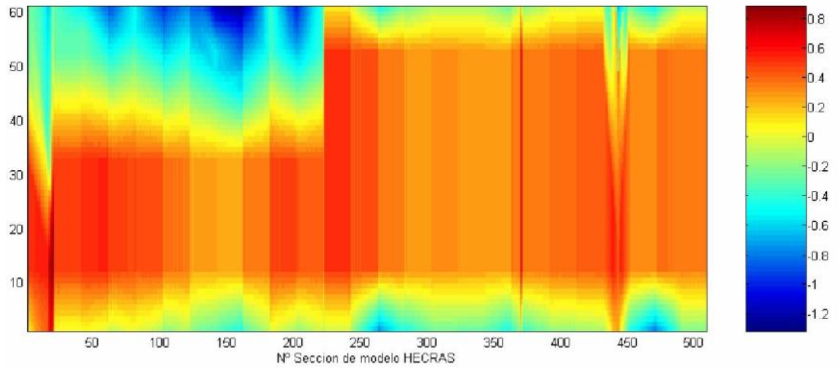

Figure 6.11: HECRAS interpolated geometry for Colina stream, based on topobatimetric and aerophotogrametric topography sections. The color scale represents the Runoff height variable (negative values in dry land). Upstream (left) and Downstream (right) chart. The longitudinal scale is 2.55 km (509 profiles of approximately 5m) and the transversal scale is 6 m (60 points with a space of 10 cm each).

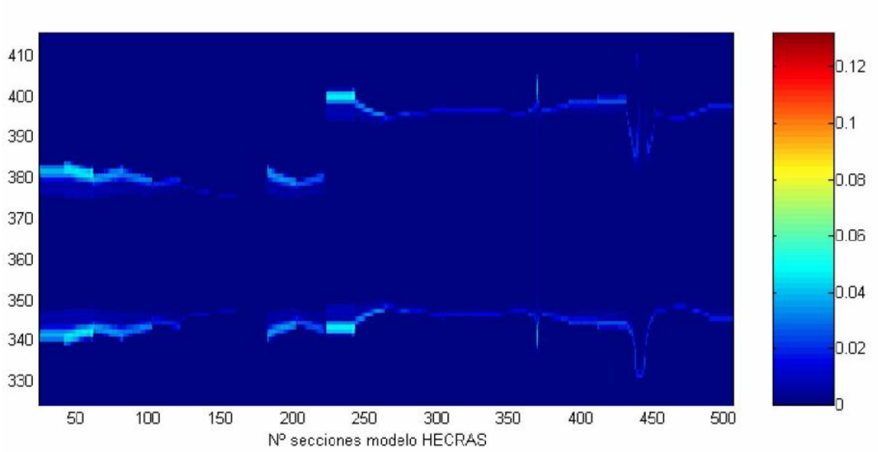

Figure 6.12: Brown trout habitability (Adult *Salmo trutta*) for Colina stream (average annual Q). The color scale represents the habitability variable (x m2). Upstream (left) and Downstream (right) chart. The longitudinal scale is 2.55 km (509 profiles of approximately 5m) and the transversal scale is 8 m (80 points with a space of 10 cm).

- **Morado Stream**

In Morado stream the Environmental Flow was assessed in 2 sections: MOR-01 and MOR-02. **Figures 6.13 and 6.14** show the geometry *and some habitability results for the brown trout (*Adult Salmo trutta).

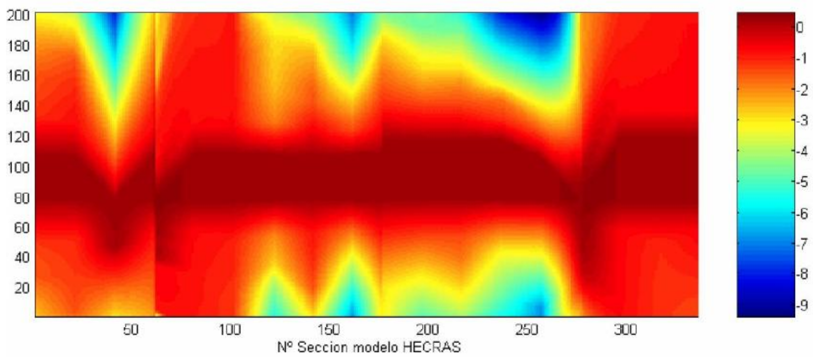

Figure 6.13: HECRAS interpolated geometry for Morado stream, based on topobatimetric and aerophotogrametric topography sections. The color scale represents the Runoff height variable (negative values in dry land). Upstream (left) and Downstream (right) chart. The longitudinal scale is 1.68 km (336 profiles of approximately 5m) and the transversal scale is 20 m (200 points with a space of 10 cm each).

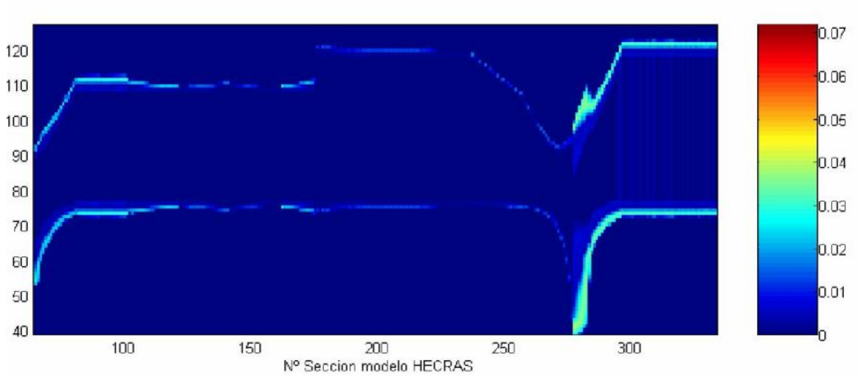

Figure 6.14: Brown trout habitability (Adult *Salmo trutta*) for Morado stream (average annual Q). The color scale represents the habitability variable (x m2). Upstream (left) and Downstream (right) chart. The longitudinal scale is 1.68 km (336 profiles of approximately 5m) and the transversal scale is 8 m (80 points with a space of 10 cm each).

- **La Engorda Stream**

In La Engorda Stream the Environmental Flow was assessed in 1 section: ENG-01. Figures **6.15 and 6.16** show the geometry and some habitability results for the brown trout (*Adult Salmo* trutta).

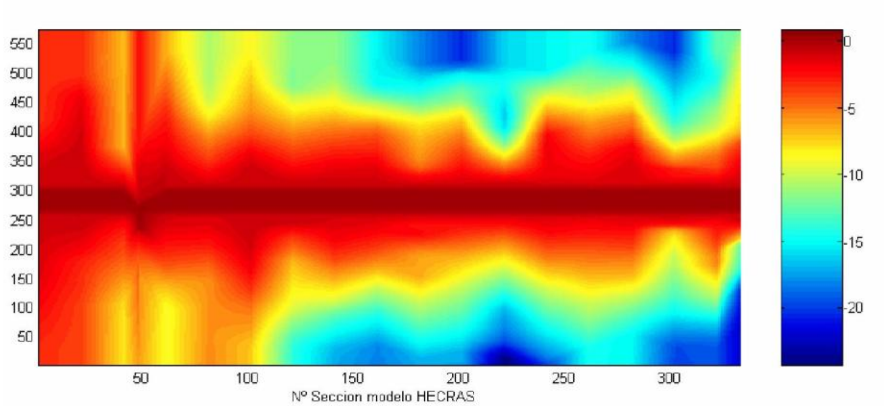

Figure 6.15: HECRAS interpolated geometry for La Engorda stream, based on topobatimetric and aerophotogrametric topography sections. The color scale represents the Runoff height variable (negative values in dry land). Upstream (left) and Downstream (right) chart. The longitudinal scale is 1.65 km (333 profiles of approximately 5m) and the transversal scale is 50 m (500 points with a space of 10 cm each).

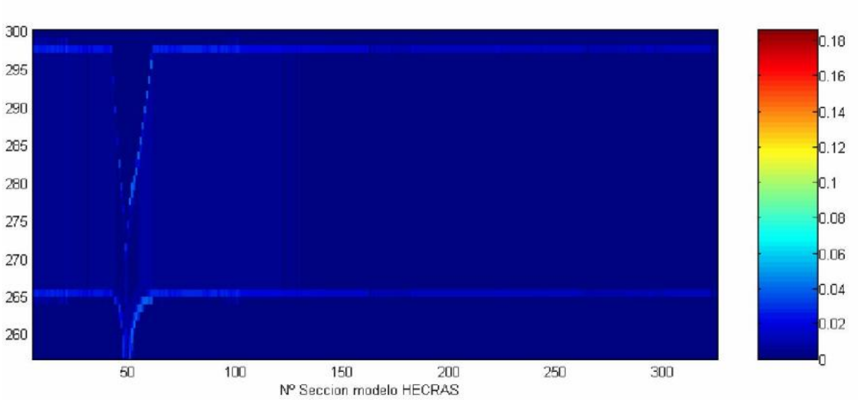

Figure 6.16: Brown trout habitability (Adult *Salmo trutta*) for Engorda stream (average annual Q). The color scale represents the habitability variable (x m2). Upstream (left) and Downstream (right) chart. The longitudinal scale is 1.65 km (333 profiles of approximately 5 m) and the transversal scale is 4 m (40 points with a space of 10 cm each).

- **Las Placas Stream**

In Colina Stream the Environmental flow was assessed in 1 section: PLACAS-01 obtained from the aerophotogrametric topography. Figures **6.17 and 6.18** show the geometry and some habitability results *for the brown trout (*Adult Salmo trutta).

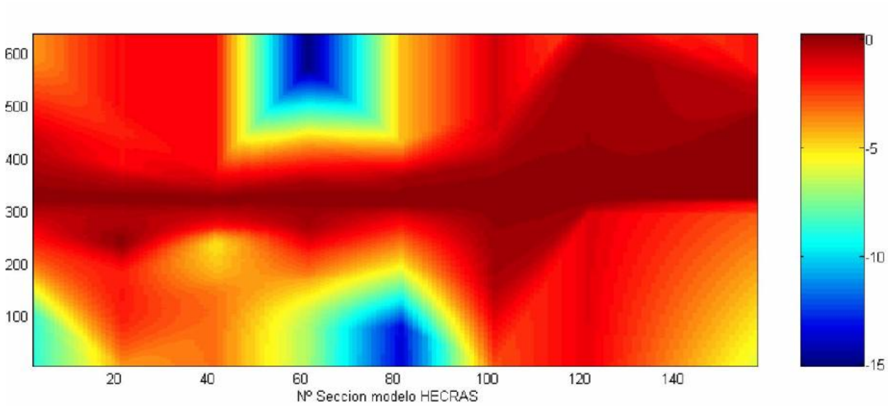

Figure 6.17: HECRAS interpolated geometry for Las Placas stream, based on topobatimetric sections. The color scale represents the Runoff height variable (negative values in dry land). Upstream (left) and Downstream (right) chart. The longitudinal scale is 0.79 km (158 profiles of approximately 5m) and the transversal scale is 60 m (600 points with a space of 10 cm each).

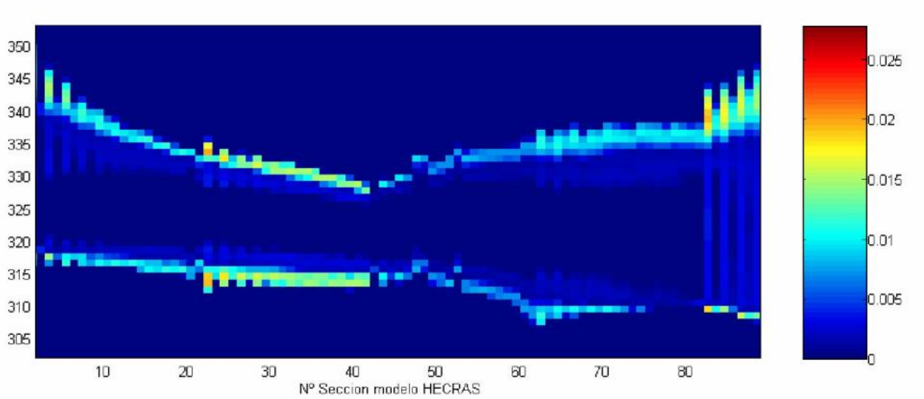

Figure 6.18: Brown trout habitability (Adult *Salmo trutta*) for Engorda stream (average annual Q). The color scale represents the habitability variable (x m2). Upstream (left) and Downstream (right) chart. The longitudinal scale is 0.79 km (158 profiles of approximately 5m) and the transversal scale is 60 m (600 points with a space of 10 cm each).

The results of the Environmental Flow calculation for each one of the AEI sections under the monthly average minimum low water level flow criterion, is shown in **Table 6.2**. The sector, the AEI section, the annual average Q, the monthly minimum Q, the environmental Q, the environmental Q percentage with the annual average Q and the most restrictive criterion that the Environmental Flow determined is shown.

ANNEX C shows all of the charts with which the Environmental Flow was assessed, taking the low water level as the monthly average minimum flow.

Table 6.2: Environmental Flow per section (monthly average minimum low water level base flow)

			MONTHLY MINIMUM HABITABILITY Q PER SECTION				
N°	**Sector**	**Section**	**Qma**	**Q min n**	**Env Q**	**%Qma**	**10% habitat decrease criterion**
1	**Colina Stream**	**Colina-01 AEI**	3.24	0.89	**0.29**	9%	Adult Salmo trutta
2	**Morado Stream**	**MOR-01 AEI**	1.71	0.56	**0.53**	31%	No habitat restriction. Q(0.2m) is applied.
3)	**Morado Stream**	**MOR-02 AEI**	1.71	0.56	**0.56**	33%	Low water level min Q lower than 0.2 m. The low water
4	**Engorda Stream**	**ENG-01 AEI**	0.99	0.32	**0.26**	26%	Young Salmo trutta
5	**Placas Stream**	**Placas-01**	0.47	0.13	**0.13**	28%	Low water level min Q lower than 0.2 m. The low water
6	**Volcán river**	**PBN11 AEI**	11.08	4.17	**1.49**	13%	Habitat N/R. Q(0.2m) is applied.
7	**Volcán river**	**PBN-18 AEI**	8.39	1.59	**1.49**	18%	Adult and young Salmo trutta
8	**Maipo River**	**PBN-07 AEI**	**and**	25.10	**13.49**	24%	Young Salmo trutta
9	**Maipo River**	**PBN-06 AEI**	68.69	30.28	**4.40**	6%	Young Salmo trutta
10	**Maipo River**	**PBN-22 AEI**	69.69	31.28	**27.00**	39%	Young Salmo trutta
11	**Maipo River**	**PBN-23 AEI**	71.09	32.68	**3.60**	5%	No habitat restriction. Q(0.2m) or Qma5% is applied
12	**Maipo River**	**PBN-05 AEI**	**and**	34.96	**4.60**	6%	No habitat restriction. Q(0.2m) is applied.
13	**Maipo River**	**Toyo AEI**	74.07	37.18	**5.10**	7%	No habitat restriction. Q(0.2m) is applied.
14	**Maipo River**	**PBN-04 AEI**	80.53	42.20	**35.60**	44%	Adult Salmo trutta
15	**Maipo River**	**Lajas AEI**	112.01	58.20	**5.60**	5%	No habitat restriction. Q(0.2m) or Qma5% is applied
16	**Colorado River**	**COL-2 and P**	0,16.05	2.90	**1.49**	9%	No habitat restriction. Q(0.2m) is applied.
17	**Colorado River**	**PBN-01 AEI**	17.55	4.40	**2.42**	14%	No habitat restriction. Q(0.2m) is applied.
18	**Colorado River**	**PBN-20 AEI**	28.44	14.09	**2.05**	7%	No habitat restriction. Q(0.2m) is applied.
19	**Yeso river**	**PBN-09 AEI**	7.91	5.90	**0.74**	9%	Young Salmo trutta
20	**Yeso river**	**PBN-15 AEI**	10.02	8.01	**2.09**	21%	Young Salmo trutta
21	**Yeso river**	**SEDIM_Y AEI**	**e**	8.58	**0.93**	9%	No habitat restriction. Q(0.2m) is applied.

N/R: No habitat restriction

Intakes

The results of the Environmental Flow calculation for each one of the AEI sections under the low water level flow with an 85% exceedance probability criterion, is shown in **Table 6.3**. The sector, the AEI section, the annual average Q, the low water level Q with an 85% exceedance probability, the environmental Q, the environmental Q percentage with the average annual Q and the most restrictive criterion that the Environmental Flow determined is shown.

ANNEX D shows all of the charts that were used for assessing the Environmental Flow, taking the Low Water Level Flow with an 85% exceedance probability as the Low Water Level.

Table 6.3: Environmental Flow per section (minimum low water level base flow with an 85% exceedance probability)

			P85% LOW WATER LEVEL Q HABITABILITY PER SECTION				
N°	**Sector**	**Section**	**Qma**	**Q85%**	**Env Q,**	**%Qma**	**10% habitat decrease criterion**
1	**Colina Stream**	**Colina-01 AEI**	3.24	0.72	**0.37**	11%	Adult Salmo trutta
2	**Morado Stream**	**MOR-01 AEI**	1.71	0.44	**0.44**	26%	Low water level min Q lower than 0.2 m. The Q low water level is applied
3)	**Morado Stream**	**MOR-02 AEI**	1.71	0.44	**0.44**	26%	Low water level min Q lower than 0.2 m. The Q low water level is applied
4	**Engorda Stream**	**ENG-01 AEI**	0.99	0.25	**0.15**	15%	Adult and young Salmo trutta
5	**Placas Stream**	**Placas-01 AEI**	0.47	0.10	**0.10**	21%	Low water level min Q lower than 0.2 m. The Q low water level is applied
6	**Volcán river**	**PBN11 AEI**	11.08	3.10	**1.49**	13%	No habitat restriction. Q(0.2m) is applied.
7	**Volcán river**	**PBN-18 AEI**	8.39	0.60	**0.42**	5%	No habitat restriction. Q(0.2m) or Qma5% is applied
8	**Maipo River**	**PBN-07 AEI**	**and**	16.66	**13.49**	24%	Young Salmo trutta
9	**Maipo River**	**PBN-06 AEI**	68.69	20.89	**5.80**	8%	Young Salmo trutta
10	**Maipo River**	**PBN-22 AEI**	69.69	21.89	**3.48**	5%	No habitat restriction. Q(0.2m) or Qma5% is applied
11	**Maipo River**	**PBN-23 AEI**	71.09	23.29	**3.55**	5%	No habitat restriction. Q(0.2m) or Qma5% is applied
12	**Maipo River**	**PBN-05 AEI**	**and**	23.69	**4.20**	6%	Adult Salmo trutta
13	**Maipo River**	**Toyo AEI**	74.07	24.68	**9.80**	13%	Young Salmo trutta
14	**Maipo River**	**PBN-04 AEI**	80.53	26.41	**24.30**	30%	Young Salmo trutta
15	**Maipo River**	**Lajas AEI**	112.01	37.75	**5.60**	5%	No habitat restriction. Q(0.2m) or Qma5% is applied
16	**Colorado River**	**COL-2 and P AEI**	16.05	0.66	**0.66**	4%	Low water level min Q lower than 0.2 m. The Q low water level is applied
17	**Colorado River**	**PBN-01 AEI**	17.55	2.17	**2.17**	12%	Low water level min Q lower than 0.2 m. The Q low water level is applied
18	**Colorado river**	**PBN-20 AEI**	28.44	10.94	**2.05**	7%	No habitat restriction. Q(0.2m) is applied.
19	**Yeso river**	**PBN-09 AEI**	7.91	0.79	**0.46**	6%	Adult Oncorhynchus mykiss
20	**Yeso river**	**PBN-15 AEI**	10.02	2.90	**1.97**	20%	Adult Salmo trutta
21	**Yeso river**	**SEDIM_Y AEI**	**e**	3.47	**1.05**	10%	Adult Salmo trutta

N/R: No habitat restriction

Intakes

6.2.2 ENVIRONMENTAL FLOW WITH THE ANTHROPIC USE METHOD

Rafting/Kayaking use

This methodology is related to the hydric environmental demand for anthropic uses of the river. In particular, there have been Rafting/Kayaking activities detected from the connection of Maipo river with Yeso river all the way to San José de Maipo.

An assessment has been considered in terms of the availability of geometric conditions for carrying out that activity. The main criteria used were the following:

- It is considered that Rafting takes place from October to April
- The critical month is April, due to the lower availability of flows. The analysis was carried out based on the natural regime hydrograph.
- The raft needs a 60 cm height runoff in the river area and in the backwater (excluding the rapids area, where naturally the runoff height has a supercritical flow).
- The activity requires a 12 m wide flow with a minimum depth of 60 cm. The 12 m width is an estimation obtained after geometrically considering a minimum of 2 raft lengths and the length of the paddles.

Figure 6.19: Rafting in Maipo river at San Alfonso, downstream from DGA's stream flow gauging station

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The assessment was carried out by assessing the grid of the hydraulic model that met the previously described conditions, as shown in **Figure 6.20**. In this case the sections of interest were: PBN-06, PBN-22, PBN-23, PBN-05 and El Toyo. All of these sections are between San Gabriel and San José de Maipo.

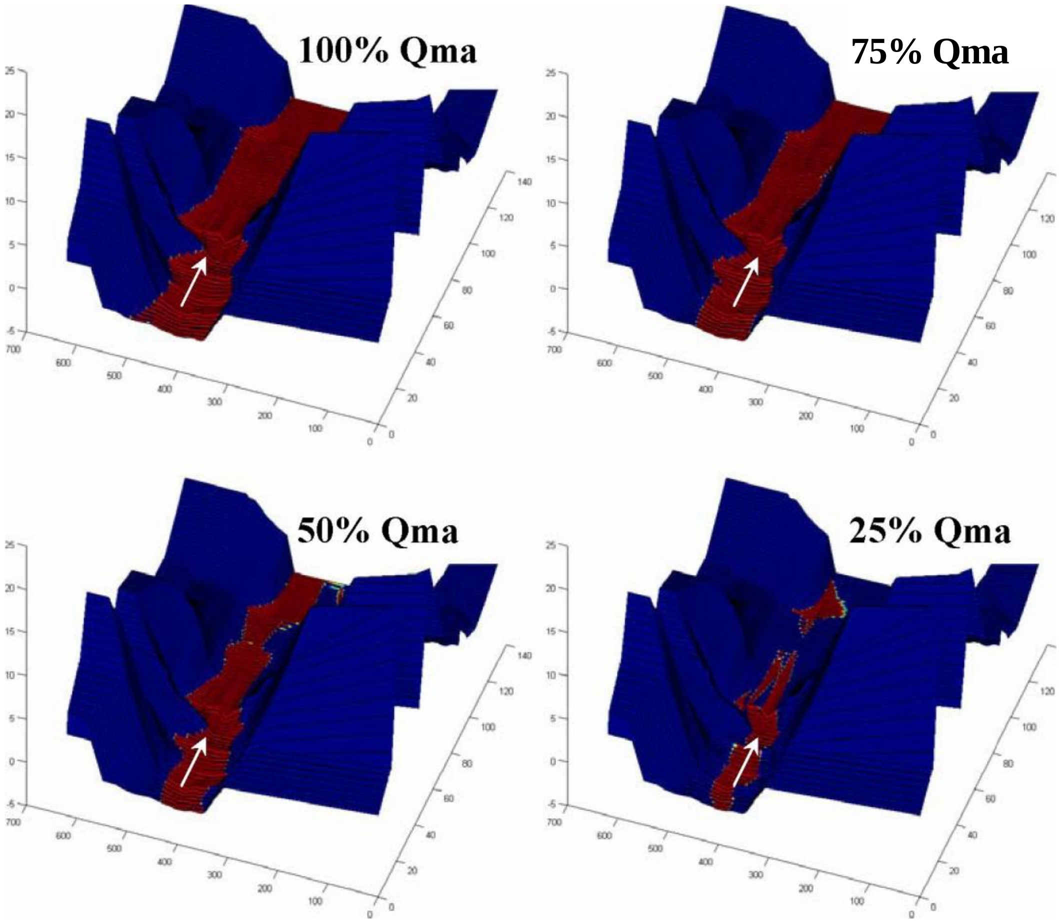

Figure 6.20: Assessment of the continuity of water depth conditions (60 cm) based on the annual average flow percentage. Cases of 100%, 75%, 50% and 25% are shown. MATLAB model results.

For each one of the control sections the necessary flow was represented in a chart in order to have a 12 m wide section with a minimum depth of 60 cm. Then, the hydrological condition was assessed: 1) April's average flow, and 2) April's flow with an 85% exceedance probability. **Figure 6.21** shows the calculation for section PBN-06. Then, the condition of the AVAILABLE flow being greater or equal than the REQUIRED flow must be met, according to **Table 6.4**.

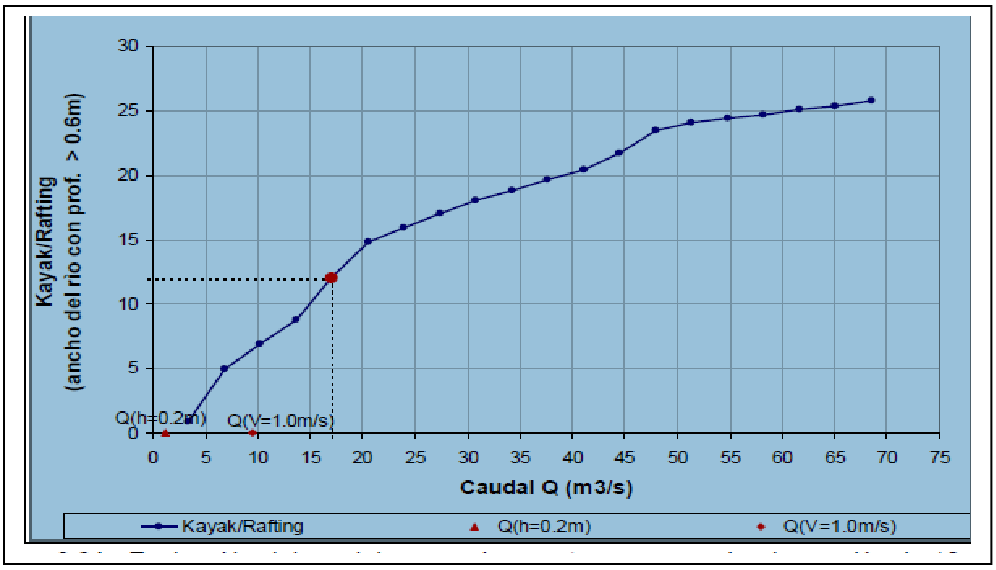

Figure 6.21: Assessment of the flow needed to have a 12 m wide section with a minimum depth of 60 cm. This section corresponds to PBN-06 and provides a flow of 17.1 m3/s (as seen in **Table 6.3**).

The results of the analysis are shown here, where it is verified that the flow conditions for the proposed criteria are met.

Table 6.4: Calculation of the Environmental Flows that flow into the Intake. Anthropic Uses Method Rafting (April is the critical month).

Sector	Section	Estimated Average Q (m3/s)	Q P85% Q (m3/s) AVAILABLE	Condition	Q Rafting in AEI section REQUIRED
Colina Intake	Colina-01 AEI	0.34	0.34		
Morado Intake	MOR-01 AEI	0.32	0.32		
Engorda Intake	ENG-01 AEI	0.12	0.12		
Placas Intake	Placas-01 AEI	0.03	0.03		
	Volcan Sur	5.28	1.87		
	P-09	6.09	2.69		
	PBN11 AEI	6.41	3.00		
	P-13	6.63	3.22		
	P-10	8.85	5.44		
	PBN-18 AEI	10.98	7.57		
	F-06	11.09	7.68		
Maipo river entrance	PBN-07 and P-02 AEI	33.93	24.43		
Yeso River entrance	P-03	37.57	28.07		
	PBN-06 AEI	37.77	28.27	>	17.10
	PBN-22 AEI	38.80	29.30	>	19.00
	PBN-23 AEI	39.79	30.29	>	22.80
	PBN-05 and F-02 AEI	41.13	31.63	>	16.70
	P-04	42.69	33.19		
	Toyo AEI	43.20	33.70	>	32.70

*Criterion 12 m wide flow with a minimum depth of 0.6 m ** In Yeso river the Environmental Flow in the intake is assumed

Aesthetic Assessment

The proposal is to assess the change in the aesthetics of the area (equivalent to the Wetted Perimeter in a section) of the river that will be exposed due to flow decrease, taking the low water level flow as a base: 1) Monthly average minimum flow, and 2) Low water level flow with an 85% exceedance probability.

The estimation of a reduction in the wetted perimeter was done based on the wetted perimeter curves according to the flow for each one of the intakes (Yeso, Colorado, Morado, Colina, Engorda, Las Placas) obtained during the hydraulic axis modeling through HEC-RAS.

The process consists in assessing the wetted perimeter based on the previously mentioned curves for the monthly average minimum flow, and the estimated flows with the project taking place and considering monthly average minimum flows and low water level flows with an 85% probability for each one of the intakes. Based on this, the difference and the percentage decrease according to the monthly average minimum flow in a situation without a project was estimated.

Aesthetics Assessment Table

Flow (m3/s) / Section	Colina-01 AEI	MOR-01 AEI	MOR-02 AEI	ENG-01 AEI	Placas-01 AEI	COL-2 and P12 AEI	PBN-09 and P-07 AEI
Qma	3.24	1.71	1.71	0.99	0.47	16.05	7.91
Monthly min. Q	0.89	0.56	0.56	0.32	0.13	2.90	5.90
Environmental Q 1 (min Month)	0.29	0.53	0.53	0.26	0.13	1.49	0.74
Environmental Q 1 (low water level P85%)	0.37	0.44	0.44	0.15	0.10	0.67	0.46
Wetted Perimeter Variation (Qmin_month)	13.5%	2.8%	2.4%	1.3%	0.0%	9.6%	43.0%
Wetted Perimeter Variation (low water level P85%)	11.5%	8.3%	7.1%	3.8%	5.3%	15.1%	40.0%

Source: Carried out by us based on the Wetted Perimeter v/s Flow curves.

The results show that the variations average for both methods is in the order of 10% (monthly average minimum Q) and 13% (P85% low water level Q).

6.3 DETERMINATION OF THE FLOW PASSING THROUGH THE INTAKE

Once the Environmental Flows for the EIA section have been determined, a calculation is done so that those requirements can translate into an equivalent of flow passing through the project's intake. The calculation consists of subtracting the natural intermediate recharges in the entire upstream stretch, until reaching the intake, from the environmental flows of each section.

In case the estimated flow in the intake is not enough, the number must be increased until the downstream section has the flow required. In this case, the downstream EIA section is restrictive and controls the flow passing through the intake.

Tables 6.5 and 6.6 show the calculation of the flow passing through the intake for the monthly average minimum and the minimum an 85% exceedance probability for low water level.

The tables show the sector, section of interest, distance of the stretch, lineal recharge performance, flow recharge of the stretch, available flow in low water level (with a project) and the flow required in the section. The condition of the Q available being greater or equal than the required Q must be met.

Table 6.5: Calculation of the Environmental Flows that flow into the Intake. Q Habitability Method Monthly Minimums per Section

Sector	**Section**	**Distance (Km)**	**Lineal Recharge (m3/s/Km)**	**Recharge Q (m3/s)**	**Estimated Q (m3/s) AVAILABLE**	**Condition**	**Env Q in AEI section REQUIRED**
Colina Intake	Colina-01 AEI	0.10	0.00	0.00	0.29	≥	0.29
Morado Intake	MOR-01 AEI	0.40	0.00	0.00	0.53	≥	0.53
Engorda Intake	ENG-01 AEI	0.20	0.00	0.00	0.26	≥	0.26
Placas Intake	Placas-01 AEI	0.00	0.00	0.00	0.13	≥	0.13
	Volcan Sur	0.00	0.00	0.00	2.84		
	P-09	0.00	0.00	0.00	4.05		
	PBN11 AEI	2.10	0.15	0.31	4.36	≥	1.49
	P-13	1.50	0.15	0.22	4.59		
	P-10	4.00	0.55	2.21	6.80		
	PBN-18 AEI	13.60	0.16	2.13	8.93	≥	1.49
Maipo river entrance	F-06	0.70	0.16	0.11	9.04		
Yeso River entrance	PBN-07 and P-02 AEI	0.70	0.07	0,05	25.98	≥	13.49
	P-03	3.00	0.08	0.23	30.60		
	PBN-06 AEI	0.50	0.40	0.20	30.80	≥	4.40
	PBN-22 AEI	2.60	0.40	1.03	31.83	≥	27.00
	PBN-23 AEI	2.50	0.40	0.99	32.82	≥	3.60
	PBN-05 and F-02 AEI	3.40	0.40	1.34	34.16	≥	4.60
	P-04	7.80	0.20	1.56	35.72		
	Toyo AEI	1.00	0.50	0.50	36.23	≥	5.10
	PBN-25	5.90	0.50	2.98	39.20		
Colorado River	PBN-04 AEI	5.60	0.50	2.82	42.03	≥	35.60
	F-01	1.30	0.50	0.66	49.07		
	Lajas AEI	5.00	0.12	0.60	49.67	≥	5.60
Colorado Intake	COL-2 and P12 AEI	0.00	0.20	0.00	1.49	≥	1.49
	PBN-01 AEI	7.70	0.20	1.51	3.00	≥	2.42
	P-06	1.10	0.20	0.22	3.21		
	PBN-20 AEI	3.30	0.23	0.75	3.96	≥	2.05
	F-03	10.70	0.23	2.43	6.39		
Yeso Intake	PBN-09 and P-07 AEI	0.00	0.15	0.00	0.74	≥	0.74
	P-08	9.30	0.15	1.36	2.10		
	PBN-15 AEI	6.20	0.12	0.75	2.85	≥	2.09
	Yeso SEDIM AEI	4.70	0.12	0.57	3.42	≥	0.93
	P-11	2.00	0.12	0.24	3.66		
	P-03	0.50	0.08	0.04	3.70		

Table 6.6: Calculation of the Environmental Flows that flow into the Intake. Q Habitability Method P85% Low Water Level per Section

Sector	Section	Distance (Km)	Lineal Recharge (m3/s/Km)	Recharge Q (m3/s)	Estimated Q (m3/s) AVAILABLE	Condition	Env Q in AEI section REQUIRED
Colina Intake	Colina-01 AEI	0.10	0.00	0.00	0.37	>	0.37
Morado Intake	MOR-01 AEI	0.40	0.00	0.00	0.44	>	0.44
Engorda Intake	ENG-01 AEI	0.20	0.00	0.00	0.15	>	0.15
Placas Intake	Placas-01 AEI	0.00	0.00	0.00	0.10	>	0.10
	Volcan Sur	0.00	0.00	0.00	2.84		
	P-09	0.00	0.00	0.00	3.90		
	PBN11 AEI	2.10	0.15	0.31	4.21	>	1.49
	P-13	1.50	0.15	0.22	4.44		
	P-10	4.00	0.55	2.21	6.65		
	PBN-18 AEI	13.60	0.16	2.13	8.78	>	0.42
Maipo river entrance	F-06	0.70	0.16	0.11	8.89		
Yeso River entrance	PBN-07 and P-02 AEI	0.70	0.07	0,05	25.83	>	13.49
	P-03	3.00	0.08	0.23	29.48		
	PBN-06 AEI	0.50	0.40	0.20	29.68	>	5.80
	PBN-22 AEI	2.60	0.40	1.03	30.71	>	3.48
	PBN-23 AEI	2.50	0.40	0.99	31.70	>	3.55
	PBN-05 and F-02 AEI	3.40	0.40	1.34	33.04	>	4.20
	P-04	7.80	0.20	1.56	34.60		
	Toyo AEI	1.00	0.50	0.50	35.11	>	9.80
	PBN-25	5.90	0.50	2.98	38.08		
Colorado River	PBN-04 AEI	5.60	0.50	2.82	40.91	>	24.30
	F-01	1.30	0.50	0.66	47.13		
	Lajas AEI	5.00	0.12	0.60	47.73	>	5.60
Colorado Intake	COL-2 and P12 AEI	0.00	0.20	0.00	0.67	>	0.66
	PBN-01 AEI	7.70	0.20	1.51	2.18	>	2.17
	P-06	1.10	0.20	0.22	2.39		
	PBN-20 AEI	3.30	0.23	0.75	3.14	>	2.05
	F-03	10.70	0.23	2.43	5.57		
Yeso Intake	PBN-09 and P-07 AEI	0.00	0.15	0.00	0.46	>	0.46
	P-08	9.30	0.15	1.36	1.82		
	PBN-15 AEI	6.20	0.12	0.75	2.57	>	1.97
	Yeso SEDIM AEI	4.70	0.12	0.57	3.14	>	1.05
	P-11	2.00	0.12	0.24	3.38		
	P-03	0.50	0.08	0.04	3.42		

6.4 ENVIRONMENTAL FLOW RESULTS

Table 6.7 shows a summary of the final results for the flows passing through the intake in order to meet the requirements of all of the control sections for Areas of Environmental Importance, according to hydrologic methods, Habitat method and anthropic use. The following must be considered:

- The flow passing through the intake has been assessed with the intermediate basin's recharge using the annual average Q.
- For Yeso and Colorado, the annual average Q has been calculated including months of Q=0. For the calculation of the Habitability method, the dry months (Q=0) have been taken out of the hydrological series. The environmental Q would apply only when there is water.
- The result of 8 hydrological methodologies has been presented as reference for the estimation of the Environmental Flow.
- The habitability method has been calculated using the low water level flow as a basis: 1) Monthly average minimum Q 2) Low water level Q with an 85% exceedance probability.
- The result of the environmental requirement Q per rafting anthropic use is shown, according to the criteria proposed in item 6.2.

Table 6.7: Environmental Flows flowing into the Intake.

Assessment Criterion for the Flow passing through the Intake	Colina Intake	Morado Intake	Engorda Intake	Las Placas Intake	Colorado Alfalfal (LB)*	Yeso Discharge (LB)*
Hydrological statistics						
Annual average Q	3.24	1.71	0.99	0.47	16.05	7.91
Monthly average minimum Q	0.89	0.56	0.32	0.13	2.90	5.90
P85% low water level Q	0.72	0.44	0.25	0.10	0.66	0.79
Hydrologic Method						
Q (10% Qma)	0.32	0.17	0.10	0.05	1.60	0.79
Q (50% low water level P95%)	0.33	0.20	0.11	0.05	0.09	0.40
Q (Q330)	0.81	0.51	0.29	0.12	1.64	1.98
Q (Q347)	0.73	0.45	0.26	0.10	1.07	0.81
Swiss Law	0.35	0.26	0.17	0.09	0.46	0.38
Principality of Asturias	0.26	0.19	0.14	0.10	0.37	0.28
New England Law	0.41	0.30	0.17	0.06	7.53	1.92
Tennant (10%) acceptable condition	0.32	0.17	0.10	0.05	1.60	0.79
Habitability Method						
Env. Q Habitat (monthly minimum Q)	0.29	0.53	0.26	0.13	1.49	0.74
Env. Q Habitat (P85% low water level Q)	0.37	0.44	0.15	0.10	0.66	0.46
Anthropic Uses Method						
Rafting Q	0.00	0.00	0.00	0.00	0.00	0.00

* Base Line. With Yeso reservoir and Alfalfal I power plant in operation

7. INTEGRATED MANAGEMENT PLAN OF SMALL CATFISH (Trichomycterus areolatus) POPULATIONS AT MAIPO RIVER UPPER BASIN.

7.1 INTRODUCTION

The importance and the ecological role of the native ichthyofauna is a recent issue of concern in the country. Thus, historically the main rivers of the country were, up to not long ago, receptors of all type of household and industrial wastes. On the other hand, in last decades, the decision of introducing exotic species in order to increase the species supply for sport fishing was taken, without considering the impact on the native fauna species. Although, the environmental quality of our main rivers have evidently improved as consequence of standards taking effect on regulation of residential and industrial sewage discharges. The Environmental Impact Assessment has also contributed to generate knowledge about native ichthyofauna species. The above is added to the enactment of the Regulations to classify species (D.S.75/2006), which has allowed the incorporation of 38 native fish species into the species list, among them the Small Catfish (Exempt Resolution N°2054/2007).

In this document, all the bibliography related to the specie is presented. This specie has not been thoroughly studied in the country and this is why the Owner has committed studies and measures aiming to sustainably manage the specie. That is to say, providing knowledge which will let adopting the most adequate decisions, considering that PHAM will modify the river flows where this specie lives. This document includes the follow up stage of the T. areolatus populations during construction and operation of the project and the measures to take responsibility, when negative effect in the habitat condition is produced and might constitute a threat for the specie.

7.1.1 Trichomycterus areolatus Biology Background[1]

Trichomycterus areolatus is endemic specie of Chile which is distributed between the III and X region, which, according to Campos et al. (1998), presents a conservation state corresponding to "Vulnerable" between the III and IX region and "Out of Danger" in the X region.

T. areolatus is a species of wide distribution and very abundant in gravel and rock substratum environments.

[1] Arratia, G. 1981. Fish genres from continental waters of Chile. Occasional Publication N° 34. National Museum of Natural History

The T. areolatus specie is a frequent catfish in rhithron environment of Chilean rivers. In the Bío Bío Region (center-south zone of Chile) has been reported in the main river flows, these are Bío Bío (Campos et al. 1993a, 1993b), Andalién (Ruiz 1994), Laja (Ruiz 1996) and Itata (Habit 1994b, 1998) rivers. Although it is considered as a vulnerable specie at domestic level (Campos et al. 1998), most of the mentioned rivers have high abundance in rock sectors and shallow waters, which constitute its preferential habitat (Arratia 1983, Campos 1985, Campos et al.1993a, 1993b, Habit 1994b, 1998, Ruiz 1994, 1996). For natural lotic environments, T areolatus has been described as bentophagous specie, exclusively preying insects (Arellano et al.1983, Campos et al. 1993a, Ruiz et al.1993, Ruiz and Berra 1994) or behaving as carnivorous predator (sensu Welcomme 1979) in systems such as Maipo river (Duarte et al. 1971). That is to say, T areolatus presents certain trophic richness, expanding its trophic niche in determined systems. In irrigation channels, Habit et al. (1998) the existence of an important zoo benthic fauna supply was reported, which suggests the presence of favorable conditions for maintenance of local populations of this fish. In terms of its reproduction, although previous works show that this happens in spring-summer months (Manríquez et al. 1988, Campos et al.1993a, Ruiz et al. 1993), it is unknown whether the local populations use the irrigation channels to reproduce themselves in them and in the same periods of the year, constituting an adequate habitat to keep resident populations of this specie.

The T. areolatus reproduction is seasonal, presenting its reproductive activity at the end of rainy season or beginning of spring, both in artificial courses as well as natural ones. The reproduction of the studied populations is synchronized with those described for Angostura, Copequén Rivers (Arellano et al.1980) and Andalién (Ruiz 1994). The highest reproductive season is between September - November, finding juveniles (<49.9 mm) from October on.

The studies done allows us to conclude that the opportunist behavior in the feed strategy of T. areolatus, its benthic habits and quick adaptation to environments, lets them have an effective settlement on irrigation channels, which given their high environmental heterogeneity (speed of the current, substratum type, vegetation), resulting from scarce maintenance and its construction without coating, allows the formation of an appropriate habitat for settlement of an abundant micro invertebrate fauna sustaining these native fish population.

7.1.2 Impacts on Ichthyofauna

PHAM operation considers the reduction of the flow of Yeso, Volcán, Colorado and Maipo rivers, which will modify the characteristics of the habitat currently used by the ichthyofauna. Nevertheless, the effects of such changes over the fish population and specially the T. areolatus, should be mitigated with the establishment of the ecological flow.

To ensure the T. areolatus population sustainability in those rivers, the following activities are proposed during the construction and operation stage of the hydroelectric plant:

- T. areolatus population follows up plan.
- T. areolatus population measures of mitigation, repair and/or compensation plan.

7.2 OBJECTIVE OF THE PLAN

7.2.1General objective

Designing and implementing a follow up program which will allow assessing the T. areolatus population during construction and operation of PHAM, in order to apply the necessary protection measures to guarantee sustainability of its population under an ecological flow regime in the Yeso, Volcán, Colorado and Maipo rivers.

7.2.2 Specific objectives

a) Register the T. areolatus population in the Maipo river upper basin.

b) Characterize the T. areolatus habitat based on the physical-chemical parameters (e.g.: O_2 dissolved, temperature, turbidity).

c) Implement a follow up plan of the populations in the influence area of the project and adjacent areas.

d) Implement an environmental protection measures plan, including sequenced mitigation, repair and/or compensation measures.

7.3 WORK METHODOLOGY

7.3.1 Trichomycterus areolatus population registry

In-field campaigns to identify the presence of T. areolatus in different rivers and affluent of the Maipo river upper basin during low water level and rise in levels will be performed.

The sampling sites showed in the Figure are preliminary proposed 7.1 and 7.2, which indicates the location where T. areolatus populations and those with potential character have been identified.

Sampling will be of qualitative-extensive type destined to identify exclusively the presence of the specie. The catching method will consist of use of electric fishing, going along the river banks during 20 minutes or 100 m distance in straight line. The caught individuals will be returned live in the same sites they had been caught.

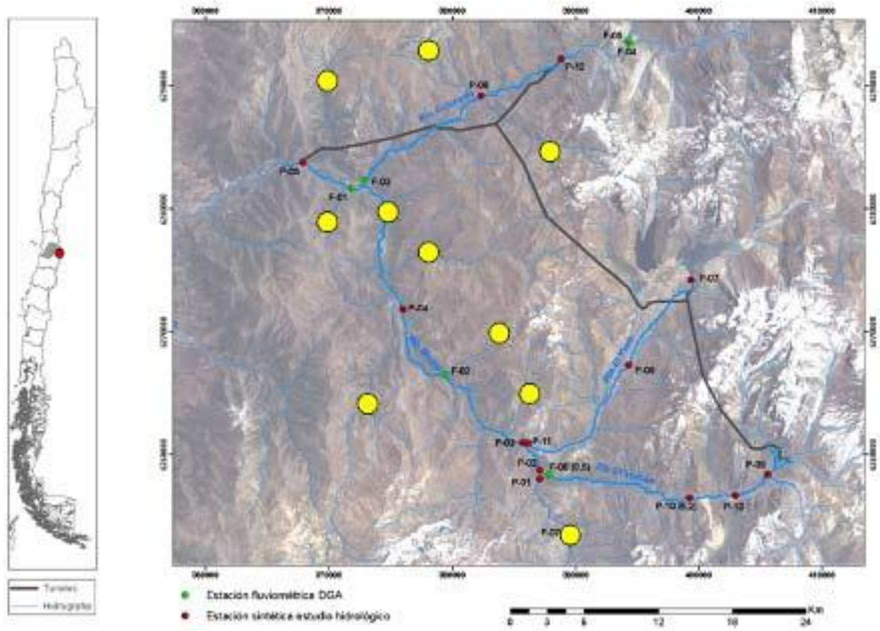

Figure 7.1. Sites with potential habitat for catfish population in Maipo river upper basin Maipo

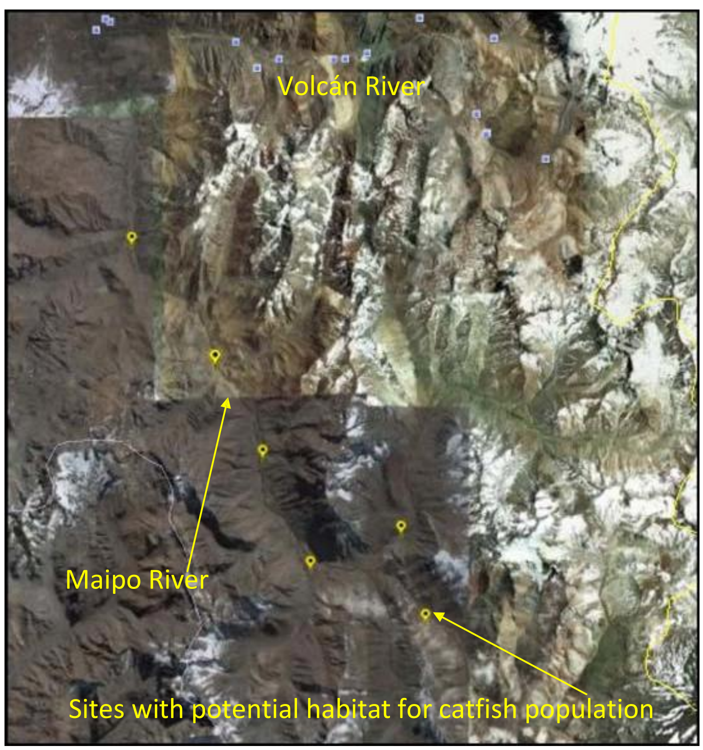

Figure 7.2. Sites with potential habitat for catfish population in Maipo river upper basin Maipo

7.3.2 T. areolatus Physical-Chemical Habitat Characterization

The parameters to be used to characterize the T. areolatus habitat correspond to the most relevant in order to identify the structure and functioning of the rivers and area those recommended by the specialized bibliography ("Limnology" R. Wetzel, 1980 and "Limnología" R. Margalef, 1984).

The T. areolatus biology is at an early level of knowledge. Without a doubt the physical environment characterization of the specie will allows us to provide important judgment elements at the moment of assessing the habitat condition of the specie. For instance, the decrease of the values in a significant parameter for ichthyofauna, such as dissolved oxygen could be showing stress levels that the specie could not bear.

7.3.3 Follow up plan of T. areolatus population in Maipo and Colorado rivers

The Follow up Plan is aimed to assess the behavior of the fish in construction and operation stages of the project. In this sense the follow up plan seeks to confirm and verify the effectiveness of the proposed measures in the Environmental Impact Study; early identification of impact events or non-predicted effects in order to design and implement mitigation, repair and/or compensation measures additional to the ecological flow to guarantee sustainability of the populations.

The follow up of the environmental condition of the fish population will be done through the control of the following parameters:

a) Composition and abundance of phytobenthic and zoobenthic

b) Composition and abundance of the ichthyofauna

c) Quality of the habitat for aquatic flora and fauna

In Table 7.1 the Follow up Plan for the flora, aquatic fauna and aquatic habitat to be assessed in the influence area of the Project is presented next.

Table 7.1. Follow Up Plan Design

Variable	Item	Construction Phase	Operation Phase
Aquatic Flora			
Phytobenthics	Frequency of Monitoring	Seasonal	Seasonal
	Amount of Seasons	10	10
	Amount of Copies	2	2
		Samples are obtained from the banks zone in rock and sediments from the rivers. Collection with sampler proposed by Davies & Gee (area 290 mm^2).Formalin fixation to 4% Methodologies Analysis consist of aliquot extraction of Used samples to obtain microscopic preparations, which are assessed with regards richness and abundance of the present micro algae (Weyzel & Likens 1991).	
	Analysis of results	Temporary, space, statistic	Temporary, space, statistic
Aquatic Fauna			
Phytobenthics	Frequency of Monitoring	Seasonal	Seasonal
	Amount of Seasons	8	8
	Amount of Copies	2	2
	Methodologies	Samples are collected with Surber mesh (area 0,09 m^2, mesh 250 μm). Samples fixed with formalin 10% for later analysis in used laboratory. Identification based on Bertrand (1995), Lopretto & Tell (1995) and Merrit & Cummin.s (1996).	
	Result analysis	Temporary, space, statistic	Temporary, space, statistic
Fish	Frequency of Monitoring	Seasonal	Seasonal
	Amount of Seasons	10	10
	Amount of Copies*	1	1

Variable	Item	Construction Phase	Operation Phase
	Methodologies Used	Electric fishing with portable generator equipment in a determined area. An electric fishing equipment will be used Brand COEFELT Model EX 350. Voltage 240V 50 Hz, Power max. 350 VA. Catch per unit effort (CPUE) will consist on going through 100 m lineal banks or 20 minutes of fishing. The caught fish, will be identified and measured, to later be released alive in the same catching sites	
Result analysis		Temporary, space, statistic with software SYSTAT 3.0.	Temporary, space, statistic with software SYSTAT 3.0.
Aquatic habitat	Frequency of Monitoring	Seasonal	Seasonal
	Amount of Seasons	Upper basin Maipo river, from the confluence with Colorado river	Upper basin Maipo river, from the confluence with Colorado river
	Amount of Copies*	1	1
		An analysis of the distribution of rapids and pools through photo interpreting o aerial photographs. The river will be classified in different tranches regarding the observed frequency of the rapids. The categories to be used are detailed next: 1) High Frequency (FA): correspond to the river tranches presenting considerable evidences of continuous turbulence. 2) Medium Frequency (FM): correspond to the river tranches presenting turbulence in the waters not as strong as in FA Methodologies, which are alternated with tranches of quiet waters. Used This alternation is presented in short tranches which does not allow classifying the section FA or FB 3) Low Frequency (FB): correspond to the river tranches which do not present considerable evidences of turbulence. The information used is incorporated into a Geographic Information System (Arc View), which will allow visualizing through thematic and coverage maps with different types of information.	
	Result analysis	space, statistic	space, statistic

The Follow up Plan will be in force for three years. At the end of this period the programme will be assessed to determine its continuity. The in force period of time of the plan will be considered depending on the quality of the information that the new data provides.

7.3.4 Mitigation, repair and/or Compensation Plan

The integrated management plan of T. areolatus considers mitigation, repair and/or compensation measures destined to guarantee the sustainability of the populations of this specie in the influence area of the project. The measures will be implemented when relevant changes in the population level of the specie is detected in the influence area of the project just like is established by the General Law of Fishing and Aquaculture. It is important to state that the critical conditions of stress that might threaten the sustainability of the species are unknown, therefore there is an uncertainty level in the decision taking that must be considered. This is why it has been decided to use the adaptive method as methodological tool, in order to adjust the measures with regards the results obtained from its application. In this case the measures will be applied in sequential manner. The criteria to be followed are next (Table 7.2):

Table 7.2. Protection Measures Sequence

Steps	Impact	Environmental Protection Measures
1	Significant alteration of habitat	Habitat reconstruction
2	Significant decrease of the population size	T. areolatus translocation
3	Decrease of T. areolatus population due to introduced predators	Predators extraction of the ecosystem
4	Unfeasible previous measures	Conservation of T. areolatus out of the influence area of the project

7.3.4.1 Mitigation Measures

- Predators removal

Modify the trophodynamic structure of the biological community to which T. areolatus belongs, through the removal of predators from the ecosystem, or by biomass manipulation of the species. In the case of T. areolatus, the close season could be eliminated an increasing the catching quota for trout (O. mykiss and S. trutta), because these are its main predators. This measure could be implemented through Special Administrative Measures, procedure contemplated in the General Law of Fishing and Aquaculture.

- Translocation of T. areolatus individuals.

Another measure of mitigation is the individuals T. areolatus translocation, from neighboring populations that are not in the influence area of the project. The individual translocation will be done when is detected in the follow up, which the mitigation measures implemented (ecological flow and trophodynamic management) does not allow maintenance of the population levels, recorded in the base line. This situation is contemplated in Article 168 of the General Law of Fishing and Aquaculture (1989).

In order to perform the T. areolatus translocation to the zones potentially affected by the operation of the project it is required:

- Genetically assess the sink population (affected) and the source population and,
- Determine the amount of individuals to be transported to the sink population (population affected by the project).

The methodology to be used in the development of the activities previously stated is presented next:

- Genetic assessment of T. areolatus population

This activity is aimed to study the flows between the populations. 20 individuals from each sampling location will be collected, which correspond to different water courses of the Maipo river upper basin (Figure 7.1 and 7.2).

Out of each individual a piece of muscle tissue will be extracted and will be kept in alcohol. The DNA extraction will be done using the saline extraction protocol described by Aljanabi & Martinez (1997). The extracted DNA will be kept at 4°C for its later amplification and sequencing.

To obtain the mitochondrial DNA Control Region sequences, primes will be used for the amplification process. Then, the fragment of the T. areolatus mitochondrial DNA control region will be amplified through PCR (Polymerase Chain Reaction) reactions. Later on, the PCR products will be purified with a QIAquick (Qiagen) kit and then sent to Macrogen Inc. (www.macrogen.com) in order to obtain the mitochondrial DNA control region sequence. Finally, the sequences will be assembly and then aligned using the ProSeq v.2.9.programme.

With this information, different genetic diversity indexes will be identified (haplotypical diversity, number of polymorphic sites, number of haplotypes, and average amount of differences between a pair of sequences) with the programme DNA Sequence Polymorphism DNA sp v. 4.10.

- Translocation of individuals

Re-population of juveniles of a source population ("stocking"), selected from the genetic analysis. Number of individuals and frequency of re-population will depend on the population levels determined through the follow up programme.

The individuals to re-populate will come from other rivers of the same hydrographical basin or from another tranche of the same river.

7.3.4.2. Repairs Measures

- Habitat reconstruction

The installation of deflectors ("Boulders"), equipped with artificial refuges. This method consists of the installation of barriers that do not obstruct the natural flow of waters in the river flows, with artificial and/or natural materials, allowing the recovery of direction of the current and sedimenthological regime. These deflectors correspond to vegetable material and/or rocks, which are installed in the river courses, allowing the sedimentation regime, refuges and feed source for aquatic biota which originally used those environments to be restored (Wesche, 1985; Huusko and Yrjana, 1997). In our country there are successful experiences of restoration of catfish habitat, performed by the Museum of Natural History of Valparaíso[2]

7.3.4.3. Compensation Measures

- Conservation of T. areolatus out of the influence area

The compensation measure proposed for Trichomycterus areolatus correspond to a conservation area out of the influence area of the project and within the hydrographical basin of Maipo river. This compensation measure will be implemented after assessing the mitigation and repair measures were not enough to keep the small catfish population in the Maipo River.

To determine the conservation area of T. areolatus, the following activities will be developed:

- Assessment of the habitats zones where Trichomycterus areolatus is located. In order to comply with this objective, the following activities will be carried out:
    - Lansat satellite images of the Maipo river basin will be analyzed to determined presence of rivers with side development through the NDVI index determination.
    - Elaboration of a digital elevation model (DEM), to analyze the slopes through SIG techniques.
    - In-field campaigns to verify the rivers in compliance with the fish physical requirements (e.g. Height, run-off, slope, granulometry, side development, riparian vegetation).

- In-field campaigns to determine the habitat and feed for the fish in the selected rivers through quick assessment methods.
- Registry of the potential threats of anthropic origin that may affect the conservation area.

- Capacity analysis of the habitat load where Trichomycterus areolatus populations are located. The load capacity will be determined comparing the areal availability of favorable habitats to keep catfish and the feed availability.

The compensation area will correspond to that one gathering the following requirements:

- Trichomycterus areolatus population presence.
- Habitats with favorable conditions for keeping the fish.
- Enough load capacity to keep fish populations.
- Absence or low presence of introduced fish fauna.
- Absence or low pressure of anthropic type.

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8 CONCLUSIONS

8.1 General Aspects

In the last years, there have been new requirements incorporated in the estimation of ecological flows, so today it takes into consideration not only the hydrological methodologies, but the Hydrobiological Methods and even the hydro systemic ones that, at the same time, have been incorporating, not just the aquatic biota requirements, but those of some other uses as well (Figure 8.1), and water river services, it is the case of the assessment for such uses as sport fishing, transport, rafting and kayak among others, considered generically as anthropic flow use, besides other concepts such as landscaping and quality of waters maintenance. In this way, it is possible to talk about the Water Environmental Demand which incorporates diverse uses and services of the river flow, a concept that is already incorporated by DGA (2002). Today is possible to assess several of these requirements through the physical micro-habitat simulation and, in this way, to assess the changes that might cause a new requirement of this resource. This based on the computational tools which allow establishing the demanded flow with regards the control variables such as depth of the flow, speed of the waters, and morphology of the flow, among others.

Each new use of the resource it starts causing changes that might be tolerable or not, nevertheless, we need to define these thresholds for acceptable changes, for which there are currently various non-formal proposals.

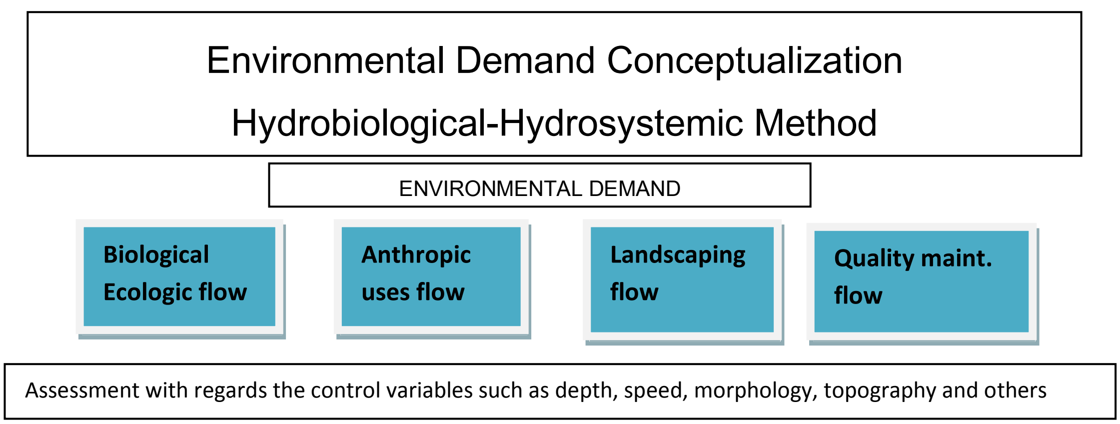

Figure 8.1 Water Environmental Demand

Another relevant aspect is the assessment of the environmentally important areas (AIA) in order to establish the applicability domain of a determined flow. In this report there are AIA defined, not just from the biological ecological flow point of view, but the anthropic and landscaping uses as well.

For each one of them, it has been determined a water environmental demand which will let to support different goods and services the rivers currently have.

The analysis presented in this report supports the hydrological information presented in the EIA and the make-up of new bathymetric profiles of all the rivers and streams, which has allowed validating and improving, in an important way, the assessment tool of the ecological flows in the environmental importance areas.

The identification of these biologic environmental importance areas with the proposed methodology, not only permits to identify those where ichthyofauna is observed, but those that are potentially suitable for the development in it as well. Thus, the previously defined sensitive areas were extended.

Identification of anthropic uses, such as rafting and kayak, and its requirements in terms of depth and width of the flow, allows assessing and giving compliance to the environmental flows supporting these activities through the definition of the anthropic environmental importance areas.

The aquatic ecosystems present in the rivers of the area of the project are in a permanent regime of disturbance of natural and artificial type, from the changes of the hydrological conditions. This last part is due to the presence of works regulating the flow from many decades ago, constituting an important environmental liability. As an example, it can be pointed the effects of the El Yeso reservoir which generates "dry river" conditions for several months each year.

The aquatic ecosystems have a low richness and abundance of organisms. In trophic terms is possible to state the aquatic ecosystem is oligotrophic, its low productivity can give rise to permanent presence of forcing agents limiting growth (for instance, hydraulic conditions, temperature, suspended solids, nutrients).

The reduction values of the area due to flow decreasing are maximum level at intakes. When comparing these spatial variations with the low water level to 85% of surplus, the results show the following: among 3.8 and 11.5% for streams, 15% for Colorado River and 40% for Yeso river. Nevertheless, downstream of the intake these zones are recovered by the flows of the intermediate basin.

8.2 Ecological flows

The applied methodology considers that the ecological flow assessment in control sections of the Environmental Importance Areas are defined according to its morphological, hydraulic, biotic and/or anthropic characteristics among other criteria. These AIA control sections require an ecological flow and a water environmental demand specific to comply with an adequate development of the ecosystems and anthropic activities. These flows are considered more as an intrinsic property of the tranche of the river to be assessed, and it is a situation that the project must safeguard. In the following point, 8.3, the final results of the ecological flow corresponding to the intake passing flows are detailed, which satisfy the ecological flow conditions doe each one of the AIA sections downstream.

8.3 Defined flows at intakes:

Volcán River and Upper Volcán Streams Area

In the Volcán river area and its streams it has not been able to report ichthyofauna, the slopes of the streams are too high, the height and temperature during winter make the flows to decrease and even get to freezing point. This situation can be reflected when the defined AIA areas area small and with potential character due to its local morphology. This context allows recommending an intake passing flow given the statistics of probability of 85% surplus.

For El Morado stream an intake passing flow of 0.44 m3/s was defined, which is the low water level with surplus probability of 85%. This is equivalent to 26% of the mid annual flow. This value comes from the hydraulic condition of keeping the height of the current run-off of the low water level periods; because this is naturally lower than 20 cm (mid height of 18 cm). The zone located after intake downstream is areas with low potential and quality in environmental terms.

For Las Placas stream an intake passing flow of 0.10 m3/s was defined, which is the low water level with surplus probability of 85%. This is equivalent to 21% of the mid annual flow. This ecological flow comes from maintaining the current low water level run-off height condition, which naturally is lower than 20cm (mid height 9cm). The zone located after intake downstream is areas with low potential and quality in environmental terms.

For Colina Stream an intake passing flow of 0.37 m3/s was defined, which has the potential habitability for an adult **Salmon trutta**. This is equivalent to 11% of the mid annual flow. This is justified given that it complies with the ecological flow of all the environmental interest areas (biological and anthropic) downstream, either these being from Volcán River or Maipo River. The zone located after intake downstream has low potential and quality in environmental terms.

For La Engorda Stream, an intake passing flow of 0.15 m3/s was defined, which has the potential habitability for an adult **Salmon trutta**. This is equivalent to 15% of the mid annual flow. This is justified given that it complies with the ecological flow of all the environmental interest areas (biological and anthropic) downstream, either these being from Volcán River or Maipo River. The zone located after intake downstream has low potential and quality in environmental terms.

Yeso River

The situation of Yeso River corresponds to an intervened river where the hydrological series is altered for the functioning of the El Yeso reservoir which regulates the flow during the whole year, leaving even some months with 0 flows. Currently generating an environmental liability, this is translated into a "dry river" condition with conditions of restrictive habitability for development of aquatic ecosystems. This situation can even be spoiled in the future because of changes in the operational rule of the reservoir and/or lower water recharge. The above, took us to establish as case the low water level conditions base of 85% surplus probability, which provides an ecological flow value at the intake passing flow of 0.46 m3/s and propose an Integrated Management Plan for the ichthyofauna in the Yeso River (Chapter 7).

Colorado River

The Colorado river situation corresponds to an intervened river where the hydrological series is altered by the Alfalfal 1 Power Plant and Maitenes Power Plant, happening at an analogue base situation in Yeso river, nevertheless, in this case the Habitability condition is not restrictive to what is suggested to be applied on the assessed flow with the low water level flow of 85% probabilities of surplus.

For Colorado River, based on the information exposed, it has been determined an intake passing flow of 0.66% m3/s, equivalent to the low water level flow of 85% probabilities of surplus. This is equivalent to 4% of the mid annual flow. This flow complies with the run-off height condition of 20 cm. This is justified given that it complies with the ecological flow of all the environmental interest areas (biological and anthropic) downstream, either these being from Colorado River or Maipo River in the assessment conditions. For the assessment of this river, it has been considered as a whole area of environmental importance.

Besides, due to morphological configuration conditions and suspended material reduction, the conditions of habitability improve at downstream the intake.

Eventually the management plan can be extended to this sector to ensure the native ichthyofauna preservation found in this sector.

Maipo River

For Maipo River, although there are flow reductions, the assessed ecological flows for the environmental important areas in all of the critical sections, both biological as anthropic, are covered by the proposed flows.

Physical-chemical quality of water

The dilution capacity of the rivers could be affected mainly at the upper part of Volcán River, due to the change of proportion mix of the flows under the situation of the project. An assessment of this impact was performed for three confluences: 1) Colina Stream with Volcán River, 2) Yeso River with Maipo River, and 3) Colorado River with Maipo River.

For effects of assessing the dilution, it has been taken as parameter the Electric Conductivity calculation (as equivalence of the salt concentrations) and it has been applied a simple mass balance with physical-chemical data from Chapter 5 and medium flows, and low water levels of the hydrological series.

The following Table shows the results of the dilution assessment downstream the quoted confluences in the situation of the project in low water level condition.

Assessment Table of water dilution downstream the confluence

Confluence	**Conductivity Change**
Colina Stream and Volcán river	12%
Yeso with Maipo river	4%
Colorado river with Maipo river	4%

The results show a low impact in the conductivity change, about 12% for Volcán River, 4% for Maipo under the Yeso, and 4% for the Maipo under Colorado River.

Ichthyofauna management plan

Considering that currently the Yeso, Volcán and El Colorado rivers correspond to an artificially regulated flow regime constituting an important environmental liability and the application of a minimum ecological flow to keep the aquatic ecosystems through the PHAM implementation, it is proposed to apply in the area an integrated management plan which will allow to recover rivers or protect some of its main feeders in order to preserve the ichthyofauna. (See Chapter 7 of this report).

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