BACKSTAGE OF THE GLOBAL CLIMATE CHANGE: A SYSTEM THAT EVERYBODY SEEMS TO THINK THAT IT RELATES TO SOMEONE ELSE

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ABSTRACT

The city of Ushuaia, located at the southern end of the world, is already one of the many regions affected by the severe consequences caused by the Global Climate Change (GCC).

The physical evidence of GCC is shown by the gradual disappearance of the mountain glaciers that surround the city of Ushuaia, and also by others factors such as the increase of mean annual temperature in the area and a substantial decrease in winter rainfall, among others. These factors appear not to bring alert to society about the significant consequences that have derived from this situation in the short and long terms.

Our research group is trying to analyze the socio-economic consequences generated by the disappearance of glaciers around the city of Ushuaia, because they are the main source of drinking water, by using a systems approach.

Thus, we conceptualize the problem by identifying its elements, the description of the relationships between themselves and the distinction of the most relevant subsystems. We were able to establish the conceptual boundaries that distinguish our system from its environment, and the multiple relationships that operate between them.

In the other hand, we have found through these studies a series of emergent properties, which are the result of the analytical perspective we have undertaken; those emergent properties are as important as those ones that were revealed at the beginning of the investigation, including the contamination problem of the glacier water tributaries and their diminishing flow.

We will present in three stages the results that have been found so far: the first stage shows the background related to the effects of the GCC over the Patagonian glaciers, Argentina, and especially those ones that surround the city of Ushuaia, highlighting the projection about their volume; then, we will show the system behavior under analysis and its relationships with the environment, indicate the existing subsystems and describe the idea of horizon of potabilization, which will allow us to lay the foundations for further developement of a mathematic model, aiming to predict the moment when the population of Ushuaia will run out of water, at least during the summer months, by considering the current state of variables and

relationships. At the end of these presentations, we will arrive at the conclusions achieved at this phase of the investigation.

Key Words: GCC, Global Climate Change, Glaciers disappearance in Ushuaia, Water, Socio-economics consequences, Horizon of potabilization.

INTRODUCTION

The city of Ushuaia, located at the southern end of the world, is already one of the many regions affected by severe consequences caused by the Global Climate Change (GCC).

The physical evidence of GCC is exposed by the gradual vanishing of the glaciers that surround the city of Ushuaia, and also by other factors such as the increase of mean annual or seasonal temperature in the area and substantial decrease in winter rainfall, among others. These factors apparently do not bring alert to society about the significant consequences that may be derived from this situation, both in the short and long terms.

Our research group is trying to analyze the socio-economic consequences generated by the disappearance of glaciers around the city of Ushuaia, because they are the main source of drinking water for the urban population, by using a systemic approach.

We will present in three stages the results that have been found so far: the first stage shows the background related to the effects of GCC over the Patagonian glaciers, Argentina, and especially those ones that surround the city of Ushuaia, highlighting the projection about its volume in the future; then, we will show the system behavior under analysis and its relationships with the environment, indicate the existing subsystems and describe the idea of horizon of potabilization, which will allow us to lay the foundation for further development of a mathematic model, aiming to predict then moment when the population of Ushuaia will run out of water, at least during the summer months, by considering the current state of variables and relationships. At the end of these presentations, we will arrive at the conclusions achieved at this phase of the investigation.

The severe consequences caused by Global Climate Change (GCC) are constantly present in the press and more often well known for most of us.

At the same time, there are studies in which it becomes clear that human irresponsible activity has greatly contributed to reach this state of issues in which there are already irreversible consequences.

Our Patagonian region is no exception to these conditions; on the contrary, the effects turn out evident with an alarming easiness in most cases. And in others, the alarming thing is because of the natural approach with which the situation is taken by the general public and the also by political leaders in particular.

This research group is composed by professors, students and teaching assistants of the degree of Public Accountant of the Faculty of Economics at the National University of Patagonia-San Juan Bosco.

This led us to seek proper tools that would allow us to approach the study of the problem in all its dimensions, for which we thought that the systems approach is appropriate for this purpose.

First, we will present the model of the system that we have defined as our object of study. The model will allow the distinction of the interaction of different

elements and through its relationships, a series of properties that characterize it emerges.

Then we will expose information about the GCC effects on the Patagonian glaciers, Argentina, and especially those that surround the city of Ushuaia, highlighting the projection of their volume.

Subsequently, we analyze the subsystems that are distinguished within the main system, as for example, the "Subsystem Environment-Society", highlighting the environmental consequences of Global Climate Change, which for our study will be treated as available published information. We will focus on the socio economic variables that are related as a result of the temporary loss of freshwater tributaries for the city, highlighting some collateral factors from GCC.

The "Subsystem Drinking Water Demand" and the "Subsystem Supply of Drinking Water" reveal the economic aspects with strong demographic contents, where government policies impact on the web of relations between these two subsystems.

As a result of these analyses, we found that the problem of shortage of drinking water is an issue that is being discussed increasingly among actors of the affected communities, detecting furthermore that these discussions are focused on the symptoms of the problem, and therefore seeking alternative solutions that have not a complete overview of the situation, thus demonstrating linear thinking and short term approach.

THE SOCIO-ECONOMIC SYSTEM UNDER STUDY

After a first stage study, we have modeled the problem as a large system with multiple actors, elements and relationships that are jointly participating in accordance with their particular interests; other actors are more concerned about the future of a resource which is essential for human life development, such as drinking water.

We also find groups of individuals that are alien to the problem of the disappearance of glaciers, since this is considered as part of the future in the medium term. These groups of persons are discussing instead problem solving on the short-term, those which require immediate action.

At this stage of the investigation, we want to stress that, given the lack of reliable planning and long term analysis by actors who have the power to make decisions on issues involving the future of the entire city, any problem is transformed over time in a situation of conjuncture, in which they tend only to analyze the manifestations of the problem, leaving aside the study of the causes that generate it.

Thus, considering the objectives of this study, in the socio-economic impact generated by the disappearance of glaciers around the city of Ushuaia, specifically those ones that supply fresh water to the city, we find three interacting subsystems involved, over which we may distinguish important emergent relationships:

- **Subsystem Environment - Society**: this subsystem corresponds to the effects caused by GCC on the glacial mass. These include the emission of greenhouse gases, the increase on mean temperature, the logging of native forests caused by land intruders in the city and changes in the landscape.
- **Subsystem Demand of Drinking Water:** this subsystem analyzes the population increase as a result of internal migration and natural

increase, the factors influencing tourism which in turn produce a seasonal demand, and permanent water supply, among others.

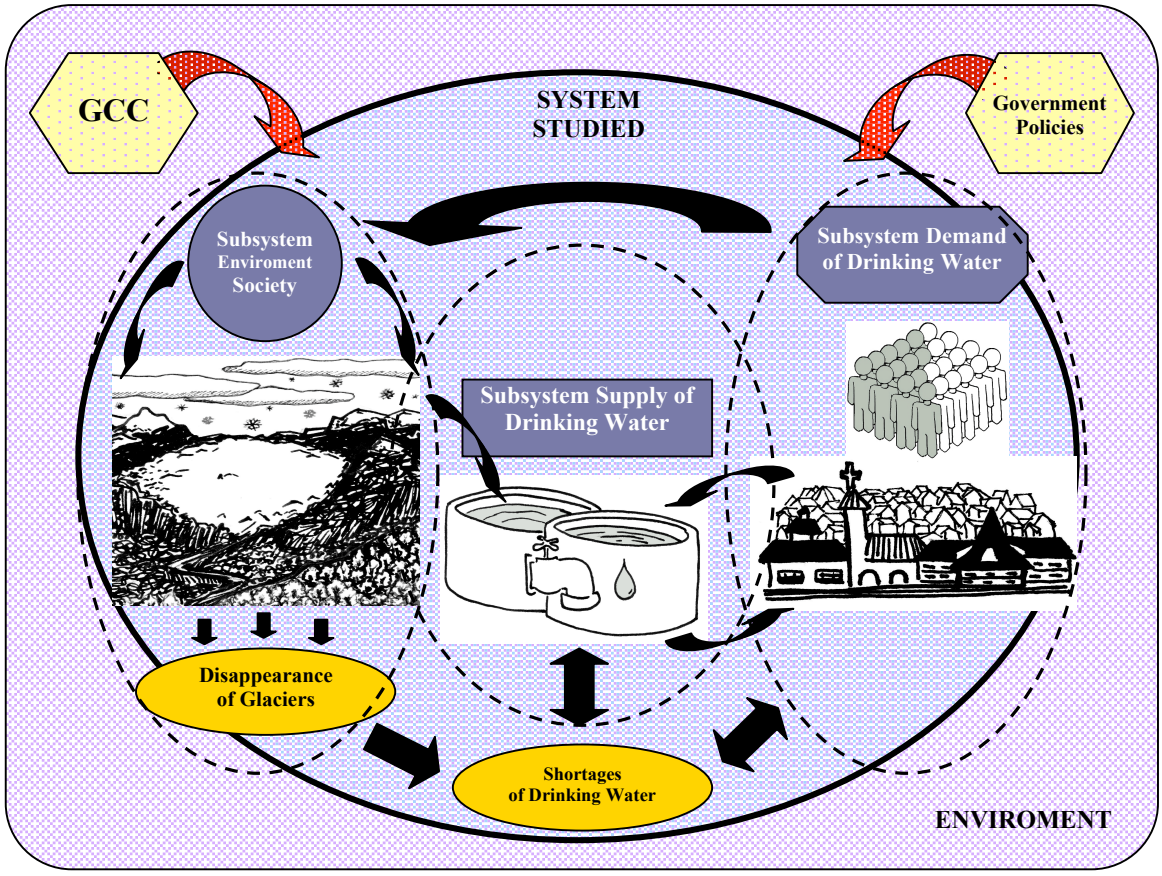
- **Subsystem Supply of Drinking Water:** this subsystem involves the production and distribution of drinking water as a result of purification of raw water that comes from the tributaries that are born in the glaciers, the need to seek for alternative sources when lower flows may take place, investment in infrastructure both for the potabilization process as for water transportation.

The network of complex interrelationships, exposed conceptually in these three subsystems, has social implications and that is why the object of study is highly dynamic, and its evolution presents a significant degree of uncertainty about the status of variables in the future.

The shortage of drinking water is a problem of the whole community of actors involved in the social life of our city, which often lose sight of the scope of consequences that are generated by the development of their daily activities, causing the deepening of the effects that are already evident.

Faced with this complex network, projected on a time horizon of medium and long term, we intend to achieve an overview of analysis, to unravel this web of interactions that crosses the different dimensions of the problems under consideration, including also the context that surrounds it in its web of relationships.

Thus, we present the conceptual model of the system analyzed, in which we distinguish the elements that concern us about the context, the interacting subsystems, and the main consequences of the joint action of all their elements.



Conceptual Model: the problem under study

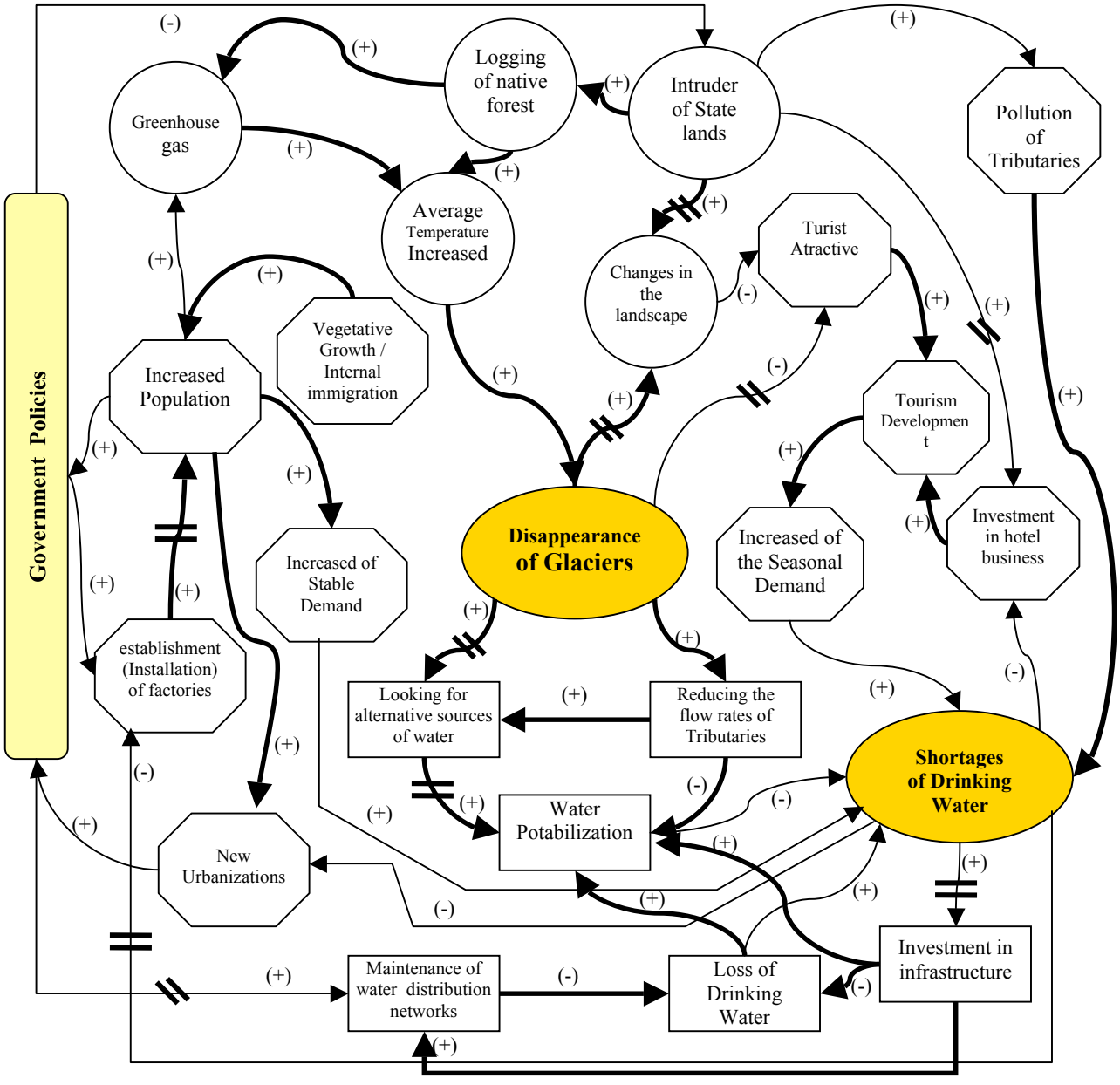
Here we can see different information flows like the one formed by climatic variables affecting the glaciers that surround the city of Ushuaia, and which are generating their disappearance, with a consequent impact on freshwater tributaries that are a source of drinking water for the city. We can see here that the routine business of the community, in some cases driven by government policies also affect climate variables, and so the feedback flow restarts.

Arriving at this point, we would like to clarify that the proposed model is provisional, since it is supplemented or modified as we get more information about the problem under study; that is why the model is dynamic.

Each of the subsystems are compose by multiple elements and relationships which are peculiar to themselves, as we will explain in detail below, turning out a complex analysis when more and more details are added to the model.

Our main concern at this time is the final result of "Shortages of Drinking Water", caused by a multiplicity of causes that are all interrelated between themselves. Therefore, we will put emphasis on relations that link the various factors that composes the problem, seeking to stress the patterns of organization that are manifested, which helps us understand the emerging phenomena which take place in the fabric actions and reactions, and to understand relationships and dependencies underlined on the model.

To do so, we will use a graphical of system dynamics, where we can see the interrelationships among the factors involved in all three dimensions analyzed, and its context:



Water Shortages and its Dynamic Relationships

As it can be seen, highlighted in these graphs, research work and literature review allow us to predict that the consequence of the problem under study will take place within a period of 12 to 15 years, with a final consequence which is the glacier disappearance.

The disappearance of the mass of ice will become significant, in terms of water supply, at least, during summer months, when there will be no ice to keep the snow in the landscape and prevent its melting out.

Those factors generating this effect are caused by climate issues that in most cases are exogenous variables to the model proposed in this study, but, however, we will provide a little detail about them. Nevertheless, it should be pointed out that some of the climate variables have been included in the model because they have a direct

impact on the system studied, even considering that it could be just a minimum impact.

It is also important to note that projections that have predicted on scientific bases the disappearance of glaciers puts beyond our grasp the opportunity to influence the causes of the problem, considering that GCC is part of the global context worldwide, but we should be able to anticipate, administrate and manage its effects.

Considering the "Shortage of Drinking Water" we find a wide range of causes that generate it, both in the "Subsystem Demand of Drinking Water" as in the "Subsystem Supply of Drinking Water", where the fabric of social events that give rise to various self-reinforcing cycles begin to emerge, revealing a portion of the social and economic consequences that will affect the city of Ushuaia.

Those consequences range from impairment of the quality of life of the inhabitants, as the negative effects on economic processes due to the lack of an essential natural resource to human life, up to the lack of interest for future economic investment in the local tourism industry.

In this case, we believe that there are concrete possibilities for action by the community and the State to reverse the effect of the shortage, either operating upon the demand as well on the supply of drinking water, enabling adoption of various strategies to minimize the effects produced by GCC.

An important part of the context is shown in government policies at the three levels of the State (Nation, Province and County), which in most cases are not coordinated on the three subsystems proposed, a fact that introduces a strong component of entropy in the problem. After passing through a brief description of the effects that climate generates on glaciers, we will present the details of each subsystem, showing their relationships and interrelationships describing the delays that have been so far identified.

THE PROBLEM OF GLOBAL CLIMATE CHANGE AND GLACIERS

To give an account of the importance of the effects of GCC in the variables analyzed in this study, we will transcribe the summary of the study by one of us (Jorge Rabassa) on the topic of glacier vanishing. Note that the full version of this paper has been recently published at www.iea.usp.br/iea/artigos/globalchangeinsouthamerica.pdf :

"Global Climate Change (GCC) can be recognized at the global level through rising mean annual or seasonal temperature, rising or diminishing regional precipitation, rising global sea level and a general increase in the frequency and intensity of extreme meteorological events. The impact of GCC has been observed in Patagonia, Tierra del Fuego, and the Antarctic Peninsula, particularly since 1978, when the Andean glaciers started to retreat. These impacts have increased in intensity with time. The cited regions are characterized by their high vulnerability, derived from their location in the Southern Hemisphere, their extreme climates, and high intrinsic climatic variability. Their geographical location with respect to the southern oceans and the Antarctic Circum-Polar Current is also very relevant to this problem. The variations have been particularly relevant to mankind during the Late Pleistocene (120 to 15 thousand radiocarbon years ago [^{14}C ka B.P.]), the Late Glacial (15-10 ^{14}C ka B.P.), and all through the Holocene (the last 10 ^{14}C ka B.P.) until present times.

The impact of GCC may be both socially and economically harmful and beneficial in human terms, both socially and economically, depending on the different

geographical areas involved or the kind of human activities considered. For example, among the beneficial impacts of GCC for South America is the displacement of the southern areas toward more benign climates and the southwestward widening of the agricultural frontier in the Argentine Pampas. However, the negative impacts are clearer and stronger, such as loss of biodiversity and forest mass, degradation of ecotonal fringes, higher frequency of extreme hydrological events such as flooding and drought, reducing or disappearing permafrost conditions in the Andean ranges above the tree line, drying of wetland and peatland ecosystems, rising climatic snowline, and fast recession of mountain glaciers and snowfields, among many others.

In the case of Patagonia and the Antarctic Peninsula, this has forced a general recession of most of the Patagonian and Fuegian glaciers, mainly due to loss of accumulation area, rising temperatures at the glacier snout elevation, and increase of ice calving in lakes or the sea. The famous Perito Moreno Glacier (Parque Nacional Glaciares, province of Santa Cruz, southernmost Patagonia [and probably its Chilean counterpart neighbor Pio XI Glacier as well (Rivera and Cassassa, 1999)] is a very particular case, because it keeps advancing actively year after year, blocking Brazo Rico, a branch of Lago Argentino, generating an ice wall that later collapses when the accumulated water pressure in the southern side of the wall exceeds the ice resistance. When the wall breaks, it is a stunning event, which is greatly appreciated by tourists and naturalists from all over the world who come in large numbers to see this event, which occurs not every year. This anomalous behavior is most likely not related to climatic factors, but to internal, glaciological forcing, or to recurrent, small magnitude seismic events, though large enough to induce glacier sliding.

The Upsala Glacier, the largest in Argentina and one the biggest in South America and the Southern Hemisphere outside of Antartica, is undergoing a clear, catastrophic recession both in its front and thickness.

A similar destiny is threatening most of the smaller, mountain glaciers and discharge ice tongues from the surviving ice sheets in Patagonia and Tierra del Fuego: the Northern Patagonian Ice Sheet, Southern Patagonian Ice Sheet, Darwin Cordillera Ice Sheet and some other smaller ice caps in the Magellanic Archipelago. On the Argentine side of the Isla Grande de Tierra del Fuego, the Alpine glaciers of the Fuegian Andes are in sharp, violent retreat. See, for example, the photographs corresponding to the Martial Glacier and the Alvear Este Glacier. Most likely, around the year 2020 A.D., most of these glaciers will have vanished, generating a priceless loss of pristine environments, water resources, alpine wetlands, scenic and tourism resources, as well as their natural, scientific and cultural legacy. The Lower Cone of the Castaño Overo Glacier was the topic of a graduate thesis in Geography (see Bertani *et al.*, 1986; Fig. 16 and 17), but it has already vanished as a permanent ice body, due to intense summer melting. Thus, in only 20 years, a focus of scientific, geographical and glaciological studies is lost forever.

The Patagonian and Fuegian glaciers have probably existed and survived continuously for at least the last 100,000 years, since the beginning of the last glaciation. However, they have been gravely injured by man-induced climate change in the last 200 years, since the "Little Ice Age". Their fading will generate enormous damage and economic loss to Patagonian tourism activities, which are today partially dependent upon their survival and perpetuation.

In other regions of Argentina, such as the central Argentine Andes, and particularly the irrigated vineyards of the Cuyo piedmont areas, and in other parts of the World as well (Central Chile; Sierra Nevada de Santa Marta, Colombia [Rabassa *et al.*, 1993]; Tibet; Eastern Africa, etc.), seasonal melting of glaciers and snowfields

has an intense contribution to agricultural irrigation or they provide fresh water resources in settled areas. For example, the city of Ushuaia, Tierra del Fuego, the southernmost city in the World, is fully reliant upon glacier melt water for fresh water supply. Also, the glaciers of the Glaciares National Park of Southern Argentina have been acknowledged as a World Mankind Heritage Site in the UNESCO program, purportedly an enduring, everlasting, perpetual recognition. Amazingly, mankind itself has doomed them in a very short time, probably before full scientific research can be accomplished.

The impact of GCC on the Antarctic Peninsula truly deserves a special comment. As a consequence of higher temperatures, the ice barriers or ice-shelves of the Weddell Sea in the eastern side of the Antarctic Peninsula have partially collapsed in recent years (and for the first time at least in 100,000 years) calving colossal icebergs named “ice islands”, that are tens of km long and thousands of square km in size. Oceanographic studies show that the Larsen-B ice shelf had not experienced a history of full recession and reformation at least since the Last Glacial Maximum.

Ice barriers, such as the Larsen Ice Shelf, would probably be incapable of regeneration in foreseeable times. In the Antarctic Peninsula, the climatic, regional snow line has also risen, predominantly along its western coast as much as 100 m to 200 m during the last 15-20 years. This is clearly verified by the occurrence of recently exposed bedrock surfaces, which have been ice covered at least since the Last Glacial Maximum, around 25,000 years ago. These expanding exposed rocky areas at or near sea level during the Austral summer have forced a large expansion of the areas for colonization by penguins and other marine birds. This fact will positively stimulate an increase in their populations, probable migrations, and other ecological consequences difficult to forecast.

A steady decline during the last decades of the thickness and a lowering of the frozen surface under permafrost conditions, and a consequent expansion of its active layer (the seasonally ice free upper portion of the soil) would generate serious structural problems in high mountain building and roads, general increase of superficial runoff, and probably an increase in frequency and intensity of mass movement catastrophic events.

Finally, the northward shift of the Antarctic Circumpolar Current as a result of GCC could cause oceanographic, climatic and ecological impacts unpredictable at the southern tip of South America.

It has long been known that the impacts of GCC will be larger in regions of higher latitude; Patagonia, Tierra del Fuego and the Antarctic Peninsula are excellent examples of this, and sad and silent testimonies of environmental damage caused by human stupidity.”

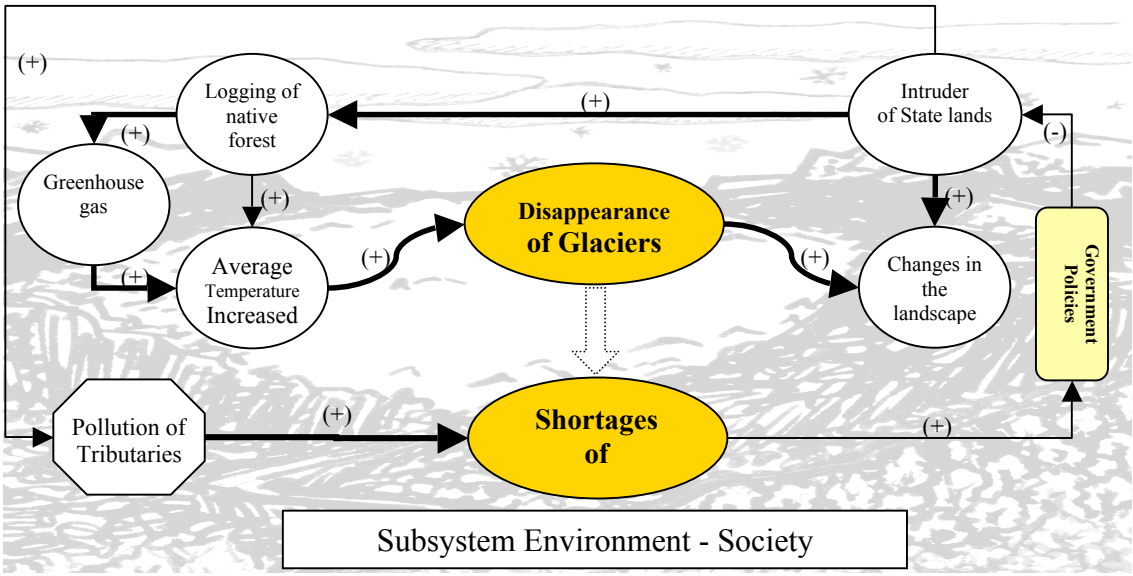
SUBSYSTEM ENVIRONMENT - SOCIETY: A STAGE ON CRITIC SUSTAINABILITY

In the report "Our Common Future", better known as the Brundtland Report, sustainability is defined as:

"Ability to meet the needs of the present without compromising the ability of future generations to meet their own needs"

When we consider the network of relationships involved in the addressed problem, the system analysis gives us an uncertain vision as well, but also highly critic considering sustainability. The climate factors determine the possibility of glacier preservation. In the particular case of the area near the city of Ushuaia,

systems approach has allowed us to recognize that these glaciers are exposed to a scene of extraordinary dynamic conditions due to the participation of both social and climatic factors, which are displayed in the chart below:



The graph above represents the dynamic relationships of the Subsystem Environment - Society, in which it is possible to recognize the impact of the factors that are related to the average temperature increase (a clear signal of GCC) that causes the gradual disappearance of our glaciers: on one hand, the greenhouse gases and secondly, the logging of native forests. We know that both factors are generated by human activity in its most varied expressions, but the second one responds to a phenomenon of significant importance in the social aspect of the system under study: the Intruders on State lands (people who occupy lands belonging to the State), whose devastating effects on the ecosystem require immediate attention by the town government through government policies that allow human settlements with the least ecological impact, not only to prevent the immediate change of scenery product of logging but also to avoid the imminent disappearance of permanent ice.

There are scientific studies that are monitoring the behavior of the main glaciers of the Island of Tierra del Fuego considering the impact of climate change,

such as the Martial Glacier –the largest source of drinking water in the city of Ushuaia-, and its conclusions are disturbing. According to a study by the Southern Center for Scientific Research (CADIC-CONICET) (Strelin & Iturraspe, 2007) the Martial Glacier has lost 70 hectares of glacier ice in the last hundred years, being the most dramatic setback for the period 1970-2000, because the glacier lost only 26 hectares of its original area between the years 1898 and 1970. From 1970 onwards, it has lost 44 hectares of ice. Currently, the glacier occupies approximately only 23 hectares, a truly very small size that does not warrant sustainability.

The projections provided by these scientists agree with the conclusions of Rabassa (2006) concerning its imminent vanishing, based on similar models and reduction indicators that allowed this author and his colleagues to predict already in 1986 the collapse of Castaño Overo Glacier (Nahuel Huapi National Park, Patagonia, Argentina), a disappearance that took place in the 90's.

SUBSYSTEM DEMAND FOR DRINKING WATER: A DYNAMIC NETWORK OF COMPLEX SOCIAL EVENTS WHICH WE MUST UNRAVEL AND REARRANGE USING SYSTEMS ANALYSIS, TRYING TO REDUCE COMPLEXITY

In the situation described above, the other two subsystems which will complement the analysis of the problem of drinking water in the city of Ushuaia should be added.

As we have stated earlier, these two subsystems are the "Subsystem Demand for Drinking Water" and the "Subsystem Supply of Drinking Water" which, as we have noted, constantly interact within a complex network of elements.

It is important to distinguish our approach in studying the relationships between the systemic dimensions of these sub-systems and their environment, as a prerequisite to address the complexity involved in analysis.

In the introduction to the study of the demographic characteristics of demand of drinking water, it is important to analyze the factors that typify the population of Ushuaia, either from the vision of the individual behaviour when they settle in the city, indicators of population and growth prospects in the short and medium term. These parameters should be able to measure the current and future demand of water.

Given the characteristics of the subsystem that we are addressing we decided to categorize the demand into two groups, whose differential behaviour will allow us to explain the composition of aggregate consumption.

THE STABLE WATER DEMAND

Firstly, we must emphasize that the population of the city of Ushuaia has maintained since the last four decades a positive growth rate: +70% from 1960 to 1970; +102% in the 1970's; +157% from 1980 to 1990; +57% from 1990 to 2001. These are adata provided by the National Institute of Statistics and Census (INDEC/Argentina). The city has currently about 65,000 inhabitants and the growth projection made by INDEC estimates a population increase of about 3% cumulative annual until 2015, based on the people registered in 2001, which amounted to 45,785 persons. This estimation was made based on assumptions regarding a regular demographic growth; thus, it can be altered in the future depending on other variables not considered in the past.

Rising population in the city responds to two demographic phenomena which are determining the "Stable Demand", being this understood as the one that should be supplied throughout all the year because it is a permanent demand. The first demographic phenomenon is the natural increase (difference between births and deaths per period); the second, with greatest impact on population, is the process of internal migration which responds to a large extent to a type of combined events within economic and social factors. This event comprises some government policies on the one hand, impacting positively on the location of productive business in the area by encouraging a favourable economic environment and an active labour market; on the other, by satisfying the demands of new urbanizations generated by the own population growth.

The establishment and development of business companies in the province of Tierra del Fuego is covered by National Law No. 19,640 (an economic government policy), which created taxes and customs exemption for those factories that are located in the province, all this in order to promote economic growth in the island. Enterprises and factories are not intensive water consumers, but they become a strong pole of attraction work, constituting another factor that encourages the establishment of permanent residents in the area.

In this first study of some relationships at a large scale, we can say that the category "Stable Water Demand", defined within the larger concept "Demand for Drinking Water", is determined by two demographic phenomena (internal migration and natural increase) and an economic phenomenon (company location), which correspond to an event of combined economic-social conditions, defined by government policies that are carried on in the city.

THE SEASONAL DEMAND OF DRINKING WATER

The second category is known as "Seasonal demand", which represents the amount of potable water which is consumed during the summer season of the year as a result of the large tourism influx between the months of October to April.

The tourist attraction provided by the natural beauty surrounding the city has allowed a significant development in tourism services, as well as highly protifable hotel and gastronomic business. This fact, coupled with a government policy that maintains a favourable exchange rate on local currency, attracts great groups of tourists from around the world, thus transforming the port of Ushuaia in the last stop for large ships after going on to Antarctica. Landing in Ushuaia Port provides them food supply and, mainly, drinking water to complete their itineraries.

The latest data published by the Ministry of Tourism of the Town of Ushuaia revealed that the total visitors during 2007 was 251,827, which include all the cruise passenger and arrivals by means of other means of transportation, projecting for 2015 a total incoming of 319,751 people.

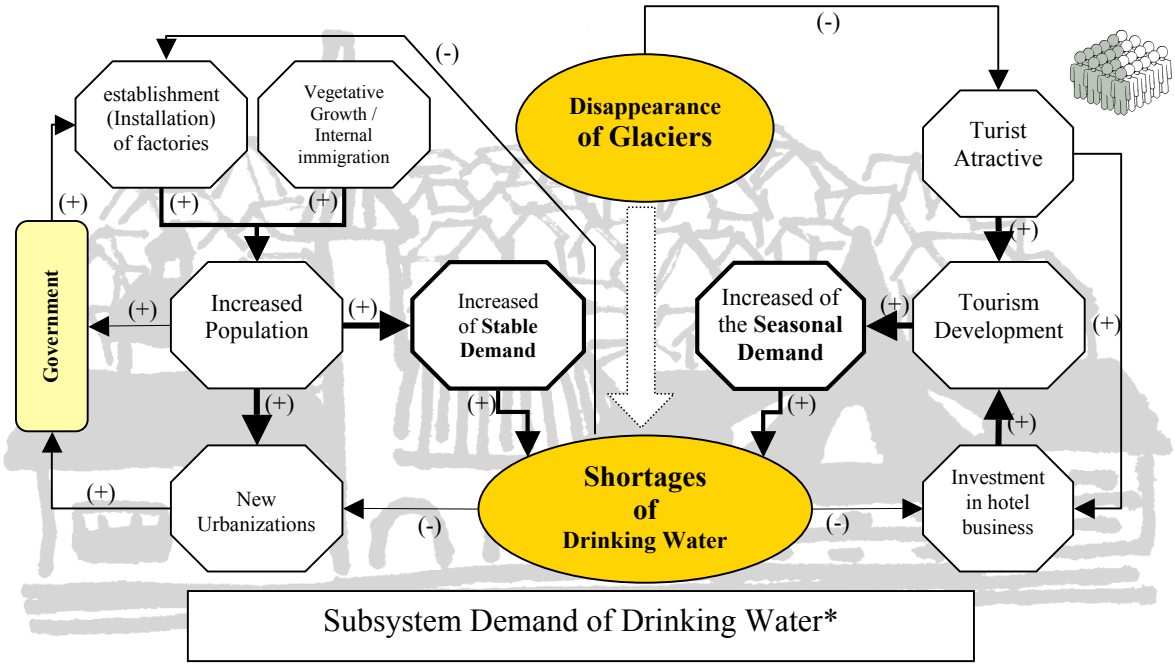
Despite the fact that tourism activity takes place during most of the year, the bulk of operating income is in the southern hemisphere spring and summer months, generating this specific "seasonal demand" of drinking water.

On the other hand, it is important to note that the total revenue generated from tourism during 2007 (according to the same source cited above) was $ 288,164,724, being projected for 2015 for the same concepts the amount of $ 558,714,177.

The latter reference is very important to highlight one of the effects that create shortage of drinking water, as it is the declining in economic activity, that next stages of this work will quantify.

THE SUBSYSTEM DEMAND OF DRINKING WATER

Previously, we were able to distinguish the major relationships that allow us to understand how they interact with social and economic phenomena in determining the aggregate total demand for water, defined by stable demand and seasonal demand. To view them integrated, we have rescued from the original graph (Water Shortages and its Dynamic Relationships) the factors of the Subsystem Demand of drinking water, which interact as follows:



* The existing relationship between the glacier disappearing and the Shortage of Drinking Water is studied under the chapter corresponding to the Subsystem Environment - Society where the determining factors of the resource offer are analyzed.

To measure in physical terms the current need of water we have taken as a reference, on one hand, data published by the last census, and on the other hand, calculating the rate of consumption of drinking water – or average consumption determined by the ratio between the total amount of purified water and the total population of the city in an annual period.

Actually, supplying water to the entire population requires making drinkable between 600 to 700 liters per inhabitant, per day. This indicator is among the highest in the country, if we consider that, for example, in the Province of Buenos Aires the average consumption is 300 iters per capita per day, according to data published by the Company Buenos Aires S.A., who is responsible for making water drinkable. Moreover, the city of Santa Fe consumed 450 litres per capita per day, whereas in Cordoba, this indicator amounts to an average of 500 litres. The World Health Organization (WHO) advised as optimal consumption per person the amount of around 250 litres per day, being the essential minimum individual requirement of 60 litres per day.

By comparison, for example in Spain, rates are still significantly lower than in our country: in Barcelona one inhabitant consumes an average of 119 litres per day, in Seville 137 litres per day and in Madrid 124 litres per day.

The apparent excess of consumption that is recorded in the city of Ushuaia in relation to its actual population may be due to many causes that are not discussed in this paper. However, we believe that there is an immediate connection between this situation and the volume of distribution of purified water, because certain inefficiencies in the supply have been observed that do not necessarily represent real consumption. To explain this relationship, we will continue discussing the Water Supply Subsystem.

SUBSYSTEM SUPPLY OF DRINKING WATER

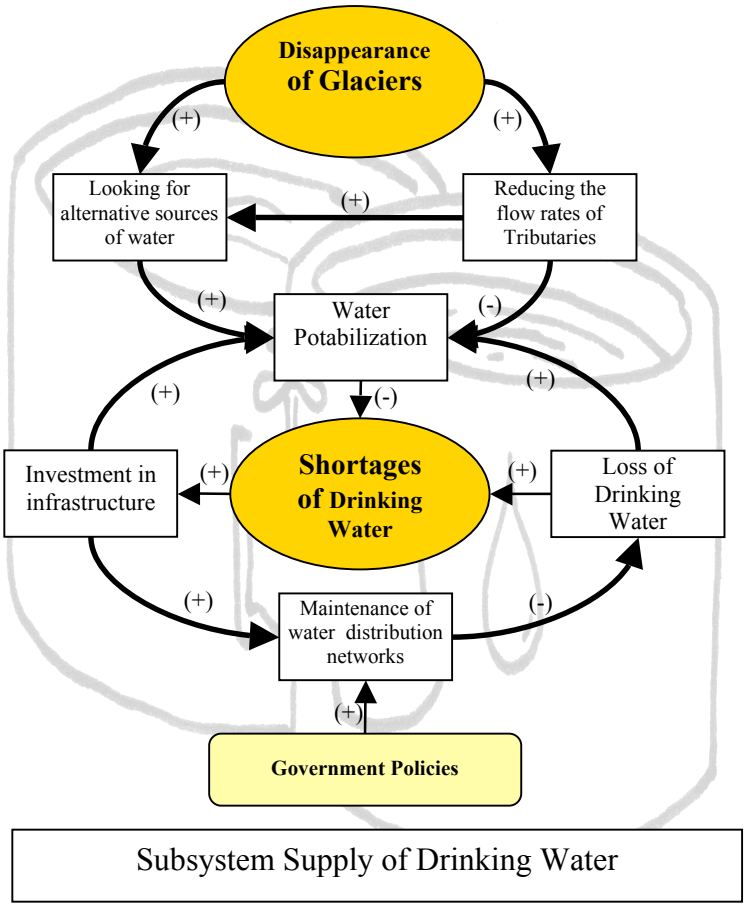
The supply of drinking water in the city of Ushuaia starts with a purification process of the water that comes from tributaries fed by melting glaciers. The main problem that will be generated after the disappearance of these ice masses due to permanent impact of GCC is the immediate seasonal reduction that will be verified concerning the actual flow of these tributaries, and consequently a reduction in the amount of water available to be purified. This situation is more obvious during the summer months of the year, because the melting of the glacier is the result of the accumulation of snow during the winter, and insofar as the size of the glacier is reduced, the amount is conditional water from melting that feeds the tributaries to a lesser extent.

If we isolate this natural behaviour of the system responding to a natural cycle of climatic factors exogenous to the system, we find that there is a variable in determination of the offer that is endogenous and of a paramount importance: the loss of drinking water mainly during the distribution process. The losses are the result of poor maintenance of supply networks which should be attended by the Government (water service provider), so we understand that government policies should be implemented towards improving operational distribution and loss reduction. However, the preventive maintenance of the network is not enough, because in some areas of the city a total replacement of networks is needed because of their deteriorating standard, or also due to the need to increase the volume of distribution in response to growing demand from the new urban settlements. Even this last factor -analyzed within the stable demand for drinking water- is already generating the need for the installation of new water treatment plants. All this, maintenance, replacement, laying of new networks and new treatment plants are all part of government policies carried out by means of increased investment in infrastructure, which is directly linked to water production.

Ushuaia faces, then, a multiple problem considering the standpoint of the supply which we are analysing: the main problem is the imminent demise of its primary source of drinking water under the impact generated by GCC, in short to medium terms and, incidentally, to a poor management of treated water during her distribution, whose effects begin to be gradually regarded as most significant while the resource becomes increasingly scarce.

Whereas the disappearance of glaciers will generate a seasonal shortage in the summer, the search for alternative sources of water is one of the strategies developed in conjunction with the comprehensive study of more efficient distribution, as both factors imply an economic cost that should be socially minimized.

The approach previously developed allows us to visualize the relationship of the emerging problem of drinking water in the following chart:



RELATIONSHIPS WITH DELAYED EFFECT

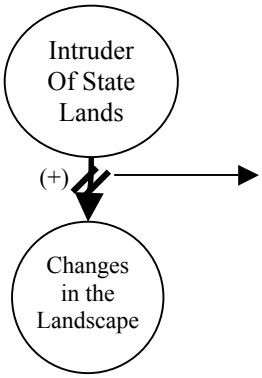
Like any social system in the complex web of relationships involved, effects that occur in many cases are transformed into causes of post effects, and so on.

In this case, in addition to this sequence of events, adding the factor of "delays" of some effects. We consider as “delay” the time between the moment in which it shows a causal relationship, and the time of collecting the impact caused by it.

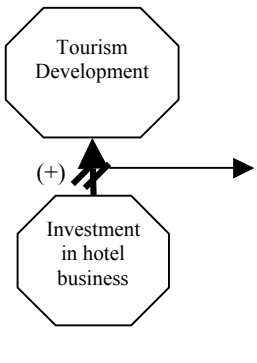
It is important to recognize the existence of delays throughout the system, while their identification, will allow us to characterize the system in a more complete manner.

The next step, if we aim to perform simulations with the model proposed, is temporarily quantify these delays, which will allow us to analyze the evolution of the variables involved in a more representative study of the problem.

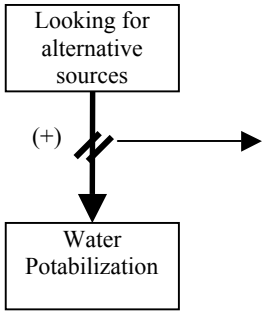
We will describe a case of delay for each one of the subsystems presented here:



Changes in the landscape caused by intruders of state lands, especially those located up in the mountains, require a time of perception by the community since precarious housing was initially set with the objective of moving unnoticed until the time comes for taking a more stable possession of the land, which is achieved through a simultaneous settlement of several families. Subsequently, the settlement intruders begin to extend their houses which involve the down cutting of native forests.
This can be later added to the urbanization sector, which produces even greater logging.



Investment in hotel business involves the construction of infrastructure, which previously required the formulation of the project, obtaining permits and financing. This period of time may vary depending on the size of the project and climatic factors affecting the process of building, which in the city of Ushuaia are very important and demanding.
Thus, since it starts from the investment up to the effective growth of tourism, there is a deadline which is considered a delay.



The search for alternative sources of fresh water requires the mobilization of the entire state system, because it is responsible for providing the service of drinking water in the city of Ushuaia.

So far, the State did not consider the socio-economic consequences that may take place when a possible shortage of drinking water starts in the future. By saying this, we stress that the time required for heavily regulated start-up procedures should be added to the studies to be carried out (there is academic research that is being devoted to the problem).

CYCLES OF SELF-REINFORCING

In any system there are relationships that cause disruption of its operation, thereby producing a destabilization that threatens the livelihood of the system itself.

In turn, if a series of disturbances relate to one another, increasing the effects produced in each cycle closes at the same place had its beginning, causing the feedback to himself, and generating a "cycle of self-reinforcing".

The cycle of self-reinforcing or positive feedback loop, amplifies the effects of destabilization caused by the system, and that is why we are paying special attention to those taking place in our system of interest.

It should also be remembered that much negative feedback loops (also known as regulators) as the positive ones are elements of endogenous generation system, we mean that the disturbance may have originated outside of it, but the regulation process or amplification takes place within the system.

Thus, we have chosen to develop a cycle of self-reinforcing that integrates the three major subsystems and that studied the consequences of which are expected to predict its evolution.

The analysis begins with the "Government Policies" that both the national and provincial state have carried out in the past, to promote "establishment of factories" in Tierra del Fuego. Originally, these policies were aimed at achieving internal migration from the rest of the country to the island, and populate a territory that was threatening to get lost because of the borders conflicts.

Over time, "Government Policies" seeking a "Increasing Population", remained until today, stressing that they have been effective, since the rate of population growth in the province has been one of the highest the country over the past decades.

The steady increase in population in the city, generates a steady growth of the emission of "greenhouse gases" in developing the daily lives of individuals, gases that

are added those issued by the rest of the planet, thus generating the "average temperature increase", showing the first effect that led to this investigation: the "Disappearance of the Glaciers" surrounding the city of Ushuaia.

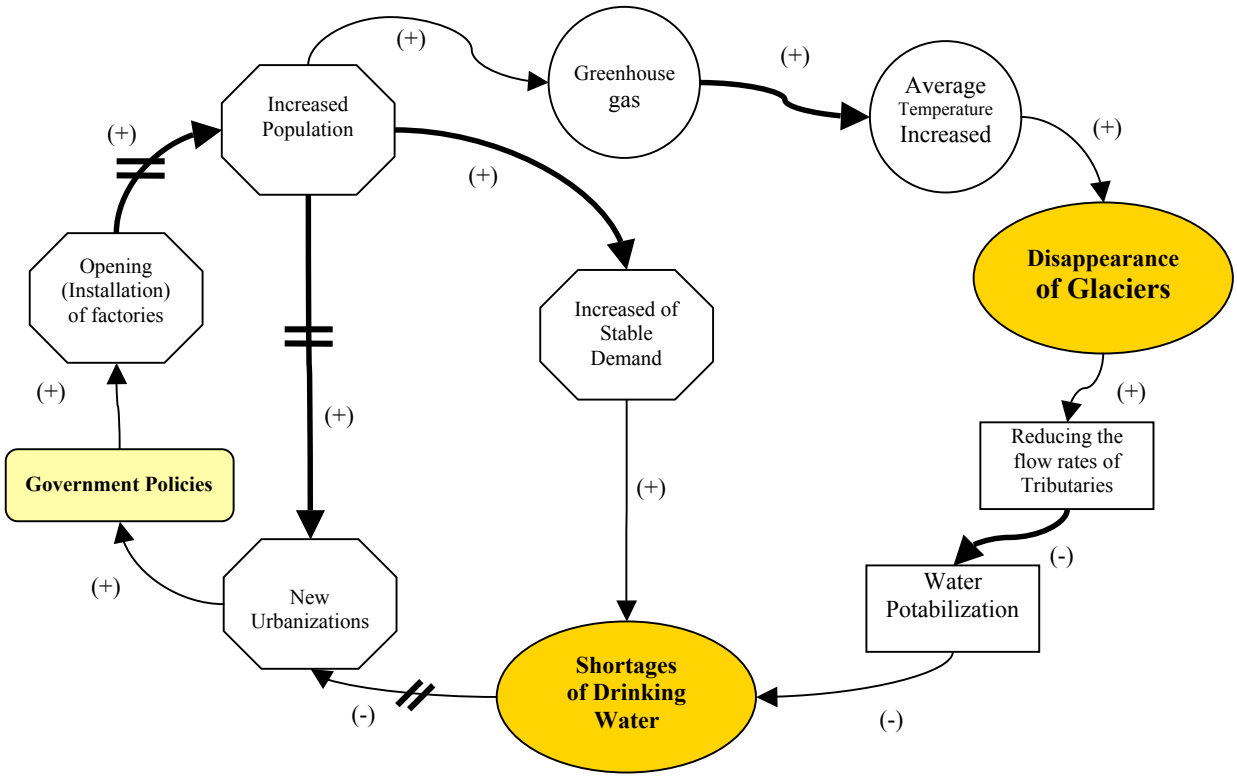
Until this point, it has been revealed five positive relationships in the loop that we are describing, adding to them the "Reducing the flow of Tributaries" that borned from the melting glacial ice.

The reduction in the flows impact directly and without any delay in "Water shortage" in our city, second effect which will cause the socio-economic consequences that we are studying.

To this are added the influence generated by the "Increased Demand Stable" in the consumption of drinking water, as the effect of increasing population, thus presenting a scenario where supply is hampered to increase infrastructure, and be able to respond to demand increase.

The needs of "new urbanizations", claimed by population growth, are affected by shortages of drinking water because the municipality does not authorize the urbanizations private or public, if they do not account with this service which is considered vital to decent living conditions of people.

Thus, we come again to the need to generate more "Government Policies", which on the one hand achieve the goal originally proposed, and on the other hand, the ultimate impact occurred, undermined that objective.



Cycle of Self-Reinforcing – The compounded situation of water shortages

CONCLUSION

The disappearance of glaciers around the city of Ushuaia, is a circumstance almost irreversible because the main factor that produces it is increasing the average temperature of our planet, and the actions that might be taken to change those facts should be at global level.

In this way, and with a forecast of disappearance of those glaciers by 2020, in our community will occur in the future a number of consequences that we aspire to predict in time and magnitude of its effects, and also to find tools that allow us manage these important changing relationships that will occur in the daily lives of the inhabitants of the city of Ushuaia.

The consumption of potable water will continue to grow as the population increases, both by internal migration as for vegetative growth, what we called "the stable demand", the same thing happens with tourist activity, for which significant increases are projected for this activity, forming part of the "seasonal demand".

The purification of potable water is closely linked with the evolution of glacial masses, that is why in critical months of higher temperatures, January and February, will decline the flows of tributaries will continue until the drought of them in the same period.

The quality of life of city dwellers will seen diminished, as well as the economic activity in it.

The problem of shortage of drinking water is already a topic of discussion at the moment that manifests itself in intermittently, but for most actors, the solution of the problem is presented as a matter of state investment in new distribution networks and water treatment plants, without considering that the greatest risk lies in the lack of raw water for the purification and distribution of it.

In our study, have emerged important relationships and properties of the system to provide a more complete vision of the whole, allowing predicts some of the causes and its effects. If we had based on a linear vision we would not have seen the whole picture.

The GCC generates a multiplicity of purposes, which are part of the ambience of the system studied here.

Moreover the system has feedback loops which seek to stabilize or amplify the effects of changes in the environment, and is to meet such information where we want to go with our work.

The lack of basic information to project the development of the variables, have led us to incorporate a new stage in the research work, as is the design of indicators that we consider critical to the system, such as: the "Index of intruders" of state land in our city,"Levels of contamination of Tributaries "and the volume of economic activities that make intensive use of drinking water.

Parallel to this fieldwork, we will start with the generation of mathematical models that will help us to project the impacts that we already have found until here, under a systemic perspective, with greater precision timing and magnitude.

With this research it stem the potential for determining the limit turning point, where investment in the search for concrete solutions to the problem of shortages, is equal to the losses caused to society by the lack of action.

They also emerge as possibilities for action, not just the management of material resources at stake, but also the integration of the community to tackle the problem and propose cultural change on water consumption and the treatment of the environment, changes that require long deadline for consolidation.

Part of this complex plot that we have achieved unravel, finding the way in various aspects that lead us back to the beginning of analysis, but no longer the very beginning, a new, enriched, which opens new perspectives proponents rethink the bases of our work, and our research will be developed under this perspective of emergent relations and dynamics interrelationships.

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