TWINLATIN

Twinning European and Latin-American River Basins for Research Enabling Sustainable Water Resources Management

An EC FP6 research project
Co-funded within the topic *'Twinning European/third countries river basins*' under the *'Global change and ecosystems'* sub-priority

Work Package 2

Monitoring & Database Construction

(TWINLATIN Deliverables D2.1. and D2.2.)

Compilation of Partner Basin Contributions

February 2009

Contents

1. WATER BALANCE & QUALITY ISSUES IN THE TWINLATIN BASINS

1.1. BASIN CLIMATE, HYDROGRAPHY & HYDROLOGY

Norrström Basin

A thorough documentation of the status and monitoring efforts in the Norrström basin was compiled in the TWINBAS project, 18 months prior to this report. Here, we give a short description of this work, updated with recent monitoring, specifically the monitoring carried out in TWINBAS. For more details please refer to the TWINBAS report WP2 – Monitoring programme (www.twinbas.org).

Figure N1.1. Location of Norrström river basin

Norrström river basin (Figure N1.1) is one of the most studied areas in Sweden, much because of its location in a densely populated area with its outlet to the Baltic Sea located in the centre of Stockholm. The basin is commonly divided into 12 tributaries, all with outlets in L Mälaren. Administratively, the Norrström basin belongs to 31 municipalities, and is a part of six different counties.

Within TWINBAS, data from different data sources and of different categories have been collected. All collected monitoring data is stored in the monitoring database of WATSHMAN. Point sources and diffuse sources in Norrström river basin and its tributaries have been analysed, in order to identify thematic and geographic areas with insufficient information for important pollutants. A limited, complementary monitoring programme was developed in TWINBAS for these areas and has been running for 18 months, with 6 more months to go.

The river basin does not suffer from water scarcity. Instead, eutrophication of the lake and algal blooms in the Baltic Sea are the main problems. Locally, high metal and pharmaceutical residue concentrations cause ecological damage.

The river basin covers an area of 22.600 km^2, which corresponds to about 5% of the area of Sweden. The basin includes two of Sweden's largest lakes; Mälaren with an area of 1120 km^2, and Hjälmaren which is about 480 km^2 (Figure N1.2). The number of people living in the area is approximately 1,2 million. Forests and mires dominate the area and cover about 70%. There are also large agricultural areas close to the lakes, covering approximately 20%, while lakes cover around 10 % of the area (Wallin et al., 2000). Mälaren and Hjälmaren are connected through river Eskilstunaån.

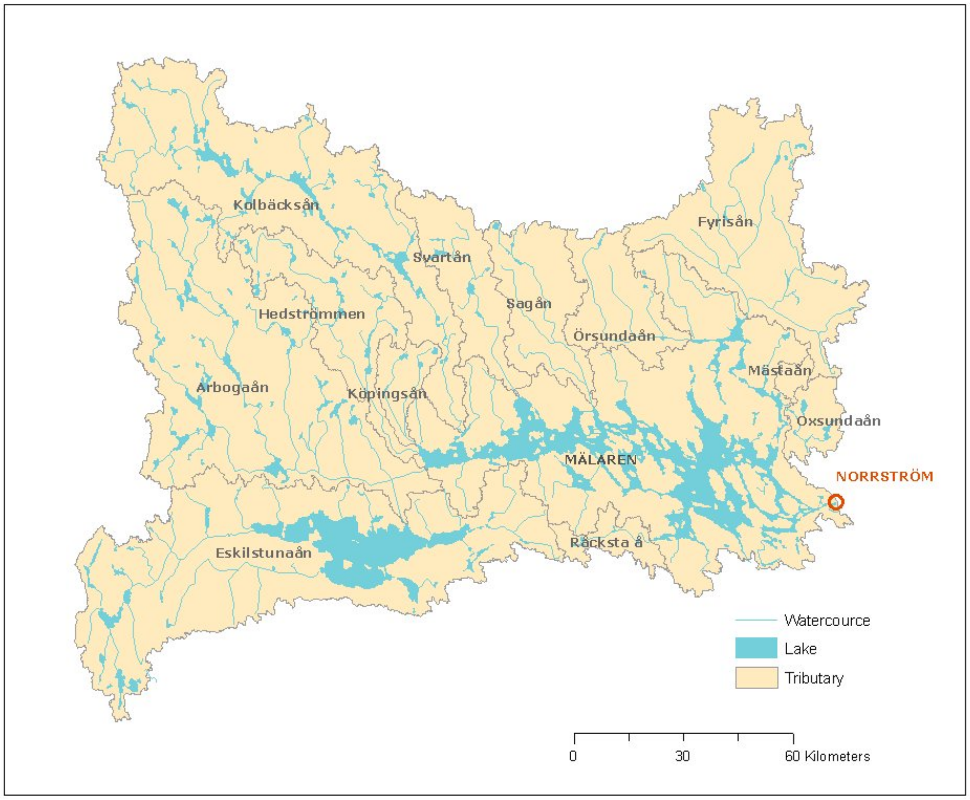


Figure N1.2. Tributaries of Norrström river basin, having its outlet in Stockholm

The lake has 12 major tributaries (Arbogaån, Kolbäcksån, Hedströmmen, Köpingsån, Svartån, Sagån, Örsundaån, Fyrisån, Märstaån, Oxundaån Råckstaån and Eskilstunaån), which together contribute with approximately 80% of the total inflow. Lake Mälaren consists of several bays and islands and has been divided into six well-defined basins. The westernmost basin, Galten, receives 46% of the total inflow, while the other sub-basins receive between 11 and 24%.

During the last 30 years the water flow at Norrström has been 164 m^3/s in average. The precipitation shows greater variation than the water flow, which shows regular variations. Average annual precipitation for period 1961 to 1990 was 618 mm in Västerås and 541 mm in Uppsala. The monitoring of Lake Mälaren started in the mid 1960's. During the late 1960's and early 1970's there were large improvements in chemical composition and biological status.

Recently, the Swedish Environmental Protection Agency identified eutrophication as the major threat to marine environment (Bernes, 2005). The same should be valid also for Norrström river basin considering its outlet to the Baltic Sea. At the same time, variation in nutrient transport from diffuse sources is great both in time and in place. Our understanding and identification of this variation is a precondition for an efficient and cost-effective abatement strategy.

The major problem in Norrström is nutrient transport, causing eutrophication both in smaller rivers and lakes as well as in Lake Mälaren and in the Baltic Sea. Agricultural land accounts for more than 50% of diffuse losses of total nitrogen (4160 tons/year) and 2/3 of the total phosphorus load (128 t/year) (Brandt and Ejhed, 2002). The contribution from agricultural land to the net load on Lake Mälaren is significant since large agricultural areas are located in the vicinity of the lake, with direct drainage to the lake and with very little retention. This has a large impact on the total nutrient transport to the lake. The area near Lake Mälaren is 4515 km^2, i.e. about 20% of the total Norrström river basin, of which 2416 km^2 is open land and 1338 km^2 forest and wetlands.

Monthly measurements on N and P are currently made close to the outlets of the main tributaries, and at a few locations upstream. In order to better model P discharge, flow-proportional measurements are needed, as well as additional measurements at points where upstream agricultural practices are known in detail. Also additional measurements in the large agricultural areas close to the lakes, discharging through small streams and large ditches, need to be monitored at more stations than the three currently running within TWINBAS.

Another problem that is receiving increased attention is effects of pharmaceutical residues. In a study on Fyrisån, it was observed that oestrogen from the Wastewater treatment plant (WWTP) of Uppsala caused endocrine effects on fish in the river. Concentrations in water are however poorly known, and river segments where summer flows are dominated by effluents from WWTPs, and consequently may have high concentrations of pharmaceutical residues, need to be identified.

Thames Basin

The Thames River basin covers an area of 13,000 km^2 (Fig. T.1.1). The basin area represents some 4% of the area of the United Kingdom. The Thames flows for 330 km from its source in a remote Gloucestershire meadow to its confluence with the North Sea at Shoeburyness in Essex. The non-tidal Thames is 237 km long and has several major tributaries, including the Pang and the Lambourn. There are 5330 km of main river and 896 km^2 of floodplain in the basin, which is rich in rivers, canals, lakes and flooded gravel pits, many of which are home to a range of wildlife. The western parts of the basin are predominantly rural, with towns concentrated along motorway corridors. In the northern and south-eastern parts, urban land uses tend to predominate, although considerable areas of rural land remain. The eastern part is dominated by Greater London which is heavily urbanised. Figure T.1.2 shows land use across the Thames basin.

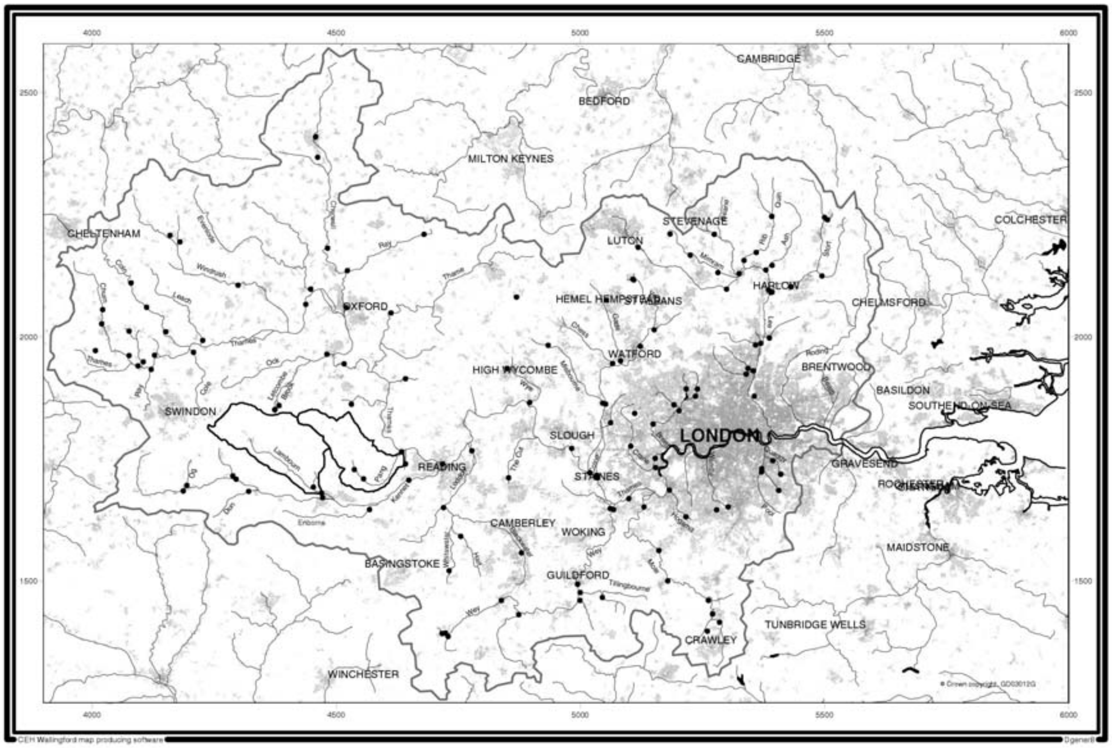


Figure T.1.1. Thames basin (UK) showing location of river gauging stations (•) and Pang and Lambourn catchments

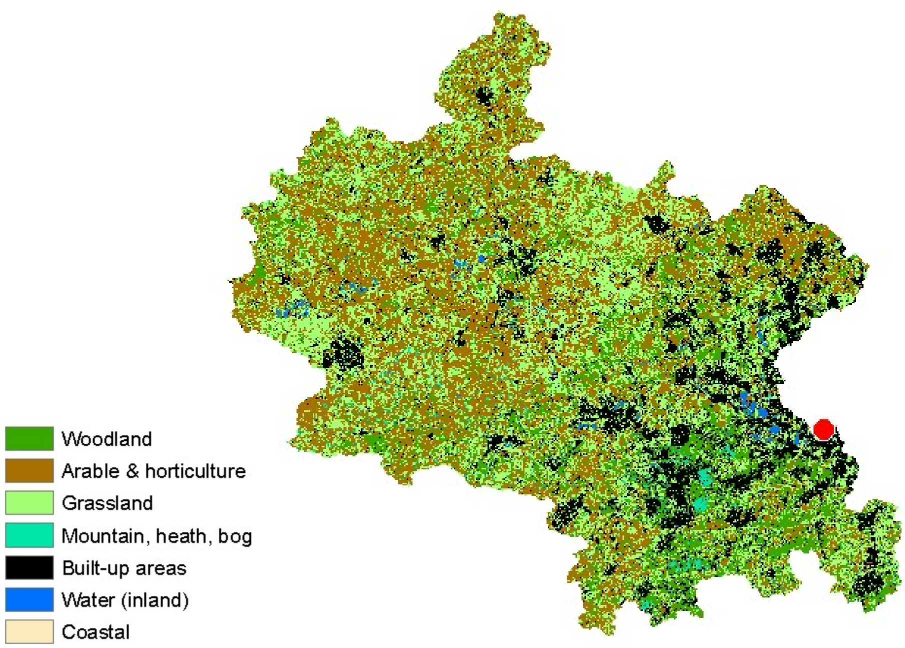


Figure T.1.2. Land use in the Thames basin (© National Water Archive, CEH)

The Thames basin receives an average of 690 mm rainfall per year, compared with a national average of 897 mm. This makes the Thames basin one of the driest parts of the UK. The mean runoff is approximately 260 mm per year, with 85-90% occurring from October to March. The character of the subcatchment flow reflects the variability in the underlying geology. A band of permeable chalk runs south-west to north-east across the basin. To the north and west of this runs impermeable Oxford clay, and beyond this oolitic limestone. The south and east of the basin are underlain by London clay. The Thames itself runs over alluvial sands and gravels for much of its length. There are fast runoff-dominated responses in the tributaries from the clay parts of the basin, and slow baseflow-dominated responses in those from the chalk. Figure T.1.3 shows the hydrogeology of the Thames basin.

Approximately 55% of the runoff in the Thames basin is abstracted, although much of this is returned to the river at some point. Of this 85% is used for public supply and the remainder is abstracted directly by agriculture and industry. The level of water resource available to users locally depends both on the specific environmental sensitivity to abstraction and current levels of abstraction. During the summer months there is no additional water available for approximately 80% of the Thames. Indeed, during dry summer months, river flows can consist of over 90% treated sewage. During the winter months, there is currently a surplus. For groundwater sources, approximately 50% of the basin has no surplus.

In the Thames basin, the predicted impacts of climate change include warmer and wetter winters, hotter and drier summers, and deteriorating air quality, with greater risk of flooding, water quality problems, and possibly drought and water shortages in summer. Increased development on floodplains, higher flow levels in the Thames and climate change are likely to increase river flooding in winter. With future demand set to rise (population is estimated to increase by 800,000 by 2025), and the uncertainties associated with climate change, effective management of the water resource provided by the river is becoming increasingly important.

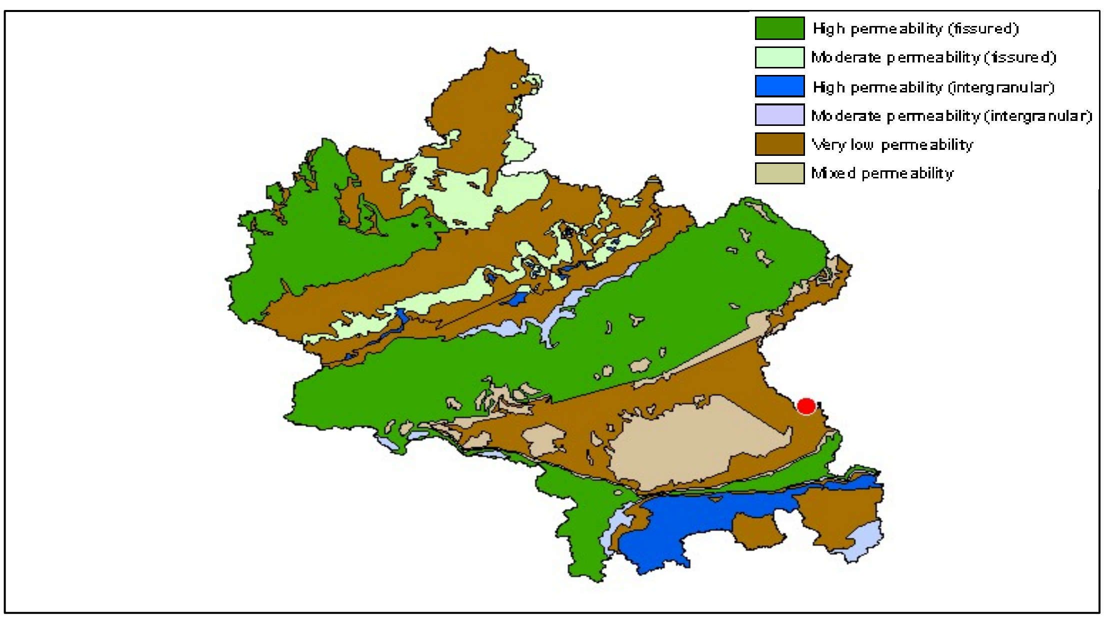


Figure T.1.3. Hydrogeology of the Thames basin (© National Water Archive, CEH)

The Environment Agency (the Agency; see reference list) is the body responsible for the management of the water resources, water quality and flood defence in England and Wales. The Agency also has responsibilities for ecology/conservation and navigation. Water management is organised on a catchment/river basis, so the entire Thames basin is covered by one administrative region, divided into three areas: north-east, south-east and west. The management of water resources within the Thames basin is important due to both the limited natural supply and the increasing demand of these resources. The Agency has divided the Thames into 14 subcatchments for which Catchment Abstraction Management Strategies (CAMS) are being developed, for managing abstraction on a local catchment scale. Furthermore, the basin contains parts of five Areas of Outstanding Natural Beauty, parts of two Environmentally Sensitive Areas, and there are 462 sites of special scientific interest.

Catamayo-Chira Basin

Climate

In the Catamayo Chira river basin, the following climate types have been identified:

Table CC.1.1. Climate types in Catamayo-Chira river basin

Climate type	River basin area (%)	Altitude (m.)
Hot	44,57	< 1.000
Semi hot	23,55	1.000 – 1.700
Warm hot	20,40	1.700 – 2.300
Warm cold	7,28	2.300 – 3.000
Semi cold	3,54	3.000 – 3.500
Moderate cold	0,66	> 3.500

Own source

The river basin climate presents noticeable variations in space and time. In the lower river basin the rainy periods are short and scarce and, with the exception of the years of the “El Niño” phenomenon, it rains from January to April with an annual average of 10 to 80 mm, with an annual average temperature of 20ºC. In the river basin medium zone the rainy period goes from December to May with annual average precipitations of 500 to 1,000 mm and annual average temperatures of 20ºC. In the high river basin, rains happen from October to May with annual averages superior to 1,000 mm and annual average temperatures of 7ºC.

Hydrography

The Catamayo Chira river basin is constituted by the sub river basins of Quiroz, Chipillico, Alamor, Macará, Catamayo and the Chira System. The main course is the Catamayo Chira River, with an overall length of 315 km. The main characteristics of these sub river basins are shown in the following table:

Table CC.1.2. Principal characteristics of the Catamayo-Chira sub basins

Sub basins	Area (km^2)	% over the total area of the basin	Average slope of the main river bed (%)	Monthly Average flow (m^3/s)
Quiroz	3.108,8	18,1	1,7	Paraje Grande 15,2
Sistema Chira	4.712,0	27,4	0,8	El Ciruelo 117,8
				Ardilla144,9

				Puente Sullana 107,5
Chipillico	1.170,9	6,8	2,0	-
Alamor	1.190,3	6,9	2,2	Alamor en Saucillo 7,0
Macará	2.833,3	16,5	1,4	Puente Internacional 40,9
Catamayo	4.184,0	24,3	1,5	Boquerón 20,8
				Santa Rosa 31,1
				Vicin 34,6
Total	**17.199,2**	**100,0**	**1,1**	-

Source: Hydric Characterization and adequation between supply and demand.
Territorial Characterization and Basic documentation. Loja – Piura, 2005. ATA – UNP –UNL

Hydrology

The Catamayo-Chira River receives the contribution of small rivers until its encounter with the Macará River. The denomination "Chira System" makes reference to the hydrographic system which, from the union of the rivers Macará and Catamayo, takes the name of Chira River, point from which this system has the character of binational. The system is formed by all the effluents that drain to the Chira River. This river, waters down, receives the contributions from the rivers Quiroz, Alamor, Chipillico and from other small gorges activated only at rainy times.

The river basin presents irregular topographies in the high part, with torrential regime sections and fluvial regime sections. The following table presents the surface water production, in the representative sub river basins and stations. It shows the annual contributions in average volume of a period of more than 27 years:

Table CC.1.3. Monthly and annual average volumes

SISTEM / SUB BASIN	STATIONS	AVERAGE VOLUME		PERIOD
		ANNUAL	MONTHLY	
Chira	El Ciruelo	3.703,2	841,8 (March)	1975-2002
	Ardilla	4.418,2	1.142,1 (March)	1976-2002
	Puente Sullana	3.285,9	929,7 (March)	1972-2002
Chipillico	-	-	-	-
Quiroz	Paraje Grande	477,2	115,1 (April)	1973-2002
Alamor	Alamor en Saucillo	218,0	59,5 (March)	1964-1999
Macará	Puente Internacional	1.280,3	291,7 (March)	1973-2001
Catamayo	Puente Boquerón	657,0	87,6 (March)	1964-1994
	Santa Rosa	980,0	130,4 (March)	1964-1994
	Puente Bacín	1087,8	144,7 (March)	1964-1994

Source: Hydric Characterization and adequation between supply and demand.
Territorial Characterization and Basic documentation. Loja – Piura, 2005. ATA – UNP -UNL

The average water production determined in 27 years registers is 4418 annual million m^3, taking as reference the entrance to Poechos reservoir.

The Catamayo Chira is a river basin that has been intensely studied in its lower part. In spite of this, there are gaps of quality information within the river basin and a lack of continuity in the registry of certain parameters. The main information gaps are related to hydrogeology (there is no information about the underground water, nor of the existent hydrogeologycal processes); meteorological information (the stations network is not sufficient and it has an irregular distribution, it is almost non-existent in the high river basin). Other important gaps are those related to hydrology (lack of measurements and bad distribution of the stations), sedimentology (no information) and biology of water bodies (it has never been studied).

Upper Cauca Basin

The Cauca River is the main tributary of the Magdalena River (river artery that crosses the country from south to north). In its path, the Cauca River is a source of water supply for domestic and agricultural sectors, and for the generation of electric power, aside from other services such as a source for the exploitation of washout materials and collector of contaminating loads from the domestic and industrial sectors.

The total length of the river, from its origin at the Macizo Colombiano to its outlet into the Magdalena river at the Brazo de la Loba is 1,350 km. The length between its headwaters to the sector of Timba (Department of Cauca) is 170 km. and from that site to La Virginia it's length is 436 km; the total length of the river from its origin to La Virginia is 606 km, and The total length of the river, from its origin at the Macizo Colombiano to its outlet into the Magdalena river at the Brazo de la Loba is 1,350 km. See Figure C1.1.

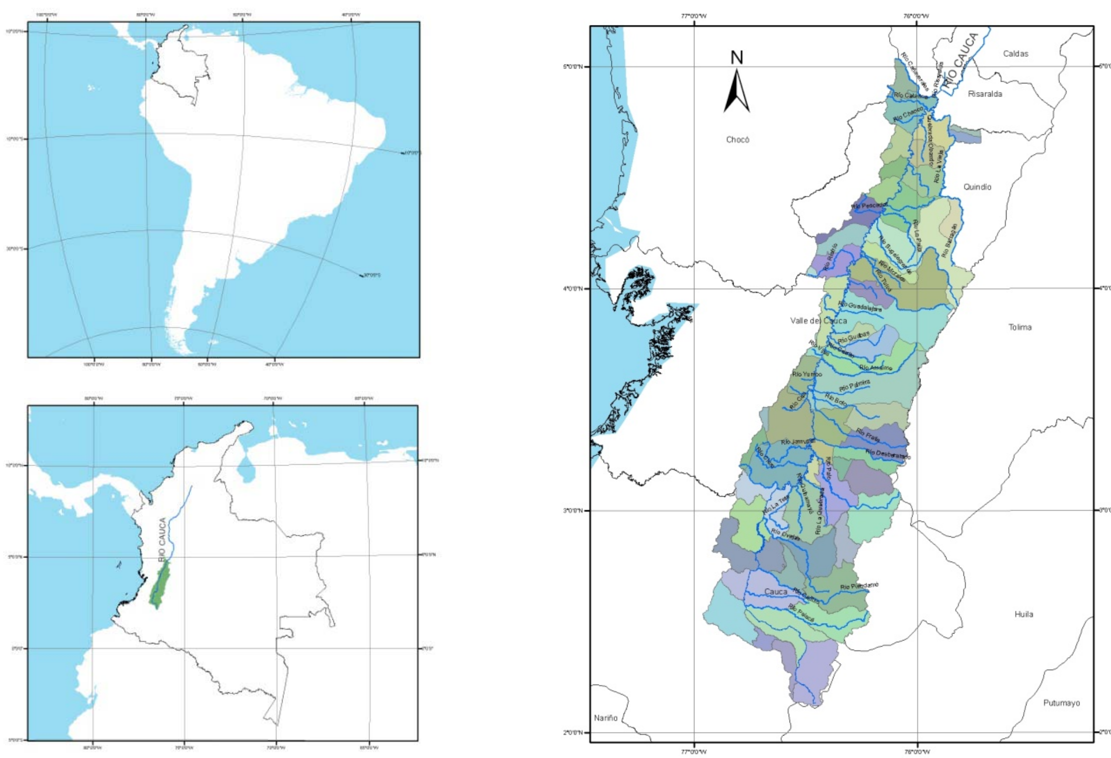


Figure C.1.1. Location of study zone

The Cauca river basin is made up by the eastern slopes of the Cordillera Occidental (Eastern Mountain Range), the geographical valley of Rio Cauca, and the western slopes of the Cordillera Central (Central Mountain Range).

	
Picture UC 1.1 Cauca river , Pan de Azúcar (Cauca)	**Picture** UC 1.2 Cauca river next to Cali

Climate

The Cauca river basin presents a tropical climate characterized by relatively high and even temperatures year round; the average temperature is 24°C with variations in the range of 10°C to 38°C. In the Cauca river basin there are different thermal floors: warm, temperate, cold and paramo.

This sector has high rainfall, with rains that increase or decrease depending on the intensity of the wind period, characterized by the existence of bimodal rainfall periods during the year. Usually there is a high rainfall period in the months of March, April and May, and another one in the months of September, October and November. The remaining months are low rainfall or transition periods. Figure C.1.2 shows the anual average precipitation of the basin and it can be seen how the pluviosity in the majority part of the region has a fluctuation between 1000 mm y 2000 mm, having larger amount of rain in the high zone of the basin, southwest part and a gradual reduction in the geographical valley, central region of the basin.

The monthly average humidity is in the range of 70-75% , mainly due to the dissipation of the clouds coming from the Pacific that are able to cross the mountain range, which become warm and move towards the Central Mountain Range (CVC, 1998 and CVC, 2002).

Hydrology

The flow regime of Rio Cauca and its most important tributaries is linked directly to the rainfall regime, presenting two wet periods between the months of April-June and October-December, and two dry periods between the months of January-March and July-September.

Most of the tributary rivers that flow into the Cauca River in this zone can be classified as torrents, according to the physiographic and morphometric characteristics of the sub-river basins. These circumstances imply a critical response to short and intense rains, and its regime is characterized by relatively low flows for the larger portion of the year and flash floods with high peaks having a brief duration.

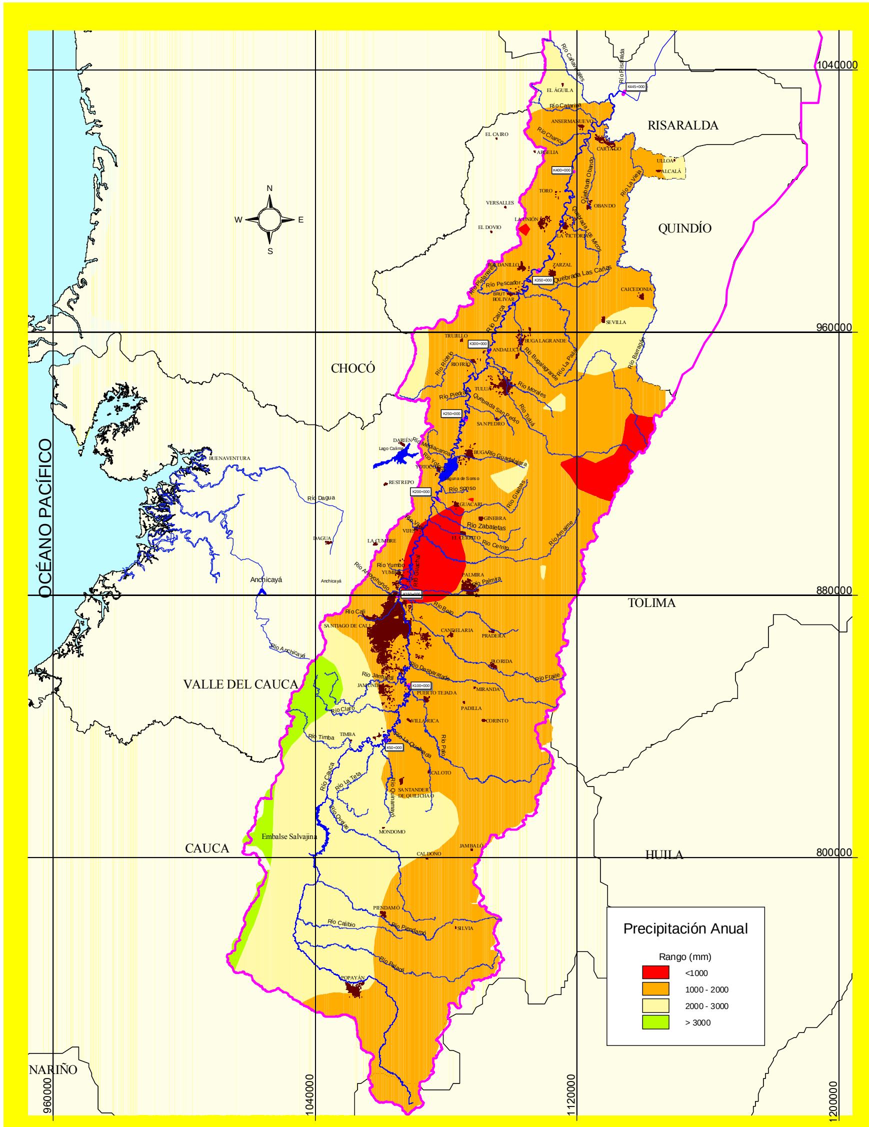


Figure C.1.2. Mean annual precipitation in the Upper Cauca

Hydrography

The Cauca river originates approximately 4000 meters above sea level and descends to 1000 meters above sea level at the municipality of La Virginia. Along its path it receives contributions from a large number of tributaries and forms alluvial fans that generate wealth for the exploitation of underground water in the different units of the aquifer of the valley.

The physiographic and morphometric characteristics of the tributary river basins, mainly the drainage density and the torrenciality ratio, indicate that a significant number of them show good to high efficiency in the superficial drainage system. On the other hand, the compacting ratio, the shape factor and the elongation indicator of the river basins present values that are close to the unit, which, added to the efficiency of superficial drainage, indicate a trend to generate flash floods in most of the tributary rivers.

The origins of the rivers that are tributaries to the Rio Cauca are on mountainous zones where the environmental authority carries out isolation and headwater recovery programs. The agricultural and cattle raising activities of these zones are usually milk cattle breeding, agro forestry, and food staple crops.

	
PictureUC 1.3 Type spoon dredge for the extraction of materials of the river. Navarro Zone	PicturUC 1.4 Type Suction dredge for the extraction of materials of the river Navarro zone.

The Cauca River is characterized by a high load of suspended sediments (washout load), product of the washout of sediments contributed by the affluent rivers. Because of this reason the Cauca river is the main source of sand for the construction sector, activity that has generated problems by the deepening of the river bed in sectors such as Hormiguero (Valle del Cauca), where river bed depths have been found that surpass the average, recording drops of up to 9m. The tributary rivers are also heavily exploited to extract washout material, situation that has made the base levels go down.

The flooding plain of Rio Cauca is a vast zone, generated by geologically young deposits (younger than 500 years). The alluvial deposits found in the zone where the project under study is framed originated by the dynamics of Rio Cauca and are overlapped by materials belonging to the alluvial cones (Qca) of the main rivers of the zone which contribute with materials having an heterogeneous grain size, the composition of which is determined by the rocks that stand above the surface in the hydrographic basins of each river, consisting of thick to very thick clastic deposits, relatively well selected stratified gravel, sandy gravels and sands with local units of silts and clays. In the margins of Valle del Rio Cauca (Cauca River Valley) there are abundant alluvial cones, generally complex, that comprise gravels and sandy gravels, with thin layers of sand. The proximal portions of the cones lack internal stratification, however, distally, the size of the grain decreases upwards, and rarely well selected sandy gravels of cross stratification fill in local canals.

Because of the wide valley it finds when entering the Department of Valle del Cauca, it has great mobility, with a high coefficient of sinuosity, leaving on its path abandoned river beds known as “madres viejas”. In some sectors lithological controls are located, and in exceptional cases, controls formed by fine grain lithic arkosic fine grain sand.

Main Water Sources

Because of the growth dynamics of the river basin, the main municipal capitals are located in the foothill zone, alluvial cone, therefore the main water sources in the study zone are made up by the Cauca river’s tributaries that supply drinking water to the population, receive pollution loads generated by the social and economic activities, and are the source of irrigation and drainage for agricultural crops. In addition, deep wells located in the geographical valley of Rio Cauca are a prioritary reserve for the river basin, providing the irrigation needs of the sugar sector in the Cauca Valley and northo of Caucaa and of the industrial sector in the Departments of Valle del Cauca and Cauca.

Surface Water

The Cauca River on its path across the study zone receives the contribution of approximately 55 tributary rivers (36 in the Department of Valle del Cauca and 19 in the Department of Cauca), located on both river banks. The tributaries on the right bank present drainage river basins with a larger extension since the western strip (right river bank) of the Cauca River has a greater width than the left strip, possibly because of the greater contribution of sediments coming from the Cordillera Central (Central Mountain range) that form long fans having a low slope pressing the river westward.

The tributary rivers that flow into the Cauca River can be classified in general, as torrents-- with a strong slope, that present considerable flash floods of short duration, and which contribute with significant sediment volumes and washout materials to the Cauca river, especially during the winter or rainy periods. The rivers flowing into the Cauca rivers that stand out the most are, in their order:

Table C.1.1 Mean flows in the principals rivers

Side left	Flow (m^3/s)		Side Right	Flow(m^3/s)
Sotará	0.8		Río Negro	1.9
Molino	1.3		Río Grande	2.7
Hondo	16.3		Las Piedras	2.3
Sucio	9.2		Palacé	23.9
Seguengue	6.4		Piendamó	14.2
Dinde	51.6		Ovejas	25.6
Timba	22.3		Quinamayó	6.8
Claro	7.0		Palo	36.3
Jamundí	11.9		Desbaratado	2.7
Cali	4.1		Guachal	11.5
Mediacanoa	1.0		Amaime	5.3
Piedras	1.0		Guadalajara	4.1
Riofrío	5.5		Tuluá	15.8
Pescador	1.6		Bugalagrande	15.2
Risaralda	41.3		La Paila	4.9
			La Vieja	94.9
	ΣQ=181.3			**ΣQ=268.10**

Groundwater

The hydro-geological studies performed by CVC in the Department of Valle del Cauca have identified two aquifer systems with well defined locations and characteristics.

The aquifers corresponding to Unit A, usually located in the first 120 m of depth, are made up by layers or gravel and sands interbedded with clays and silts; with their thickness varies from less than one meter to over 20 m in the proximity of the Cauca river. The wells that exploit the aquifers in

Unit A have yields that go from a few liters per second in the high parts of the alluvial cones, to more than 100 liters per second in the alluvial plains towards the right bank of the Cauca river.

The groundwater of the superficial aquifer of Unit A used for irrigation purposes is classified as C2S1 and C1S1. In certain sectors it usually presents high iron and manganese contents that limit its exploitation for public drinking water supply and for some industrial uses.

The aquifers corresponding to Unit C are usually found under 180 m in depth and are made up by layers of sands, gravels and sometimes rounded pebbles. They have a confined character and in most cases present uneven flows. The yield of the wells that exploit the aquifers of Unit C is higher than 100 lts/seg. The quality of water from these aquifers is excellent, it does not present any type of bacteriological contamination and the physical and chemical determinations indicate it can be used for most type of uses with very few restrictions.

Current explotation of the resource

Today there are 1555 deep wells in operation, from which between 600 and 800 million TN are extracted per year, and which are used to irrigate the 117,000 hectares planted in sugar cane, transitory crops, grasses and fruit trees; 261 industries that depend on underground water benefit, and 985,000 inhabitants of the Department use this resource for public water supply.

Table C.1.2. Groundwater exploitation

Use	Well Number	Percentage	Flow (l/s)
Agricultural	1064	53.04%	116.2
Industry	261	13.01%	9.7
Drinking supply	230	11.47%	5.7
Forsake	415	20.69%	---
In Study	36	1.79%	---
Total	**2006**	**100%**	**131**

Availability of groundwater

The total volume of stored water is 10,000 x 106 m^3, which is the total water stored in the system, and which should not be exploited in its totality because the resource would deplete.

The natural annual recharge is 3492 x 106 m3 (110.7 m3/seg.). CVC has established this as the availability limit, because in theory, if annual extractions do not surpass this volume, the system would remain in equilibrium without progressive drops of the piezometric levels.

In summary, the total availability of underground water in the aquifers of Unit A and Unit C, calculated using the regional water balance with records of 10 years (1987 - 1996) is of 110.7 m^3/s and the estimated value for Unit C is 9.5 m^3/s, thus the average recharge for aquifers in Unit A for the period analyzed is 101.2 m^3/s approximately.

From 1996, when a fee was established for the use of underground water (CVC Agreement No. 16 of July 28, 1995), an agreement was made with the users to install meters in the wells to be able to measure the actual consumption of each well in m3, and based on that information, invoice the amount payable. This action has allowed the user to know the real cost of operating his well per each cubic meter extracted, and to optimize the consumption of water reducing it by 30% in relation to the consumption estimated by CVC before the year 1996.

The highest demand of underground water at the Department of Valle del Cauca takes place in the municipalities of Palmira, Candelaria and El Cerrito; Approximately 50% of the water exploited in Valle del Cauca is pumped in those three municipalities. The municipality of Candelaria completely depends on underground water for its public water supply given the bad quality of its surface water and the low availability of this source in dry or summer seasons.

The estimate for the future is that close to 40% of the population in the Department of Valle del Cauca will be able to benefit from underground waters for its water supply, especially in those urban nuclei located on the flat zone, close to the alluvial plain of the Cauca River.

The highest density of deep wells in the Department is located between the municipalities of Candelaria and Tulúa; to the north of department the exploitation of underground water is less intensive, even though during the last few years the construction of deep wells has increased for the irrigation of sugar cane crops in the municipalities of Obando and Cartago. There is an important demand of underground water for public water supply in the municipalities of Tuluá, Roldanillo, La Unión, La Victoria and Bolivar.

Potential demand is represented by the applications to perforate wells filed by users and approved by CVC. However, they have not been built to date, in most cases due to economic difficulties given the high investment costs and economic recession problems. The picture UC1.3 presents the distribution of the explotation wells of underground waters in the high cauca basin and it is observed how they are located mainly in the plain zone of the geographical valley of the basin.

Cuareim/Quarai Basin

The Cuareim River, tributary of the Uruguay River on its left margin, is located at the extreme south of the Federative Republic of Brazil (Campanha physiographic region, which includes the Municipalities of Santana de Livramento, Quaraí, and Uruguayana) and to the northeast of the

Oriental Republic of Uruguay (Artigas Department) (64º West Longitude; 33°52' South Latitude) (TWINLATIN Working Package 1).

The Cuareim River Basin (Figure CQ.1.1) is therefore a bi-national river basin, with a drainage area of approximately 14.800 km^2, 44 % of it in Brazilian territory and 56% in Uruguayan territory.

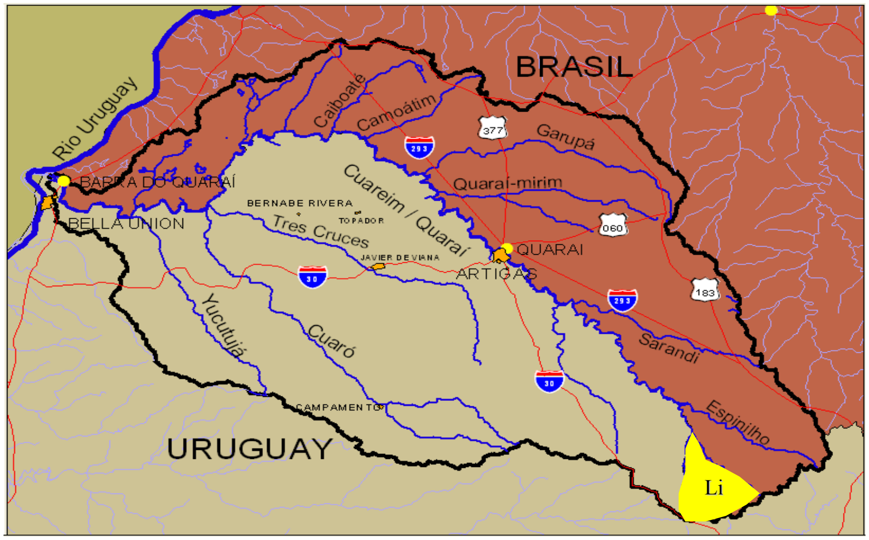


Figure CQ.1. 1. Cuareim River Basin

The main channel of the Cuareim River has a total length of 351km, with a difference in altitude between its source and mouth of 326m; and an average altitude of 200m (Datum Torres-SGE Brazil).

The basin has a variety of lithologyc units. In the upper and medium basins basalt igneous rocks frequently show up among sedimentary rocks. Their shallow soils (depth up to 0.5m) determine low soil water-storage capacity, which consequently generates fast-response run-off that may cause flooding in the cities of Artigas and Quaraí. Downstream the situation changes: deeper soils with high soil fertility are found with high contents of clay. These soils are marginal for dry land agriculture but very fit for paddy rice.

The average annual precipitation varies between 1300-1500mm. This one is characterized by a high month variability index (above 80%) and low annual variability index (less than 30%). The average annual pan evaporation is on average close to 1800 mm.

The area has a subtropical humid temperate climate. Daily thermal amplitudes are big (during the coldest month daily temperatures may vary from 3°C up to 18°C and in the hottest month temperatures frequently are above 35°C). The average annual temperature is 19.7°C.

Statistical analysis of stream flows at Concordia Bridge, that links the Uruguayan city of Artigas to Quaraí in the Brazilian side, and where the basin area is close to 4600 km^2, shows a maximum flow of 4.813 m^3/s, a minimum flow of zero, and an average flow of 95.6 m^3/s.

The whole Cuareim river basin lies above the Guaraní Aquifer System. The aquifer is a group of sandy rocks that were deposited between 245 and 144 million years ago. Successive lava spills of basalts on the aquifer arrive at thicknesses of 1500m in certain areas to the north, but are much thinner in the Cuareim region.

The main land uses in the Cuareim River basin are farming, cattle raising, mining, and urban areas; being the first one of biggest importance in relation to water consumption, mostly for the production of rice. To meet these needs, there are many dams and direct intakes in the Cuareim River and its tributaries.

Lake Cocibolca Basin

Lake Nicaragua basin has a hydrographic area of 23,844 km^2, approximately, with a terrestrial area of 15,844 Km^2. This basin belongs to River San Juan basin, or Basin 069 according the INETER nomenclature, which has 41,638 Km^2 approx. Main morphological characteristics of Lake Cocibolca and water balance are indicated in Table LC.1.1. In WP1, are the stream flows of the main rivers draining to Lake Cocibolca.

Table LC.1.1. Lake Cocibolca: Morphological Characteristics

Characteristics	Dimensions
Mean Elevation	31.4 masl
Larger axis longitude	160 km (Panaloya – San Carlos)
Minor axis longitude	70 km (La Virgen – San Ubaldo)
Mean Depth	13 m
Maximum Depth	40 m
Historical minimum level	29.57 msnm (May 1886)
Historical maximum level	33.84 msnm (November 1861)
Influent flow	870 m^3/s
Surface Evaporation	399 m^3/s
Discharge	475 m^3/s

From southeast to northwest Lake Cocibolca receives a rainfall from almost 6,000 mm to 1,500 mm being the southeast the most humid area of Nicaragua.

Table LC.1.2 and LC.1.3 shows main rivers draining to Lake Cocibolca and their subbasins. Also population in each sub basin is indicated. Soon almost one million people will live inside the basin but also people living outside the basin will use its water in the next years. So the importance of protect its water quality.

Table LC.1.2. Main rivers draining to Lake Cocibolca

Drainage	River name	Longitude (km)	Tributary
East drainage	Malacatoya	122	Fonseca, Ayoya y El Barco
	Tecolostote	55	
	Mayales	80	Cuapa, Pirre y Comalapa
	Acoyapa	45	Ojocuapa
	Oyate	70	El Cacao
	Tepenaguasapa	62	El Jícaro
	Camastro	52	
	Tule	62	
West Drainage	Tipitapa		
	Ochomogo	25	Aguacate
	Ostayo		

Table LC.1.3. Sub Basin of the Hydrological System of Lake Cocibolca

Drainage	Sub Basin	Area km^2	Population (2001)
East	Malacatoya	1,527.70	133,993
	Tecolostote	607.27	20,793
	Mayales	1,362.62	56,844
	Acoyapa	900.14	17,777
	Oyate	1,220.74	16,893
	Tepenaguasapa	1,214.88	11,589
	Camastro	417.99	6,657
	Tule	902.70	15,950
South	Frío y otros	1,748.00	2,180
	Zapote y otros	2,913.90	8,743
West	Amayo y Ostayo	156.59	16,768
	Lajas - Limón	149.11	15,471
	Lajas - En Medio	434.25	45,627
	Ochomogo	270.69	28,802
	Pital	468.46	134,118
	Tipitapa	889.92	293,281
Inside	Isla de Ometepe	274.21	31,816
	Total	15,184.96	857,302

Nowadays none governmental institution controls the water quality neither monitoring the lake water physical chemical characteristics. There is a scarcity of data. In last 10 years only three or four set of data had been taken.

All the volcano peaks inside the basin, same lagoons and several peak mountains to the northeast, are natural reserve or protected areas but they represent only a few hundreds of square kilometers.

Baker Basin

The binational Baker River Basin is located in Patagonia, Southern South America, between 46º00' and 48º00' Southern Latitude and between 71º00' and 73º30' Western Longitude. With a total drainage area of 26,726 km^2 (IGM, 1984), it is the second-largest river basin in Chile. Unlike most other Chilean Basins further north, the Baker River Basin starts off the upper eastern slope of the Andes -which is largely covered by the Northern Patagonian Icefield- and stretches out across the international border into the plains of the Argentinean Steppe ("pampa"). At its southwestern tip, the basin drains into the Chilean fjord system, which in turn connects it to the Pacific Ocean. Maximum elevations in the basin are well above 3,000 m.a.m.s.l, while the mean elevation is around 900 m.a.m.s.l.

Most of the basin's surface area falls within the Chilean Region of Aysén, but approx. 5,850 km^2 are located within the Argentinean Province of Santa Cruz. As a consequence of the highly pronounced precipitation gradient that exists from west to east, the presence of a well-developed perennial river network is mostly restricted to the Chilean part of the basin. Activities within the context of TWINLATIN will focus on the Chilean side of the Basin, whereas the whole of the river basin may be addressed in future initiatives.

Hydrography

The dominant hydrographic feature within the Baker River Basin is the "**Lago General Carrera**". This lake has a total surface area of 1,848 km^2, of which approx. 850 km^2 are located in Argentina (where it is called "Lake Buenos Aires"). The lake is located at approximately 200 m.a.m.s.l. It receives the contributions of a multitude of rivers and streams, but almost all important contributions come form the Chilean side, mainly through a series of tributaries located on its northern shore: the **Ibáñez**, **Avellanos**, **Murta**, **Engaño** and **Leones** River. On its southern shore, the main contribution to the lake comes from the **Jeinimeni** River (in the SE, on the Chilean-Argentinan limit); several other smaller rivers and streams exist in this area, most of them located to the W of Jeinimeni. The "General Carrera" Lake connects to the SW to **Lake Bertrand** (50 km^2), from where the **Baker River** springs. The Baker River drains into the Chilean fjord system (Pacific Ocean) through a 3-armed delta located just north of the village of "Caleta Tortel", after flowing S-SW wards for approximately 170 km. The Baker River has the highest mean annual discharge rate of all Chilean rivers (1,133 m^3/s – DGA, 1987). Its most important direct tributaries are: the **Nef**, "**de la Colonia**" and **Ventisquero** Rivers, which drain from the Northern Patagonian Icefield located in the west, and the **Chacabuco**, **Cochrane**, "**del Salto"** and "**de los Ñadis**" Rivers, which flow to the Baker from the east. Covering almost 3,000 km^2, the biggest subbasin is that of the Cochrane River, which drains from **Lake Cochrane** (350 km^2; called Pueyrredón in Argentina).

Climate

Three of the five main Köppen climate classes are represented in the basin. The "Cold" climate class is represented by the **EFH** ("**Polar Highland Ice Caps**") climate type, and is mainly present in the area of the Northern Patagonian Ice Field. Most of the basin however belongs to the "Temperate" climate class, which is represented by both the **Cfc** ("**Maritime SubArctic**") climate type and the **Cfbs** ("**Maritime Temperate**") climate type (precipitations throughout the year for both types, but more regularly distributed towards the coast). The "Dry" climate class, finally, is represented by the **Bsk's** ("**Middle-Lattitude, Semi-Arid Steppe with Winter Precipitations**") climate type. It is typical for the area around Chile Chico. (source: *http://www.puc.cl/sw_educ/geografia/cartografiainteractiva*)

The Agroclimatic Map of Chile ("*Mapa Agroclimatico de Chile*", INEA 1989) differentiates between five main climate types in the Baker Basin:

- *a)* **Polar Marine Climate** ("*Clima Marino Polar"*), represented in the basin by the "Cerro Benete" Agroclimate.
- *b)* **Humid Alpine Polar Climate** ("*Clima Polar Alpino Húmedo"*), represented in the basin by the "Cordillera Austral" Agroclimate.
- *c)* **Humid Marine Patagonian Climate** ("*Clima Marino Húmedo Patagónico"),* represented by the "Río Baker" Agroclimate.
- *d)* **Polar Alpine Climate** ("*Clima Polar Alpino"*), represented in the basin by the"*Hielo Perpetuo"* Agroclimate.
- e) **Cold Mediterranean Climate** ("Clima Mediterraneo Frío"), represented in the basin by the "Chile Chico" Agroclimate.

Hydrology

The hydrological regime of the river network in the Baker River Basin is of the mixed type, with contributions to the individual hydrographs from both glacial & snow melt and from direct rainfall; the relative importance of these contributions varies widely and is highly dependent on both season and geographical location. The *Ibáñez River* constitutes the most important tributary on the Northern shore of the General Carrera Lake. It originates from a glacier that comes down from the glaciated Massif of Cerro Hudson. The *Murta River***:** due to its length and discharge rate, it constitutes together with the Ibáñez River one of the most important tributaries to the General Carrera Lake. It receives the waters from numerous small glacial streams, and is mostly flanked by high mountains; in its lower reaches it meanders through an alluvial plain and reaches the lake through its estuary at Murta Bay. *Jeinimeni River* the most important tributary to the southern shore of the General Carrera Lake; it originates from the Jeinimeni Lake. Its middle and lower reaches constitute the international border between Chile & Argentina. Jeinimeni discharge rates are highly variable throughout the year. High discharge rates due to glacial/snow melt are typically observed in December, while winter rainfall contributes to higher values between July and September. "*Del Baño" Stream*: located to the W of the village of Chile Chico, this small sub-basin is monitored by DGA due to its strategic importante for the mining & irrigation activities in the area. Hydrological regime is similar to that of the Jeinimeni River. The *Cochrane River* tributes to the Baker River 24 km E downstream from its source, the Lake Cochrane (Pueyrredón Lake in Argentina). It runs through a big depression that starts on the Patagonian plateau and penetrates between the Chacabuco (to the N) and Esmeralda (S) Mountain Range. The Baker River itself sprouts from the Bertrand Lake, which in turn receives the draining waters from the General Carrera Lake. The fluviometric station on the first segment of the river downstream from Lake Bertrand ("Angostura" sector) clearly shows the regulating power of these lakes on the hydrology of the Upper Baker River. The most important tributaries to this segment are the Nef and Chacabuco River. The combination of snowmelt and rainfall contributions lead to the peak values typically observed during the summer station (Feb).

1.2. MAIN POINT SOURCES IN THE BASINS

Norrström Basin

The major point sources in the Norrström river basin can be divided into three groups; mining sites, waste water treatment plants and other industries (Figure N.3). There are also small point sources, for instance rural households. Most emission data in Sweden is registered in the database EMIR, which is a database system developed to handle information about permits from the environmental court and county administrative board. This database contains yearly loads of emissions from large point sources, but there are gaps in data and quality assurance is necessary. This is however still the best available database of point sources in Sweden. EMIR is described in the TWINBAS report and within the TWINBAS project emission data from point sources of Nitrogen (N) and Phosphorus (P) was collected, and sources of Copper (Cu), Cadmium (Cd), Zink (Zn) and Mercury (Hg) were identified. These sources and the emissions they give rise to have thus been thoroughly described within TWINBAS and are briefly described below:

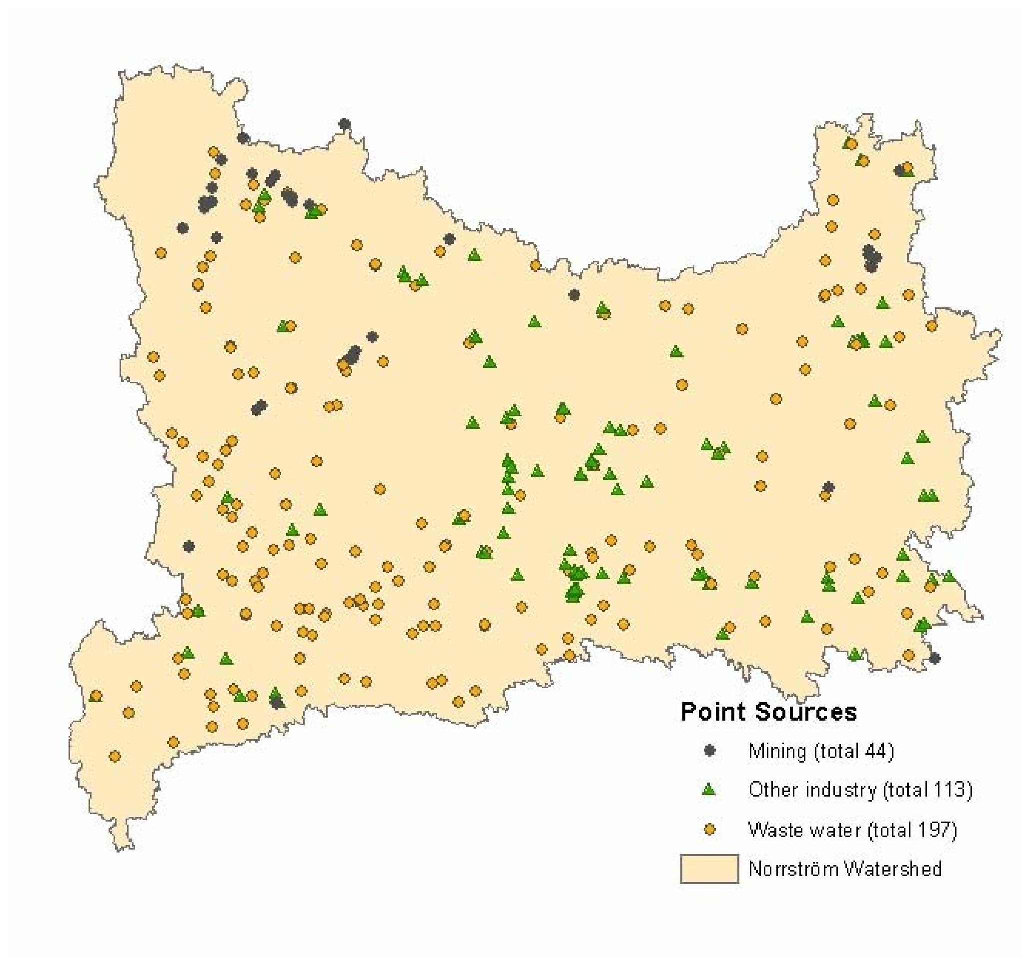


Figure N1.3 The major point sources in the Norrström river basin.

Municipal sewage treatment plants

There are in total 46 municipal sewage treatment plants (larger than 2000 p.e) in the Norrström river basin, whereof 19 larger than 10 000 p.e. Emissions from these vary between different plants, depending on the kind of industries connected, material and condition of the sewage systems and storm water connection.

The load from the municipal sewage treatment plants within Norrström in 2003 has been estimated to 2880 ton total nitrogen and 43 ton total phosphorous. Table N1.1 shows total emissions of other reported substances for 2003 (for details please refer to the TWINBAS report).

Table N1.1. Emissions to water 2003 from municipal sewage treatment plants in Norrström river basin reported in the database EMIR

Substance	Emission 2003
BOD7	525 ton
Cd	13 kg
COD-Cr	3160 ton
Cr	0.1 ton
Cu	0.6 ton
Hg	3 kg
Ni	0.4 ton
Pb	65 kg
Susp-TS	134 ton
TOC	103 ton
Zn	1 ton

In addition to the municipal waste water treatment plants there are a number of small plants. As shown in Figre N1.3 the total number of waste water treatment plants is 197. Emissions (N and P) from these plants are presently being estimated within TWINBAS, and the result will be presented in a report that will be available from the project's website.

Pulp and paper industry

There are five active plants within the pulp and paper sector in Norrström river basin, all located in the tributary Arbogaån. Three of them have direct emissions to recipient water; the other two are connected to municipal sewage treatment plants and are located in the sub basins of Eskilstunaån and Mälaren. Table N1.2 shows the total direct and indirect emissions from the sector 2003 (Skogsindustrierna, 2004).

Table N1.2 Emissions from pulp and paper industry in Norrström river basin 2003. Source: Skogsindustrierna (2004)

	Q_{water} *1000m³*	**COD** *Ton*	**N-tot** *Ton*	**P-tot** *Ton*	**Susp GF/A** *Ton*	**Susp SÄ 70** *Ton*	**AOX** *Ton*	**Cd** *Kg*	**Cu** *Kg*	**Zn** *Ton*	**Hg** *Kg*
Direct emissions to recipient	22720	2160	113	3	405	26	1	21	74	1.7	1
To municipal sewage treatment plants	1013	393	11	1	352	0	0	0.1	0	0	0.1

Mining

The contamination from mining activities is usually from leakage of dissolved metals to the surface and ground water, and also through dust and water erosion (Andersson, 2005). The substance of ores varies but usually contains high levels of As, Pb, Cu or Zn. The leakage of metals can continue many years after the mine has closed down.

Current mining data from EMIR as well as past mining data (Ejhed et al., 2005) was collected in the TWINBAS project. All the counties were also contacted regarding past and present mining activities in their county for the purpose of collecting additional information. From Dalarna, which is the most intensely mined county in the Norrström river basin, a detailed data set of leakage from all old mines in the area was acquired. From the counties of Västmanland, Uppsala, Stockholm and Örebro, the coordinates of past and present mining sites were collected. In the county of Södermanland there was no information about the locations of the mines, as this is not a priority in the county due to the low number of mines. The TWINBAS project has contributed to a comprehensive database of the location of past and present mines. It has also collected all the available data of leakage from different kinds of mining activities. In all counties there are currently inventories taking place (called the MIFO-inventories). These inventories will give a better understanding of how past mining activities are affecting the environment. Therefore it would be very interesting to continuing updating this database of mining activities in the Norrström river basin.

Other point sources

Reports from more than 100 plants in the Norrström basin show that in addition to heavy metals and nutrients a large number of other substances are emitted to the tributaries in the Norrström basin (for details please refer to the TWINBAS report). However, within TWINLATIN as well as in TWINBAS focus is on nutrients and to some extent on heavy metals.

Fish farms, pleasure boats and rural households are the small point sources that have been identified as important for nitrogen and phosphorus (Ekstrand et al., 2003). Some of the smaller point sources are registered in EMIR, but most of them are not.

Thames Basin

At present, the Thames basin includes many licensed sites which provide potential point sources of pollution, including:

- 9018 effluent discharge consents
- 135 major industrial processes
- 274 sites using radioactive materials
- 7 nuclear sites
- 845 waste management sites
- 13093 licensed waste carriers or brokers

These sites can be closely monitored and controlled by the Agency as necessary. Maps showing surface and groundwater bodies in the Thames basin at risk from point sources of pollution have been produced by the Agency and are published in defra (2005; http://www.defra.gov.uk/environment/water/wfd/pdf/thamesmaps.pdf).

Catamayo-Chira Basin

The main point sources of the river basin are Urban and Industrial wastewater discharges. Figure CC1.1. shows the distribution of the main point sources of water contamination in the basin. This is a preliminary map of the main sources, but it is not complete and it would be necessary to update it.

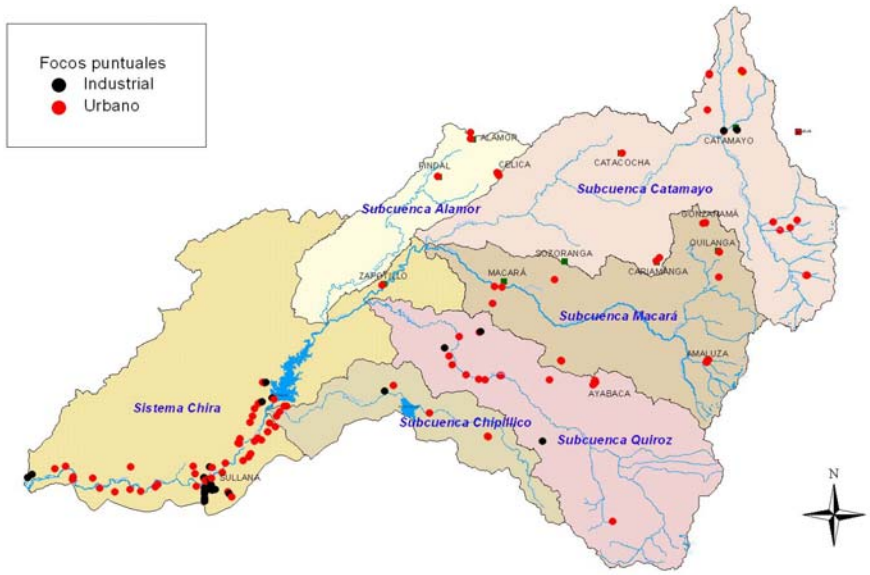


Figure CC.1.1. Point sources in the Catamayo-Chira Basin

Urban wastewater discharges

The main source of water quality alteration, in the Catamayo Chira river basin, are waste waters which, mostly, are spilled to channels without any previous treatment and conform quite an evident contamination in some parts of the river, as Sullana. Only 15% of total urban wastewaters in the river basin have some kind of treatment. Furthermore, only 25% of the existing treatment plants work correctly. The urban wastewater discharges are thought to be the main source of water contamination in the Catamayo Chira River basin.

The most important wastewater discharge points are located in the main towns of the basin, as shown in the map 1 and in the following table:

Table CC.1.4. Urban wastewater discharge points

Subbasin				
Catamayo	**Macará**	**Alamor**	**Quiroz**	**Chira system**
Yangana Vilcabamba San Pedro de Vilcabamba Malacatos Catamayo Chuquiribamba El Cisne	Macará Amaluza Quilanga	Alamor Pindal	Ayabaca Pacaipampa and Suyo	Sullana Marcavelica El Arenal Querecotillo Salitral

Catacocha Zapotillo Cariamanga Gonzanamá				

The lower part of the Chira system has the most important focus of waste water discharges pollution because the area has the higher level of development and the bigger population density of the basin.

Industrial wastewater discharges

The main economic activity in the Catamayo Chira River Basin is the agriculture. Only 8.1% of the active population works in the secondary sector, which consists on, basically, artisan activities and little industries. Of these, the main activities are food industry and agro industry, production of furniture, non metallic minerals (mostly quarries and chemical industries), and textiles; artisan mining, wood manufacture, padding products manufacture, textile and paper industry, fuel and gas storage deposits, petrol plants and stations, etc.

Even if nowadays the industry is not very significant in the river basin economy, it represents an important point source of water pollution because in most of the cases, the plants discharge its spills to the channels without any previous treatment, and often these spills are mixed with the urban wastewaters.

In the Catamayo Subbasin, the Malacatos - Catamayo area is an important zone of industrial pollution. In this area, there are alcohol, brick and tile industries that emit its industrial and sanitary wastewaters to the river. This zone also has the biggest agro industry of the river basin (sugar production, “Ingenio Azucarero Monterrey”) that also discharges its sanitary and industrial discharges directly to the river. The plant also has an area of 2,000 ha. of cane sugar production, where an intensive use of pesticides and chemical fertilizers is being done. Also in this area, the distilling industry (*industria de la destilación de aguardiente*) produces a residue (called *mosto*) that is spilled to the channels and water courses. This waste has a high temperature, an acid pH and contents a high percentage of alcohol residues. In the area these discharges are frequent because there are ten industries of this kind that produces the *mosto*.

The industrial activity in the Peruvian area is located mostly in the lower part of the basin. This zone that presents a medium level of industrialization includes approximately the area between Poechos reservoir and the estuary of the Catamayo Chira. Mostly, industries (agro industries, pisciculture plants, etc.) spill their waste waters directly to the urban sewage system or to the channels.

Upper Cauca Basin

In the basin in the study received various water discharges from mainly industrial and domestic. There are also sources product of agricultural activity (cane sugar) that is carried out mainly in the flat area.

The river on its journey through the study area receives pollution from a direct or indirect involvement of Cauca Department, municipalities, such as: Sotará, Puracé, Timbio, Popayán, Totoró, El Tambo, Cajibio, Silvia, Inzá, Páez, Piendamó, Morales, Caldono, Jambaló, Toribio, Buenos Aires, Caloto, Corinto, Miranda, Padilla, Santander de Quilichao and Puerto Tejada. In the department of Valle de Cauca deterioration of the quality of the Cauca River becomes more noticeable as the municipality of Cali, the industrial zone of Yumbo and other municipal settled along the river, among others, Jamundí, Yumbo, Palmira, Guacarí, Cerrito, Buga, Vijes, Tuluá, Bugalagrande, Riofrio, Obando, Bolivar and Zarzal, as well as a significant industrial sector in the country dump their waste water with high pollution load.

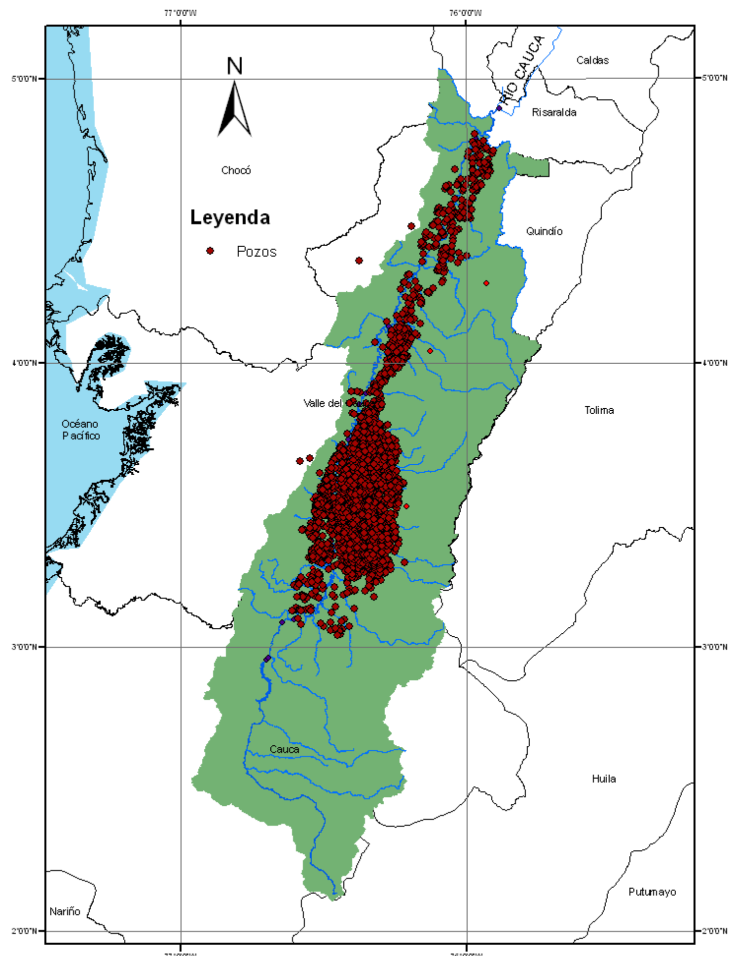


Figura C.1.3 Location of Wellts on the Upper Cauca Basin

Figure C1.4. shows the location**s** of the main sources of Cauca River contamination registered between Suárez and La Virginia. This figure shows many discharges into tributary rivers which bear pressure from urban centers, both as water supply sources and waste water receiving bodies. However, the Cauca River finally receives and transports the contaminated load that is not diluted by the initial receptor.

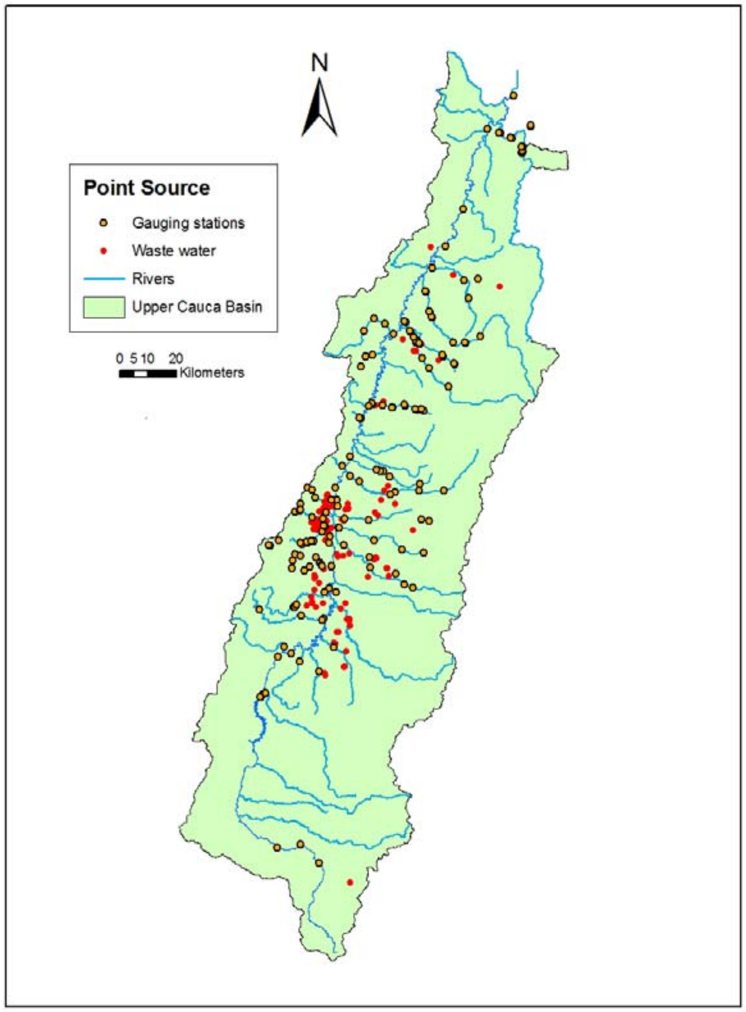


Figure C.1.4. Location of Quality Control and Waste Water Stations

Cuareim/Quarai Basin

The major urban area is Artigas/Quaraí (twin cities separated by the Cuareim river), of approximately 70.000 inhabitants. On the left margin, in Uruguayan territory, based on the Census of 1996 are found: the cities of Artigas and Bella Unión, with approximately 44.000 and 16.000 inhabitants respectively; Tomás Gomensoro and Pintadito with 1.000 and 3.000 inhabitants respectively, and 8 more urban areas with less than 1.000 inhabitants (7 less than 500). On the right margin, in Brazilian territory, the major urban areas are Quaraí (twin city of Artigas, separated by the Cuareim river) with 25000 inhabitants and Barra do Quaraí with 5000 (twin city of Bella Unión separated by the Cuareim river). The principal point source pollution is due to the effluents generated from the cities of Artigas/Quaraí.

The industrial activity is practically null.

Lake Cocibolca Basin

Lake Cocibolca receives permanent effluents of domestic waste water treatment plants (stabilization ponds) of the cities:

- Rivas
- Granada

During the rainy season Lake Cocibolca receives the runoff, loaded with solid wastes, not only of that cities but the following cities and towns, which are on or near the coast, also:

- San Jorge
- Buenos Aires
- Cárdenas
- Moyogalpa
- Altagracia
- El Paso de Panaloya
- Malacatoya
- Puerto Díaz
- San Ubaldo
- Morrito
- San Miguelito
- Morillo

Important cities that drain to the Lake through rivers, but are located some far away of lake shore are:

- Juigalpa
- Acoyapa

Even though Decree 33-95 establishes maximum allowable limits in organic load, nutrients and other substances there is no monitoring of effluent quality of waste water treatment plants neither of the runoff to the lake.

Baker Basin

Human activities in the Baker Basin are reduced, as compared to other Chilean Basins further North. Very little industrial activity takes place. According to Orrego (2002), the main point sources in the basin correspond to Urban Wastewater Discharges, the most important ones being:

- Urban wastewater from the locality of Cochrane, which discharges 2,8 l/s to the Baker River (activated sludge treatment), corresponding to a total annual BOD_5 load of 3 ton/yr.
- Urban wastewater from the locality of Chile Chico, which discharges 3,6 l/s to the General Carrera Lake (activated sludge treatment), with a total annual BOD_5 load of 4 ton/yr.
- Urban wastewater from the locality of Puerto Ibáñez, which is discharged into septical pits

Another kind of point sources, which are yet to be described in a more detailed way, correspond to effluents from the mining industry, mainly present on the shores of the General Carrera Lake.

"Point pressures", not related to discharge but rather to water abstraction, corresponds to the existing rights for extractive water use in the basin, which are issued by the DGA. According to DGA (2003), 70 water rights covering a total volume of > 2,000 m^3/s had been issued in the Baker River Basin by December 2003. Table B.1.1 gives an overview of the issued rights, as well as the associated volume per type of use.

Table B.1.1 Issued water rights in the Baker River Basin by December 2003 (DGA)

Type of Use	Q (l/s)
Energy	2,072,400.00
Irrigation	2,247.00
Mining	1,391.00
Agriculture & Livestock	781.03
Sanitary Provisions	345.20
Without information	342.00
Others	5.80

According to what was communicated by the Sanitary Services Division, Súper Intendencia de Servicios Sanitarios (SISS), within the Baker River it is possible to identify only two precise sources of liquid residues associated with wastewater. These sources correspond to the wastewater treatment plants of Cochrane and Chile Chico, which treat the waste water of about 2800 and 3600 habitants, respectively. The discharges of these cities is 2.8 l/s, corresponding to a total annual DBO_5 load of 3 tons for the city of Cochrane, and of 3.6 l/s, corresponding to a total annual BOD_5 at the level of 4 tons for the city of Chile Chico (Orrego, 2002).

Regarding the discharges produced by industrial activity, SISS has no background information of Industrial Residual Liquids (RILES) in the basin.

1.3. MAIN DIFFUSE SOURCES IN THE BASINS

Norrström Basin

Land use and nutrients

The land use for Norrström basin is presented in Figure N1.4, showing that forest dominate the area (>50%), while about 30% consist of agricultural land/open land and 10% is water.

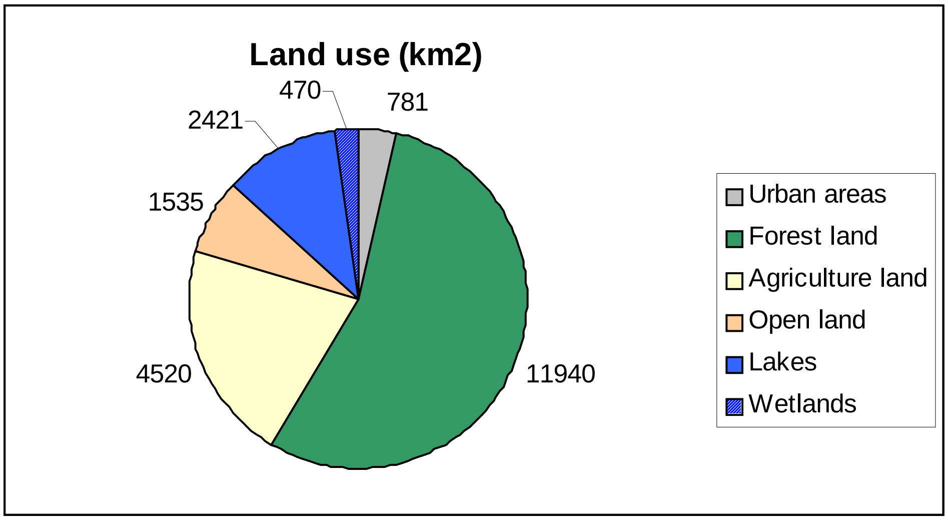


Figure N1.4 Land use (km^2) in Norrström basin, based on results from Brandt and Ejhed (2002)

Studies have shown that agricultural land contribute with more than 50% of the diffuse leakage of nitrogen and 2/3 of the phosphorous load calculated on gross level (Figure N1.5 and Figure N1.6) (Brandt and Ejhed, 2002).

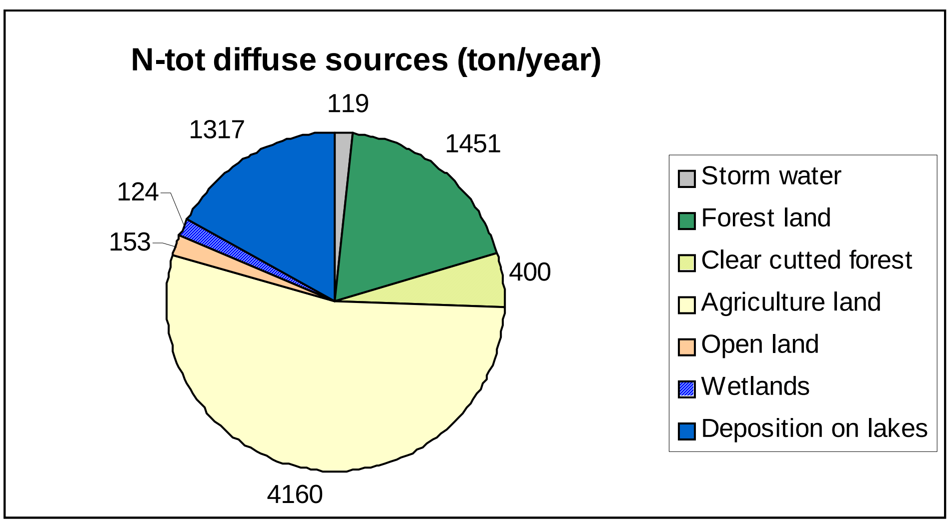


Figure N1.5 Gross load of total nitrogen from diffuse sources in Norrström basin, based on results from Brandt and Ejhed,(2002)

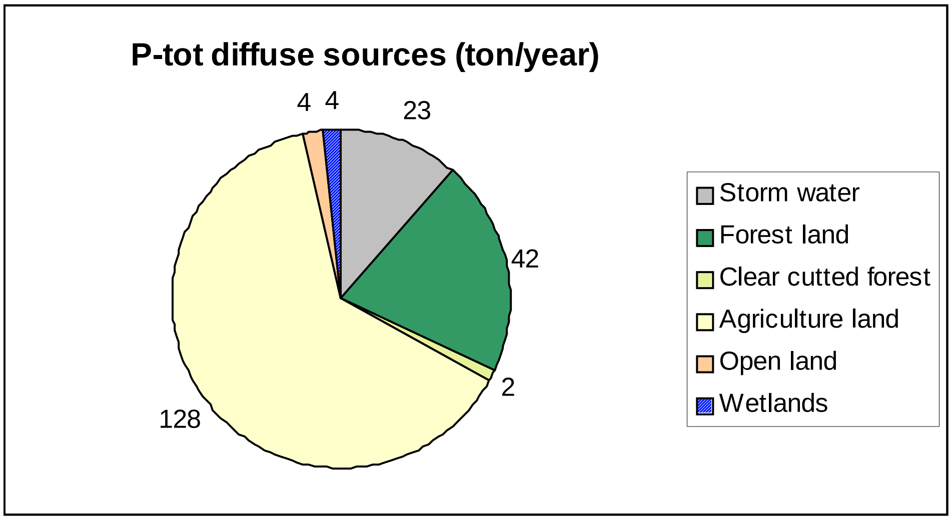


Figure N1.6 Gross load of total phosphorous from diffuse sources in Norrström basin, based on results from the TRK-project (Brandt and Ejhed, 2002)

The proportional contribution of the net load of nutrients from agricultural land to L Mälaren is however probably much larger since large agricultural areas are located close to the lake, with direct drainage to the lake and with very little retention. Also in the catchments of the larger tributaries, the agricultural areas are most often found in the areas closest to rivers and the outlet to Mälaren.

The agricultural areas close to the large lakes within the basin probably have a large (but unknown) impact on the total nutrient transport to the lakes. The area nearby L Mälaren (not included in any of the tributaries) is 4515 km^2, corresponding to around 20% of the total Norrström river basin. This area includes 2416 km^2 open land and 1338 km^2 forest and wetlands. This area has contributed with approximately 23% of the phosphorous transport (91 ton) (Wallin et al., 2000). However, estimations based on areal losses in a study area in the county of Västmanland give the result that the total load from agriculture is higher; 280 ton phosphorous and 3400 ton nitrogen. Please refer to the TWINBAS report for details.

Metals from agricultural land

The leakage of metals from agricultural land is not very well known, since data as well as appropriate calculation methods are missing. However, studies have shown that diffuse sources may have a significant impact on the total leakage of metals. Metal concentrations in manure can e.g. be rather high since feeds can contain both copper and zinc. Concentrations of cadmium are often increased when zinc concentration is high, since the two metals are closely related (Ekstrand et al., 2004). There are few data on metal content in fertilisers available; but studies show for example that the fertiliser P20 contains all metals on the WFD prioritised list. Sewage sludge contains in many cases 10-1000 times as high concentrations as in manure and fertilisers (Ekstrand et al., 2004).

Within the TWINBAS project the total metal load from Norrström basin (4520km^2 agricultural land) was estimated to: 27 kg Cd, 1944 kg Cu and 3390 kg Zn. Calculations were based on leakage estimates from Andersson (1992).

Pesticides

Among the prioritised substances in the WFD Isoproturon and Chlorpyrifos are the only two pesticides still permitted in Sweden (Sternbeck et al., 2003). Neither of these have been found in studies where agricultural areas, surface water and sediments in Norrström have been investigated. Other banned pesticides have however been found in sediments. Leakage of pesticides from agricultural land is quite hard to model, since the way the farmers handle the pesticides seems to have a larger impact on the leakage than parameters such as soil types and crop types. For more information, please refer to the TWINBAS report.

Storm water from urban areas

About three percent (761 km^2) of the catchment area of Norrström consist of urban land. Storm water usually contains a large number of substances and studies have shown that pollution most often is correlated to the amount of suspended material in storm water. The exception is metals from roof of copper and sheet metal etc. Storm water from roads normally has the highest concentrations of pollutants, except for PCB and dioxins. The pollution concentration increases with the traffic intensity, but also depends on the road surface, terrain etc. The concentrations in storm water are highest in winter and spring because of high amounts of suspended materials and snow melting can cause extremely high concentrations. Copper and sheet metal roof can give very high concentrations of copper, zinc and cadmium in storm water. Content of lead and oil in storm water has decreased drastically during the 1990's, but concentrations of chromium have increased (Stockholm stad, 2001).

Results from recent calculations of nutrients in storm water from the major cities within the Norrström basin are shown in Table N1.3. The total load, from all urban areas within the basin was calculated to 359 ton nitrogen/year, and 38 ton phosphorous per year.

Table N1.3 Nutrient load from the 20 largest cities within the Norrström basin. Source: IVL

Inhabitants	City	N ton/year	P ton/year
1212196	Stockholm	88	9,9
124036	Uppsala	17	1,9
102548	Västerås	22	2,5
95354	Örebro	16	1,8
59342	Södertälje	10	1,1
57867	Eskilstuna	11	1,3
57834	Täby	10	1,1
35919	Upplands-Väsby	4,7	0,5
34101	Tumba	5,9	0,6
24755	Vallentuna	4,7	0,5
22121	Märsta	2,5	0,3
19147	Enköping	3,5	0,4
17296	Köping	4,7	0,5
14410	Ludvika	3,5	0,5
12891	Bålsta	3,5	0,4
12592	Kumla	2,9	0,3
12118	Sala	4,9	0,6
12010	Strängnäs	2,0	0,2
11029	Fagersta	3,8	0,4
10764	Arboga	3,5	0,4

Deposition

Atmospheric deposition is an important part of the total leakage from soil for many substances. IVL is data host for deposition data in Sweden. This is described below, in the section concerning current monitoring activities. Monitoring include metals, PoPs and other substances. Approximately 80% of the atmospheric deposition of Hg, Pb and Cd comes from other countries.

Boats

Antifouling is used to prevent algae grow on boats and ships. The most commonly used substance in the past has been Tributyltin (TBT, now banned). TBT has been found in sediments in Stockholm (Sternbeck et al., 2003). Previously, paint containing copper was used, but is banned since 2000 (Ekstrand et al., 2004A).

Weathering

Estimations have shown that *weathering* has a significant contribution in comparison with other sources for Cd, Cu, Zn and Sb and can even dominate the total river transport for Tl, Be, Ge, As, Li and Ba. (Ekstrand et al., 2004A). Weathering is highly correlated with low pH in soil.

Forestry

More than half the Norrström river basin is covered by forest. About 16 500 private forestry companies own 53 % of the forests. The forest consists mostly of coniferous trees, but there are also birch, alder, oak, ash and sallow. In 2003, 148 km^2 forest was cut down in the area of Mälaren, and the forestry is of great importance to the regional economy.

Nutrients

Nutrients in forest land mainly origin from atmospheric deposition (N) and weathering (P). Previous studies have shown that 25% of the nitrogen and 20% of the phosphorous (gross load from diffuse sources) come from forest and clear cut areas (Brant and Ejhed, 2002).

Metals

Metals in forestland origin from deposition and weathering. The leakage of metals increases with the acidifying effect of cutting forest. Metal concentrations in terrestrial mosses were dramatically decreased during 1968-1995. The concentration of Hg and Pb in soil is however still increasing, due to accumulation, even though the deposition decreases. The concentration of Cd is decreasing due to decreased deposition and increased leakage caused by acidification (Ekstrand et al., 2004A).

Organic compounds

Pesticides are used in forestry at new plantations. There is also a certain leakage of organic substances from forestland caused by atmospheric deposition (Ekstrand et al., 2004A).

Country side population

Countryside population not connected to the municipal sewage systems may strongly contribute to the load of nutrients and organic substances to the surface and ground water. There are many uncertainties when calculating the load from these households since the status and the facility types most often are unknown, though many municipalities have initiated inventories lately. Estimations of nutrient load from these households are presently carried out at IVL. The estimations are based on interviews of municipalities concerning facility types. In addition to this data concerning households, populations, etc were obtained from Statistics Sweden.

Pharmaceutical residues

Both metals and organic compounds are discharged from food and medical intake and other use (Ekstrand et al., 2004A). No studies of the extent of this have been found so far.

Thames Basin

In contrast to point-source pollution, diffuse pollution cannot easily be controlled by issuing licenses or permits as it tends to arise from sites not directly regulated by the Agency. Approaches need to be more subtle and in many cases need to be well-connected to the land use planning system. The EC WFD may offer fresh opportunities for this.

Current risks of diffuse pollution in the Thames basin identified by the Agency include:

- Nutrients such as nitrogen and phosphorus from over-application of fertilizers and manures;
- Faecal and other pathogens from livestock and from overloaded and badly connected drainage systems;
- Soil particles from arable and livestock farming, upland erosion, forestry, urban areas and construction and demolition sites;
- Pesticides, veterinary medicines and biocides from industrial, municipal and agricultural use, poor storage and handling, and runoff;
- Organic wastes that are poorly stored or disposed of and spread to land;
- Oil and hydrocarbons from vehicle maintenance, disposal of waste oils, spills from storage and handling, road and industrial runoff;
- Chlorinated solvents from industrial areas where use of solvents is ubiquitous;
- Metals, including iron, acidifying pollutants and chemicals from atmospheric deposition, abandoned mines, industrial processes, etc.

Maps showing surface and groundwater bodies in the Thames basin at risk from diffuse sources of pollution have been produced by the Agency and are published in defra (2005; http://www.defra.gov.uk/environment/water/wfd/pdf/thamesmaps.pdf).

Catamayo-Chira Basin

The main diffuse sources of water pollution in the basin are urban, industrial, mining and agricultural wastes. Another important diffuse source of water contamination is the erosion, which supposes an important problem in the river basin.

Urban wastes

The most common sources of diffuse pollution are urban waste disposals. The uncontrolled waste disposal areas are very frequent and suppose an important cause of groundwater contamination.

Furthermore, mostly in rural areas, there are many towns that still do not have a public sewage system. For that reason, houses spill their waste waters to private cesspits. Frequently, these cesspits are collapsed and become, also, an important source of waste discharges that end up polluting the aquifers and other water courses.

Industrial wastes

Industrial solid wastes in the area do not receive a specific treatment. They are treated as urban wastes, deposited in controlled and uncontrolled waste disposal areas, with the associated risks this implies.

The gas emissions of some industries also pollute the water. For example, in the Malacatos area there are some brick industries. The main impact of these industries is the emission of fine particulate matter, which deposits on water courses.

Mining solid wastes

In the area the mining activity is mainly artisan (formal and informal). There are metallic mining and non metallic mining activities (quarries). That is because in the basin, there are a variety of minerals. The most important minerals that can be found are gold and silver, associated to other basic minerals like copper, zinc and iron.

The main artisanal mining areas in the River Basin are:

- Catamayo Subbasin, after the confluence of the Playas River with the Catamayo
- In the confluence of Chira System, Quiroz and Alamor Subbasins
- In the confluence of Chira, Quiroz and Chipillico Subbasins

The impact that mining may have on water systems are: acid mine drainage, release of metals (mainly mercury), cyanide, siltation and water use. Clearly, any large mining operation should have a proportionately greater impact on the environment than a smaller mining operation located in the same area. However, many small mining operations very often cannot afford to implement effective environmental management programmes and their impacts on the environment are sometimes disproportionately large. This is clearly evident in the case of small-scale and artisan mining operations, where little or no attention is directed towards minimizing impacts on the surrounding environment and that is the case of Catamayo Chira, where, besides, the existence of significant concentrations of heavy metals has been proved.

Agricultural wastes

As said, the main economic activity in the Catamayo Chira River Basin is the agriculture. In the River Basin there are some areas where an intensive agricultural activity is developed. The main impacts of these agricultural areas to the water quality are the agricultural discharges (intensive agricultural use of pesticides and fertilizers). For example, the irrigated agriculture in some areas of the Catamayo Subbasin (Vilcabamba, Malacatos, El Tambo, Indiucho, La Era, La Merced, Chichaca, Macará, Espíndola, etc.) and of the low part of the Chira System (from Poechos Reservoir to the outfall of the Chira River) is very intensive and uses high quantities of chemical inputs as insecticides, fungicides, chemical fertilizers, etc. There is no control of these uses and some of the products being used are restricted or even forbidden in other countries. Figure CC.1.2 shows the main agrarian areas of the river basin, where an intensive use of agrochemical is done.

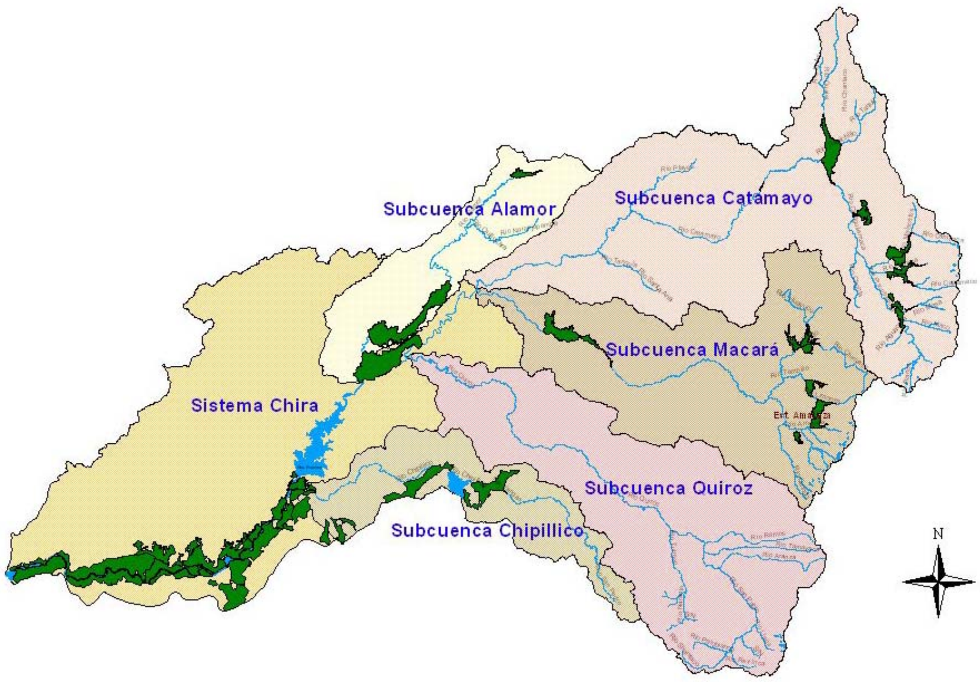


Figure CC.1.2. Principal agricultural areas in the Basin

Erosion

In the Catamayo Subbasin, the erosion issue is a critical environmental problem, because it is considered that 70% of the total surface of this Subbasin it is affected by this problem.

Upper Cauca Basin

Land use distribution in the Upper Cauca is shown in Figure C1.5. it identifies three important contaminating agents that generate pressure of the basin, through the difusse contamination: First, animal husbandry through extensive cattle raising pastures. The second contamination source is caused by agricultural activities, mostly intensive sugar cane cultivation, covering 15% of the total agricultural area. Last, but not east, And the Third source, not less important, because of the covered area, but for the caused contamination

Figure C1.6 depicts the map showing land use in the Upper Cauca Basin. It is important to note that the agricultural production zone, mainly with sugar cane plantations, is concentrated in the geographical valley of the Cauca River, corresponding to the flat area of the basin, covering a large strip by the river, that goes from the Central Zone where Cali, the largest urban center is located, up to the northern part of the basin. Direct pressure by the agricultural sector includes agricultural drainage discharged into the Cauca River and its tributaries, deteriorating water quality. Poor irrigation practices with inefficient systems and methods using underground water caused soil acidity and salinity. Another problem is the use of heavy machinery in the sector, which causes soil compacting. Agro-chemical and pesticide products for intensive sugar cane production and the corresponding burning activities required to harvest the crop negatively impact the soil and air. All of these factors represent a problem that increases diffuse contamination of soil, water sources and air.

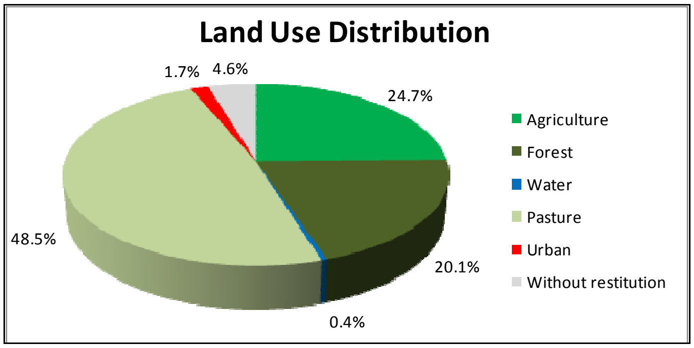


Figure UC1.5- Land Use Distribution in the Basin

Most of the current economic development of the region is related to the agro-industrial sector, especially sugar cane bio-diesel production. Application of agro-chemical and fertilizing products derived from agro-industrial processes, such as vinazas, generate consequences not yet determined, that may have a negative impact on the soil and aquifers.

Another diffuse source of contamination is produced by animal husbandry in cattle raising pastures, causing strong soil erosion in the foothills. Poor agricultural production practices in mountain areas accelerate erosion processes in the basin.

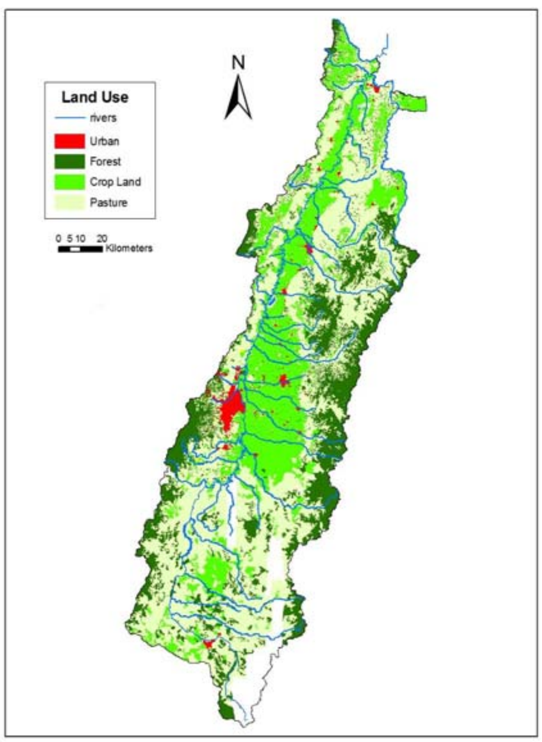


Figure UC1.6. Land Use Map of the Upper Cauca River Basin

Cuareim/Quarai Basin

The basin has three principal land uses: urban, crops (mainly rice), and cattle land.

The consequences on the water quality of the basin due to the use of **agrochemicals** in agriculture is not known. There is still no research at the national level regarding this issue. Farming without tillage, has become a normal practice among farmers. Under no-till, mechanical tillage is replaced with herbicide application for weed control. Even though it is an improvement for the soil (specially less erosion) it can become a threat to the quality of the water resources.

During storm events, **polluted urban runoff** from the cities of Artigas/Quaraí is considerable. This phenomenon occurs with a return period of 2 years. On the other hand during droughts, there may be a considerable decrease in flow and therefore reduced capabilities of autodepuration.

Erosion is another diffuse source of pollution to be considered in the Cuareim River basin, as in Uruguay is the most important one.

Lake Cocibolca Basin

All around the lake are agricultural and livestock activities and during the rainy season all the substances (organic and inorganic, biodegradable and not, nutrients and biocides, pesticides, etc) are lead to lake.

Baker Basin

The potential sources of diffuse in the Baker River basin are associated with agricultural and industrial ground use. These activities are carried out principally on the eastern borders of the General Carrera Lake. Figure B.1.2, shows the different land uses (CONAF, CONAMA and BIRF, 1999) where it can be seen that only a small part of the basin's surface is used for this type of activity. This means that the diffuse sources would not generate, a priori, a problem with water quality at a level of the entire basin. In spite of this observation, 4 potential areas (see figure 1, enlarged), that could be receiving chemical and sediment discharges during precipitation-hillside erosion processes in a spatially distributed way, were identified. Two of the previously mentioned correspond to the cities of Chile Chico and Puerto Ingeniero Ibáñez, associated with important agricultural zones, in relation to the rest of the basin. These areas of agricultural development correspond to the sub-basins of the Jeinimeni and Ibáñez rivers. Besides the two previously mentioned areas, there are other zones potential of being a source of diffuse contamination, which are associated to mining activities, and correspond to the Fachinal and Cerro Bayo Mining Companies. The activities carried out by these two mining companies could be affecting the water quality of the Aviles River, the Baño stream, and locally influencing the water quality of General Carrera Lake, at the points where these two river bodies discharge their waters in the lake.

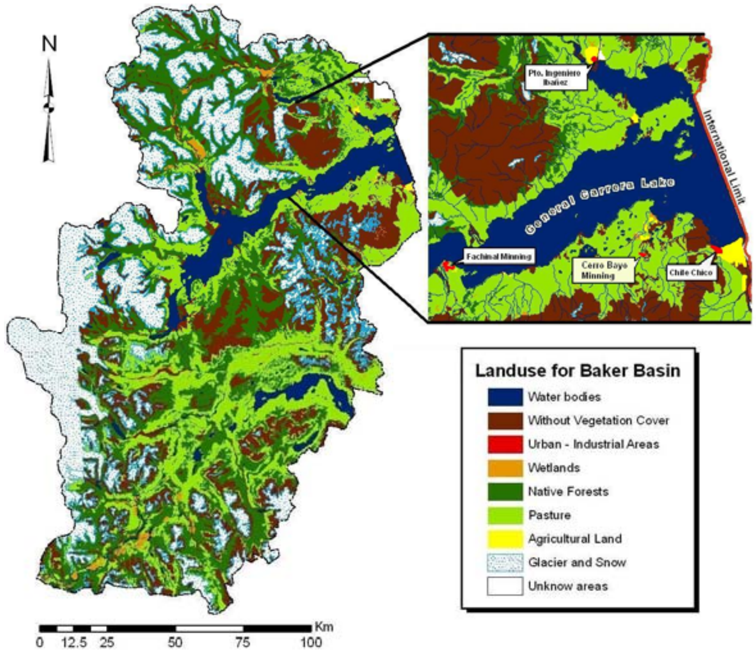


Figure B.1.2. Land use for Baker River basin and three potential zones for non point sources pollution

1.4. WATER QUALITY CRITERIA & CLASSIFICATION SCHEMES

Norrström Basin

The Swedish Environmental Protection Agency's"Criteria for Environmental Quality Assessments" constitute a system of classification which facilitates the interpretation of environmental data. The system can be used to determine whether measured values are low or high in relation to either a national average or baseline readings. Information concerning the classification system is available at EPA's website (http://www.internat.naturvardsverket.se/). However, the below described criteria are presently being revised to be consistent with the European water framework directive. The new criteria will be in use from 2007 (Vattenportalen, 2006).

The criteria are described in detail in the TWINBAS report, and only briefly described here: Guidelines for lakes and watercourses provide a base for assessing the status of aquatic areas in terms of physical and chemical factors such as nutrients/eutrophication, oxygen levels and oxygen-consuming substances, visibility, acidity/acidification and metals. There are also guidelines concerning data on which to base an assessment of biological conditions in the form of species balance and quantities of planktonic algae, aquatic plants, diatoms, benthic macroinvertebrates and fish.

The assessment involves two aspects: an appraisal of the state of the environment per se in terms of the quality of the ecosystem; and an appraisal of the extent to which the recorded state deviates from a "comparative value". In most cases the comparative value represents an estimate of a "natural" state. The results of both appraisals are expressed on a scale of 1-5 (Naturvårdsverket, 2000).

Nutrients

In the criteria for *lakes*

- Phosphorus is used as a general indicator of eutrophication.
- The quotient between nitrogen and phosphorus is used as an indicator of which nutrient is the limiting factor, and of the occurrence of nitrogen fixation, including fixing cyanobacteria.
- Additional criteria for nitrogen alone classify concentrations by their frequency of appearance, not by biological/biochemical effects like the two criteria above.

For assessments of *watercourses*, criteria are based on transports of nutrients. The area-specific losses of phosphorus and nitrogen, calculated from concentration and flow measurements (or modelling), are assessed by empirical criteria. The area-specific losses indicate the balance between fertilisation, soil function and cropping and thus function as indicators for the terrestrial system. However, they also indicate nutrient load on lakes and coastal waters and have a dual use (Naturvårdsverket, 2006).

Metals

Metals are measured in water, sediment, moss and fish. The following metals are measured: Cu, Zn, Cd, Pb, Cr, Ni and As in water (the condition values are applicable primarily in lakes and smaller watercourses, since background values often are higher in larger watercourses), sediments and moss. Hg is measured in fish (pike).

Assessment of Current Conditions

Assessment of current conditions and reference values for nutrients as well as for metals are described in detail in the TWINBAS report.

Thames Basin

In addition to point and diffuse sources of pollution, surface and ground water bodies can be put under stress from abstraction and flow regulation for domestic, agricultural and industrial activities, from morphological pressures such as physical alterations like weirs, dams or flood defences, and from anything that may disrupt the native ecosystem like the invasion of alien species.

The Agency is responsible for maintaining or improving the quality of fresh, marine, surface and underground water, with standards that are uniform across England and Wales. River water quality is assessed using a survey called the *General Quality Assessment* (GQA) scheme. This measures four aspects of quality: biology, chemistry, nutrients and aesthetic quality. Quality is monitored at about 7000 sites representing 40000 km of rivers and canals. Figures from the 2003 survey for the Thames basin are shown in Table T.1.1.

The biological GQA is based on macro-invertebrates, such as the larvae of insects (e.g. mayfly, caddis fly) and snails, shrimps and worms. Macro-invertebrates are used because they are found in virtually all rivers, they do not move far and they respond to water pollutants as well as to physical damage to their habitat. The survey measures the difference between the macro-invertebrates found in the river and those expected if the river was unpolluted and undamaged.

The chemical GQA looks at chemical water quality in terms of dissolved oxygen (DO), biochemical oxygen demand (BOD) and ammonia. DO is essential to aquatic life. BOD is an indicator of organic pollution from treated and untreated sewage, agriculture and industry. Ammonia is another indicator of organic pollution, mainly from sewage treatment works and farms, but is also poisonous to fish and other aquatic life.

The nutrients scheme measures the average concentrations of phosphate and nitrate in rivers. These are the nutrients whose presence is most likely to be affected by human activities. Naturally, phosphate concentrations in rivers tend to be low and thus limit the amount of algae growth.

Perceptions of the quality of a river are usually based on sight and smell, and so the aesthetics scheme measures aspects such as litter on the banks and in the river, sewage-derived waste (cotton buds, sanitary towels, etc), the colour and smell of the water, oil, scum, foam, sewage fungus and ochreous deposits, and dog fouling.

The Agency also uses the *EC Dangerous Substances Directive* to improve water quality through the elimination and/or reduction of dangerous substances, such as certain metals and pesticides, discharged to the aquatic environment. These substances are discussed more ahead, in a special section of this report. The Agency monitors for compliance in three areas:

- Sites below discharges from industrial plants and sewage treatment works, where there is a possibility that the effluent will contain dangerous substances;

- Sites just upstream of the tidal limit of all major rivers, including the Thames;

- The discharge is also monitored to assess whether it is complying with its individual consent to discharge.

The cause of every non-compliance is investigated and action plans to remedy the situation put in place.

Another directive, amongst many, which is used to set water standards is the *EC Freshwater Fish Directive* to safeguard freshwater fisheries. About 2500 river stretches are monitored. Compliance with the directive requires a minimum sampling frequency of once per month and comparison against quality standards. The UK government is planning to increase the scope of the directive by designating and monitoring many more rivers and still waters.

Although the GQA and existing European directives have been successful in helping the Agency to clean up rivers, there are further issues to address such as the diffuse sources of pollution mentioned earlier. It is anticipated that the WFD will help the Agency address such remaining water quality issues whilst also making sure that the improvements already made are not lost. However, a preliminary survey of water bodies in the Thames basin indicates that more than 90% of rivers, lakes and groundwater bodies, and all transitional and coastal water bodies, are at risk of not achieving WFD standards.

Table T.1.1. Results from 2003 GQA survey in Thames basin

	Percentage of river length					
	A*	B	C	D	E	F
Biology	36.7	33.6	18.1	7.8	3.6	0.1
Chemistry	22.0	42.3	20.2	10.1	5.0	0.4
Nitrate	0.6	3.7	15.5	26.1	36.7	17.4
Phosphate	2.7	10.0	10.2	13.5	49.0	14.5
Aesthetics†	n/a	47.3	n/a	25.5	9.1	18.2

*For **biology and chemistry**, A is very good, B is good, C is fairly good, D is far, E is poor, F is bad.
For **nutrients**, A is very low, B is low, C is moderately low, D is moderate, E is high, F is very high.
† For aesthetics, survey date is 2000; percentage is of sites surveyed, not river length; classes A and C not used.

Catamayo-Chira Basin

The criteria and classification to be used are the Peruvian and Ecuadorian standards established by the national laws. In Peru, according to the General Water Law (Supreme Decrees Nº 007-83-SA and Nº 003-2003-SA) administered by the Ministry of Health (DIGESA), the classification is done according to the predominant use of the water and distinguishes the following categories:

I. Raw water used for domestic purposes that is made potable by treating with simple disinfectation processes.
II. Raw water used for domestic purposes that is made potable by treating with coagulation, sedimentation, filtration and chlorination, as approved by the Department of Health
III. Raw water used for vegetable irrigation and animal (livestock) consumption.
IV. Raw water used for recreational purposes with primary contact (baths and similar).
V. Raw water used for bivalve seafood fishing.
VI. Raw water for the preservation of aquatic fauna and recreational or commercial fishing.

Following this classification, standards for analytes of concern are presented in the Table CC.1.5.

In Ecuador, the water quality criteria are established in the Law for the Prevention and Control of the Pollution and in its regulation. Even if the Law distinguishes different types of water uses (domestic and human consumption, flora and fauna preservation, agricultural uses, farming, recreational uses, industrial, transport and aesthetical uses), the water quality criteria established are specific for the following types:

A. - Raw water that requires conventional treatment for using it as human consumption and domestic purposes
B. - Raw water for human consumption and domestic purposes that only require disinfection for its potabilization
C. - Raw water used for agricultural purposes
D. - Raw water used for farming purposes
E. - Raw water used for recreational purposes with primary contact (excluding swimming pools)
F. - Raw water used for recreational purposes with secondary contact (nautical sports and recreational fishing)
G. - Raw water used for aesthetical uses
H. - Raw water used for flora and fauna preservation purposes[1]

Table CC.1.5. Maximum limits of the Peruvian General Water Law

Parameter	Unit	Maximum limits of the Peruvian General Water Law					
		I	II	III	IV	V	VI
I.- Bacteriological limits							
Total coliform	mpn/100mL	8.8	20,000	5,000	5,000	1,000	20,000
Fecal coliform	mpn/100mL	0	4,000	1,000	1,000	200	4,000
II.- Biological oxygen demand limits							
BOD_5	mg/L	5	15	10	10	10	-
DO	mg/L	3	3	3	3	5	4
III.- Potentially dangerous substances limits							
Selenium	mg/m^3(µg/L)	10	10	50	na	5	10
Mercury	mg/m^3(µg/L)	2	2	10	na	0.1	0.2
PCB's	mg/m^3(µg/L)	1	1	1+	na	2	2
Esters	mg/m^3(µg/L)	0.3	0.3	0.3	na	0.3	0.3
Cadmium	mg/m^3(µg/L)	10	10	50	na	0.2	4
Chromium	mg/m^3(µg/L)	50	50	1,000	na	50	50
Nickel	mg/m^3(µg/L)	2	2	1+	na	2	**
Copper	mg/m^3(µg/L)	1,000	1,000	500	na	10	*
Lead	mg/m^3(µg/L)	50	50	100	na	10	30
Zinc	mg/m^3(µg/L)	5,000	5,000	25,000	na	20	**
Cyanide (CN)	mg/m^3(µg/L)	80 (WAD)	80 (WAD)	100 (WAD)	na	22 (Libre)	22 (Libre)
Phenol	mg/m^3(µg/L)	0.5	1	1+	na	5	5
Sulphides	mg/m^3(µg/L)	1	2	1+	na	2	2
Arsenic	mg/m^3(µg/L)	100	100	200	na	10	50
Nitrates	mg/m^3(µg/L)	10	10	100	na	na	na
Pesticides	For every use the criteria of the EPA (USA) will be applied						
IV.- Potentially harmful substances limits							
MEH [2]	mg/L	1.5	1.5	0.5	0.2	-	-
SAAM[3]	mg/L	0.5	0.5	1.0	0.5	-	-
CAE	mg/L	1.5	1.5	5.0	5.0	-	-
CCE	mg/L	0.3	0.3	1.0	1.0	-	-

[1] Valores máximos permisibles para aguas dulces y frías
[2] Material extraíble con hexano
[3] Substances actives to the Blue Metilen

Following this classification, standards for analytes of concern are presented in the following table:

Table CC.1.6. Maximum limits of the Ecuadorian Law for the prevention and control of the pollution

Parameter	Unit	Ecuador Law for the Prevention and Control of the Pollution Maximum limits						
		A	B	C	D	E	F	H
Tº	ºC	N.C. ± 3	N.C. ± 3	-	-	6.5–8.5	5 - 9	+3 CN <32
Ph	-	6 - 9	6 - 9	6 – 9	-	80% of saturation O_2 and never less than 6 mg/L	80% of saturation O_2	6.5 - 9.0
DO	mg/L	80% of saturation O_2 and never less than 6 mg/L	80% of saturation O_2 and never less than 6 mg/L	-	-	-	-	80% of saturation O_2 and never less than 6 mg/L
BOD_5	mg/L	10% of BOD_5 admissible and maximum of 2mg/L	10% of BOD_5 admissible and maximum of 2mg/L	-	-	15:1	-	-
Relation Nitrogen - Organic Phosphorous		-	-	-		1,000	4,000	-
Total coliform	mpn/ $100cm^3$	3,000	100	1,000	-	200	-	-
Fecal coliform	mpn/ $100cm^3$	600	20	-	-	-	-	70
Parasites eggs		-	-	Absence	-	Absence	Absence	-
Greases and oils	Visible film	Absence	Absence	Absence	-	-	-	Absence
Dissolved solids	mg/L	1,000	1,000	-	TDS ≤ 3,000.0	(visibility with Secchi ≤ 2 meters)	-	-
Turbidity	UTF	100	10	-	-	-	-	-
Colour	Real colour (colour units)	100	20	-	-	-	-	-
Smell and taste		Smell and taste removable by convention al treatment are allowed	Absence	-	-	Absence	Absence	-
Floating material		Absence	Absence	Absence	-	-	-	-
Ammoniac	mg/L	1.0	1.0	-	-	-	-	0.1 CL^{96}_{50}
Arsenic	mg/L	0.05	0.05	0.1	0.2	-	-	0.1 CL^{96}_{50}

Barium	mg/L	1.0	1.0	-	-	-	-	0.1 CL^{96}_{50}
Cadmium	mg/L	0.01	0.01	0.01	0.05	-	-	0.01 CL^{96}_{50}
Cyanide (CN)	mg/L	0.2	0.2	-	-	-	-	0.05 CL^{96}_{50}
Zinc	mg/L	5.0	5.0	2.0	25.0	-	-	0.01 CL^{96}_{50}
Chlorine	mg/L	-	-	-	-	-	-	0.1 CL^{96}_{50}
Chloride	mg/L	250.0	250.0	-	-	-	-	-
Copper	mg/L	1.0	1.0	0.2	0.5	0.002	-	0.1 CL^{96}_{50}
Phenolic compounds	mg/L	0.002	0.002	-	-	-	-	0.5 (clorophenols) 1.0 CL^{96}_{50} (phenols)
Chromium	mg/L	0.05	0.05	0.1	1.0	-	-	0.01 CL^{96}_{50}
Difenil policlorados	mg/L	Non detectable	Non detectable	-	-	-	-	0.001 CL^{96}_{50}
Mercury	mg/L	0.002	0.002	-	0.01	-	-	0.01 CL^{96}_{50}
Nitrates	mg/L	10.0	10.0	-	Nitrates + nitrites $\leq$ 10.0	-	-	-
Nitrites	mg/L	1.0	1.0	-	1.0	-	-	-
Silver	mg/L	0.05	0.05	-	-	-	-	0.01 CL^{96}_{50}
Lead	mg/L	0.05	0.05	0.05	0.05	-	-	0.01 CL^{96}_{50}
Selenium	mg/L	0.01	0.01	0.02	-	-	-	0.01 CL^{96}_{50}
Vanadium	mg/L	-	-	0.1	-	-	-	-
H_2S	mg/L	-	-	-	-	-	-	0.0002
Sulphates	mg/L	400.0	400.0	-	-	0.5	0.5	-
Tensoactives[4]	mg/L	0.5	0.5	-	-	-	-	0.143 CL^{96}_{50}
Aluminium	mg/L	-	-	5.0	5.0	-	-	-
Beryllium	mg/L	-	-	0.1	-	-	-	0.1 CL^{96}_{50}
Boron	mg/L	-	-	1.0	5.0	-	-	-
Cobalt	mg/L	-	-	0.05	-	-	-	-
Fluor	mg/L	-	-	1.0	-	-	-	-
Iron	mg/L	-	-	5.0	-	-	-	0.1 CL^{96}_{50}
Lithium	mg/L	-	-	2.5	-	-	-	-
Manganese	mg/L	-	-	0.2	-	-	-	0.1 CL^{96}_{50}
Molybdenum	mg/L	-	-	0.01	-	-	-	-
Nyquil	mg/L	-	-	0.2	-			0.01 CL^{96}_{50}
Organochlorine pesticides	mg/L							0.001 CL^{96}_{50} (every type)
Organophosphates pesticides	mg/L							0.05 CL^{96}_{50} (every type)

The criteria for the G class (raw water used for aesthetical uses):

Table CC.1.7. Criteria for the Ecuadorian water quality G class

Parameter	Unit	Ecuador Law for the Prevention and Control of the Pollution Maximum limits G
DO	mg/L	60% of saturation O_2 and never less than 6 mg/L
Greases and oils	Visible film	Absence
Floating material and foam	Visible film	Absence
Absence of substances that produce objectionable colour, odour, taste and turbidity		
Conditions and substances (or combinations of both) that produce undesirable aquatic life		

[4] Substances actives to the Blue Metilen

Upper Cauca Basin

Water quality and contamination indicators of the Cauca River and some of its tributaries' have been established in the sector between Salvajina Dam and La Virginia. Some critical additional parameters affecting the quality of water have been identified in order to optimize monitoring activities.

These analyses have been developed with CVC quarterly measurements taken up to 2003, Made at a rate of 3 to 4 times per year at gauging stations on the Cauca River and its tributaries in the Valle del Cauca sector.

Environmental quality indexes are a tool designed to facilitate information analysis, connecting various parameters or elements involved in such analysis, avoiding the study of individual parameters which allow us to better understand and compare the quality of a specific environment.

Attachment A describes the different ICA quality indexes implemented by CVC to classify water resources for human consumption and the Dinius index for agricultural use. Likewise, four contamination indexes (ICOs) were determined as criteria for the assessment of water contamination. These indexes provide conclusions on different aspects, such as mineralization (ICOMI), organic matter (ICOMO), suspended solids (ICOSUS) and trophic levels (ICOTRO). The graph shows five quality levels. According to ICA's version adapted by Rojas, water from the Cauca River at the different gauging stations does not provide an optimum quality under the meteorological conditions studied. Excellet for the ICAof the CETESB.

Based on water quality sampling done by CVC between 1996 - 2003 from selected river tributary monitoring stations, water quality indexes were determined in order to know the general river conditions and the influence climate has on them. The above mentioned indexes were used to classify water quality in the Salvajina-La Virginia sector in 19 water quality gauging stations and in the main tributary rivers discharging their water into this sector. These stations were:

- Cali
- Yumbo
- Guachal
- Amaime
- Tuluá
- Guadalajara
- Bugalagrande
- La Vieja

The above rivers are the main water supply sources, as well as transporters of contaminated loads. Graphs showing these indexes are included in the "Description of the Upper Cauca River Basin" report.

Cuareim/Quarai Basin

Water bodies are not classified in the basin neither in Brazil nor in Uruguay. In the framework of TWINLATIN a preliminary classification is proposed in Working Package 7.

To evaluate the results of the water quality monitoring done in TWINLATIN, the norm in-force in Uruguay, Decree 253/79 and modifications, was used, as there is not a norm shared by Brazil and Uruguay for the preservation of the shared water resource.

DECREE 253/79 and modifications

CLASS 3

Waters for the preservation of fish in general and other members of the flora and fauna in the water, and also waters for the irrigation of crops that are not for natural consumption or if they are for natural consumption, the irrigation system does not wet the product.

PARAMETER	STANDARD
Odor	Not perceptible
Floating materials and unnatural foams	Absent
Unnatural color	Absent
Turbidity	Max 50 UNT
Ph	Between 6.5 and 8.5
DO	Min 5 mg/l
BOD5	Max 10mg/l
Oils and fats	Virtually absent
Detergents	Max 1 mg/l in LAS
Phenolic substances	Max 0.2 mg/l in C6H5OH
Free ammoniac	Max 0.02 mg/l
Nitrates	Max 10 mg/l in N
Total phosphorous	Max 0.025 mg/l in P
Fecal Coliforms	Not to exceed the limit of 2000 FC/100ml in none of
Cyanide	Max 0.005 mg/l
Arsenic	Max 0.005 mg/l
Cadmium	Max 0.001 mg/l
Copper	Max 0.2 mg/l
Total Chromium	Max 0.05 mg/l
Mercury	Max 0.0002 mg/l
Nickel	Max 0.02 mg/l
Lead	Max 0.03 mg/l
Zinc	Max 0.03 mg/l

Lake Cocibolca Basin

Nowadays there is a very little human use of the waters of the lake but there are advanced works to provide Juigalpa, head of the department Chontales, with the waters of lake for human consume. And in a few years it is a foreseen water source for Managua and other cities.

However, there is not any management authority of the lake for the maintenance or for the surveillance of water quality of the lake. We don´t know if permanent measurement stations exist in any point of the lake additional to the site where tilapia culture exist.

Fortunately only one city, Granada, has some industrial activity in the surroundings of the lake and the main source pollution is coming from agricultural and livestock activities.

The Nicaraguan Institute of Waterworks and Sewers (INAA) has a Normative for the Classification of Hydrics Resources According its Use. There are 6 types of waters:

Type 1: Waters for human consume and industrial use
Type 2: Waters for agricultural use and livestock
Type 3: Marine waters for mollusk breeding place
Type 4: Waters for swiming , aquatic sports, etc
Type 5: Waters for industrial use
Type 6: Waters for navigation and electric generation

Each type should full fill allowable limits in certain physical chemical parameters, as is shown in the tables below.

Table LC.1.5. Waters Type 1 Physical Chemical Characteristics

Parameter	Maximum Allowable Limit or Range	
	Category 1 A (Needs only disinfection)	Category 1 B (Needs Conventional Treatment)
Dissolved Oxygen	> 4 mg/L	> 4 mg/L
Chemical Oxygen Demand	2.0 mg COD_5/L	5.0 mg COD_5/L
pH	6.0 – 8.5	6.0 – 8.5
Real Color	< 15 U Pt-Co	< 150 U Pt-Co
Turbidity	< 5 NTU	< 250 NTU
Fluor	0.7 a 1.5 mg/L	< 1.7 mg/L
Total Ferrum (Iron)	0.3 mg/L	3.0 mg/L
Total Mercury	0.001 mg/L	0.01 mg/L
Total Lead	0.01 mg/L	0.05 mg/L
Total Dissolved Solids	1,000 mg/L	1,500 mg/L
Sulpahtes	250 mg/L	400 mg/L
Zinc	3 mg/L	5 mg/L
Total Coliforms	< 2,000 NMP/100 ml	10,000 NMP/100 ml
Total Cyanide	0.100 mg/L	0.100 mg/L
Total Copper		2.00 mg/L
Total Chromiun		0.050 mg/L
Phenols		0.002 mg/L
Total Manganese		0.050 mg/L
Sodium		200.00 mg/L
Organophosphorated compounds and Carbamates		0.100 mg/L
Organoclhorated compound		0.200 mg/L

Table LC.1.6. Drinking Water Quality Standards in Nicaragua

Organoleptic Parameters	Unit	Recommended value	Maximum allowable value
True Color	Pt-Co	1	15
Turbidity	NTU	1	5
Odor		0	
Taste		0	
Physical Chemical Parameters			
Temperature	ºC	18 a 30	
pH		6.5 – 8.5	
Residual Chlorine	mg/L	0.5 – 1.0	
Chloride	mg/L	25	250

Conductivity	µs/cm	400	
Hardness	mg/L $CaCO_3$	400	
Sulphate	mg/L	25	250
Aluminum	mg/L		0.2
Calcium	mg/L	100	
Copper	mg/L	1.0	2.0
Magnesium	mg/LMgC O_3	30	50
Sodium	mg/L	25	200
Potasium	mg/L		10
Total Dissolved Sol	mg/L		1,000
Zinc	mg/L		3.0

Table LC.1.7. Drinking Water Quality Standards in Nicaragua (cont'd)

Parameter	Recommended Value (mg/L)	Maximum Allowable Value (mg/L)
Inorganic substances		
Nitrate	25	45
Nitrite	0.1	1
Ammonia	0.05	0.5
Iron		0.3
Magnesium	0.1	0.5
Fluoride		0.7 – 1.5
Hydrogen sulfide		0.05
Arsenic		0.01
Cadmium		0.05
Cyanide		0.05
Chromium		0.05
Mercury		0.001
Nickel		0.05
Lead		0.01
Antimonium		0.05
Selenium		0.01
Organic compounds		MAV µg/L
Toluen		700
Xylen		500
Etilbencene		300
Estirene		20
Total Aromatic Hydr Pol		0.2
Total PCB		0.5
Pesticides (some)		
Aldrin/dieldrin		0.03
Clordano		0.2
DDT		2.0
Heptaclhor		0.03
Lindano		2.0
Pentaclhrophenol		9.0

Baker Basin

For the Baker River basin, a classification of the current water quality was carried out by Salas (2004) called “Diagnosis and Classification of Water Quality in the Baker River Basin according to Quality Objectives”. This study is within the plan of action of ACCA Project, and its objective was the application of the “Instructive for the Establishment of Secondary Norms of Environmental Quality for Surface Continental and Marine Waters” (CONAMA, 2003). For this analysis, water quality data from DGA, CONAMA, SAG, Cerro Bayo mining and from the EULA-Chile Center, (the mentioned monitoring is specified later in this document). As previously mentioned, the criterion for the classification of water quality was the CONAMA instructive (previously known as the Presidential Instructive) for the establishment of Secondary Norms, which classifies water quality into five classes, shown in Table B.1.2.

Table B.1.2. Classes of Water Quality for the Establishment of Secondary Standard

Class	**This class indicates:**
Exceptional (Exception Class or Class 0)	Indicates that the water us a better quality than Class 1, due to extraordinary purity and shortage, forming a unique part of the environmental wealth of the country. This quality is also adequate for the conservation of aquatic communities and other defined uses whose quality requirements are inferior to this class.
Class 1	**Very Good Quality**. Indicates water suitable for the protection and conservation of aquatic communities, for unrestricted irrigation and for the uses included in Classes 2 and 3.
Class 2	**Good Quality.** Indicates water suitable for agricultural, sport and recreation fishing, and for the uses included in Class 3.
Class 3	**Regular Quality**. Indicates water suitable for drinking by animals, and for restricted irrigation.
Class 4	**Not adequate for the conservation of aquatic communities,** or for the priority uses to those they made reference to, however its use in purification with appropriate treatment, or for industrial use, is possible.

Source: CONAMA 2003

The analysis was carried out for the principal tributaries of the basin, and for the main bed, where water quality data was available, which were divided into 43 stretches. All of the stretches present an Exception Quality (Class 0), in general, except for some stretches where Aluminum, Suspended Solids, Sulfate, Iron, and Copper concentrations are found. The obtained result is presented in the following figure, and Table 2, where it is specified which where the parameters that were classified as Class 0.

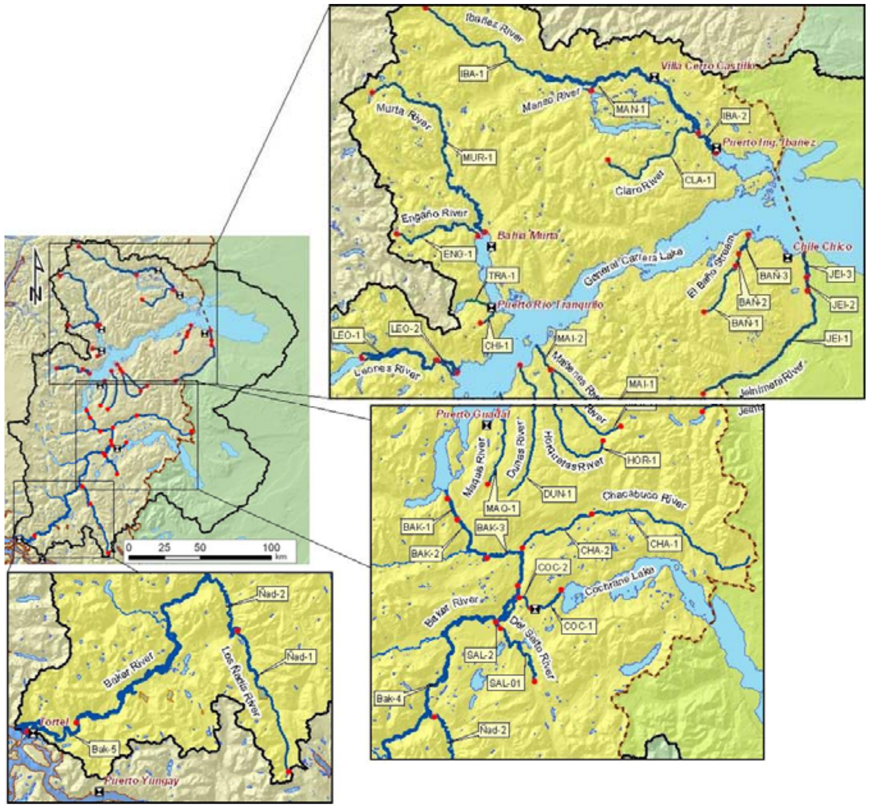


Figure B.1.2. Reach and node for water quality classification according to Salas (2004)

Table B.1.3. Parameters outside exception class (class 0), for reach of figure 3 (extract to Salas, 2004)

Reach	Class 1	Class 2	Class 3	Class 4
JEI-01				Suspended solid
JEI-02			Aluminum	
BAÑ-01		Iron	Aluminum	
BAÑ-02		Iron	Aluminum	
BAÑ-03	Iron		Aluminum	
MAI-01			Aluminum	
DUN-01			Aluminum	
IBA-01	BOD, Fecal Coliform		Aluminum	
CLA-01	Boron			
MUR-01			Aluminum	Sulphide, Suspended solid
ENG-01			Aluminum	
TRA-01			Aluminum	
CHI-01		Copper		
LEO-01	Sulphide, suspended solid		Aluminum, Iron	
CHA-01		Iron, Manganese	Aluminum	
CHA-02			Aluminum	
COC-01			Aluminum	
COC-02	Total and fecal Coliform			
SAL-01			Aluminum	
ÑAD-02	Molybdenum		Aluminum	
BAK-02			Aluminum	
BAK-03			Aluminum	
BAK-04			Aluminum	

2. EXISTING MONITORING DATA & PROGRAMS

2.1. HYDROMETEOROLOGICAL MONITORING

Norrström Basin

As previously mentioned, Norrström is one of the most studied areas in Sweden, and there are vast amounts of monitoring data.

Meteorology

The Swedish Meteorological and Hydrological Institute (SMHI) is the major owner of meteorological and hydrological data in Sweden. From SMHI historical data from 96 closed meteorological stations for precipitation and 32 for temperature in Norrström river basin is available. The stations are shown in Figure N2.1

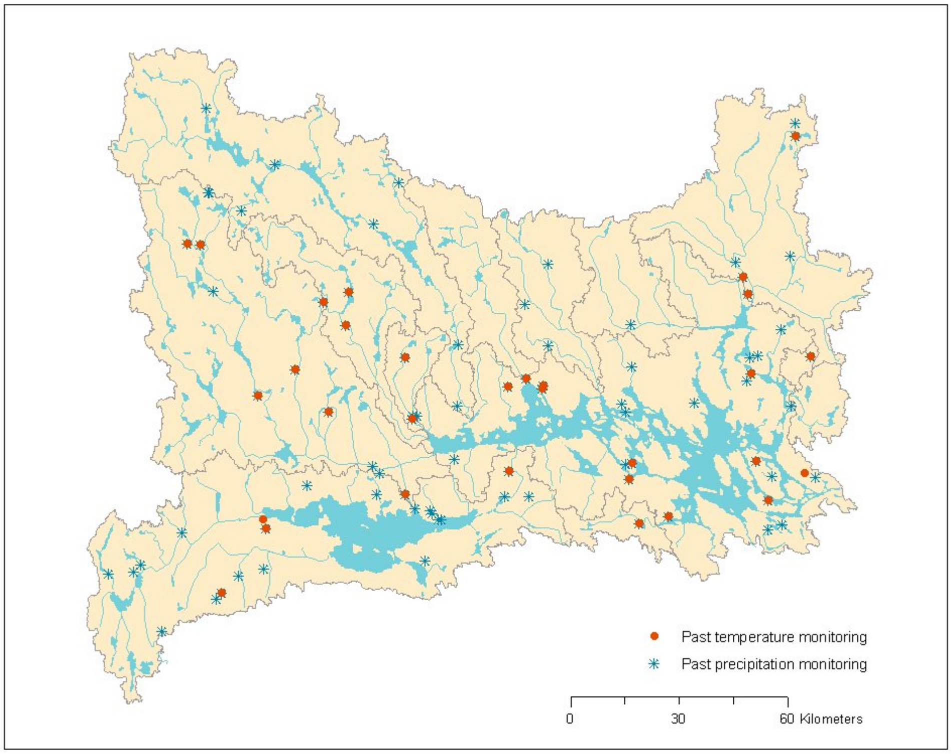


Figure N2.1 Meterorological stations previously handled by SMHI, no longer in use

The 55 meteorological stations for precipitation and 16 for temperature where SMHI has ongoing monitoring are shown in Figure N2.2.

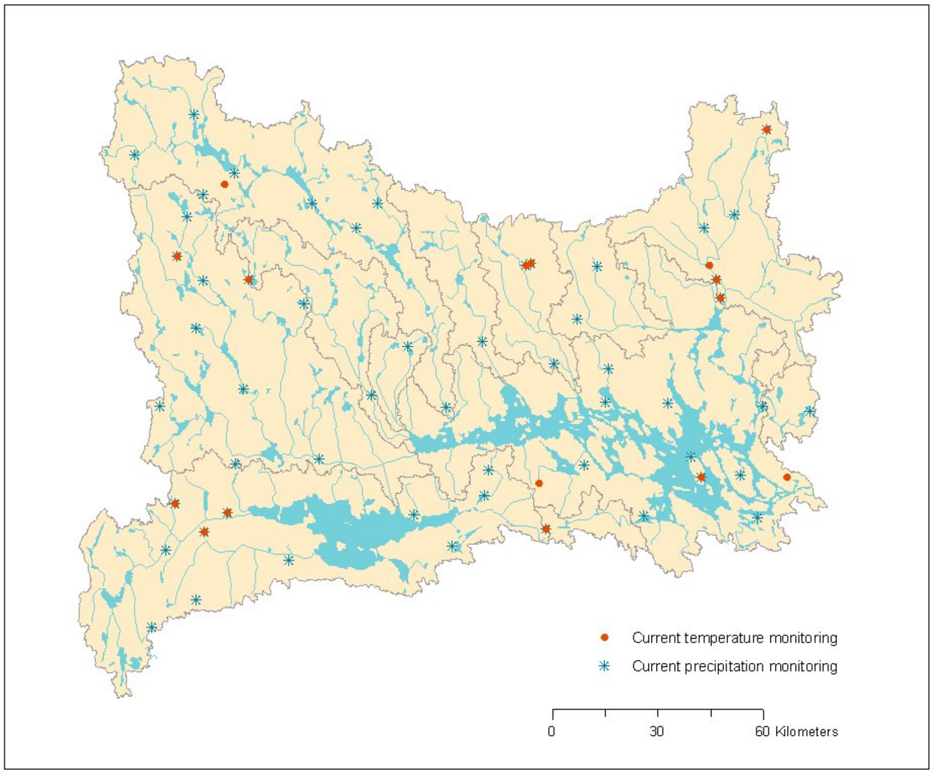


Figure N2.2 Meteorological stations currently handled by SMHI

Hydrology

Historical data concerning water discharge and water level from 10 hydrological stations within the basin that are no longer in use are available from SMHI. There are also a number of stations, where SMHI has modelled water discharge. This data is often used in calculation of transport of nutrients and metals in annual reports from recipient control monitoring programmes. Current and past hydrological monitoring stations are shown in Figure N2.3.

In addition to the above described data, municipalities, hydropower companies, etc might have other stations for meteorology as well as for hydrology, but this has not been investigated, since data from SMHI has been regarded as sufficient.

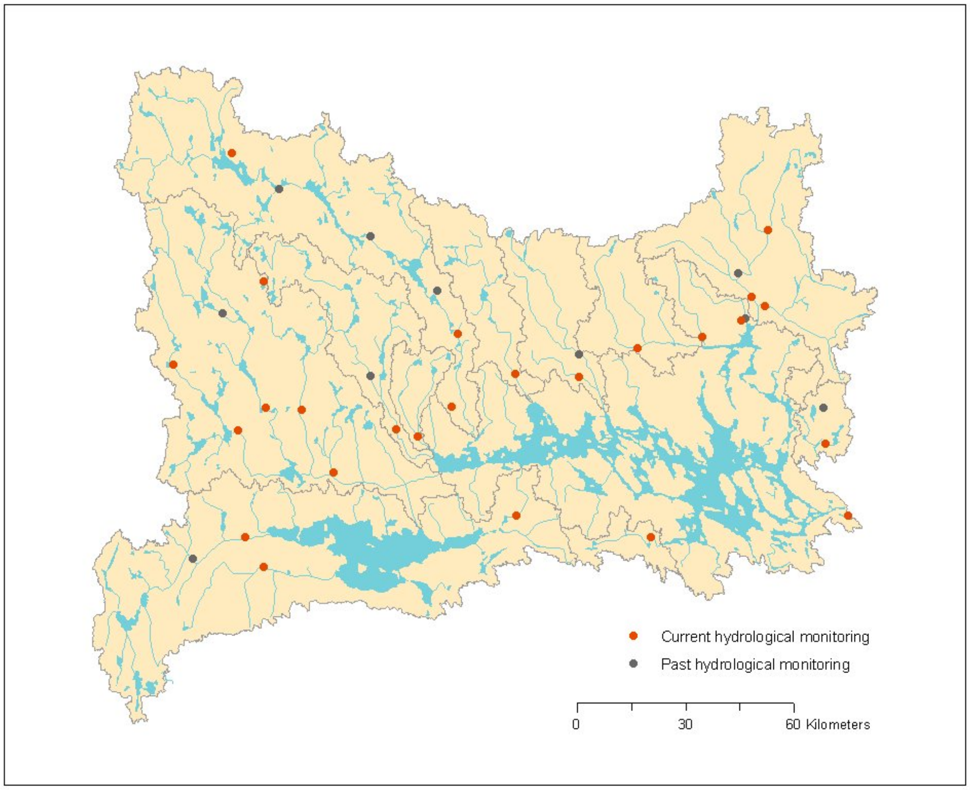


Figure N2.3. Current and past hydrological monitoring handled by SMHI

Even though many stations were closed down during the 1990's there are still a number of stations where monitoring is still running, and it is possible to get long time-series. Since SMHI has special rules that apply to projects that have a research background that serve to make necessary data for these projects less expensive it was possible to buy long time-series of data of up to 30 years within TWINBAS. This provided input data of high resolution needed for the AvSWAT (Table N2.1).

Table N2.1. Input data to AvSWAT model and its temporal resolution

Classification	Type of data	Resolution
Meterological	Precipitation	Daily
Meterological	Mini & Max temperature	Daily
Meterological	Air humidity	Daily
Meterological	Wind speed & Solar radiation	Daily
Water flow	m^3/s	Daily

Historical data from 25 current hydrological stations for water discharge and water level are available from SMHI (Figure N2.3). There are also a number of stations, where SMHI has modelled water discharge. This data is often used in calculation of transport of nutrients and metals in annual reports from recipient control monitoring programmes.

Thames Basin

The Thames is an extensively monitored river basin. Long records exist for most hydrometeorological variables. These have been collected primarily through routine monitoring programmes operated by the Agency and its predecessors. Data are also held by a variety of other organisations, many concerned with research e.g. CEH.

A recent example of a research project in the Thames basin is the thematic research programme called LOCAR funded by the UK Natural Environment Research Council (see references list). The objective of LOCAR is to study key water resource issues in the lowlands of the English chalklands. LOCAR examines surface and groundwater supplies, changes in water quality and their impacts on fisheries and wetlands in five intensely instrumented catchments, including the Pang and Lambourn tributaries of the Thames.

The Thames basin is also a representative river basin in the HarmoniRiB project funded by the EU (see references list). HarmoniRiB aims to harmonise techniques for assessment and use of uncertainty information in integrated water management using data from a network of European representative river basis. Clearly, the objective of the project gives it strong links to the TWINLATIN and TWINBAS projects and, like the twinning projects, the relevance of the project to the implementation of the EC Water Framework Directive is high.

The new Thames Regional Telemetry System enables the Agency to have faster access to more accurate and detailed environmental information to assist with flood forecasting and the management of droughts, pollution and environmental protection, and water resources generally, throughout the Thames basin.

The Thames basin is intensively monitored for rainfall and river flow, as well as other hydrometeorological variables. Past/current monitoring activities in the basin are described under the “*Meteorology*” and “*Hydrology*” sections. Parts of the basin, particularly tributaries of special interest like the Pang and the Lambourn, have amongst the most spatially intensive and highest quality hydrological networks in the UK, and current/future monitoring activities in these subcatchments are described in the “*Future monitoring efforts*” section.

Meteorology

The primary sources of meteorological data are the Agency and the UK Met Office (see references list), though CEH also has 42-year rainfall records and 10 years weather station records from its own meteorological site and past research projects. Figure T.2.1 shows standard average annual rainfall for the period 1961-90 across the Thames basin.

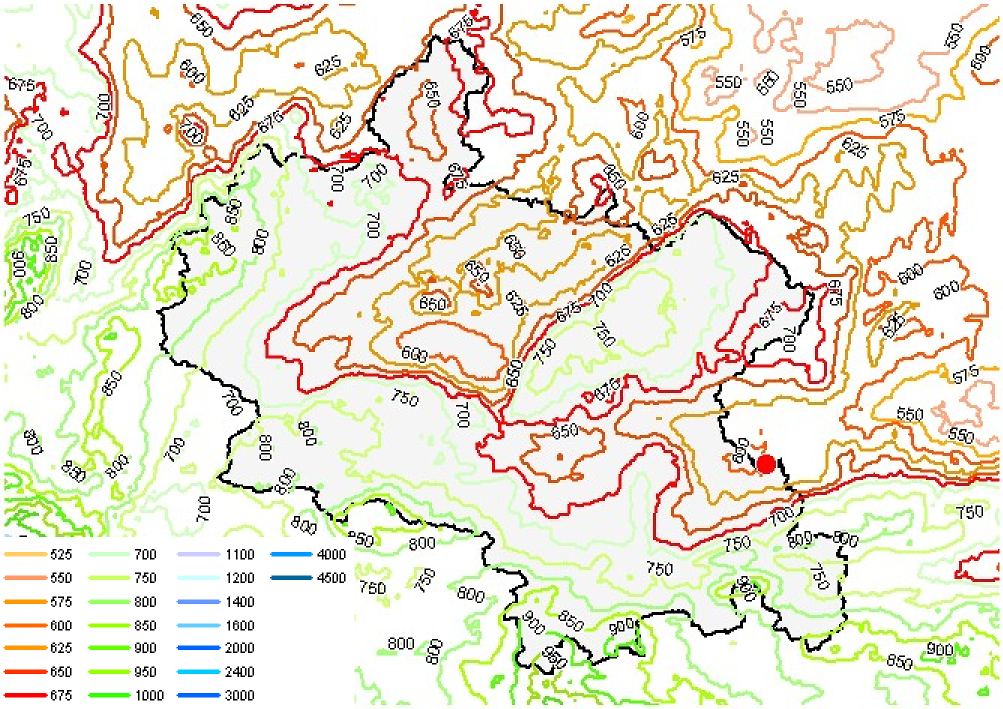


Figure T.2.1. Standard Average Annual Rainfall 1961-90 for the Thames basin
(© National Water Archive, CEH)

In the Pang and Lambourn catchments, there are records from 16 and 18 period raingauges, respectively, the majority of which are read daily. However, six of the gauges in the Pang, and 8 of those in the Lambourn, have been recently discontinued, though replaced with 4 new gauges in the Pang and 2 in the Lambourn. The network gives sufficient coverage to accurately describe rainfall surfaces across the West Berkshire Downs, from which it is possible to interpolate rainfall at specific sites and obtain good estimates of catchment average rainfall. However, additional gauges in the higher altitude parts of the catchments would improve the accuracy of estimates. The climate site at CEH is the nearest to the Pang and Lambourn catchments, though MORECS (Met Office Rainfall and Evaporation Calculation System) provides regional (40 km x 40 km) monthly evaporation data.

The Thames basin is covered by two weather radars: Chennies and South Downs, which provide 5-minute rainfall data on a 2 km x 2 km grid. The radar data are used primarily for flood forecasting purposes.

Hydrology

Surface Water

The Agency is the main organisation responsible for monitoring UK rivers and collects hydrometric, water quality and ecological information. There are about 150 gauging stations in the Thames basin (Figure T2.2), and at most of these water levels are recorded at sub-daily intervals and daily mean flows are derived. The earliest gauges date from 1883 at Kingston on the Thames and at Fields Weir on the Lee tributary. A non-continuous record from 1841 exists for Wendover Springs. The mean flow at Kingston is about 80 m^3s^{-1}.

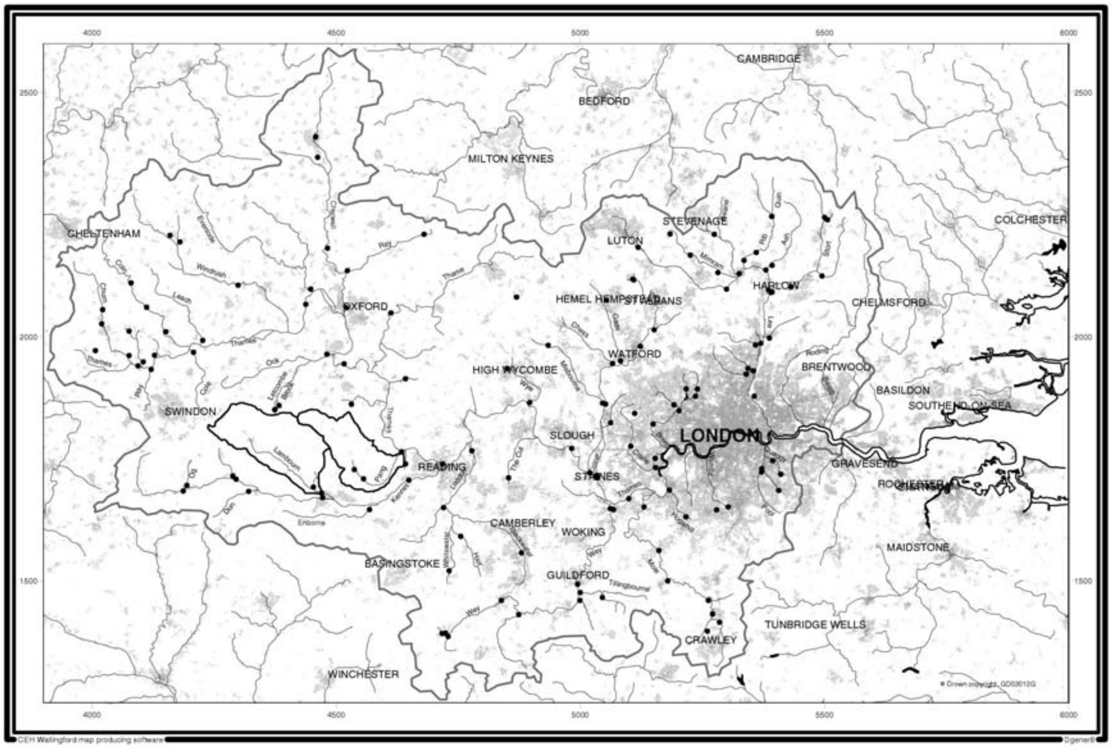


Figure T.2.2. Thames basin (UK) showing location of river gauging stations (•) and Pang and Lambourn catchments

The main growth in the network took place in the 1960s following the 1963 Water Resources Act which established the Water Resources Boards (precursor of the Environment Agency) and provided funds for gauging station construction. The main trunk of the Thames has eight ultrasonic gauges which have proved very successful, but the rest of the network is dominated by structures (weirs) to measure flow. The network is reasonably stable, though periodic reviews are undertaken to check for redundancy.

There are records for three gauging stations in the Pang catchment and four in the Lambourn catchment, details of which are given in Table T2.1. The gauges were installed for operational water resources purposes, mainly to monitor the effects of heavy groundwater abstractions in the two catchments as part of the West Berkshire Groundwater Scheme.

There is also a flood warning station on the Pang at Tidmarsh and a temporary weir at Hampton Norreys where the Pang is frequently dry. The east Shefford station on the Lambourn has been temporarily reopened for use by Birmingham University.

To service a very broadly-based need for river flow data the UK National River Flow Archive, based at CEH, provides stewardship for, and access to over 50,000 years of daily and monthly flow data deriving from over 1300 gauging stations across the UK. More information is provided in the annex.

Table T.2.1. Gauging stations in the Pang and Lambourn catchments

Pang

Number	Name	Area (km^2)	Type	Period of record	RF (mm)	RO (mm)	MF (m^3s^{-1})	Q_{10} (m^3s^{-1})	Q_{90} (m^3s^{-1})	BFI
39027	Pangbourne	170.9	C	1968+	707	116	0.63	1.1	0.19	0.86
39114	Frilsham	89.8	FV	1991+	760	66	0.19	0.5	-	0.95
39115	Bucklebury	109.0	FV	1991+	749	57	0.20	0.6	-	0.87

Lambourn

Number	Name	Area (km^2)	Type	Period of record	RF (mm)	RO (mm)	MF (m^3s^{-1})	Q_{10} (m^3s^{-1})	Q_{90} (m^3s^{-1})	BFI
39019	Shaw	234.1	C	1962+	745	231	1.71	2.8	0.75	0.97
39031	Welford	176.0	CC	'62-83	762	183	1.02	1.7	0.41	0.98
39032	E Shefford	154.0	CC	'66-83	758	157	0.77	1.6	0.10	0.98
39033	Bagnor*	49.2	C	1962+	730	106	0.17	0.3	0.05	0.96

* Bagnor station is on Winterbourne tributary of Lambourn

Key:

RF is mean annual rainfall, RO is mean annual runoff, MF is mean flow, Q10 is 10 percentile flow, Q90 is 90 percentile flow, BFI is baseflow index

Station type is crump weir C, compound crump weir CC, flat V triangular profile weir FV

Groundwater

There are hundreds of groundwater sources in use in the Thames basin, and the total volume abstracted is over 1500 Ml per day, making up 40% of public water supply. Overabstraction of groundwater is an important management issue in the upper reaches of the Thames and its tributaries.

Hydrogeological information are collected and held by both the Agency and the British Geological Survey (BGS; see reference list), including main well records covering water level and groundwater chemistry and abstraction licence data. Information about actual quantities abstracted is confidential.

The groundwater level monitoring network in the Pang and Lambourn catchments comprises 124 boreholes which are dipped at 6-monthly, monthly or weekly intervals or are monitored bay data loggers. There is also a groundwater quality monitoring network consisting of 28 boreholes for which the information is not readily available, though it is known that the frequency of measurement and length of record are highly variable.

Until recently, CEH has run 13 neutron probe access sites in the Pang catchment, most of which have been read on a regular basis over the past three years, providing much information about the spatial distribution of soil moisture in the Pang.

Other data

Terrain and river network data are held by CEH, but licences are required and a copy-right fee is payable to the Ordnance Survey (see reference list).

Routine Agency cross-sectional surveys are available for both the Pang and the Lambourn, though no intensive or repeated bed sediment surveys; bed sediments are mainly gravels, sometimes with a top layer or matrix of fines and some cobbles.

Apart from a network of sampling locations and some long-term data, which is generally descriptive including comparatively few numerical datasets, there is no specific ecological infrastructure.

Information about the basin population is collected at 10-yearly intervals through the National Census, results of which are published by the Office of National Statistics (see reference list).

Water industry-specific information e.g. water use figures, is held by the water companies themselves. In the Thames basin, the main operator is Thames Water (see reference list).

Ongoing and future monitoring efforts

As mentioned earlier, two subcatchments within the Thames basin that are extensively instrumented, and are being further instrumented, are the Pang and Lambourn tributaries. Many studies have been previously made investigating the groundwater resources and the ecological implications of groundwater abstraction on the Pang and Lambourn, and the two catchments already have one of the most spatially intensive and high quality hydrometeorological networks on the chalk of the UK.

The Pang (170 km^2) and Lambourn (235 km^2) are adjacent permeable catchments, but very different in character. The upper reaches of the Pang are influenced by groundwater abstraction, and the water quality of the lower is affected by a variety of human activities including pig farming, salmonid fisheries and Christmas-tree growing. There have been problems of increased sediment in the river resulting from surface runoff from arable land and bacterial contamination. In contrast, the Lambourn remains a more natural stream, with much of the channel retaining geomorphological diversity. It has less groundwater abstraction than the Pang; indeed, river flows increase downstream as groundwater enters along the lines of dry valleys. The Lambourn is one of 462 Sites of Special Scientific Interest in the Thames basin.

New instrumented sites have been set up within the two catchments to monitor rainfall, evaporation, infiltration, groundwater levels and river flows, so that all the components of the hydrological cycle can be measured automatically (Figure T.2.3). Samples of water are taken at regular intervals and during storms to monitor the movement of chemicals and sediments. The additional instrumentation installed by CEH under LOCAR includes:

- 2 automatic weather stations, one in each catchment;
- 7 recharge sites, each with access tubes for soil moisture, evaporation measuring facilities, deep boreholes and shallow wells;
- 5 stream water quality monitoring sites and associated turbidity measurements;
- improvements to one gauging station, and 2 new gauging stations;
- one site for detailed studies of surface-groundwater interaction with boreholes and shallow wells for groundwater and soul water;
- a detailed “wetland facility” at the head of the Lambourn with 11 boreholes of various depths.

Information will also have to be collected about the geology, ecology and use of the catchment areas and rivers. Annual surveys of the habitat conditions of the rivers and of the land use examine how changes within the catchment areas affect conditions within the rivers.

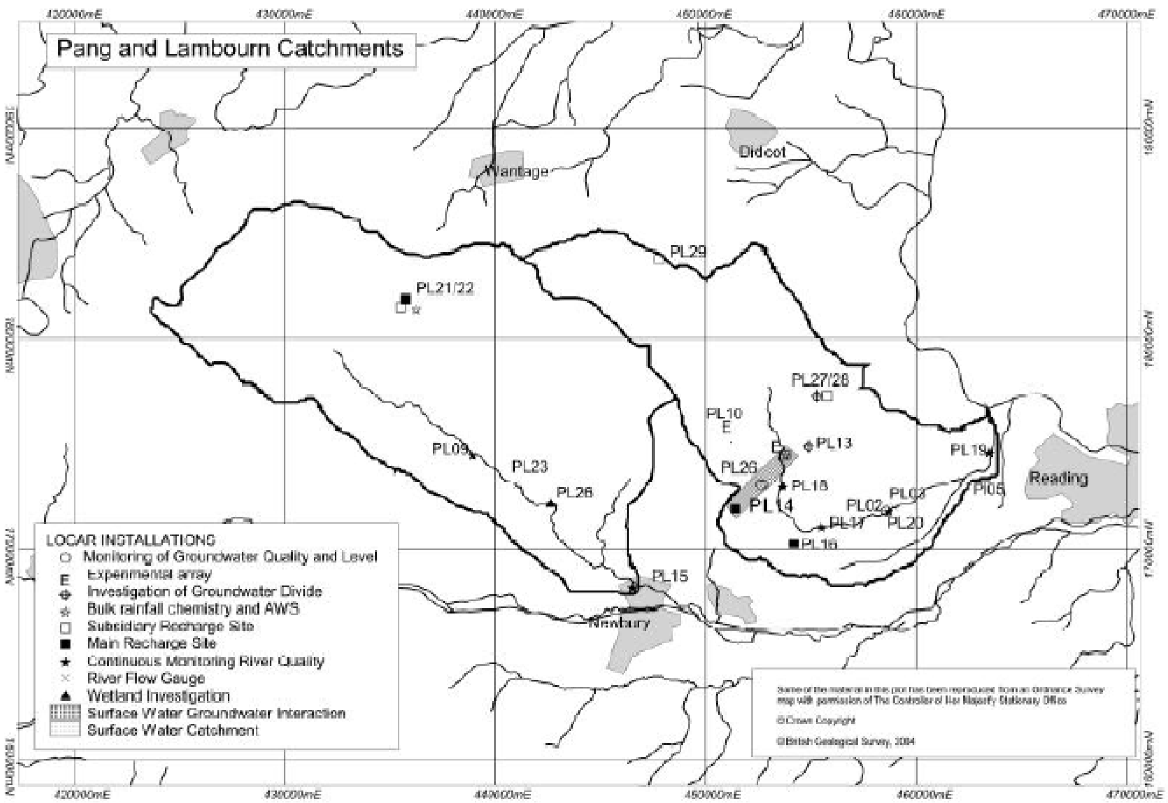


Figure T.2.3. Location of LOCAR infrastructure installed in the Pang and Lambourn catchments (BGS, 2003)

Catamayo-Chira Basin

Meteorology & Hydrology

The monitoring activities developed in the Catamayo Chira River Basin have been, mainly, those related to the hydrometeorological station network. This network is considered to be insufficient and unsuitably distributed (there is a lack of information of the high river basin). Besides, more than 50% of these stations need some kind of improvement, because of the obsolete instrumental, the need of instruments reparation, reallocation, etc. In addition, the information accessibility is another limitation. In some cases, this is due to an excessive bureaucratic proceeding or to the high costs of the information.

Figure CC.2.1 shows the type and the distribution of the hydrometeorological stations described in the mentioned table.

Figure CC.2.1. Hydrometeorological stations network for the Catamayo Chira River Basin

Upper Cauca Basin

The Regional Autonomous Corporations participating in the present study and IDEAM are the entities in charge of monitoring meteorological and hydrological variables. The objective of monitoring variables is to provide ample and sufficient information to plan, promote and execute environmental management programs and projects.
Information collected in monitoring programs is a key ingredient. Some examples in which information plays a very important role are: The construction of hydraulic infrastructure works, protection against floods, granting water concessions to users, setting decontamination goals, estimating industry compensation rates, implementation of hydrodynamic, hydrologic, morphologic and water quality mathematical models

There has been a wide monitoring network since the incorporation of CVC in 1954. This network has gone through several modifications, such as the suspension of some stations and the construction of new ones. The network complements itself with other institutions' and private corporations' stations. Information from stations under the environmental authority is centralized in the Regional Autonomous Corporations and is available for the different users. Figure C2.1 shows the geographic location of the network weather condition monitoring stations. Figure C2.2 shows the different water flow stations.

Table C2.1. Active Measurement Stations (CVC-CRC)

Stations	Amount
Pluviometric	94
Pluviographic	23
Evaporimetric	9
Climatological	15
Limnimetric	17
Limnigraphic	26

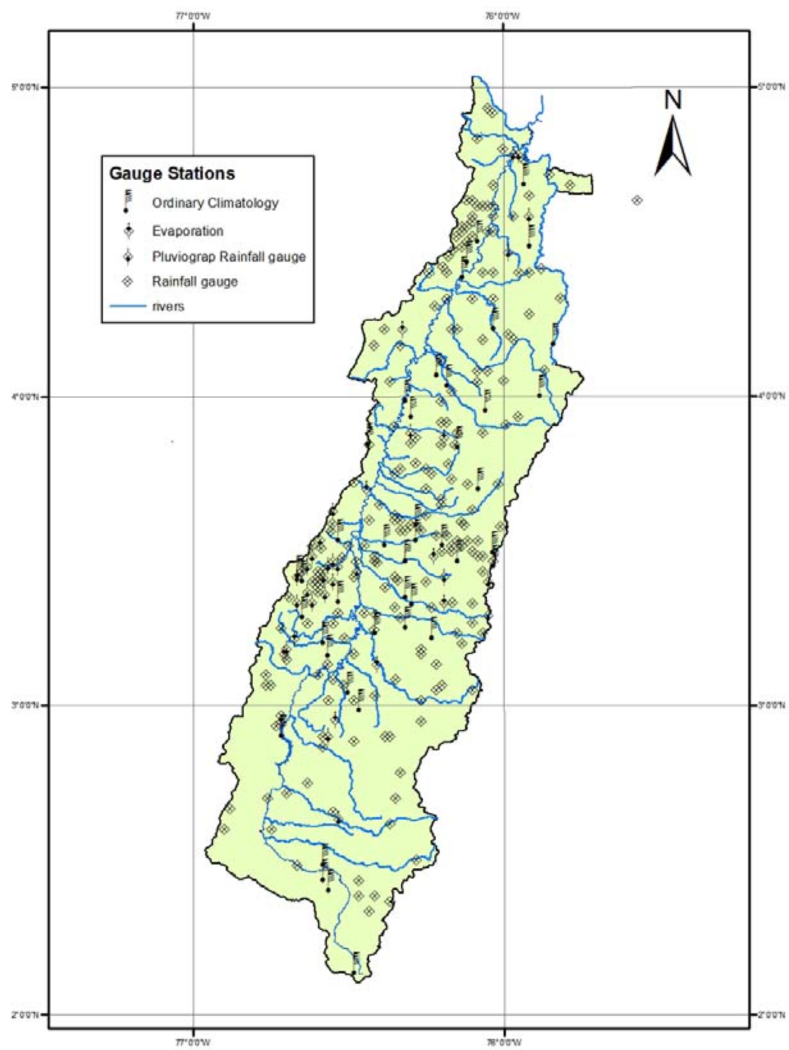


Figure C2.1- Location of climatologic and pluviographic gauge stations

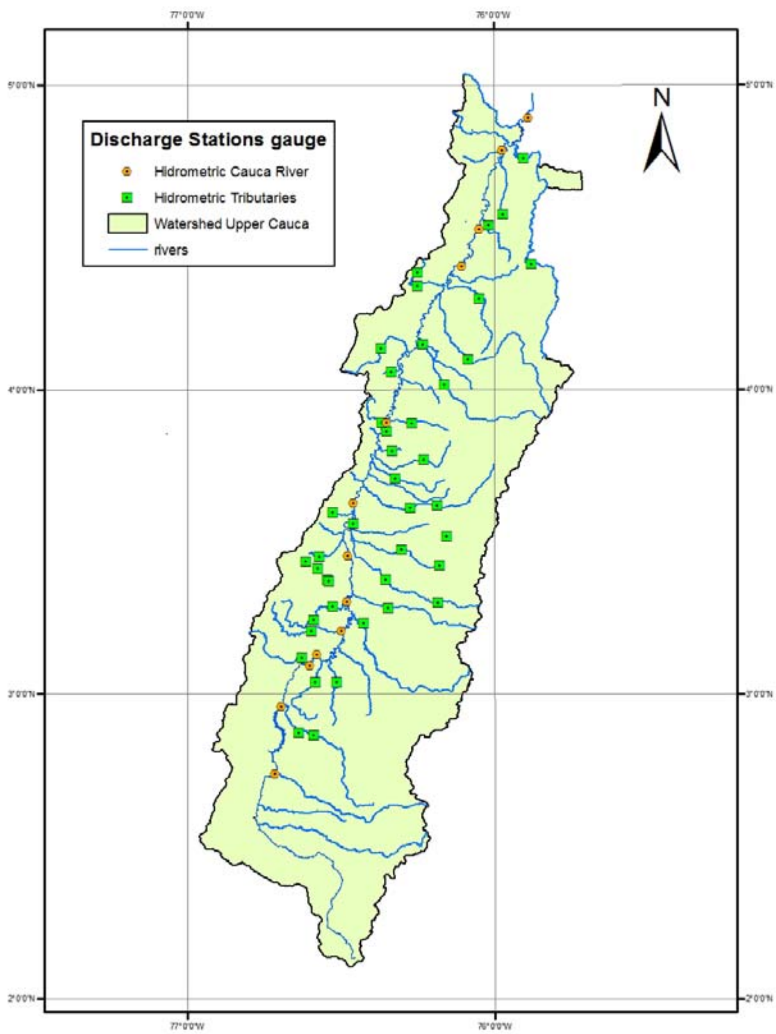


Figure C2.2. Location of Hydrometric Stations

Meteorology

Climatic studies start by measuring meteorological parameters using the appropriate instruments in order to establish climatologic behavior in the different basin zones. This type of study is fundamental in determining the vulnerability, impact and profitability of the different investment and environmental protection projects in the area. Table C2.2 shows the variables, units and intervals that the current environmental authority frequently monitors in the Upper Cauca River Basin.

Tabla C2.2. Climatic Variables Monitored in the Upper Cauca River Basin

Variable	Units	Interval
Rainfall	Mm	Hourly and Daily
Evaporation	Mm	Daily

Temperature	°C	Daily
Relative Humidity	Mm	Daily
Sunlight	Light hours	Daily
Wind speed	m/hour	Daily

At the pluviometric stations, one reading is made per day, at 7 am. However, values with hourly aggregation may be obtained at the stations, if required. Temperature is measured at 7 am and at 3 pm. The sunlight paper is changed daily, but the data is processed in order to obtain the monthly figure. To measure wind speed, a monthly average is the result of daily measurements. Evaporation is measured daily (7:00 a.m), relative humidity is taken 3 times a day (6:00 a.m, 12 m, 6:00 p.m) and is averaged to obtain the monthly data.

Once the information is processed and stored in the database, it is possible to obtain minimum, average and maximum data. Hourly, monthly and annual reports are processed, providing information on:

- Total rainfall
- Maximum rainfall
- Minimum rainfall
- Total Evaporation
- Maximum Evaporation
- Maximum Temperature
- Mean Temperature
- Minimum Temperature
- Relative Humidity
- Sunlight
- Average Sunlight
- Days of rain

Equipment

Following is a brief description of the equipment used at the gauge stations:

- ***Pluviometer***: Used to measure rainfall using a graduated cylinder or rule (in millimeters).
- ***Pluviograph***: Continuously records rainfall on a paper graph scale. Information such as time of beginning, end and intensity of rainfall can be obtained from its analysis.
- ***Evaporation Tank***: A cylindrical tank, 121 cm in diameter and 25.5 cm. in height, with a still tank and a micrometric screw. The amount of evaporated water is calculated from the difference in readings of the micrometric screw during a determined period of time.
- ***Maximum Temperature Thermometer***: A thermometer with a choke valve in the capillary tube close to the bulb or deposit. When temperature rises, the mercury deposit dilates strongly to overcome the choking, going up through the capillary to indicate the maximum day temperature.
- ***Minimum Temperature Thermometer***: The sensitive element used is generally alcohol, having inside an index of enamel submerged in the liquid. When the temperature rises, alcohol can freely pass between the tube walls and the index. In this case, the index has no movement, but when the temperature decreases, the alcohol drags the back movement of the index due to the high resistance encountered to exit the tube. The index position shows the lowest temperature at a given period of time.

- ***Psychrometer***: Two mercury thermometers; one dry and one wet. They are used to measure air temperature. The difference between the two thermometers allows the calculation of the relative humidity content.
- ***Thermohydrograph***: Continuously records on a graph the variation of air temperature in degrees centigrade and the relative humidity percentage. Its sensitive elements are a bimetallic ring and a bundle of human hair.
- ***Heliograph***: Records sunlight hours throughout the day with a glass sphere acting as a converging lens receiving solar rays that burn a graph in a semi-ring located at a focal distance from the sphere.
- ***Anemograph***: Constantly measures wind direction and speed, making the recording on a graph moved by a clock mechanism.
- ***Automatic Station***: Formed by a set of sensors that automatically record and transmit meteorological and/or hydrological information by satellite. Its function is the collection and monitoring of the different variables in real time.
- ***Limnimeter***: A 100 cm rule forged in aluminum used to measure water level variations.
- ***Limnigraph***: Constantly records water level variations on a paper graph, allowing the analysis of frequency of levels, overflow and duration curves.

Following are some pictures of the gauge stations and the installed gauging equipment.

	
Picture UC 2.1 Climatologic Station	Picture UC 2.2 Evaporimetric Station
	
Picture UC 2.3 Pluviograph	Picture UC 2.4 Pluviometric Station
	
Picture UC 2.5 Heliograph	Picture UC 2.6 Anemograph

Hydrology

Gauge stations allow determining hydrological parameters, such as:

- Level, as a direct variable
- Flow, as an indirect variable

As it is the case with pluviometric stations, hydrometric gauging stations perform three daily readings at 6:00 am, 1:00 pm and 6:00 pm. However, limnigraphic and telemetric stations may also obtain values with hourly aggregation, if required.

Information is processed to obtain hourly, monthly, annual flow and level records, determining minimum, mean and maximum values.

	
Picture UC 2.7 Limnigraphic stations	Picture UC 2.8 Limnigraph

The monitoring network stations have not functioned continuously. There have been periods of interruption for some of them due to equipment failure, lack of observers, station destruction, among others.

Monitoring Network Operation

The monitoring network includes conventional and automatic or telemetric stations. The last ones are equipped with a solar panel, a data transmission antenna, sensors (pluviometer and limnigraph), decoder (measures river levels), data-logger (for data storage and transmission) and a 12V battery. The decoder takes a level reading every 15 minutes, averaging data every hour and transmits the data to CVC every 4 hours, reporting the readings for the previous 4 hours.

The automatic stations include; 19 pluviometric stations, 7 of which use a pluviometer to measure level and rainfall, 2 air stations and 3 quality stations (located at Cartón de Colombia, Yumbo and the water treatment plant of Mallarino. However, these stations are still under observation-).

Once data has been obtained with the previously explained frequency, a field team from CVC (2 officers), collect it from an observer or directly at the gauge station, in case of graphing instruments. In the Cali area, data is collected once per week. In other nearby stations, data is collected monthly. The collection of data in remote areas is done every 2 or 3 months. During these field team visits, observers are paid. Conventional stations have an observer, who usually lives close to the station, who is in charge of taking the readings.

Picture UC 2.9 Water quality measurement equipment.

Once data is received at CVC, the name of the officer providing the information is recorded in a form that includes the delivery data and status, as well as the status of data received. It is important to mention that in the group managing gauging network information (climate and flow) each officer has responsibility over certain stations. There are three officers for the climatology gauging stations and three officers for the level and flow gauging stations.

Data quality analysis is done, ensuring data is within the usual average and that it corresponds to behavior of other variables measured in nearby stations. In case of doubt, data collection is investigated in detail.

Analyzed data enters the system adapted to statistically store and process the data. Data is downloaded daily, and monthly, annual, and multi-annual reports are issued. When dealing with river level data, information on maximum and minimum instantaneous levels and maximum and minimum averages is also obtained.

Data is saved in a Windows compatible ORACLE data base to manage client-server relations. In this case, the CVC client is the management team. Each member of the monitoring team has their own password, and only one person is authorized to modify data.

Presently there is no integrated system for storage, processing and analysis of information on water amounts and climate including water and underground quality data. Therefore, CVC is working on the implementation of an Integrated Water Resource Management System (SIGRH II), with the objective of unifying information related to water quality, monitoring, standardization of water flow and deep wells. Requirements are currently being analyzed to start building the system.

Daily Report

CVC issues a daily report on climate conditions and Cauca River flow and levels, as well as those of its main tributaries. This report feeds the HBV model for rainfall-runoff flow generation used to "manage" the Salvajina Dam. This report is available every day between 8:30 a.m and 9:00 a.m. It is published in the CVC web page and is delivered to communication media and CVC offices.

Data entering the control center comes from automatic stations, as well as some conventional stations with telephone data transmission capability. This data is stored in the appropriate data bases at the control center.

Maintenance and Gauging

Whenever possible, one measurement per station is performed monthly. This is sometimes difficult due to access and security problems. Gauging is performed by request from CVC users. Each officer in charge of a station enters gauging data collected by the field team. Through data base processing, gauging station transversal section graphs are obtained. However, other important analysis calculations relating hydraulic and geometric variables are obtained from the gauging data.

Preventive and scheduled gauging station maintenance is performed on a quarterly basis. Maintenance includes changing paper rolls in graph instruments, grass mowing, well cleaning if obstructed by river sediments, general housekeeping and instrument revision and calibration. In the event of doubtful data, corrective maintenance is scheduled.

Each station has its own file system.

Stored and processed data is sold to general public according to prices established by CVC. This service is free of charge for government institutions.

Cuareim/Quarai Basin

Meteorology

Monitoring data is available from a number of sources. Below is a summary of the monitoring stations present in the basin. Complete information on variables measured and Time Series can be found in TWINLATIN Work Package 1.

The main existing monitoring data consist of pluviometric, hydrological, and meteorological observations. On the Brazilian side of the basin, the first ones are collected by CPRM (Brazilian Geological Service - operator) on behalf of ANA (National Water Agency - responsible). On the Uruguayan side, this information is collected by the DNM (National Meteorological Service). Hydrological information is collected on the Brazilian side also by CPRM on behalf of ANA, and in the Uruguayan side it is gathered by DNH (National Hydrological Service).

To facilitate Salto Grande Power-Dam operation (located downstream of the Cuareim/Quaraí river), in the basin there are also several pluviometric and water level stations that collect information on real time, this stations are located only on the Uruguayan part of the basin, and they are operated by the CTM-SG (Salto Grande Technical Commission).

Figures CQ.2.1 and CQ.2.2. show the precipitation and hydrometric stations in the basin respectively.

There are five meteorological stations with climate information: temperature, pan evaporation, atmospheric pressure, wind velocity and direction, heliofany, and soil moisture among others. Even though not all the stations are located within the basin, due to the proximity its parameters can be used for the studies to be carried out in the basin or to fill gaps that may exist in long records of other stations. Table 1.1 presents basic information from each station.

Table CQ.2.1. Meteorological stations

Code	Station	Period w/info		Longitude	Latitude
		Start	End		
83927	Uruguayana (br)	No info	Working	-57.08	-29.75
83931	Alegrete (br)	No info	Working	-55.52	-29.68
330	Artigas (uy)	3/1940	Working	-56.50	-30.35
350	Rivera (uy)	No info	Working	-55.52	-30.92
315	Bella Unión (uy)	7/1980	Working	-57.58	-30.20

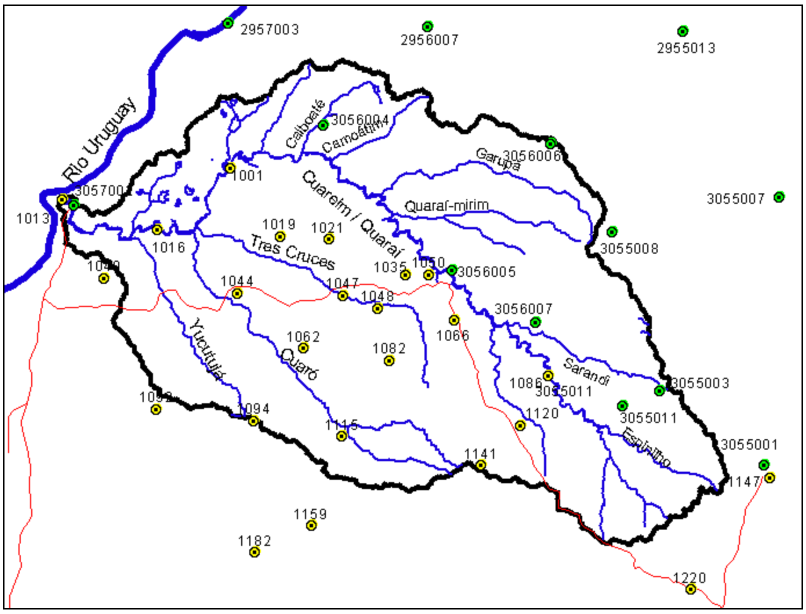


Figure CQ.2.1 Spatial distribution of the precipitation stations in the basin

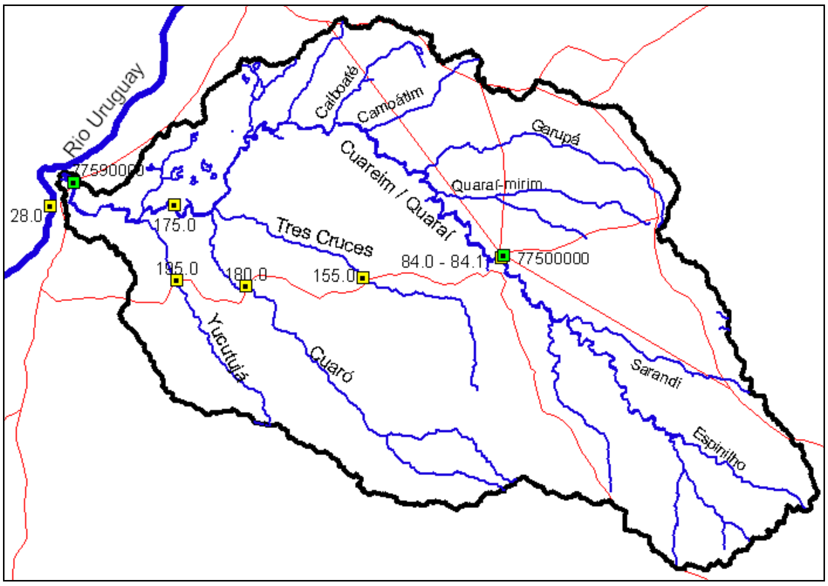


Figure CQ.2.2 Stream gauging stations in the basin

Hydrology

Streamflow monitoring seems to be the major monitoring problem today in the Quarai/Cuareim river basin. There is only one point on the main river where streamflow is systematically measured and where there is a well established rating curve and relatively long record of river stage. The only point is located in Artigas, close to the bridge between this city and Quaraí. At this point, both Brazilian and Uruguayan authorities do stage measurements.
Records of stage are also available in a point at the Arroyo Tres Cruces, a tributary from the left side, in Passo do Leão and in Barra do Quaraí, as can be seen in Figure CQ.2.3.

It can be seen from Figure CQ.2.2. that the coverage of flow gauges in the basin is quite low. The only streamflow gauging point is located far upstream of the river mouth, so it is fairly hard to estimate the mean discharge of the whole basin. Basin area at the streamgauge in Artigas/Quaraí is less than 50% of the total basin area.

At Barra do Quaraí, immediately upstream of the inflow in the Uruguay river, there is a stage measuring station. At this point there is a strong backwater effect from the water level in the Uruguay river, so it´s not possible to establish a good rating curve.

Periodic discharge measuring is made for the Artigas gauging station and for the Quaraí station, which are practically at the same point, on the main stream of the river. There is only one tributary with discharge measurements, namely the Javier de Viana station, on the Tres Cruces Creek. Table CQ.2.2. shows the extension of the streamflow records at these stations.

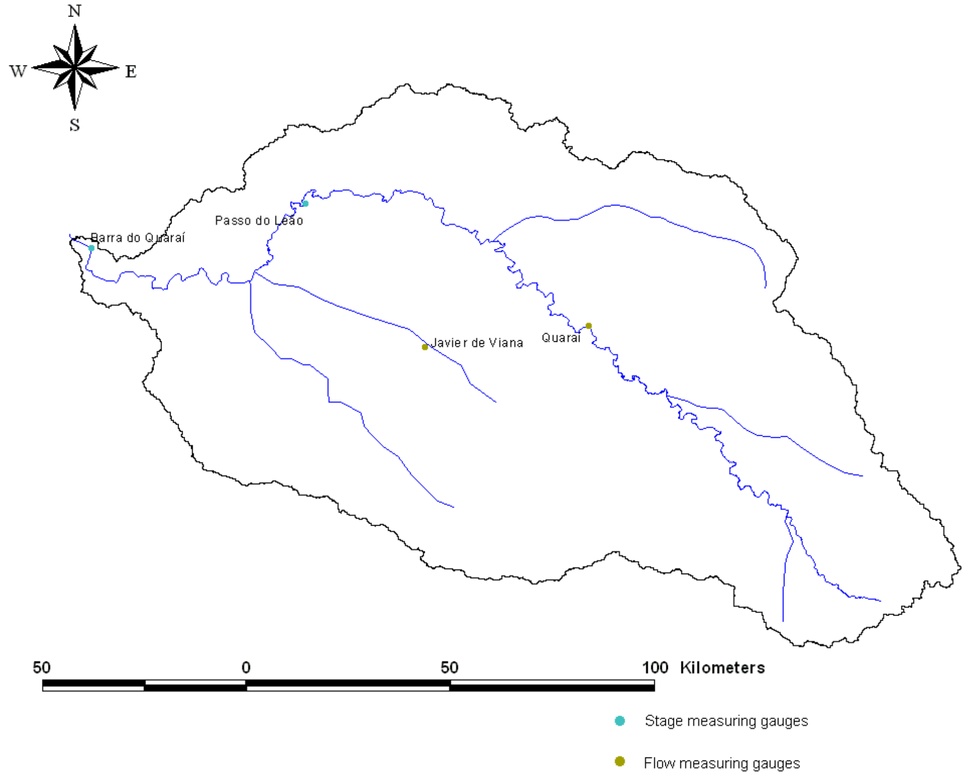


Figure CQ.2.3. River stations with continuous stage and/or discharge measuring

Table CQ.2.2. Discharge measuring stations

Stations	River	Period
Artigas	Cuareim/Quaraí	1980-2002
Quaraí	Cuareim/Quaraí	1985-2002
Javier de Viana	Tres Cruces	1982-2002

Although being practically on the same point of the river, time series from the Artigas and Quaraí river stations show some differences. The most important differences are found during floods. During the highest flow of record since 1980, the maximum flow registered in Quaraí was 2213 m^3/s, on 2/6/2001, while the gauge at Artigas registered 4813 m^3/s at the same day. Evidences suggest that the rating curve at Artigas is more reliable, since discharge measurements here were made also during floods. Figure 2.1.5.5 shows the measurements made at Quaraí aind the adjusted rating curve.

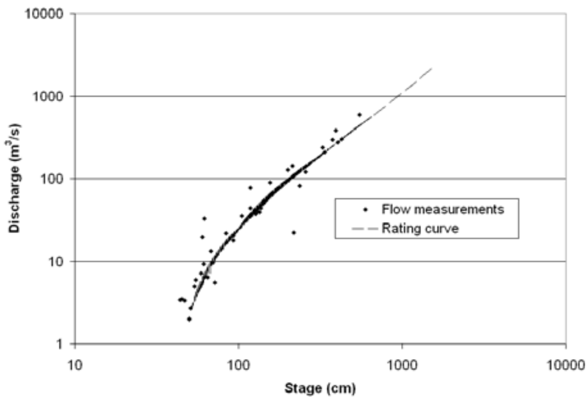


Figure CQ.2.4. Flow measurements at Quaraí and adjusted rating curve

It can be seen in Figure CQ.2.4. that there is a high level of extrapolation at the rating curve of Quaraí. While the highest measured discharge was at a stage of 548 cm, the highest registered stage was 1534 cm, what means a degree of extrapolation of almost 200%. At Artigas, on the other hand, discharge was measured even during the flood of 2/6/2001 on the binational bridge. Figure CQ.2.5. shows the hydrographs of the flood of june 2001 at the stations of Artigas and Quaraí.

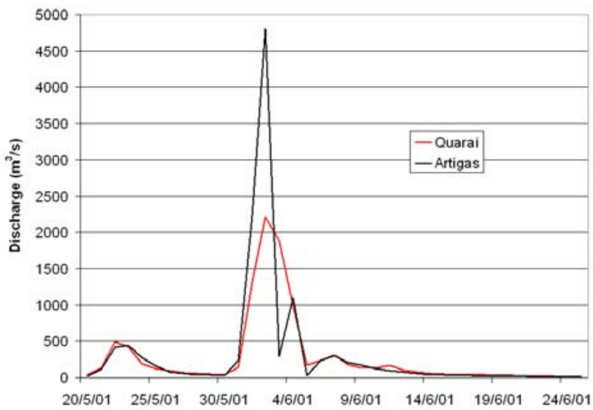


Figure CQ.2.5. Registers of the flood of june 2001at Quaraí and ad Artigas, showing the differences of both stations

Also at low flows, stations show some differences, as can be seen in Figure CQ.2.6., which shows the flow duration curves for both gauging stations: Artigas and Quaraí.

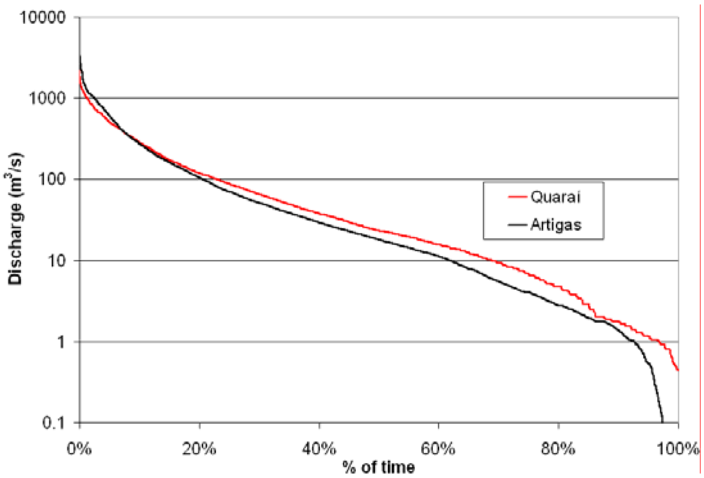


Figure CQ.2.6. Flow duration curve of Cuareim/Quaraí river at Artigas and at Quaraí

Figure CQ.2.6. shows that there is a significative difference between the curves, particularly at their lower segments. That uncertainty is particularly important for water management. The Q95 discharge, for example, which gives the streamflow that is equaled or exceeded in 95% of the time, is estimated at 1,1 m^3/s using data from Quarai, and at 0,5 m^3/s using data from Artigas.
Integration of hydrological measuring services could incorporate discharge measurements of both stations into one single rating curve, adjusting the respective time series and providing data maintainers of both coutries with this information.
Another characteristic of the basin which can be observed in the duration curves is the large variation in streamflow. As can be seen baseflows are very low, while high flows are really high considering the relatively small area of the basin. The flow duration curve for the Javier Viana station on the Arroyo Tres Cruces shows low flows very close to zero, as can be seen in Figure CQ.2.7.

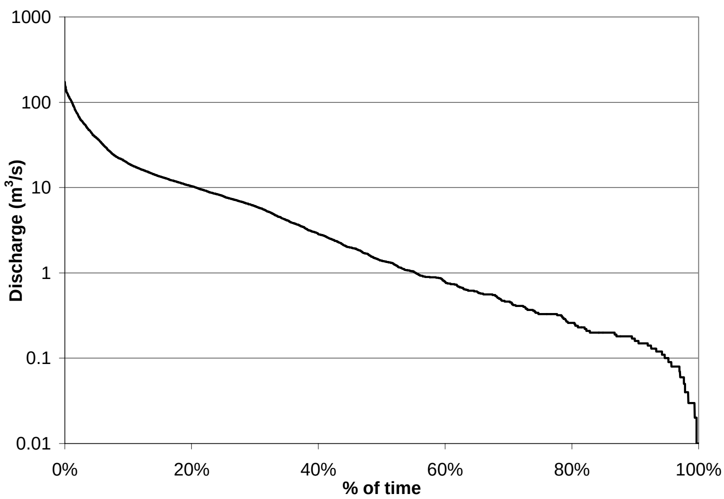


Figure CQ.2.7. Flow duration curve at Javier de Viana on the Tres Cruces Creek

Finally, Table CQ.2.3. shows the extension of the time series at both stage measuring stations.

Table CQ.2.3. Monitoring period of stations measuring water level

Station	Period
Passo do Leão	1941-1986
Barra do Quaraí	1971-2006

At Barra do Quaraí, discharge measurements are not used to be made because there is a strong backwater effect and even inversion of flow due to the flow in the Uruguay River. However, data from this station may be useful as a boundary condition if hydrodinamic modelling should be made.

At Passo do Leão, discharge measurements were apparently never made, making it difficult to extract time series of discharges at this place.

Aditionally, earlier work done by IPH and DNH (OMM, 2005) obtained topographic data from river cross-sections along the main stream of the Cuareim-Quaraí. This data can be used for modelling purposes, including hydrodinamic modelling. Location of these cross-section is shown on figure 2.1.5.9.

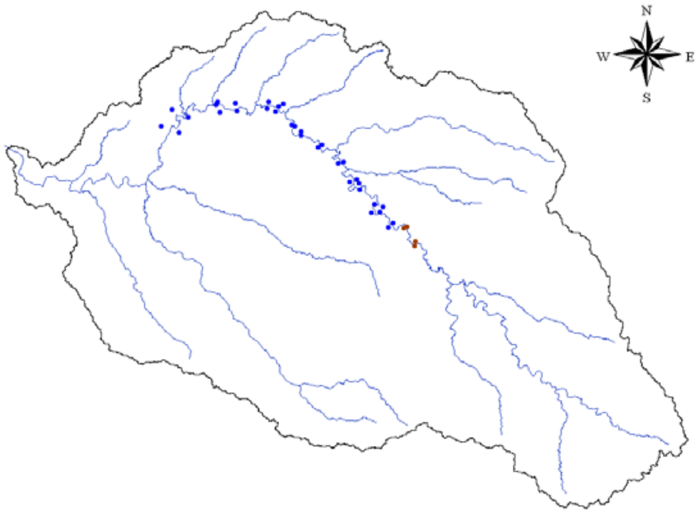


Figure CQ.2.8. Location of cross-sections measured by IMFIA (2004)

Lake Cocibolca Basin

Meteorology

The Nicaraguan Institute of Territorial Studies (INETER) is entity in charge of monitoring climate, weather, rivers, and others related issues of Nicaragua through the Direction of Meteorology. Inside Basin 069 there are 166 meteorological stations: 9 main stations, 8 hydro meteorological, 134 pluviometer, 5 pluviograph, 9 telemetric and 1 of upper air. In the very Cocibolca basin there are 65 meteorological stations y 11 hydrometrics.

However the Project Cocibolca could not have, directly, meteorological and hydrological data of the Costa Rica area shared in the basin. So data were picked up from NOAA data base.

INETER data

Collected data are daily precipitation from 84 stations, 57 of them inside the basin and 27 out and near of the basin border. The time series of these stations can be used to interpolate rain spatial pattern into the basin. Some of the daily precipitation records are from 1954.

Data base also incluyes 19 sations with mean daily temperature, 8 stations with daily records of relative humidity, mean wind velocity, maximum and minimum temperature, solar bright, evaporation. Data are available in digital way at the Direction of Meteorology of INETER.

Some stations, like the 69027 (International Airport of Managua) have hourly precipitation records. Intensity data were extracted from 5 pluviographs in ordet to use them in the calculation of the rain erosivity factor (WP07). The used data interval is 10 minutes.

Table LC.2.1. shows meteorological INETER stations spatial distribution into the basin. The graph bars represent data precipitation availability from decade to decade in each station.

NOAA data

There are 12 meteorological stations inside the basin and 38 other stations near the border of the basin. Two stations have daily precipitation and the 48 other stations have monthly precipitation. Graph 2 bars indicate precipitation data availability from decade to decade for each station.

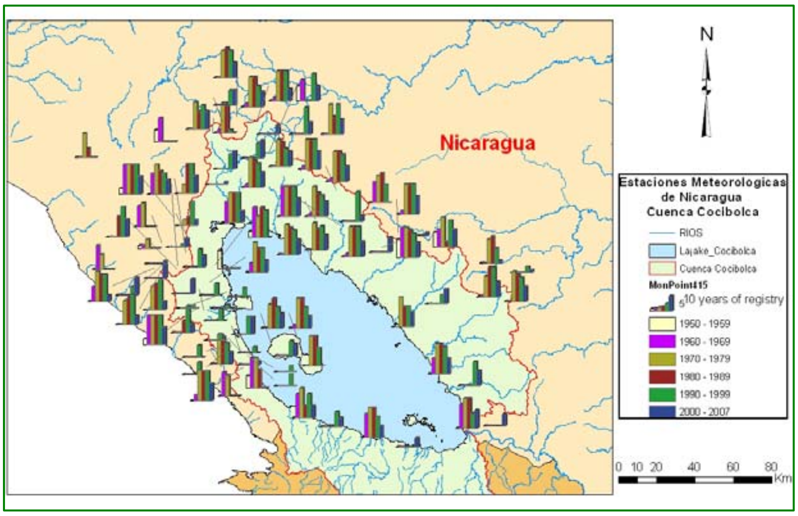


Figure LC.2.1. Daily precipitation time series available at INETER, Nicaragua

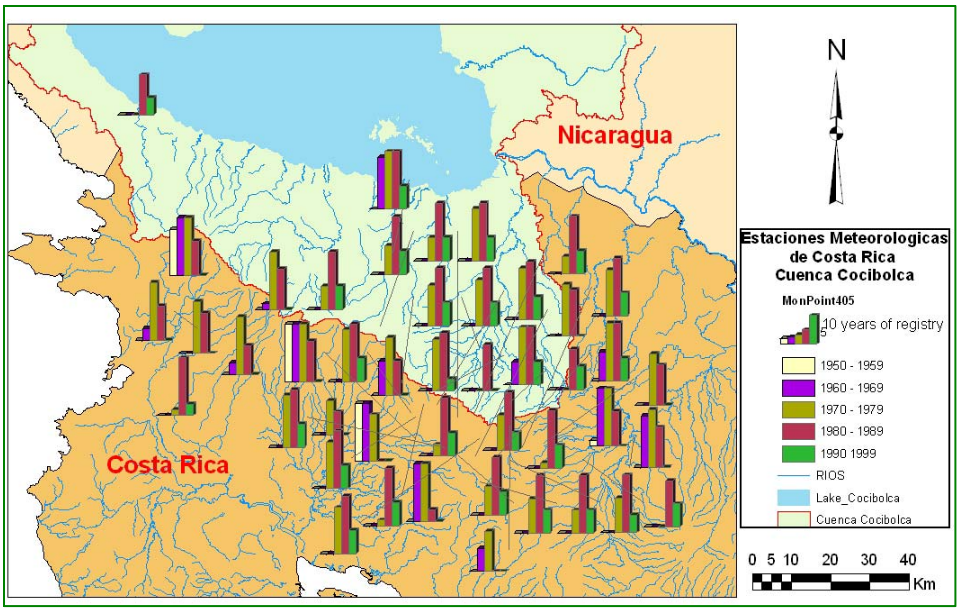


Figure LC.2.2. Monthly precipitation time series of Costa Rica side available at NOAA

So data base contains precipitation records from 134 stations both Nicaraguan and Costarrican. Spatial distribution of meteorological stations at Lake Cocibolca basin are show in Figure LC.2.3.

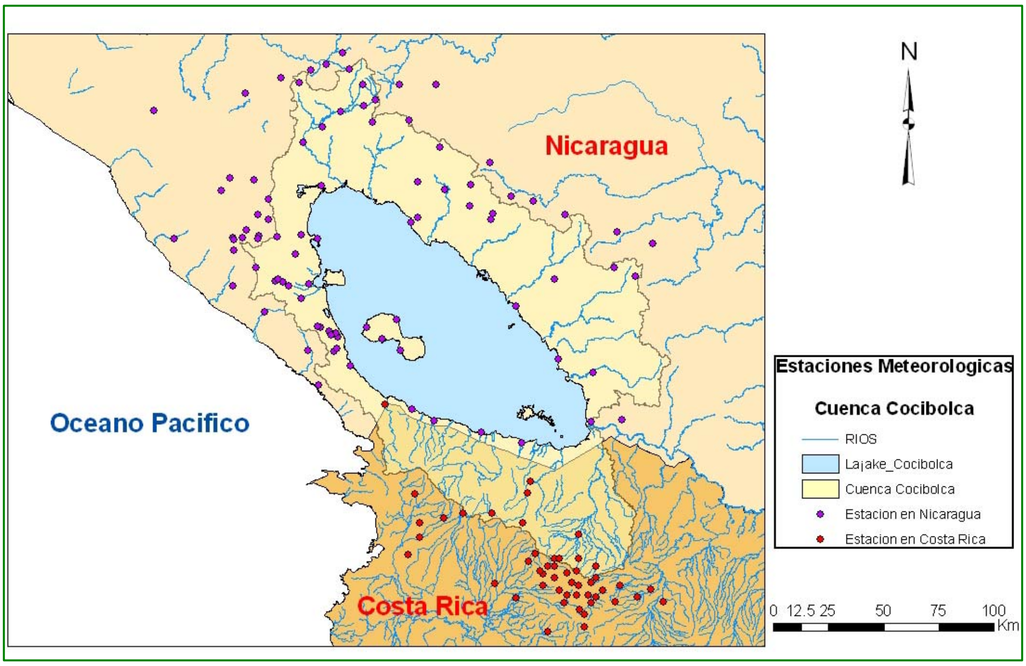


Figure LC.2.3. Meteorological stations inside and around Lake Cocibolca basin

Figure LC.2.4. shows the gaps in pluviometric time series in each of the meteorological stations (red color indicate gaps and the green one indicates continuity). Figure LC.2.5 shows the time series extension of daily temperature which have too much gaps.

2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950	estación	codigo	subcuenca
0	0	100	100	100	100	100	76	100	100	100	99	99	0	0	0	0	0	0	100	100	100	100	100	99	100	100	100	100	98	99	96	99	100	99	97	100	100	100	99	100	100	78	100	100	58	0	0	0	0	0	0	0	0	0	0	0	0	San Carlos	69090	Sabalo
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	El Tule	69144	Tule
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0	33	83	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	San Miguelito	69018	Camastro
0	0	0	100	100	100	100	100	95	0	100	100	100	100	100	100	46	0	100	0	33	100	100	57	100	100	82	78	82	87	83	100	100	99	100	99	100	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Caracito	69080	
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Abisinia	69095	Tepenaguasapa
0	0	0	100	100	100	100	100	100	0	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	El Almendro	69154	
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	100	100	100	100	100	100	81	100	100	100	100	100	99	100	98	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Morrito	69071	Oyate
0	0	0	100	100	100	100	100	95	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Oyate	69153	
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	99	0	0	0	50	100	100	100	92	83	72	100	100	50	58	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	92	99	98	100	100	100	100	95	0	0	0	0	Lovago	69024	
0	0	0	100	100	100	100	100	100	100	100	100	100	100	99	100	45	8	100	100	100	100	100	100	100	99	100	91	97	98	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	La Palma	69053	Acoyapa
0	0	0	100	100	100	99	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Acoyapa	69206	
0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	92	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	24	0	0	0	0	0	0	0	0	0	0	Juigalpa	69034	
0	0	0	100	100	100	100	100	100	100	100	100	100	0	100	100	33	67	100	92	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	95	100	100	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Cuapa	69055	
0	0	0	100	100	100	100	100	94	0	100	100	100	100	100	30	0	0	0	0	100	100	100	99	100	100	100	100	83	100	100	100	100	100	100	100	100	100	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	San esteban	69057	Mayales
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0	0	0	91	100	100	100	100	100	100	100	100	48	100	100	92	100	100	100	100	100	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Puerto Diaz	69073	
0	0	0	100	100	100	100	99	100	100	100	100	100	100	100	100	0	0	0	0	0	27	0	50	86	99	100	100	63	92	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Guapinolapa	69083	
0	0	0	0	0	100	100	0	92	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Plantel Altamra	69134	
0	0	0	92	100	100	100	100	100	100	100	100	100	100	100	100	0	0	0	100	100	100	100	100	100	100	81	95	98	100	100	100	100	100	100	100	100	100	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	San Lorenzo	69056	Tecolostote
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	46	0	0	100	100	100	100	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Tecolostote	69119	
0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	58	94	83	91	0	0	0	74	92	100	100	100	100	100	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	83	100	100	75	100	100	0	0	0	0	0	El Cascabel	69023	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	92	100	100	100	100	100	100	100	100	84	100	41	100	100	100	100	100	92	100	100	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BAJO LOS ORTEGA	69060	
0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	92	83	97	100	100	92	94	100	100	100	100	100	100	85	100	100	100	92	100	73	91	100	100	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	San Jose Remates	69067	
0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	25	100	99	100	98	98	97	96	76	97	99	100	100	100	100	99	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Boaco	69084	
0	0	95	100	100	100	99	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Las Canoas	69150	Malacatoya
0	0	82	100	100	100	100	100	100	100	77	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Teustepe	69151	
0	0	0	100	100	100	100	100	100	100	77	8	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Coyusne	69152	
0	0	0	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Santa Lucía	69207	
0	0	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LAS BANDERAS	69208	
0	0	0	0	0	0	100	100	100	0	100	100	100	100	100	75	100	100	100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	92	100	100	89	100	100	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Inasaf	69007	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	Managua (FCP)	69017	
0	0	100	100	100	100	100	100	100	100	100	100	100	99	99	99	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	100	100	100	100	100	99	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	Managua	69027	
0	0	0	0	0	0	0	0	50	100	100	100	100	100	100	23	0	16	100	100	100	65	67	72	97	100	100	100	92	100	100	100	100	100	100	0	0	0	58	92	100	97	100	92	100	100	97	100	100	58	0	0	0	0	0	0	0	0	Granada (INA)	69030	
0	0	0	100	0	81	100	0	100	100	100	0	100	100	100	100	100	67	99	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	75	0	0	0	0	0	0	0	0	0	0	0	0	0	PANALOYA	69044	
0	0	8	100	0	83	100	100	100	100	100	100	100	100	99	0	0	0	0	0	82	100	100	100	100	99	100	100	73	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	37	0	0	0	0	0	0	0	0	0	0	0	0	0	Masatepe	69049	
0	0	0	0	0	0	90	100	100	100	100	100	100	100	100	0	0	0	0	0	0	100	100	100	0	0	0	0	0	0	0	0	0	0	92	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Saimsa	69104	
0	0	0	100	0	100	100	100	100	100	100	100	100	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Catarina	69106	Tipitapa
0	0	100	100	100	100	100	77	100	100	100	100	100	100	100	100	100	100	99	100	100	100	100	99	100	100	100	92	91	100	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Masaya (L.Oxid.)	69115	
0	0	0	0	0	97	100	100	86	100	100	100	100	100	100	100	100	100	0	100	100	100	100	91	100	100	100	100	93	100	100	100	100	100	100	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	San Dionisio II	69117	
0	0	100	100	100	100	100	100	100	100	100	100	100	100	93	100	99	98	98	98	100	99	100	99	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Campoz azules	69129	
0	0	93	100	98	99	100	100	100	100	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	La Concepción	69149	
0	0	100	0	94	0	0	92	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Volcan Masaya	69201	
0	0	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Alejandría	69205	
0	0	0	100	84	99	100	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Diriamba	69210	

Figure LC.2.4. Pluviometric time series extension and gaps in each INETER meteorological station (green color indicate continuity in data)

2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950	estación	codigo	subcuenca
0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Valle Menier	69001	
0	0	100	100	100	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	99	99	100	99	99	99	97	48	100	100	99	99	100	88	79	97	98	92	97	100	100	100	100	100	100	100	100	100	100	97	0	0	0	0	0	0	0	0	Nandaime (IXG)	69033	
0	0	0	0	0	0	0	0	0	0	100	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Mercedes	69166	
0	0	0	0	0	0	0	0	0	0	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Zavala	69168	Ochomogo
0	0	0	0	0	0	0	0	0	0	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Ochomogo	69188	
0	0	0	100	0	94	100	100	100	100	100	100	100	100	100	100	0	0	0	77	100	100	92	50	72	100	67	0	78	100	100	61	100	100	100	61	20	53	83	84	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Santa Teresa	69209	
0	0	100	100	100	98	100	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	98	99	100	100	99	99	100	100	100	100	98	98	96	99	97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Rivas	69070	
0	0	0	0	0	0	0	100	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Popoyuapa	69148	
0	0	0	0	0	0	0	0	0	100	100	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Santa Fe II	69158	
0	0	0	0	0	0	0	0	0	100	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	San Fernando	69160	
0	0	0	0	0	0	0	0	0	0	0	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Sucuya	69161	Lajas en medio
0	0	0	0	0	0	0	0	0	100	100	100	0	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Los Arcos	69164	
0	0	0	0	0	0	0	0	0	100	100	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	San Jeronimo II	69165	
0	0	0	0	0	0	0	0	0	0	0	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Salitre	69169	
0	0	76	100	91	87	33	100	100	100	100	100	57	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CASUR Ltda.	69170	
0	0	0	100	0	99	100	100	100	100	100	100	100	100	100	100	33	0	0	0	58	100	83	58	0	12	100	100	100	91	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	58	0	0	0	0	0	0	La Virgen	69026	Limon
0	0	0	100	0	99	100	100	100	100	100	100	100	100	100	58	0	0	0	0	0	0	0	0	50	95	84	49	57	99	97	100	91	100	100	100	100	100	100	100	100	100	99	100	92	97	0	0	0	0	0	0	0	0	0	0	0	0	Cardenas	69013	
0	0	0	100	0	100	100	100	100	100	99	100	100	99	100	0	0	0	8	100	100	100	100	90	100	100	75	24	33	100	100	100	100	70	100	100	99	100	83	100	100	100	100	100	67	55	0	0	0	0	0	0	0	0	0	0	0	0	Colon	69041	Zapote
0	0	0	94	0	0	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Santa Helena	69133	
0	0	0	0	0	91	92	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Papaturo	69203	
0	0	0	100	0	80	98	0	99	92	100	0	100	100	48	0	0	0	83	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ALTAGRACIA	69068	
0	0	0	100	83	83	100	100	0	0	99	0	100	100	100	100	32	0	75	100	100	100	100	100	100	100	100	92	0	0	100	100	100	92	100	100	100	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MOYOGALPA	69075	Isla Zapatera
0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	92	100	98	100	100	87	83	99	100	100	50	100	92	100	100	100	100	100	100	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MERIDA	69077	
0	0	0	100	0	75	100	0	100	100	100	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EL MOGOTE	69146	
0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	0	0	7.9	0	0	0	0	100	96	100	100	100	100	100	100	100	100	100	99	100	100	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LOS PLACERES	69087	San Antonio
0	0	100	100	0	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LAS AZUCENAS	69193	Melchora
0	0	0	71	0	100	100	0	92	100	77	100	100	100	100	100	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EL PARAISO	55015	Olama
0	0	43	100	100	100	100	0	100	100	100	0	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CAMOAPA	55017	Murra
0	0	0	100	100	100	100	0	100	100	100	0	100	100	100	100	100	100	0	100	100	100	100	100	0	0	0	16	100	100	100	100	100	100	100	100	92	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SANTA RITA	55023	
0	0	0	100	100	100	100	100	100	100	100	0	100	100	65	0	0	0	49	100	100	100	99	100	100	100	100	100	80	100	100	100	100	100	99	98	99	99	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ESQUIPULAS	55018	
0	0	0	100	99	100	100	67	100	100	100	0	100	100	100	100	100	0	25	100	100	100	100	100	100	100	100	100	100	100	100	99	100	100	47	100	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LA MAJADA	55028	Grande de Matagalpa
0	0	0	100	100	100	100	0	100	100	99	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EL CACAO DE LOS	55060	
0	0	100	100	100	100	100	0	100	100	100	0	100	100	100	100	46	0	0	0	0	0	0	100	100	0	0	0	33	100	100	100	100	100	100	100	100	100	100	100	8.5	100	100	100	0	0	0	0	0	100	100	100	100	100	0	0	0	0	MUHAM	61005	
0	0	100	67	100	100	100	0	100	100	100	0	100	100	100	100	47	92	100	100	100	100	100	83	100	99	91	100	49	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SANTO TOMAS	61008	Mico
0	0	0	0	0	0	0	0	0	0	99	100	100	100	100	82	0	0	23	30	97	99	100	99	100	100	88	100	92	100	100	92	99	98	100	100	100	0	100	0	83	100	100	100	100	50	0	0	0	0	0	0	0	0	0	0	0	0	LA LIBERTAD	61021	
0	0	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	VILLA SANDINO II	61051	
0	0	0	0	0	0	0	0	0	100	100	0	0	100	100	32	0	0	0	58	99	100	100	100	100	100	75	100	45	77	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EL CORAL	61020	Rama
0	0	0	0	0	0	0	84	83	0	0	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	JACINTO BACA	61047	
0	0	0	100	0	82	100	0	70	100	100	0	100	100	100	100	50	50	99	92	100	100	100	100	62	0	25	31	33	100	100	100	100	100	100	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	LAS MERCEDES C	68027	Grande
0	0	0	100	0	0	100	0	100	100	100	0	100	100	100	100	100	0	0	0	83	100	99	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EL TERRENO	68031	Escalante
0	0	0	58	0	82	100	0	0	0	100	0	100	100	99	83	79	0	0	83	100	100	100	100	100	100	99	91	67	100	100	93	99	99	83	100	100	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	TOLA	70001	Brito

Figure LC.2.4. Pluviometric time series extension and gaps in each INETER meteorological station (continued)

estación	codigo	subcuenca	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
Rivas	69070	Lajas en medio	0	0	100	100	100	98	100	99	100	100	99	100	98	100	100	99	100	99
Boaco	69084	Malacatoya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guapinolapa	69083	Mayales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juigalpa	69034	Mayales	0	0	100	99	100	100	100	100	100	100	100	100	100	100	100	100	99	100
Morrito	69071	Oyate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Carlos	69090	Sabalo	0	0	100	90	100	99	100	76	100	83	99	46	0	0	0	0	0	0
Granada (INA)	69030	Tipitapa	0	0	0	0	0	0	0	0	50	100	100	100	0	0	75	23	0	16
Masatepe	69049	Tipitapa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Masaya (L. oxid)	69115	Tipitapa	0	0	0	100	100	100	100	77	100	100	100	100	100	100	100	100	100	100
Campos azules	69129	Tipitapa	0	0	100	100	100	100	100	100	100	100	100	100	100	100	99	100	99	99
Saimsa	69104	Tipitapa	0	0	0	0	0	0	68	98	13	0	0	0	0	0	18	33	0	0
Managua (air)	69027	Tipitapa	0	0	100	100	100	100	100	100	100	100	100	100	100	100	99	100	100	100
Papaturo	69203	Zapote	0	0	0	0	0	45	96	62	0	0	0	0	0	0	0	0	0	0
ESQUIPULAS	55018	Grande de Matagalpa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LA LIBERTAD	61021	Mico	0	0	0	0	0	0	0	0	0	0	0	0	66	0	16	82	0	0
ALTAGRACIA	69068	Isla Zapatera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOLA	70001	Brito	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	75	0

estación	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Rivas	100	100	100	100	100	100	100	84	99	100	93	98	100	100	100	99	100	98	97	87
Boaco	0	0	24	100	98	97	98	95	90	94	72	93	98	99	99	97	100	90	66	0
Guapinolapa	0	0	58	27	0	51	88	100	100	100	61	92	100	100	99	99	100	100	98	0
Juigalpa	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Morrito	0	0	0	50	100	100	100	100	99	99	80	100	100	99	33	100	98	95	84	92
San Carlos	6	100	100	100	100	100	91	100	98	99	98	100	99	89	99	100	97	0	0	0
Granada (INA)	100	100	100	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Masatepe	0	0	0	0	0	0	0	0	100	100	73	100	100	100	100	100	100	100	100	100
Masaya (L. oxid)	92	100	100	99	100	99	100	100	100	92	91	100	32	0	0	0	0	0	0	0
Campos azules	97	100	97	100	92	99	50	0	0	0	0	0	0	0	0	0	0	0	0	0
Saimsa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Managua (air)	91	92	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	97	100
Papaturo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ESQUIPULAS	49	100	100	100	99	98	99	99	99	99	78	87	100	99	100	100	99	96	83	98
LA LIBERTAD	23	30	98	99	85	99	100	100	95	100	91	100	100	92	99	100	98	100	25	0
ALTAGRACIA	0	0	0	0	0	0	0	0	0	0	0	99	100	99	99	98	99	100	100	42
TOLA	0	75	94	99	100	100	99	100	97	91	62	100	100	93	84	22	0	0	0	0

estación	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950
Rivas	96	61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boaco	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guapinolapa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juigalpa	100	100	100	99	99	100	100	100	100	24	0	0	0	0	0	0	0	0	0	0
Morrito	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Carlos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Granada (INA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Masatepe	99	100	100	92	100	100	38	0	0	0	0	0	0	0	0	0	0	0	0	0
Masaya (L. oxid)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Campos azules	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saimsa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Managua (air)	100	100	98	100	99	100	100	100	99	100	100	100	0	0	0	0	0	0	0	0
Papaturo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ESQUIPULAS	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LA LIBERTAD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ALTAGRACIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOLA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure LC.2.5. Temperature time series extension and gaps in each INETER meteorological station

Hydrology

Hydrometric data (level and flow) are generated through hydrometric network managed by the Direction of Water Resources of INETER. Inside Lake Cocibolca basin are installed 10 lymnigraphycs stations and 2 lymnimetrics, 7 of them are installed in Lake Cocibolca tributary rivers, one in the Lake and 4 on San Juan river. Data are recorded daily in 8 stations and monthly in 4 stations. Graph 6 shows spatial hydrometric network distribution on the basin. Bars on graph indicate data availability from decade to decade for each station.

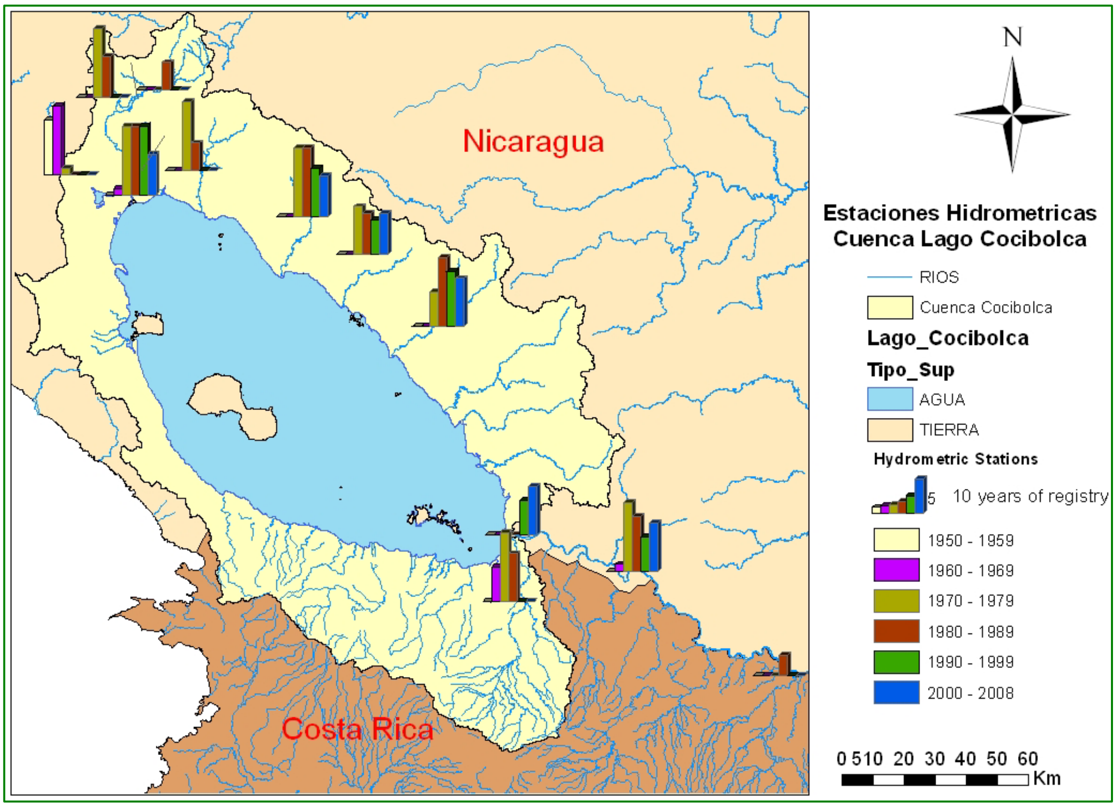


Figure LC.2.6. Hydrometric stations on Lake Cocibolca Basin

There are many gaps in flow time series, they are too shorts and located on the Eastern side of the basin and on the San Juan river. There is a lymnigraphic station in Granada harbor with daily records since 1970 to 2000. There is no records of Rio Frio flows which is the largest river from Costa Rica discharging on Lake Cocibolca.

Figure LC.2.7. shows the span of daily flows time series of each hydrometric station (green color indicates continuity in data series) and Figure LC.2.8. shows monthly flow data series length of four hydrometric stations on San Juan river.

codigo	subcuenca	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
690504	Malacatoya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	76	83	53	0	0	0	0
690503	Malacatoya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	100	100	100	100	97
690501	Malacatoya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690502	Malacatoya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	27	67	100
690801	Mayales	0	0	35	63	65	85	49	72	49	67	87	22	0	0	51	6	45	0	83	7	65	77	56	100	100	66	67	65
691001	Acoyapa	0	0	45	16	89	83	9	92	100	84	94	61	48	0	0	0	0	0	0	0	65	0	0	67	89	78	100	100
691201	Oyate	0	27	61	66	37	43	77	48	10	78	87	26	39	80	93	55	0	0	25	14	83	83	75	99	78	62	86	100

codigo	subcuenca	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950
690504	Malacatoya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690503	Malacatoya	90	99	100	96	93	100	100	100	100	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690501	Malacatoya	0	0	0	0	0	0	0	0	0	33	99	100	92	100	100	100	100	100	100	84	100	93	96	100	100	100	100	34	0	0
690502	Malacatoya	74	100	93	75	59	54	94	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690801	Mayales	36	84	100	100	100	79	56	100	74	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
691001	Acoyapa	74	38	68	93	0	91	89	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
691201	Oyate	89	100	100	86	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure LC.2.7. Daily flow data series, length and gaps, in hydrometric stations on tributary rivers of Lake Cocibolca

Codigo	Cuenca	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
690101	San Juan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.7	83	33	67	58	67	75
690102		0	100	83	100	100	75	100	83	100	83	100	100	75	8.3	0	0	0	0	58	8.3	100	50	92	67	92	92	92	92
690104		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.33	92	100	83
690112		0	67	83	75	92	67	58	75	50	75	100	92	67	8.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Codigo	Cuenca	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950
690101	San Juan	33	67	100	100	92	83	100	100	100	100	100	92	100	100	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690102		50	100	100	100	100	67	100	100	92	100	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690104		33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
690112		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure LC.2.8. Monthly flow data series, length and gaps, in hydrometric stations on San Juan river

Surface Water

Some of rivers draining to lake have hydrological measurements accomplished by INETER. There is not a study of currents into the Lake. It is accepted that, by the influence of winds from the east and southeast there is a superficial current forced by winds in that direction and compensating this there is a bottom current in opposite way. The Lake Cocibolca is not deep lake and its possible that stratification not occurs in it.

Groundwater

In Report Cocibolca WP1 are described the aquifers surrounding Lake Cocibolca and some aspects of its water quality. Main cities on the east side of basin are supplied booth water of rivers and with water wells but these have small flow so only abstraction of aquifer can´t satisfy the human needs.

Baker Basin

Meteorology

Meteorological data for the basin are available from a range of sources. The most important are the Chilean General Water Administration **DGA** (“*Dirección General de Aguas”*) and the National Meteorological Service **DMC** (“*Dirección Meteorológica de Chile”*). Next, some of the main meteorological monitoring networks for the basin are shown with the state of the station, the monitored parameters and the availability of data in the basin.

DGA

This measuring network has been primarily established in order to provide information relevant to the study & management of the basin’s water resources. The first measurements date from 1961. Initially, the network was operated by the hydropower company Endesa, which at that time was state-owned. The network was transferred to DGA in September of 2002, with the signing of an agreement; the station operation by part of the de la DGA began in 2003. In this agreement, Endesa agrees to turn in the information from the last three years, a situation that to date is found being carried out at the Central Level of the DGA.

The network consists of 8 stations located within the Baker River Basin, for which daily rainfall data are obtained (Fig. B.2.1.). Of these 8 stations, at present 7 stations are active. Time series from approx. 3 additional stations, located in the immediate vicinity of the Baker River Basin, may also provide information of interest, as they can eventually be used in interpolation procedures, or to establish regional trends in precipitation patterns. More recently, 4 of DGA’s pluviometer stations within the Basin have been equipped with satellite transmitters, and now provide hourly precipitation data.

The spatial distribution of the measuring network (Fig.B.2.2.) shows that the stations are mainly located at lower elevations, generally in the vicinity of urban settlements. The current measurement network does thus not cover the altitudinal gradients that most certainly exist within the basin. This fact complicates the establishment of water balances at the (sub) basin level, and limits possibilities for modeling applications.

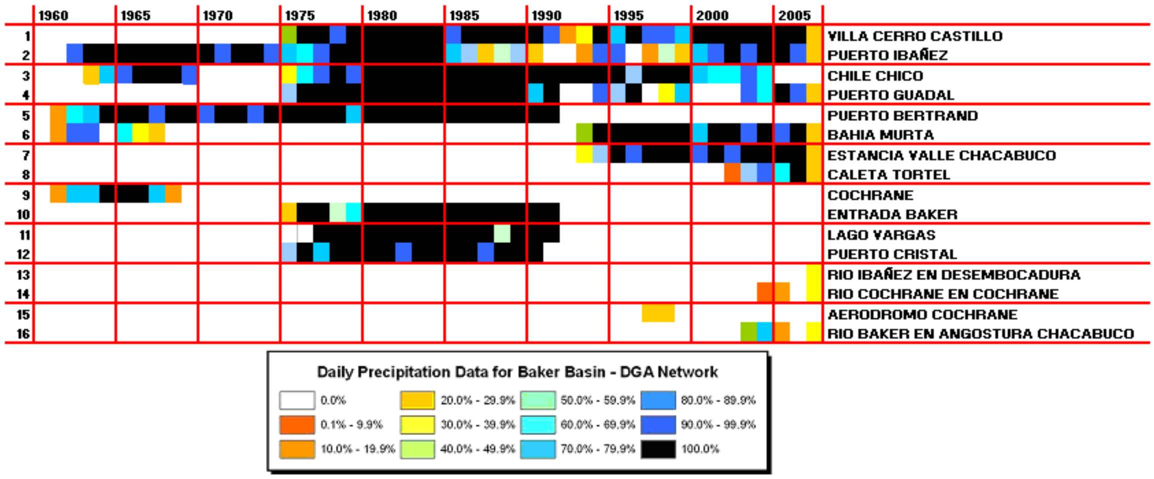


Figure B.2.1. Extent and completeness (%) of the daily time series of precipitation data for the Baker River Basin

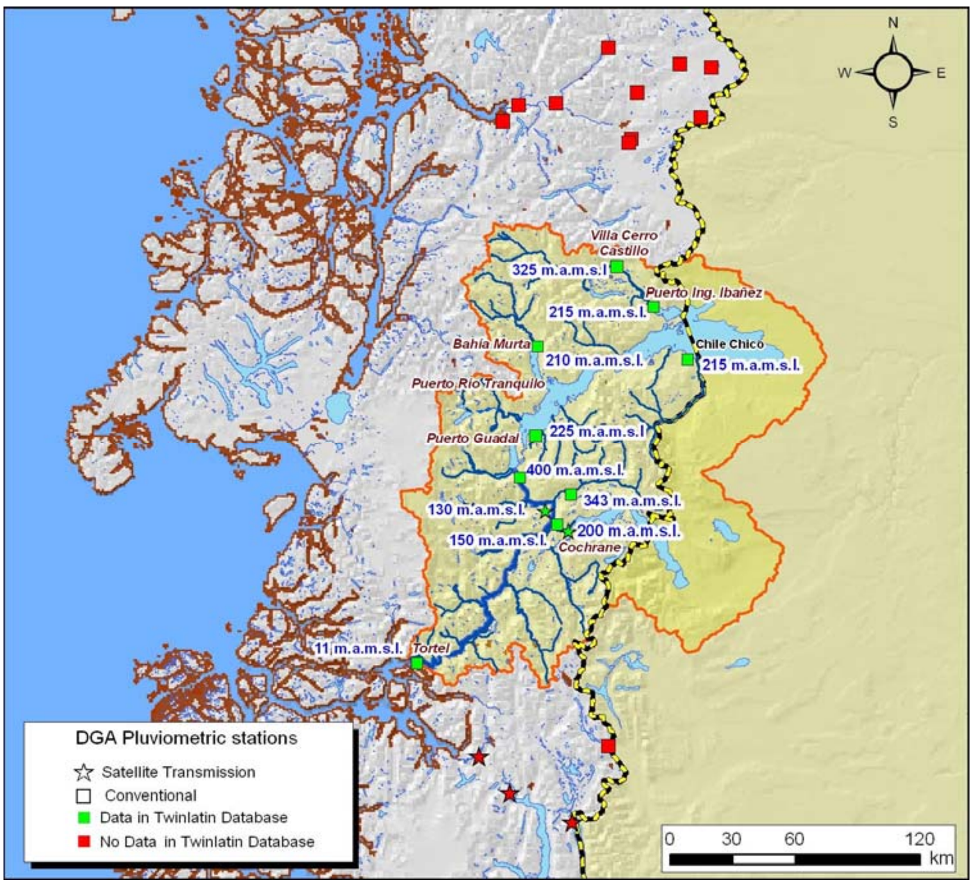


Figure B.2.2. Daily & hourly precipitation stations from DGA

DGA currently has register stations of evaporation, wind direction, relative humidity and extreme temperatures.

The daily time series data can be obtained from DGA's National Water Database **BNA** (*"Banco Nacional de Aguas"*). Private users pay Chilean Peso $205 for annual, $70 for monthly and $15 for daily data. However, within the framework of TWINLATIN, EULA will have access to these datasets through a collaborative research agreement with DGA. The data from the stations with satellite transmission can be freely downloaded through a web-based application (http://dgasatel.moptt.cl/).

DMC

The National Meteorological Service DMC, as part of the General Directorate of Civil Aviation DGAC ("*Dirección General de Aeronáutica Civil*"), operates 5 meteorological stations in the Aysén Region. Of these, only 2 are located within the Baker River Basin itself, while the other 3 stations are located to the north of the Basin. Available information from this network consists of **daily precipitation** and **minimum & maximum temperature**, as well as **wind, pressure, cloudiness, humidity** and **sun hours**. In general, time series go back as far as 1970, with the exception of the Puerto Aysén Station, which was discontinued in 1995. A cooperation agreement between DMC and EULA, established for the Biobío Basin in the framework of the TWINBAS Project (EC 6th FP), is to be extended to the Baker Basin, in order to facilitate access to the mentioned data sets.

One additional station exists, which is administered but not directly operated by DMC. It is located in Villa O'Higgins (S of the Basin) and registers daily precipitation and extreme temperatures (operational since 1996).

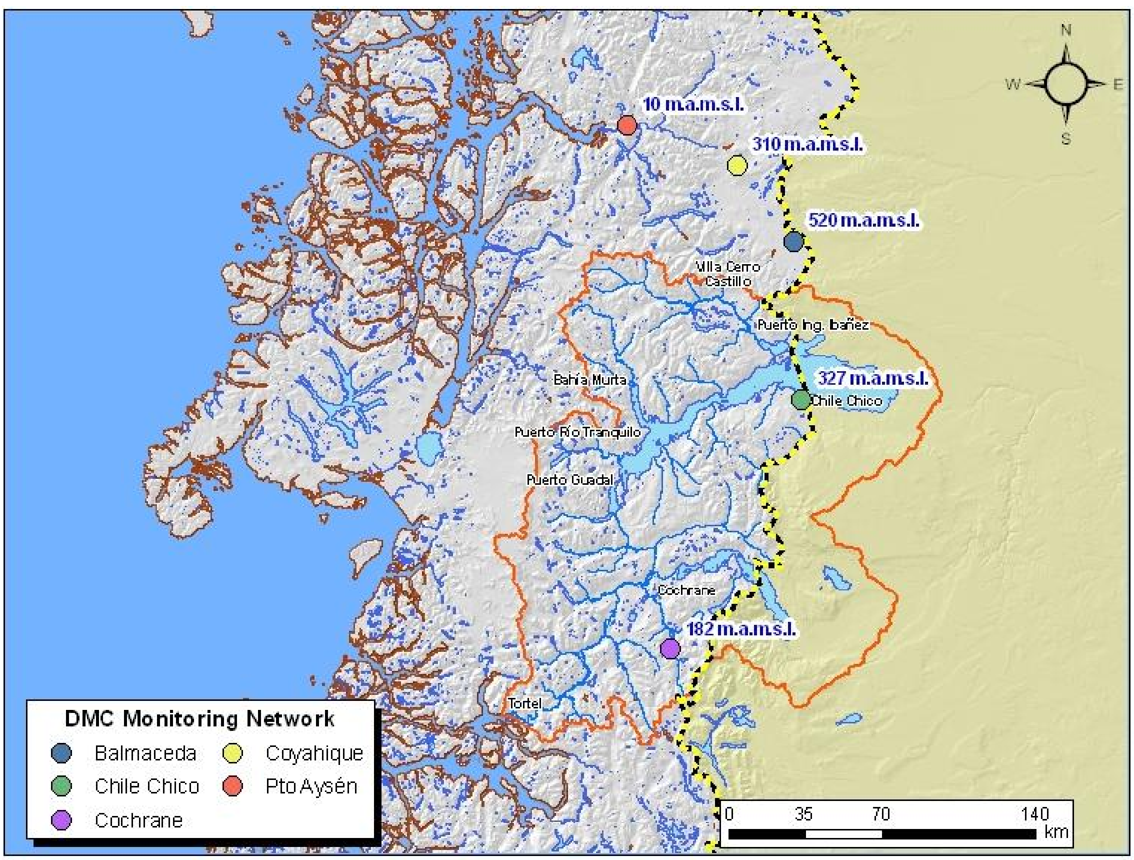


Figure B.2.3. DMC meteorological monitoring network for the Aysén Region

ENDESA

Endesa still holds part of the historical time series from the monitoring network currently operated by DGA. This information is not available from DGA.

INIA

The National Agriculture & Livestock Research Institute INIA ("*Instituto Nacional de Investigación Agropecuaria*") administers a series of meteorological stations, mainly in the area of Chile Chico and Puerto Ibañez. Modalities for data exchange with INIA are currently being investigated.

Hydrology

DGA

Almost all hydrological data (**daily discharge & water levels**) are generated through DGA's network of fluviometric stations, and are thus contained in the BNA. For the Baker Basin, the institution has time series from traditional limnigraphs which go back to 1970. The spatial distribution of the monitoring network is given in Figure B.2.4. At present, 9 stations are operational in the Basin. Of these, 6 have been recently equipped with satellite data transmission, and now register at the hourly time step.

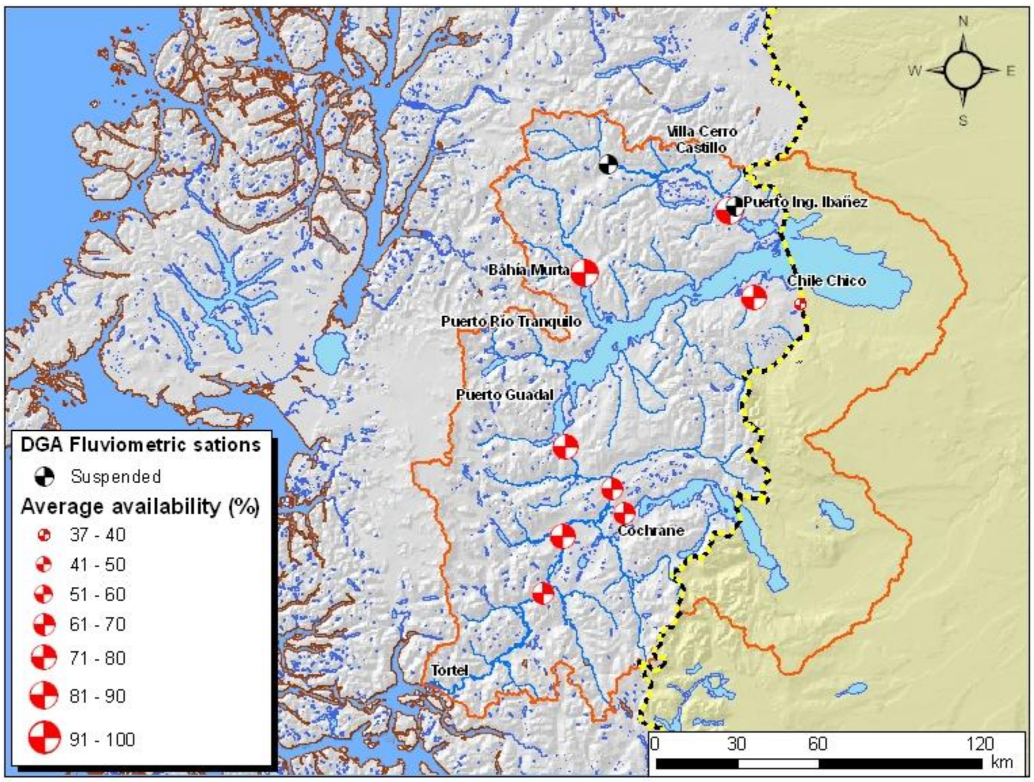


Figure B.2.4. DGA's fluviometric network in the Baker Basin

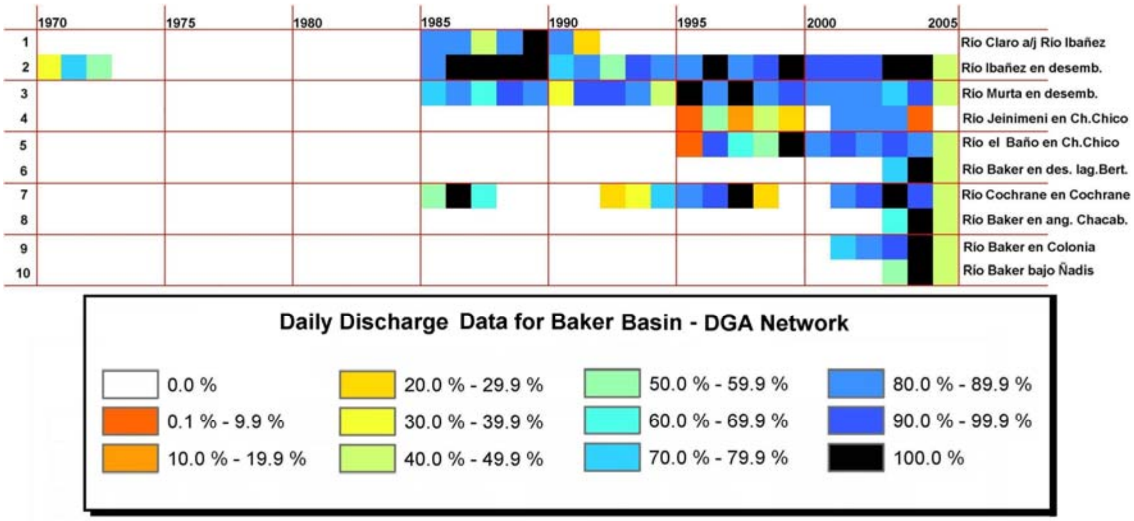


Figure B.2.5. Extent and completeness (%) of the daily discharge data time series

IRD

In cooperation with DGA, the French ‘Research for Development’ Institute **IRD** “*Institut de Recherche pour le Dévelopement*” installed a limnigraph on the Nef River, shortly downstream from the Nef Glacier, during 2005. Approximately 1 year of water level measurements are currently available, and a calibration curve relating water level to discharge rate is in the process of being established. This instrument will undoubtedly provide very interesting information on the contribution of the most important glacier-fed tributary located upstream of the first planned hydropower development site on the Baker River. However, access to this monitoring site is complicated and requires the organization of a special expedition, for which a considerable amount of time will be needed for completing the calibration curve of this instrument.

2.2. Water quality monitoring

Norrström Basin

There are large amounts of monitoring data for the Norrström river basin from different monitoring programmes. Since Norrström is very well investigated when it concerns common substances the problem is rather to overview the data and its quality. Unfortunately, data is stored in many different locations and in different structures. Attempts have been made by the county councils in the water district of L Mälaren to create a meta database collecting data concerning ongoing and finished monitoring in the district. The results of these efforts are however not fully known.

SLU (Swedish University of Agricultural Sciences) is data host for the national monitoring programme initiated by Swedish EPA. This data is available from SLU’s website (www.slu.se). Parameters and sampling frequences varies, as well as the length of time-series available. In total there are data available from 92 national monitoring stations within Norrström river basin.

Data from regional monitoring programmes and recipient control monitoring programmes is available from the county councils or from the water associations. There is a central database that some of the county councils use for storage of water quality data from regional monitoring programmes. Other county councils have data in Excel-files or in reports instead. The central database contains 1700 monitoring stations within Norrström river basin. Not all of these are within the recipient control monitoring programmes and not all of these are still active. The municipalities might have their own monitoring programmes or be responsible for recipient monitoring programs.

Finally there are monitoring programmes on five small agricultural dominated areas in the Norrström basin co-ordinated by SLU. Data from these studies is of high resolution. For details, please refer to the TWINBAS report.

Figure N2.4 shows the 92 national and regional monitoring stations from SLU. Monitoring frequency is normally no higher than once a month. The number of parameters measured varies between different stations, but normally pH, nutrients, organic material, oxygen and common cations are included. Metals in water and water-mosses are analysed in some areas, especially in the old mining areas in the north-western part of the basin. Benthic fauna is also analysed in some stations.

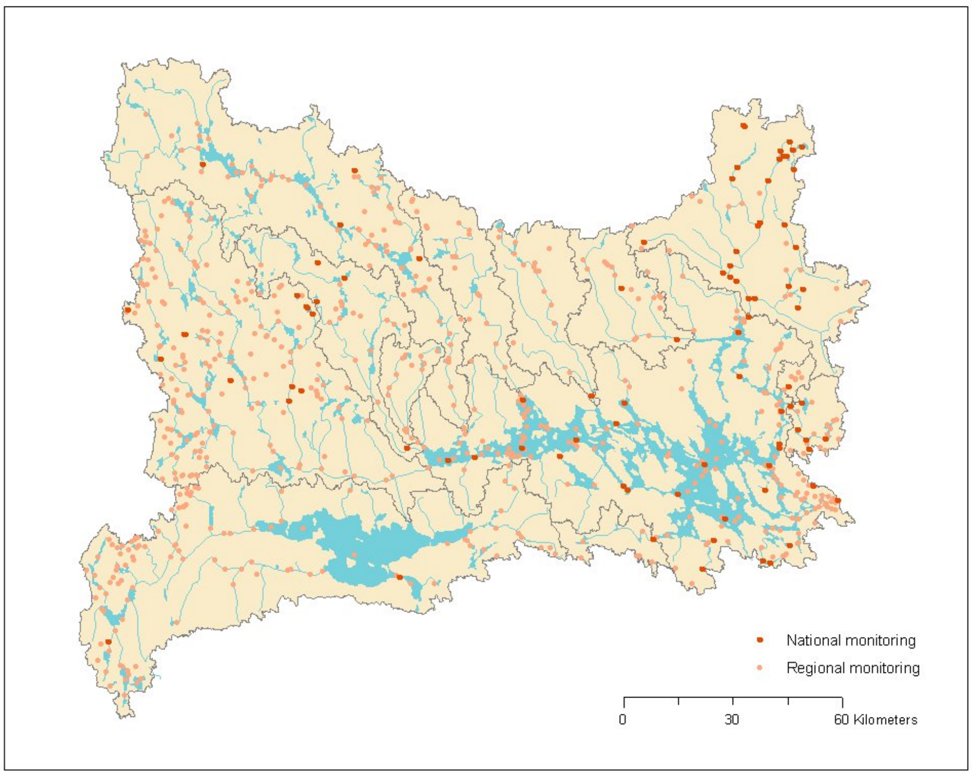


Figure N2.4. National and regional water quality monitoring. Note that locations of regional monitoring stations are not complete or quality assured

As mentioned previously there are several different monitoring programs in the Norrström river basin regarding water quality. Data from SLU has high quality and accuracy and was therefore used in the modelling in TWINBAS. IVL has also started a monitoring program to fill in the gaps of knowledge identified in TWINBAS (see below).

Other Monitoring

Monitoring of deposition of metals

Deposition of heavy metals (As, Cd, Co, Cr, Cu, Mn, Ni, Pb, V, Zn) is currently measured in three stations in Sweden. A major amount, 80%, of the atmospheric deposition of Hg, Pb and Cd comes from other countries. Metals are also measured within the TWINBAS project, as described in the following section.

POPs and other substances

Deposition of POPs are measured at four stations: Aspvreten, Pallas, Råö and Rövik (Figure N2.5).

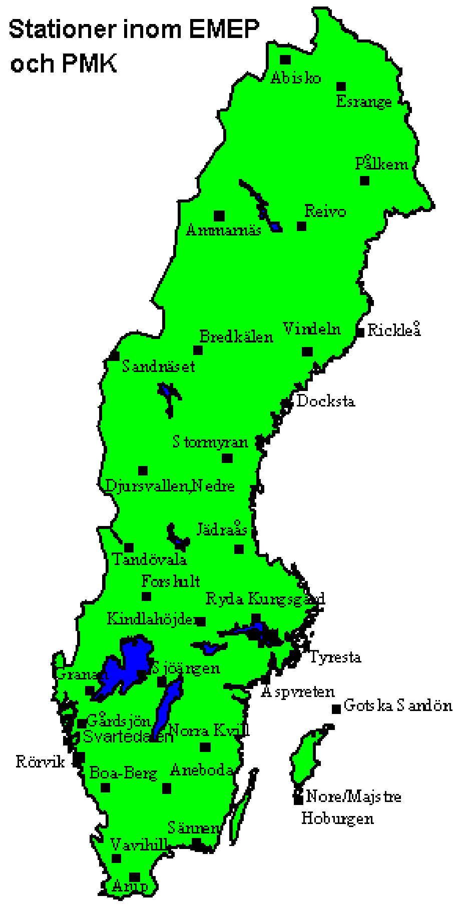


Figure N2.5 Stations in the Swedish monitoring programme of air borne pollution. Source: IVL.

On-going monitoring within the TWINBAS project

L Mälaren and its tributaries are very well investigated with respect to the common substances. Within the Twinbas project a lot of effort was put on getting an overview of existing data and its quality. Three areas were identified where existing information was insufficient and complementary monitoring needed:

1. Nutrient leakage from agricultural land in the nearby area to L Mälaren
2. Leakage of heavy metals from agricultural land
3. WFD-prioritised substances, persistent organic compounds

Nutrients from nearby agricultural land

Based on this, IVL started a monitoring program in the fall of 2004 within the TWINBAS project. Three agricultural rivers were identified as suitable for measurements of nutrient leakage within Twinbas (**Error! Reference source not found.**). Their land use and total size is shown in **Error! Reference source not found.**. The purpose was to fill a gap in knowledge regarding nutrient levels in small streams that are highly affected by agricultural and to strengthen the calibration and validation of modelling. The samples taken are analysed for three fractions of nitrogen (N-tot, NH4 and NO-N) and two fractions of phosphorous (P-tot and PO4).

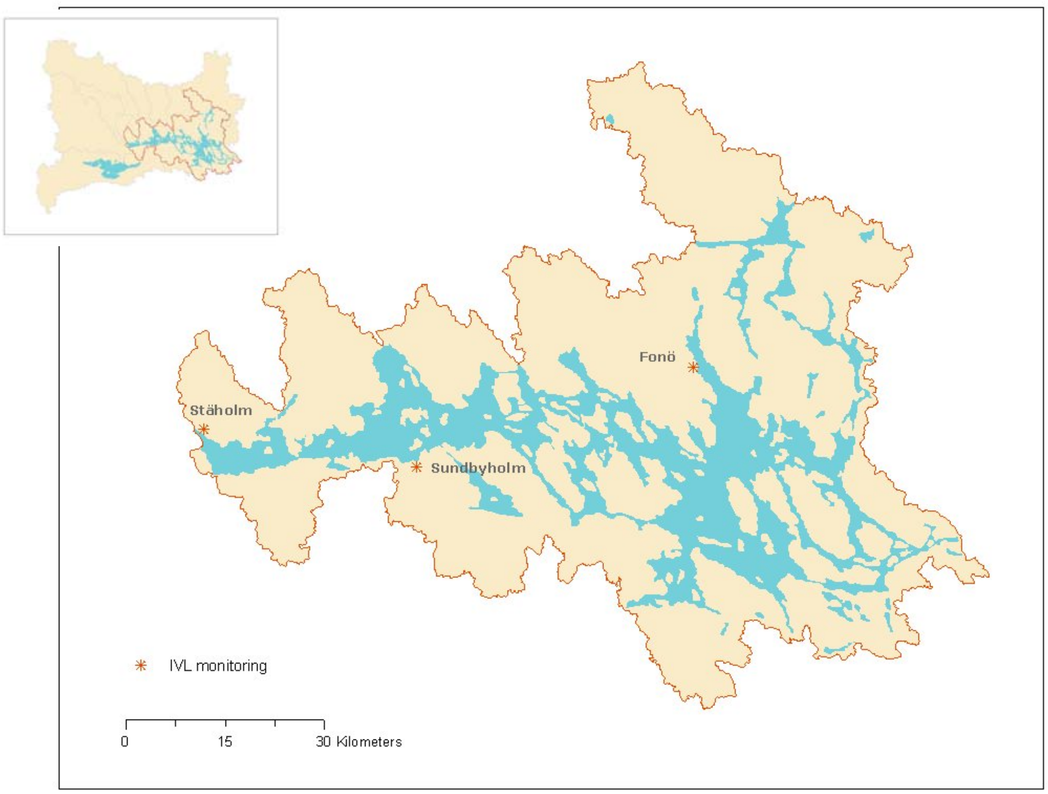


Figure N.2.6 TWINBAS monitoring sites in agricultural rivers in nearby area to L Mälaren.

Table N2.2. Land use in new monitoring sites

Landuse	Stäholm (%)	Tegelviken (%)	Fånö (%)
Agriculture land	53	49	63
Clear-cut forest	3	1	1
Forest	34	38	35
Open land	10	11	12
Urban areas	0	0	0
Water	0	0	0
Wetland	0	1	1
Total area (km2)	**67**	**61**	**43**

The streams show clear differences in nutrient concentrations (Figure N2.7). As the proportion of agricultural land in the tributaries cannot explain the differences in nutrient concentrations in the streams other possible sources have been discussed. The causes to the unexpected variability will be further studied in order to identify possible causes, e.g. differences in the number of rural households in the catchments, differences in agricultural practices.

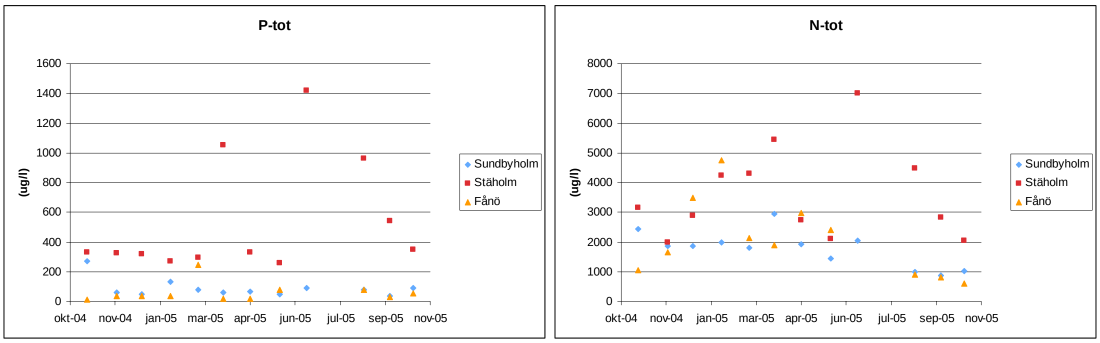


Figure N2.7 Monitoring results from IVL:s monitoring program of small streams with a high share of agricultural land in their tributaries. Ståholm stands out for extremely high concentrations of both phosphorous and nitrogen.

Metals from agricultural land

In 2004 IVL also started monitoring heavy metals within TWINBAS. These samples are taken in cooperation with one of the monitoring programs at the Swedish University of Agricultural Sciences. The monitored metals are cadmium, copper, lead, mercury and zink. Preliminary results from analysis of heavy metals in the streams have registered one peak last winter in otherwise fairly regular levels.

In one of the sites sampling is done manually, about 30 times a year, with higher frequency during wet season. SMHI has a flow station at the monitoring station, with continuous registration. The other site is handled by SLU, through an automatic flow driven sampler. Samples are collected weekly and analysed at SLU's laboratory, but metal analysis are performed on monthly collective samples. For further details, please refer to the TWINBAS project.

Thames Basin

Spot samples are taken at about 5000 sites in the Thames basin to monitor water quality. There are also data on river habitats and macro-invertebrates. The majority of the gauged flow data for the Thames basin is artificially influenced by abstractions or discharges upstream. Abstractions and discharges are also monitored by the Agency, but much of this information is confidential, though the licensed amounts can be obtained for research purposes.

Previous surveys have indicated that the surface water quality of the Pang varies along its length, and there are three distinct hydrochemical regions within the channel: the upper Pang, the middle Pang down to the confluence with the Winterbourne and the lower Pang. Discharges from the Chievely sewage treatment works have an impact on the water quality of the Winterbourne. However, no corresponding surveys of the Lambourn have been undertaken. Any surveys will highlight nutrient enrichment from sewage in the river near its confluence with the Kennet at Newbury.

There is no routine manual monitoring of river sediment loads for either the Pang or the Lambourn, nor regular bulk sampling for suspended solids, nor continuous measurements of river turbidity. There is random sampling of effluent discharges and spatial investigations of pollution incidents.

Catamayo-Chira Basin

A systematic water quality monitoring program in the River Basin had never been done. The monitoring activities developed in the area, in the period 1978 to 2006, were done by several institutions with different purposes and different methodologies. Most of these monitoring activities had been done sporadically and do not had a temporal continuity.

Table CC.2.1. presents a synthesis of the water quality monitoring activities (from 1978 to 2002), developed in the area. It describes who monitored, the type and objectives of the monitoring, the sampling sites and the parameters being monitored, its frequency and the location of the information.

The better part of this collected information corresponds to the lower part of the River Basin, the Chira System Subbasin, (Poechos reservoir and its hydraulic system) and Chipillico Subbasin (San Lorenzo reservoir and its derivation channel). Besides, most of the monitoring activities have measured only physical and chemical parameters with irrigation and drinkable water supply purposes. Other measured parameters are those microbiological and biochemical. Very few institutions have measured heavy metals and non institution has measured pesticides. It is important to notice that monitoring activities have never been done in the higher parts of the river basin (Ecuadorian and Peruvian). Furthermore, there is no information about sampling proceedings and analysis protocols, and that's why an exercise of harmonisation and comparison of the information can not be done. Even do, it is important to highlight that the collected information shows concerning levels of mercury, cadmium and lead that put in evidence the need of monitoring this parameters.

Currently, there are only 3 institutions doing water quality monitoring activities in the Peruvian part of the River Basin. These are DESA Sullana, EPS Grau and SINERSA. In the Ecuadorian side, no institution is working on water quality monitoring at this moment.

Table CC.2.1. Main characteristics of the existing monitoring sites

<table>
<tr><th rowspan="2">Institution</th><th rowspan="2">Purposes</th><th colspan="3">Monitoring sites</th><th rowspan="2">Parameters</th><th rowspan="2">Frequency</th></tr>
<tr><th>Denomination</th><th>Location</th><th>Subbasin</th></tr>
<tr><td rowspan="12">DESA Sullana</td><td rowspan="12">Environmental sanitation</td><td>E01A</td><td>Portachuelo</td><td>Quiroz</td><td rowspan="12">Microbiological</td><td rowspan="12">2 times per year</td></tr>
<tr><td>E01B</td><td>El Tambo</td><td>Quiroz</td></tr>
<tr><td>E01C</td><td>Frejolito</td><td>Quiroz</td></tr>
<tr><td>E01D</td><td>Frejolito</td><td>Quiroz</td></tr>
<tr><td>E01</td><td>Paimas</td><td>Quiroz</td></tr>
<tr><td>E02</td><td>Encuentro de Quiroz</td><td>Quiroz</td></tr>
<tr><td>E03</td><td>Chilaco</td><td>Chipillico</td></tr>
<tr><td>E04</td><td>Chilaco</td><td>Chipillico</td></tr>
<tr><td>E05</td><td>Santa Victoria</td><td>Chira</td></tr>
<tr><td>E06</td><td>Sullana</td><td>Chira</td></tr>
<tr><td>E07</td><td>Sojo</td><td>Chira</td></tr>
<tr><td>E08</td><td>Miramar</td><td>Chira</td></tr>
<tr><td>EPS Grau</td><td>Drinkable water supply</td><td>EPS 1</td><td>Chira Piura channel km. 34</td><td>Chira</td><td>Physical
Chemical
Microbiological</td><td>Every three months</td></tr>
</table>

		EPS 2	Zona Bellavista	Chipillico	Heavy Metals	
		EPS 3	El Arenal	Chira		
		EPS 4	Lancones irrigation channel	Chipillico		
SINERSA	Hydro Energy	Curumuy	Canal de derivación Miguel Escobar		Temperature, pH, oils and total suspended solids	Monthly
		Poechos 1	Intake point of the hydroelectric plant of Poechos	Chira	Temperature, pH, oils and total suspended solids	Monthly
		Poechos 2	Output point of the hydroelectric plant of Poechos	Chira	Temperature, pH, oils and total suspended solids	Monthly
		Sullana	Reservoir	Chira	Temperature, pH, CE, calcium, chlorides, total hardness, iron, manganese, magnesium, nitrates, total SS, sulfates and turbidity	Punctual monitoring
		Chira-Chipillico confluence	500 m downstream of the confluence	Chira	Temperature, pH, CE, calcium, chlorides, total hardness, iron, manganese, magnesium, nitrates, total SS, sulfates and turbidity	Punctual monitoring

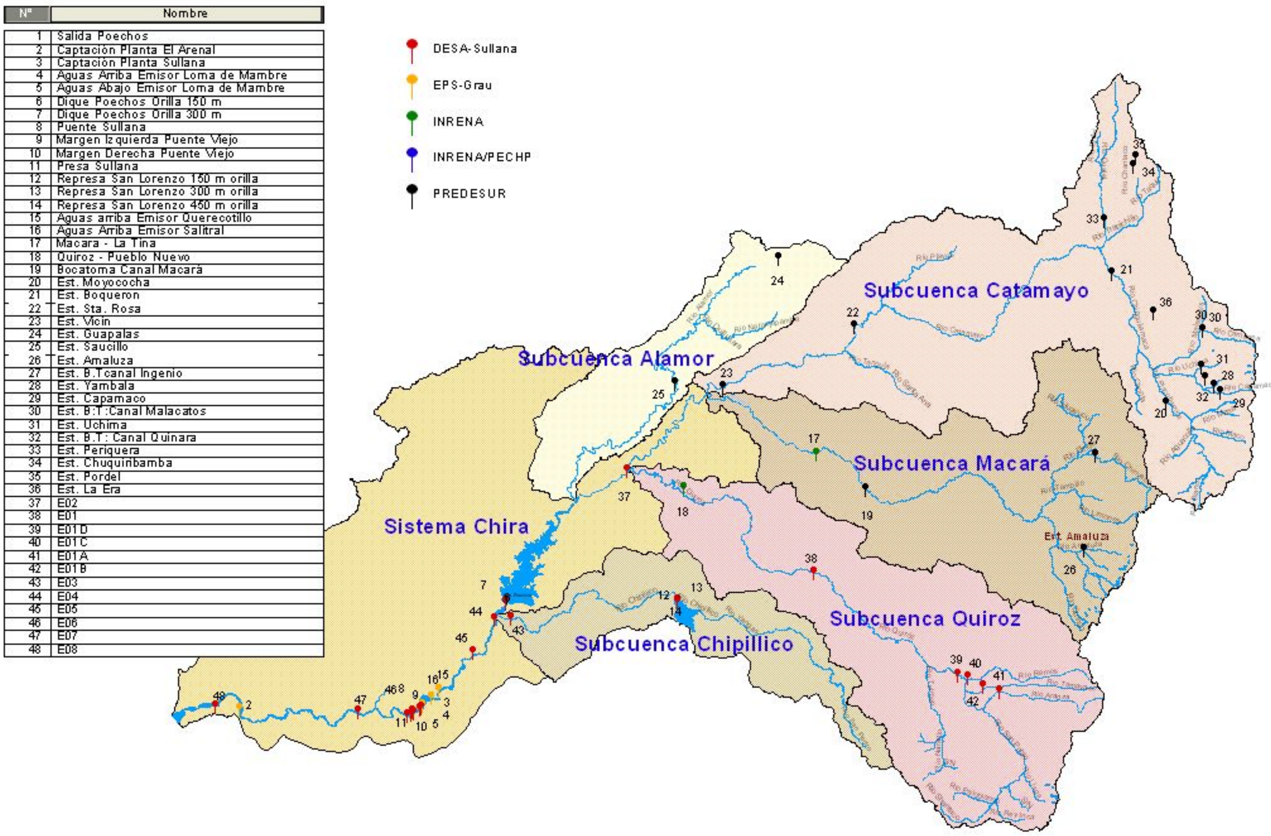


Figure CC.2.2. Historic water quality monitoring stations network

Upper Cauca Basin

According to current standards, water usage is determined by its quality. In order to control contaminant loads in the receiving bodies, the environmental authority established a baseline quality for the different rivers. This baseline determines quality objectives that lead to the determination of contamination reduction goals in the municipal and industrial sectors. Therefore, water quality parameter monitoring is a priority for proper environmental management. These parameters determine water quality:

• Temperature	• Calcium
• pH,	• Magnesium
• Alkalinity	• Sodium
• Bicarbonates	• Potassium
• OD	• Iron
• BOD_5	• Manganese
• Total solids	• Total Phosphorus
• Suspended solids	• Phosphates
• Dissolved solids	• Copper
• Color	• Zinc
• Turbidity	• Cadmium
• Total and fecal coliforms	• Chromium
• Total Hardness	• Nickel
• Calcium Hardness	• Lead
• Magnesium Hardness	• Total Nitrogen

• DQO • Chlorides • Sulfates • Electrical conductivity	• Ammonia Nitrogen • Nitrates • Nitrites

Monitoring studies by CRC do not test iron, manganese and ammonia nitrogen.

For water quality monitoring, CVC permanently measures surface and underground sources, as well as liquid discharges, dams, ponds and wetlands of Valle del Cauca. This also occurs at the area of influence of CRC, where several industrial zones are located. Table UC2.3 shows the number of surface water stations monitored for each of the Cauca River tributaries. Main contaminating sources are quality monitored, especially in the industrial and municipality zones.

CVC has made periodical follow up and control of waste water discharged from more than 352 industries within its jurisdiction. Figure C2.3 shows the location of this industrial and urban waste discharge, as well as the corresponding water quality monitoring stations.

Table C2.3- Location of Water Quality Stations

Monitoring site		**Number of stations**	
Cauca River:		19 stations	
Stations located at the point of delivery of the Cauca River Tributaries:		32 stations	
Upstream Stations for the Cauca Affluents			
River	**No. Stations**	**River**	**No. Stations**
La Vieja River	7	Morales River	4
Guadalajara River	6	Yumbo River	4
Nima River	3	Bugalagrande River	5
Palmira River	4	Frayle River	4
Amaime River	5	Párraga River	3
Piedras River	4	Bolo River	4
Riofrío River	6	Guachal River	1
Cali River	7	Meléndez River	3
Pance River	6	Cañaveralejo River	3
Claro River	3	Lili River	3
Jamundí River	5	Navarro Canal	1
Arroyohondo River	6	La Paila River	4
Cerrito River	5	Mediacanoa River	3
Tuluá River	5	Guabas River	5

Stations monitored before the Salvajina Dam are monitored four times per year, at specific sampling sites. These are:

- Before the Vinagre River
- Before the discharge into the Piedras River
- Before entering Popayán
- At the Popayán exit.

Tributary rivers monitored by CRC only have data from 2005 and 2006. The information is as follows:

- Piedras River: Monitored by the Río Piedras Foundation at 5 stations
- Molino River: 2 stations are monitored
- Desbaratado River: Monitoring work is currently being done to feed the modeling software that will soon be implemented.
- La Quebrada River: 5 stations are monitored
- Quinamayó River: 10 stations are monitored
- Ovejas River : 3 stations for water quality monitoring
- Ejido River: 2 stations for water quality monitoring

Water quality monitoring information collected by CVC and CRC is managed by the Environmental Laboratory. Although currently the information is not integrated into the hydroclimatologic monitoring data base, it is stored in a data base management system.

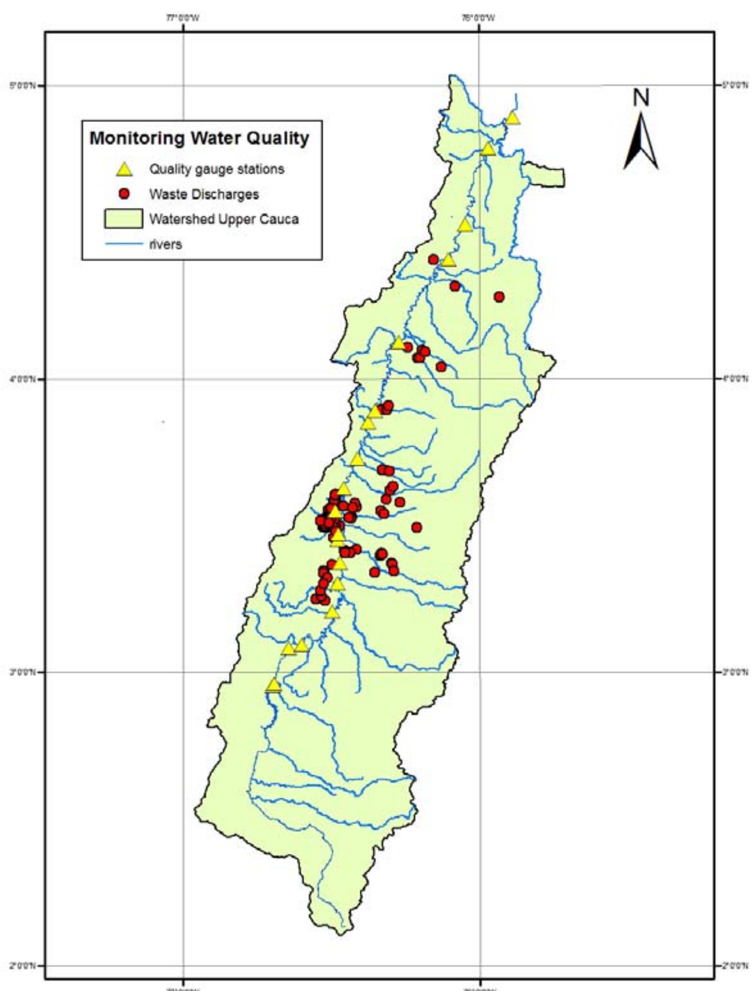


Figure UC2.3- Location of Water Quality Stations

Water monitoring has been made for the Cauca River since 1990 and since 1996 for the rest of the sources. Underground water monitoring has been classified by year, by well name and by location. Tributary river monitoring has been organizad by monitoring station name, plane coordinates, type of information, chronolical order and frequency, and those of the Cauca River are organized according to station and sampling date for every year. Industrial sampling has been organized according to industry name, location, time period and parameter.

Air Quality Monitoring

CVC and DAGMA have fixed and mobile air quality gauge stations. DAGMA measurements are concentrated in the cities of Cali, Yumbo and Palmira.

Fixed station monitoring includes carbon monoxide, nitrogen oxide, sulphur dioxide, ozone and fine particle material hourly analysis, as well as monitoring of wind, rainfall, temperature, relative humidity and sunlight.

Foto UC 2.10 Fixed station

Foto UC 2.11 Mobile station

Other Environmental Monitoring

Less frequently than done with the above mentioned variables, hydrobiological monitoring is performed at wetlands, dams, rivers and creeks. Also, responding to other specific studies, measurements of air quality (in fixed and mobile stations) and noise (through sound metering devices) are carried out. Studies on the industrial discharge toxicity, bottom sediment transportation and reaireation rate of the Cauca River have been performed.

Additionally, permanent measurements are taken at the hydrometric stations using transversal river sections. This allows making a follow up of river bed changes at specific locations, determining the river's hydraulic-geometric variables. Solid measurements were previously made to study material transportation, but these were suspended due to Corporate policies.

Cuareim/Quarai Basin

With respect to water quality data in the Cuareim River Basin, there are no monitoring programs in operation for the basin, although some plans were prepared in 2004. On the Brazilian side there is information collected during April, 1996 of the following parameters: pH, BOD5, phosphate, nitrate, total solids, turbidity, dissolved oxygen, fecal coliforms, lead, total chrome, mercury, nickel, cadmium, and zinc.

In Brazil, regular surface water quality information is collected by CPRM on behalf of ANA in Quaraí and Barra do Quaraí. In Uruguay regular surface water quality information is available from the Water Supply Company of Uruguay (OSE) at the direct intake of Artigas city (from 1995 up to the present time).

During 2004, the Uruguayan Delegation of the Bi-national Cuareim River Commission (CRC) carried out two monitoring campaigns (June and July) in the Cuareim River as well as in four of its Uruguayan tributaries. The measured parameters were: pH, temperature, dissolved oxygen, alkalinity, BOD5, chemical demand of oxygen, oils and fats, Escherichia coli, Phosphorous, Nitrogen, Total Solids, fixed and volatile total solids, suspended solids, total hardness, sodium, calcium, magnesium (no determinations of agro toxics or metals have been made). In addition to this, the National Directorate of Environment (Uy) is seeking the involvement of Artigas Municipality to establish a monitoring program in the basin.

Figure CQ.2.9. shows the location of the two river stations where measurements of water quality have been made in the Cuareim/Quaraí river basin.

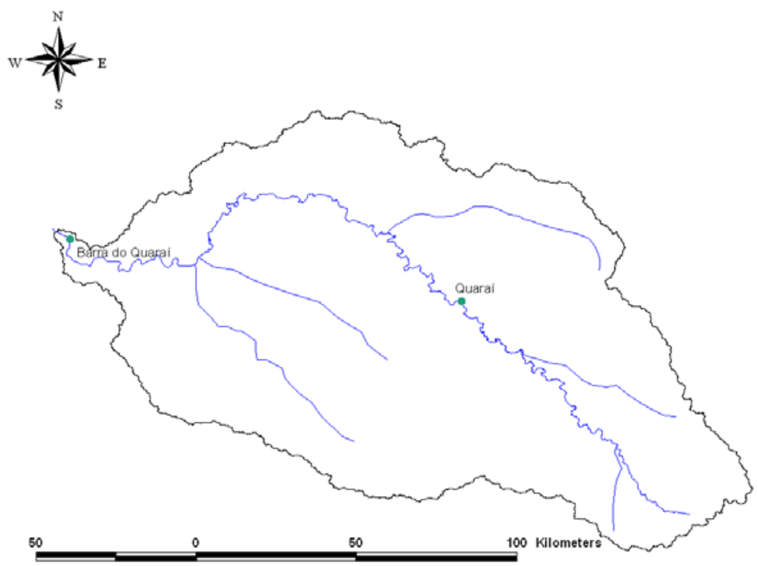


Figure CQ.2.9. Points of periodic water quality monitoring at the Cuareim/Quaraí basin

Water quality analyses have been done at Quaraí/Artigas by CPRM, the brazilian agency for mining research, from 1989 up to date. Table CQ.2.4. lists the parameters that are evaluated and the number of measurements for each parameter.

Table CQ.2.4. Parameters measured at station Quaraí and number of measurements

Parameter	Number of measurements from 1989 to 2005
Air temperature	30
Sample temperature	30
pH	31
Color	10
Turbidity	10
Electric conductivity	25

Hardness	10
QOD	10
BOD	10
Dissolved oxygen	30
Suspended solids	10
Detergents	10
Alcalinity	1
Phosphorus	2
Nytrogen	9
Ntrate	10
Nitrite	10
Cadmium	7
Lead	8
Mercury	6
Phenol	8
Total Coliform	8
Faecal coliform	7
Aldrin	1
Heptachlorine	1
Lindane	1
Fat oils	10
Total Alcalinity	9
Ortophosphorus	7
Discharge	20

At Barra do Quaraí, measurements used to be done during the last decade, but were interrupted in 1998. Table CQ.2.5. resumes the analyses that were made.

Table CQ.2.5. parameters measured at station Barra do Quaraí and number of measurements

Parameter	number of measurements from 1992 to 1998
Air temperature	10
Sample temperature	10
pH	12
Color	7
Turbidity	7
Electric conductivity	9
Hardness	7
QOD	7
BOD	7
Dissolved Oxygen	10
Suspended solids	7
Detergents	4
Total Phosphorus	2
Ammoniacal nytrogen	5
Nitrates	7
Nitrite	7
Cadmium	5
Lead	5
Mercury	5

Phenol index	7
Total coliphorm	7
Faecal coliphorm	4
Fat oils	7
Total alcalinity	7
Ortophosphorus	5
Flow discharge	2

According to the Brazilian water quality classification scheme, which follows Resolução 357/2005 from the National Environment Council (CONAMA), waters frequently show water quality class inferior than 1 (see chapter 3 of this Work Package). Figure CQ.2.10. shows the frequency of water quality samples for each water quality class at Quaraí and Barra do Quaraí.

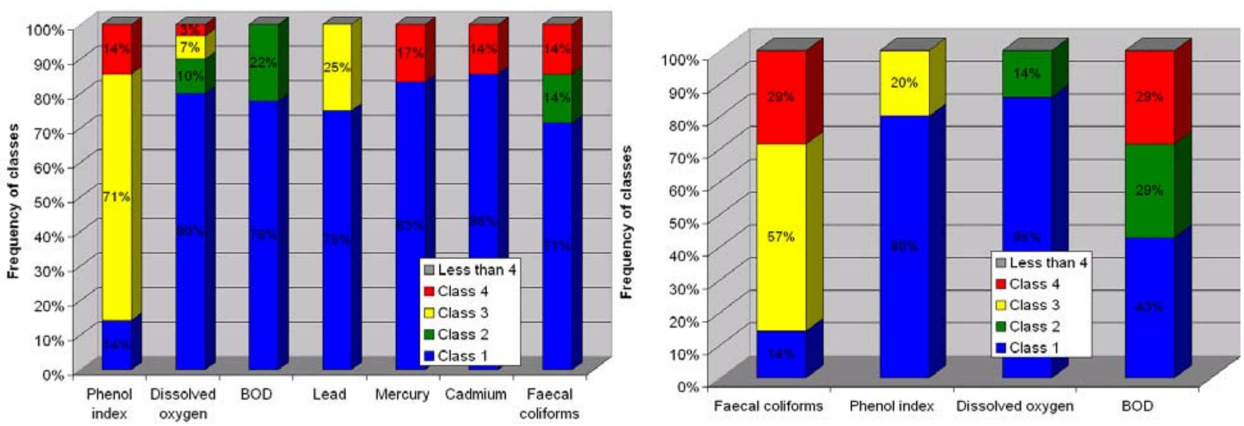


Figure CQ.2.10. Frequency of CONAMA 357 classes for several water quality parameters at Quaraí and Barra do Quaraí

Figure CQ.2.10. shows high frequency of samples under class 1 due to phenols at Quaraí and faecal coliforms at Barra do Quaraí. Heavy metals also appear frequently. Class limits for each water quality parameter are found on resolução 357, annexed to this work package report.

Lake Cocibolca Basin

Water quality

Lake Cocibolca water quality is not monitored in a systematic way. Some data exist but they do not obey to any systematic monitoring program, they are scattered and spread out in time (see Tables LC2.2. to LC.2.6).

Since the last months of 2002 until middle of 2003 three sampling campaigns were executed on water and sediments of Lake Cocibolca and some of its tributaries. The results of the analysis are showed in the tables below. WP1 report contains the results of the point of monitoring in the zone of the Tilapia farms.

Table LC.2.2. Sampling days of main tributary rivers of Lake Cocibolca

River	1th sampling	2nd sampling	3th sampling
Malacatoya	19 feb 2003	6 may 2003	4 jun 2003
Mayales	13 nov 2002	7 apr 2003	10 jul 2003
Acoyapa	13 nov 2002	8 apr 2003	9 jul 2003

Oyate	12 dic 2002	10 apr 2003	8 jul 2003
Tepenaguasapa	14 nov 2002	9 apr 2003	8 jul 2003
Papaturro	15 dec 2002	29 apr 2003	26 jun 2003
Ochomogo	24 feb 2003	7 may 2003	5 jun 2003

Table LC.2.3. Results of Test on Suspended Sediments in Affluents of Lake Cocibolca

Parameter	Compound	Detectable	Quantification microg/kg Highest values
CPB		No detectable	
POC	Dieldrin		2.21 (Río Sábalos)
	p,p´DDE	Detectable	8.80 (Inlet to Río San Juan)
	Lindano	Detectable	3.90 (Outlet of Río San Juan)
HAP		Detectable	No contamination level
Heavy Metals		Detectable	Natural level

CPB: Compuestos Bifenílicos Policlorados; POC: Plaguicidas Organo Clorados
HAP: Hidrocarburos Aromáticos Policíclicos; Surveys done Nov 2002 and July 2003

Table LC2.4. Results Water Analysis of Tributary Rivers to Lake Cocibolca

Parameter	Compound	Detectable	Quantification ng/L Observation
CPB		No Detectable	
POC	p,p´-DDE	Detectable	Compatible levels with aquatic life and drinking water
	Lindano	Detectable	
	P,p´-DDT	Detectable	
HAP	Acenafteno	Detectable	HAP total concentration is smaller than maximum allowable value for drinking water: 200 nanog/L 13.71 – 0.38
	Fenantreno	Detectable	
	Benzo (a) Antraceno	Detectable	
	Pireno	Detectable	
	Benzo (a) pireno	Detectable	
	naftaleno	Detectable	
Heavy Metals	Cd, Cu, Zn, Cr, Mn	Detectable	Below guidelines values for drinking water WHO
	Pb, Ni, Al, Fe	Detectable	Above guideline values for drinking water WHO

Table LC2.5. Physical Chemicals Parameters Lake Cocibolca water

Parameter	Range	Guideline Value
Dissolved Oxigen (mg/L)	9.02 - 5.94	> 4
pH (±0.02)	7.69 – 8.49	4.0 – 9.0
SDT (mg/L)	94 – 148	< 10
Conductivity (μmhos)	206 – 260	50 – 1,500
Transparence (m)	0.60 – 0.80	
Total Hardness (mg $CaCO_3$/L)	62.35 – 73.75	< 120
Silicates (mg/L)	9.28 – 12.76	150 – 500
Total Phosphate (mg/L)	0.012 – 0.067	0.025 – 0.10
Amonia (mg/L)	0.042 – 0.145	< 0.1

Surveys August-Nov 2002 and Jan-March 2003

Table LC.2.6. Nutrients load estimation by tributaries to Lake Cocibolca and outlet by River San Juan

Concept	Total Nitrogen	Total Phosphorus
Bigger instantly load in rainy season	Tepenaguasapa	Tepenaguasapa
	Mayales	Oyate
	Oyate	Acoyapa
Instantly load entrance to Lake by superficial basin drainage, land use and geology, population and rain	4,984 ton/year	907 ton/year
Instantly load discharged by Lake	8,929 ton/year	585 ton/year

Subbasins with the greatest loads were Mayales, Zapote y Tipitapa related to land use and geology.

Sediments in Lake Cocibolca

From the outlet of River Tipitapa and along of East Lake shore the water depth (isobata) 5 m is located 2 km away of shore but in two zones, in front of Río Mayales outlet (Mayales Point) and in front of Rio Las Delicias that isobata is located to 4 or 5 km away of shore. Also between archipelago Solentiname and San Carlos city waters are shallow and the 5 m isobata is founded 10 to 14 km away of shore.

Along west shore of the lake, from Isla Zapatera, the 5 m depth is 1 km away from shore and remains in such way until near Cardenas town in the outlet zone of rivers Cardenas and Sabalos that come from Costa Rica. From there the 5 m isobata move away the shore until to meet the zone of archipelago Solentiname that comes from the east shore. (See Fig. LC.2.9. and LC.2.10.)

Table LC.2.7. Sediment sampling zones in lake bed

Río Nacascolo	Frente Sapoá	Frente Río Mena	Frente Río Pizote
Fte Río Papaturro	Zapote	Desembocadura Río Frío	Fte Río Tule
Río Camastro	Río Ayote	Burro Negro	Río Mayales
Estero El Toro	Estero El Guayabo	Fte Río Malacatoya	Fte San Miguelito
Fte San Carlos	Fte San Jorge	Fte Bahía El Menco	

Table LC.2.8. Results of Test in Sediments of Lake Cocibolca

Parameter	Compound	Detectable	Observation Quantification
CPB		No detectable	
POC	p,p´DDE	Detectable	From 125 to 1,918 pg/g
	Lindano	Detectable	From 81 to 4,201 pg/g
HAP			No contamination level
Heavy Metal		Detectable	Natural level

CPB: Compuestos Bifenílicos Policlorados
POC: Plaguicidas Organo Clorados
HAP: Hidrocarburos Aromáticos Policíclicos
Surveys done on August 14th 2002 and January 27th 2003

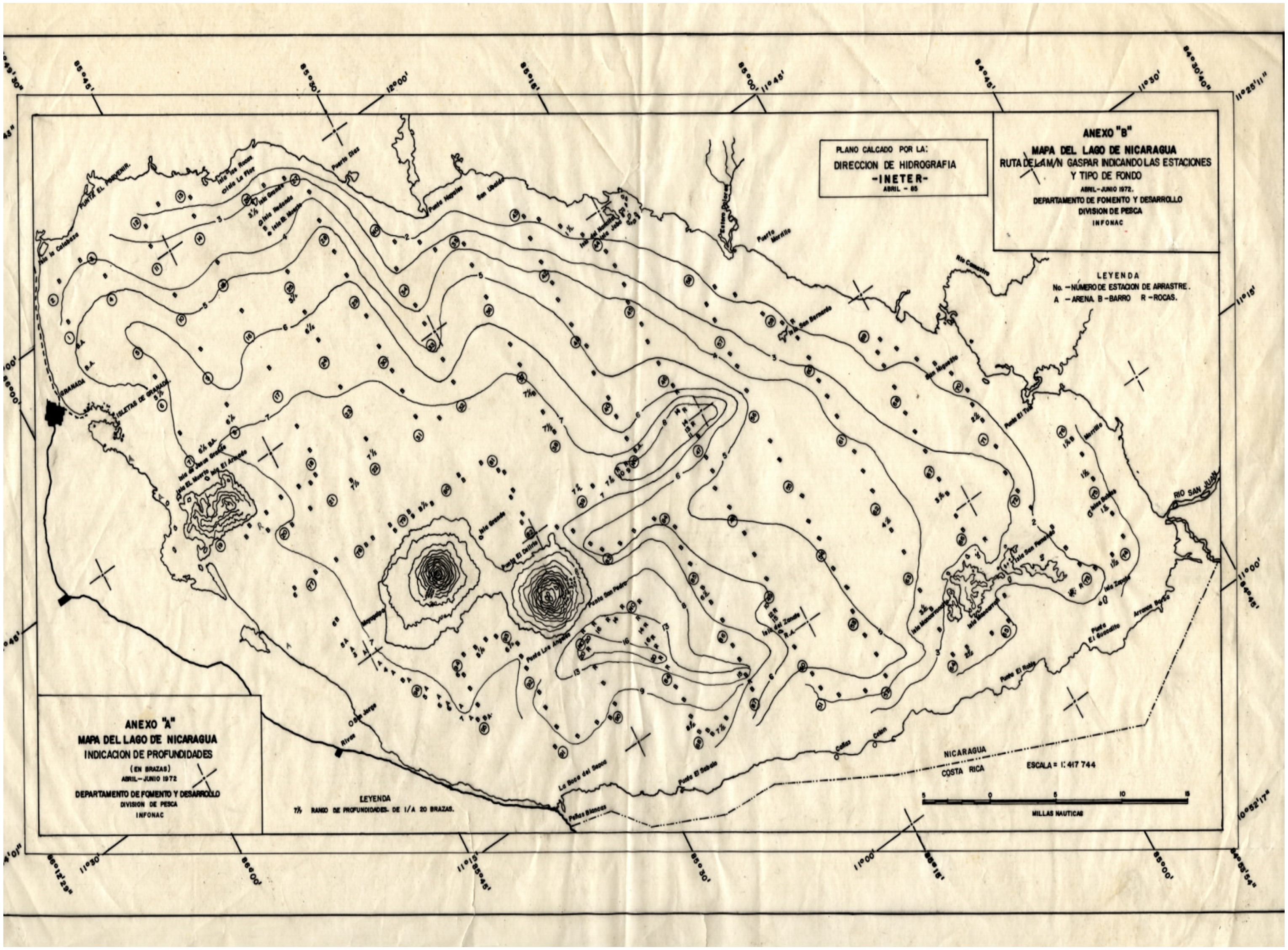
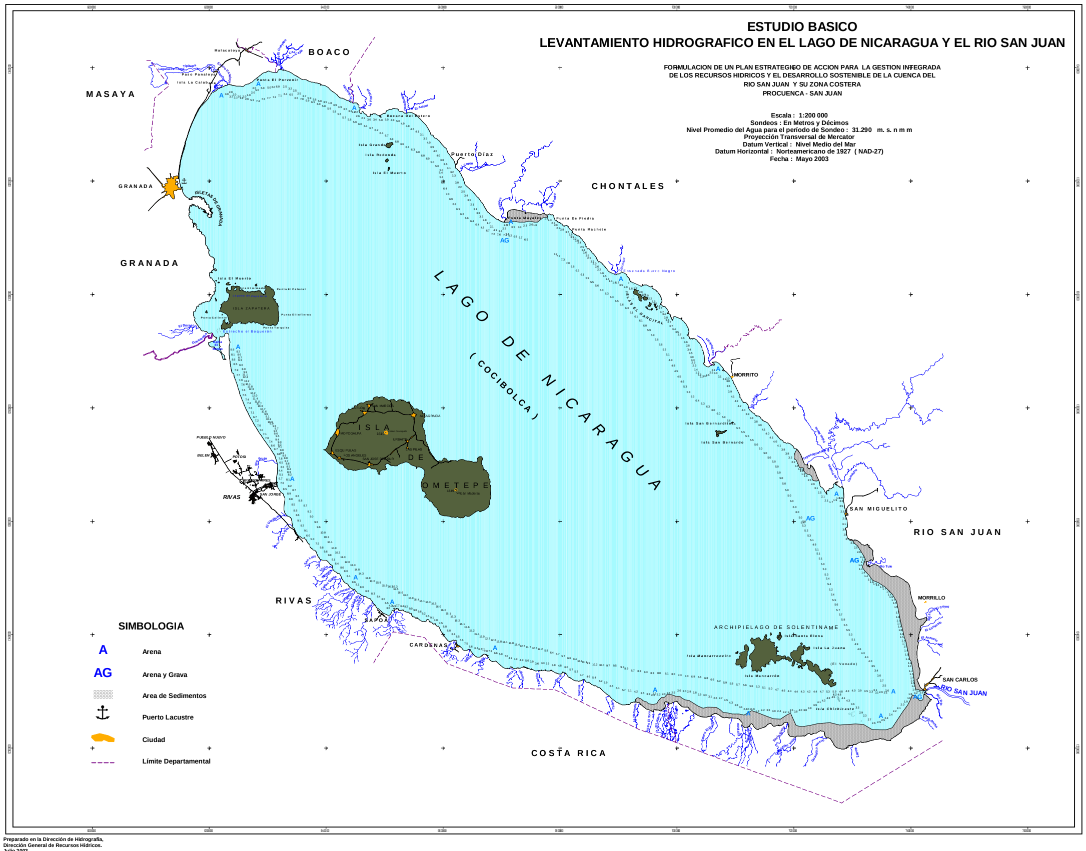


Figure LC.2.9. Bathymetry map for the Cocibolca Lake



INSTITUTO NICARAGÜENSE DE ESTUDIOS TERRITORIALES

MINISTERIO DEL AMBIENTE Y ENERGIA GOBIERNO DE COSTA RICA

MINISTERIO DEL AMBIENTE Y LOS RECURSOS NATURALES GOBIERNO DE NICARAGUA

PROGRAMA DE LAS NACIONES UNIDAS PARA EL MEDIO AMBIENTE

FONDO PARA EL MEDIO AMBIENTE MUNDIAL

UNIDAD DE DESARROLLO SOSTENIBLE Y MEDIO AMBIENTE / OEA

Figure LC.2.10. Cocibolca Lake & tributaries with indication of coastal bathymetry

In addition to the former, there are different sources of water quality data of Lake Cocibolca that were gathered under TWINLATIN. NICANOR, the private company that has Tilapia farms in cages at southwest of Ometepe Island, has seven sampling points, since year 2003, around Ometepe Island and in front of Granada city. Others institutions that have water quality data are CIRA and recently CIEMA, because of this Project, and ENACAL in August - September 2007.

Baker Basin

DGA

The DGA of the Aysén Region has an ongoing water quality monitoring program which includes 5 stations on the Baker river network. First monitoring took place in December 1997. Station names and monitoring frequency for the period 1997-2003 is given in Table B.2.1. The spatial distribution of the stations is shown in Fig. B.2.6.

Table B.2.1. Sampling frequency of the DGA network for the 1997-2003 period

Station	Sampling Period						
	1997	1998	1999	2000	2001	2002	2003
Ibañez River at mouth	1	3	2	3	4	4	3
Engaño River – Austral Highway	1	3	2	3	4	4	3
Tranquilo River – Austral Highway	1	3	1	3	4	4	4
Los Leones River – Austral Highway	1	3	2	3	4	4	3
Outlet General Carrera Lake	1	3	2	3	4	4	3

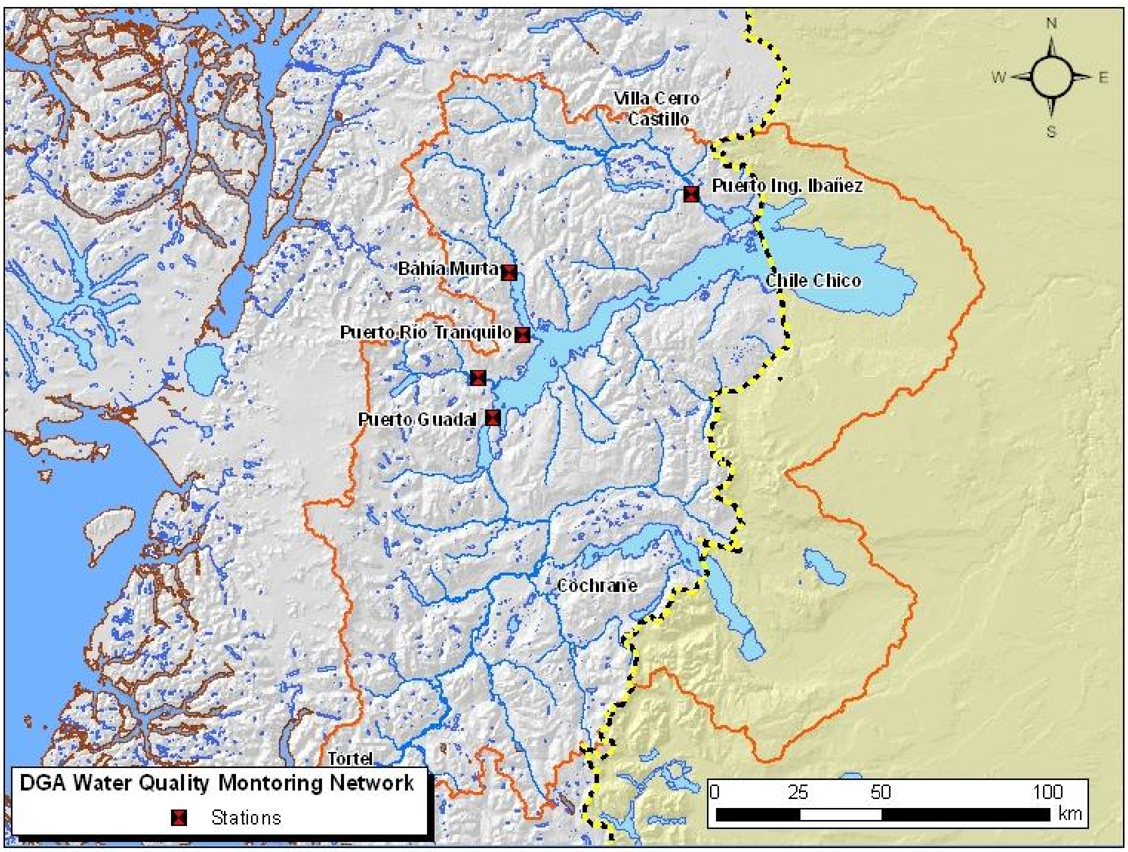


Figure B.2.6. Monitoring stations of the DGA network

Additionally, in 1995, DGA finished a study called: "Análisis redes de vigilancia calidad aguas terrestres". This study included a one-time monitoring effort at 16 stations, realized during August 1991. Two of the stations monitored in this study are also included in the formerly mentioned ongoing DGA monitoring program.

Table B.2.2. The 16 stations monitored in August 1991

Station name & description	Monitoring Date
Outlet General Carrera Lake	18-08-91
Baker River at "*balsa*"	19-08-91
Baker River at Bertrand	19-08-91
Claro River at Aquaculture site (Piscicultura)	20-08-91
Cochrane River upstream of hydropower plant	18-08-91
Cochrane River in Cochrane	18-08-91
Chacabuco River at mouth	18-08-91
Chirifo River at water abstraction point	19-08-91
Chirifo River at mouth	19-08-91
Ibáñez River at mouth	20-08-91
Ibáñez River at bridge Levicán road	17-08-91
Jeinimeni River upstream of irrigation channel	17-08-91
Jeinimeni River at pedestrian crossing (pasarela?)	19-08-91
Los Leones River at mouth	19-08-91
Murta River at mouth	19-08-91
Murta River at km 165	¿?

Three additional monitoring campaigns were executed between 2003 and 2005. Estas campañas tiene como objetivo adquirir mas datos en la cuenca de manera de tener una mejor linea base para futuros proyectos y además contar con datos necesarios para poder establecer la norma secundaría para el río Baker, la cual se encuentra priorizada según el "10° programa priorizado de normas ambientales 2005-2006". The first campaign took place during December 2003, with a total of 22 sampling points. The second one was executed during March 2004, with 17 sampling points, while the third one was executed in December 2005. In this last campaign, 19 points were sampled (Fig. B.2.7). Samples were analyzed by DGA, EULA and "Aguas Patagonia". Analyses included physicochemical parameters, biological parameters such as benthonic macro-invertebrates, periphyton, bird fauna (field observations), and the bacteriological parameter faecal coliforms.

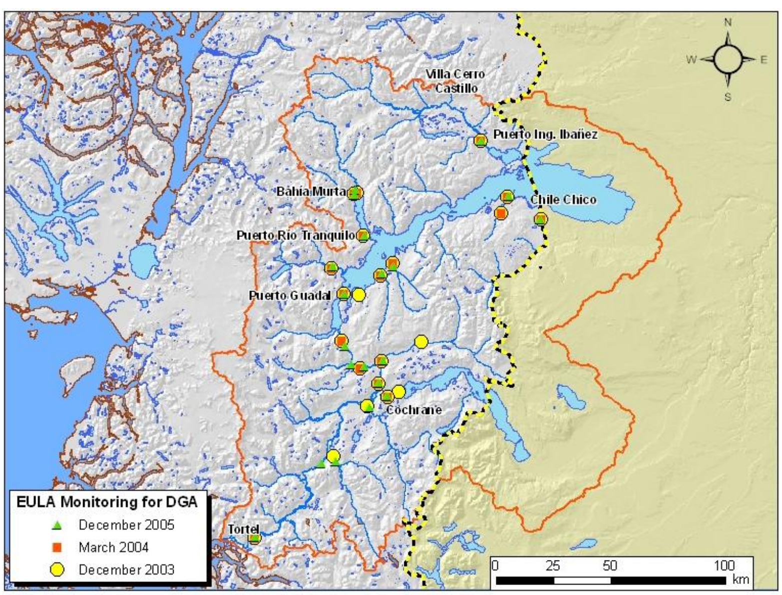


Figure B.2.7. Station sampled by DGA during the 3 additional field campaigns

Those extra monitoring campaigns were made because in some parts of the river the information is very scarce or inexistent, and extra parameters, like pesticides, were measure at the segment were water quality information was available.

In the design of these campaigns, the following criteria were used for selecting the location of the sampling stations:

- the availability of flow data from fluviometric stations (Ibañez, Jeinimeni, Cochrane and Baker River, as well as the "el Baño" Stream)
- the location of stations from DGA's ongoing monitoring program (Ibañez, Tranquilo, Leones and Engaño River, and the outlet of the General Carrera Lake)
- Importance of water use from the different rivers (Maitenes, Duna, Chacabuco, Furioso, Los Ñadis River and the "del Salto" Stream)

CONAMA

The Chilean National Environmental Commission CONAMA of the Aysén Region conducted 2 studies in the framework of the **ACCA** Project ("*Área de Conservación de Cultura y del Ambiente*"). El proyecto ACCA busca mejorar el conocimiento y protección del patrimonio natural y cultural del territorio sur de Aysén, incorporar principios de uso sustentable de los recursos naturales en los procesos productivos, favorecer el desarrollo de una cultura ambiental local, promover que los asentamientos humanos crezcan en armonía con el entorno natural, cultural y socioproductivo, producir la consolidación de las estructuras de gestión del territorio y promover las identidades locales y la imagen de marca del territorio del ACCA.. La creación de esta Área de Conservación, pionera en Chile, incluye 5 comunas (Río Ibáñez, Chile Chico, Cochrane, Tortel y O'Higgins); más de 5.000.000 de hectáreas de territorio; cerca de 10.000 habitantes (distribuidos en 15 localidades2); 2 Parques Nacionales3 y 4 Reservas Nacionales4; Una Reserva de la Biosfera5; 9 Monumentos Nacionales6; y varios íconos regionales, como los Campos de Hielo (Norte y Sur), los 3 Lagos Binacionales (General Carrera/Buenos Aires, Cochrane/Pueyrredón y O'Higgins/San Martín), la Laguna San Rafael, el río Baker y los principales destinos de montaña (Cerro Castillo y Cerro San Lorenzo).

Both studies include the analysis of water quality. The first study (2002) is called "*Hydrobiological Protection of the Jeinimeni River*". The second one (2003) is called "*Limnological study of the General Carrera Lake*".

In the first study, samples were taken 4 times during 2002 at 6 points (Table B.2.3).

Table B.2.3. Stations from the "Hydrobiological Protection of the Jeinimeni River" Project

Station	Name	Date of monitoring			
		12/09/2002	23/09/2002	07/11/2002	26/11/2002
1	Start of Jeinimeni River		X		
5	"Pedregoso" Creek			X	X
6	"Quebrada Honda" Creek			X	X
7	Water Intake, last gate	X		X	X
8	2 km upstr from "Jeinimeni 2" bridge	X		X	X
9	Gates of Auxiliary Water Intake	X		X	X

Figure B.2.8. Location of the sampling stations in the Jeinimeni Subbasin

The second study on the General Carrera Lake included 8 sectors which were sampled 6 times (March-April 2001; August–September 2001; March-April 2002; September 2002; March 2003 and August 2003). The sampling network included the bays of: Murta, Tranquilo, Guadal, Fachinal, Jara, Chile Chico and Ibañez, the main tributaries to these bays and the outlet of the lake ("*La Pasarela*" sector) (Fig. B.2.9., Table B2.4). La tercera campaña de muestreo, al igual que las primeras dos consideró un nuevo monitoreo de calidad de agua, metales pesados y nutrientes, manteniendo los sectores y estaciones de muestreo. Las campañas 4, 5 y 6 se focalizaron solamente en el análisis de fósforo y nitrógeno. In each bay, three stations were sampled for sediment and water (nitrógeno total, fósforo total, sólidos totales disueltos y clorofila a), and in one station in situ determination of physicochemical water quality parameters was conducted (temperature, conductivity, disolved oxigen and redox potencial), Secchi depth was also measured. Se muestrearon sedimentos (estación 1 a la 4) mediante una draga de tenazas con la finalidad de analizar metales pesados (cadmio, cobre, cromo, hierro, manganeso, plomo, zinc y mercurio). .In the selected tributaries, biological (benthos, plankton) and chemical (metals, nutrients) sampling was done in both water and sediments.

Table B.2.4. Sectores y estaciones de muestreo de agua. Estación 1: tributario principal; Estaciones 2 a 4: muestreo de agua y sedimentos; Estación 5: medición *in situ* de parámetros físico-químicos

Sector	Estación
Puerto Guadal	Estero Los Sapos (Estación 1)
	Estación 2
	Estación 3
	Estación 4
	Estación 5 (sonda)
Pto. Tranquilo	Río Tranquilo (Estación 1)
	Estación 2
	Estación 3
	Estación 4
	Estación 5 (sonda)
Bahía Murta	Río Murta (Estación 1)
	Estación 2
	Estación 3

	Estación 4
	Estación 5 (sonda)
Puerto Ibañez	Río Ibañez (Estación 1)
	Estación 2
	Estación 3
	Estación 4
	Estación 5 (sonda)
Chile Chico	Río Jeinimeni (Estación 1)
	Estación 2
	Estación 3
	Estación 4
	Estación 5 (sonda)
Bahía Jara	Estero Las Chacras (Estación 1)
	Estación 2
	Estación 3
	Estación 4
	Estación 5 (sonda)
Fachinal	Río Avilés (Estación 1)
	Estación 2
	Estación 3
	Estación 4
	Estación 5 (sonda)
La Pasarela	

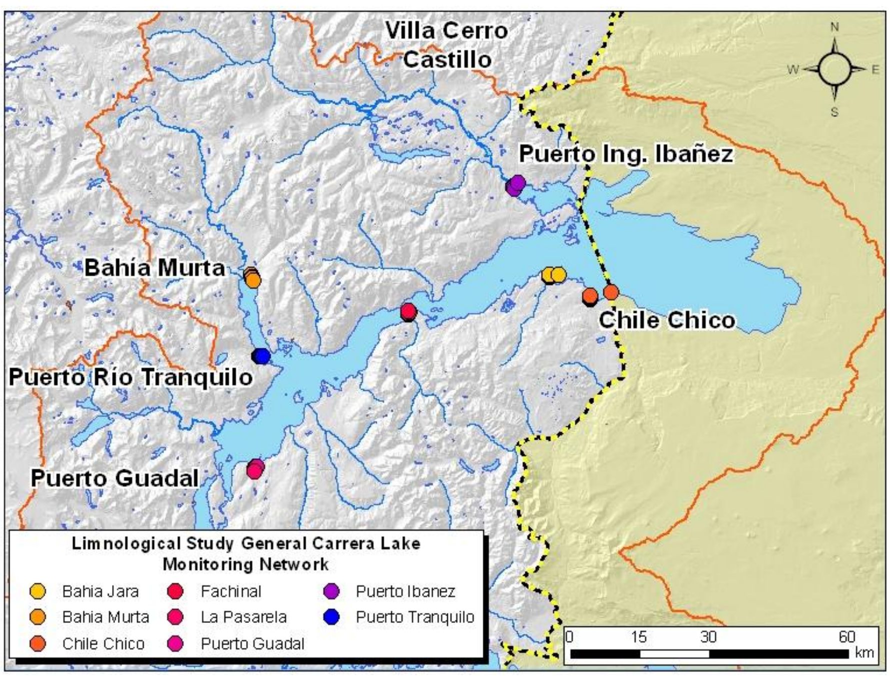


Figure B.2.9. Sampling stations of the "Limnological Study of the General Carrera Lake"

SAG

Another source of water quality information is the Chilean Agriculture & Livestock Service **SAG.** SAG has information on water quality from 14 points within the Baker River Basin, for the period between 1999 and 2003 (Table B.2.5).

Table B.2.5. Number of samples per station/year of the SAG monitoring

River	Location	Sampling per year				
		1999	2000	2001	2002	2003
Chacabuco	Bridge	4	1	1		
Cochrane	Escobar Bridge	2	2	3		
Cochrane	Turbine	2	2	3		
Horquetas	Bridge	1	1	2		
Ibañez	DGA Station	3	0	2		
Jeinimeni	Water Intake	0	1	1		
Jeinimeni	Mouth	0	1	1		
Leones	Bridge	3	1	2		
Maitenes	Bridge	2	0	0		
Manso	Bridge	3	0	4	1	1
Maquis	Bridge	3	1	2		
Murta	DGA Station	3	1	2		
Ñadis	Bridge 1	1	1	1		
Tranquilo	1000 m	3	1	2		

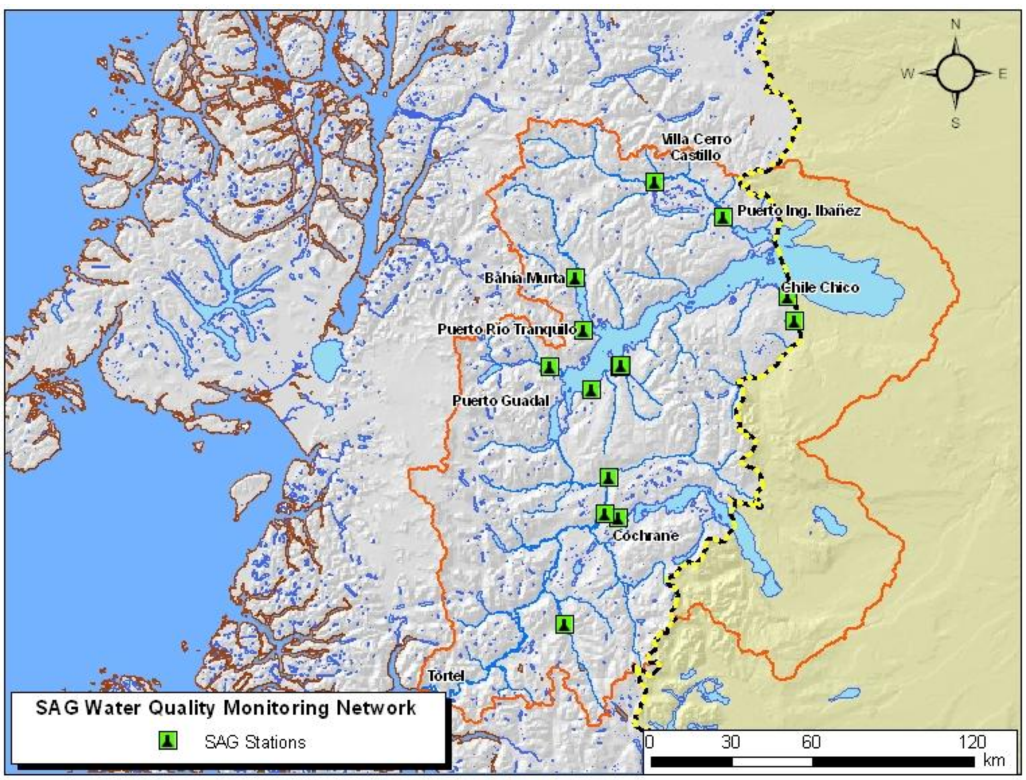


Figure B.2.10. Location of the SAG monitoring sites

- **Cerro Bayo Mining Company**

Finally, the Cerro Bayo Minning Company, which is loacted around 20 km southwest from Chile Chico, between Puerto Guadal and Cochrane, had a monitoring program running between 1995 and 2003. This program considered sampling at 10 points (Fig. B.2.11).

Por otro lado en mayo del año 2005 la Compañía minera Cerro Bayo y CONAMA firman un convenio de cooperación ambiental, dicho acuerdo tiene por finalidad la implementación de medidas de gestión para la conservación de la biodiversidad asociada a Jeinimeni - Bahía Jara, lugar donde se inserta la compañía minera. Esto se enmarca en la Estrategia Nacional de Biodiversidad, cuyos objetivos son: relevar la diversidad biológica, valorarla y generar mecanismos para su conservación. En la Región de Aysén se priorizaron 6 sectores relevantes: 3 marinos y tres terrestres. Terrestres: Sector Hudson; Jeinimeni- Bahía Jara y Entrada Baker-Valle Chacabuco. Marinos: Islas Oceánicas; Corredor Isla Kent-Quitralco y Bahía Anna Pink-Taitao.

Table B.2.6. Cerro Bayo Mining sampling Frequency. Detach the three stations we have data
(data from stations marked in blue is currently available from the TWINLATIN database)

River	Station Code	Sampling per year			
		1995	1996	1997	2003
"la Tina" Stream	FS-4	2	2	1	0
	FS-5	3	2	1	0
"El Baño" Stream	FS-6	3	2	1	3
	FS-7	3	2	1	3
	FS-8	3	2	1	0
General Carrera Lake	FS-9	3	3	0	2
	FS-10	3	3	0	0
"Laguna Verde" lake	FS-11	3	3	0	2
Chacabuco River		0	0	0	1
Horquetas River		0	0	0	1

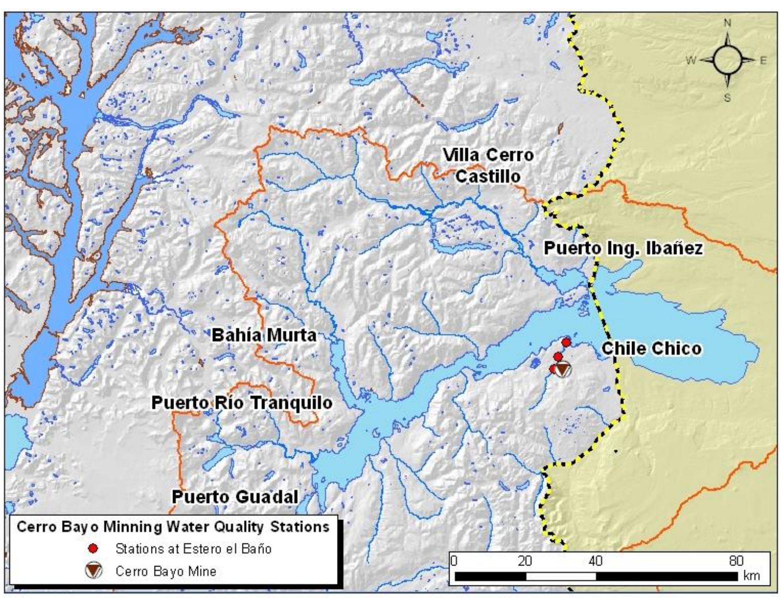


Figure B.2.11. Monitoring stations from Cerro Bayo currently incorporated in the TWINLATIN Baker River Database

In the Baker River basin a series of monitoring of water quality has been carried out, since approximately 1991, which have been executed by universities, governmental institutions, and private companies. Next, the more important monitoring done in the basin and this that are currently in process are described. These include physical-chemical, as well as biological parameters.

Table B.2.7. Sampled parameters in the different campaigns

Parameter	DGA 1991	DGA Red Monit.	DGA Campaigns (2003 – 2005)	SAG	CONAMA	Cerro Bayo
Conductivity	x	x	x	x	x	x
Temperature	x	x	x		x	x
Ph	x	x	x	x	x	x
Dissolved Oxygen		x	x		x	
Boron	x	x				x
Chloride		x				x
Sulfide			x			x
Aluminum		x				x
Arsenic	x	x		x		x
Cadmium		x		x	x	x
Copper	x	x		x	x	x
Chrome		x		x	x	x
Iron	x	x			x	x
Manganese		x		x	x	x
Mercury		x		x	x	x
Molybdenum		x		x		x
Nickel		x				x
Lead		x		x	x	x
Selenium		x		x		x
Zinc		x		x	x	x
Reason d		x		x		
Dissolved Solids			x	x		x
Suspended Solids			x		x	
Detergents			x			
Total Coliforms			x			x
Fecal Coliforms			x			x
DBO5			x		x	x
Color			x			
Captan			x			
Dimetoato			x			
Cyanide					x	x
Bicarbonate		x				
Carbonate		x				
Nitrate		x		x		
Total Nitrogen			x			
Phosphorus		x				
Total Phosphorus			x			
Phosphate				x		
DQO		x				x
Calcium	x	x		x		
Magnesium	x	x		x		
Silver		x				x
Potassium	x	x		x		
Fluorine			x			x
Turbidity			x			
% Salinity				x		
Na %				x		
Gold						x
Barium						x

Beryllium						x
Lithium						x
Vanadium						x

3. MONITORING UNDER TWINLATIN

Norrström Basin

Flow-driven sampling of phosphorus and nitrogen in agricultural areas near Lake Mälaren

Introduction

Eutrophication of the Baltic Sea and Lake Mälaren, the latter providing drinking water for 1,5 million people, poses a serious environmental problem with increased algae blooms and oxygen depleted bottoms. The area nearby Lake Mälaren covers 20 % of the Norrström basin and is dominated by agricultural areas and open land. Agriculture accounts for 2/3 of the total loss of phosphorus which means that the area nearby Lake Mälaren have a large impact on total transport to the lake, especially since the transport pathways are short due to direct drainage with little retention from small streams, ditches and tiles. Estimates of the total losses of phosphorus from the area ranges from 103 to 280 tonnes/year and these large uncertainties suggests that there is a need for improved modelling of the phosphorus cycle as well as better estimates of the internal load from Lake Mälaren, which can be substantial. The standard procedure of nutrient monitoring is fixed-interval sampling of phosphorus and nitrogen at a large number of locations, typically in larger lakes and streams. The fixed-interval sampling means that the accuracy is suffering during periods with high flow rates and during the snow-melt in the spring when phosphorus is flushed out at high concentrations. The combination of high flow rates and high concentrations is giving rise to a substantial amount of the annual mass transport during short periods of time. One way to overcome this problem is flow-driven sampling at fewer but representative locations. This will lead to more accurate quantification of total loads and a better understanding of the dynamics of phosphorus (and nitrogen) losses from agricultural land.

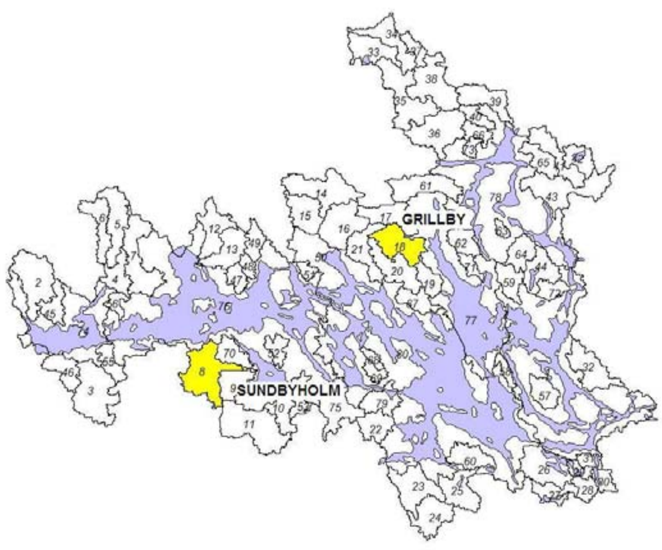


Figure N.3.1. Lake Mälaren catchment as represented in the SWAT-model. Sub-basin division coincides with the swedish national division system. The catchments where the flow-driven sampling stations are located are indicated with yellow

Distributed hydrological modelling of nutrient transport for the area nearby Lake Mälaren is carried out in the TWINLATIN-project and to support the modelling efforts flow-driven sampling were performed at two relatively large catchments that are dominated by agricultural land with streams draining directly to Lake Mälaren.

Research catchments

For the TWINLATIN research in the Norrström basin flow-driven sampling stations were installed in two catchments with streams draining the south-western (Sundbyholm) and north-eastern (Grillby) parts of Lake Mälaren. The catchments were chosen to coincide with the national sub-basin division system and to have at least 50 % of the landuse as agricultural land and no major known point source discharges to the streams (e.g. waste water treatment plants). The catchments were the measurement were made are also sub-basins in the SWAT-model set-up for the area nearby Lake Mälaren (Fig. N.3.1.) The Sundbyholm catchment in the SW is 85 km^2 and 52 % is occupied by agricultural land and the estimated annual mean stream discharge is 510 l/s. The Grillby catchment is 40 km^2 and 66 % of the catchment is occupied by agricultural land and the stream has an annual mean discharge of an estimated 240 l/s. More information on the characteristics of the region (e.g. topography, land-use, soil types and climatology) can be found in the chapter dealing with nutrient modelleing in the Norrström basin.

Flow-driven sampling

The measurement principle of flow-driven sampling is that a predefined volume of streamwater pass between each sample is taken. The ISCO sampling device is connected to a velocity sensor using Doppler technology placed on the bottom of the stream which together with the measured area of the cross-section at different depths gives the flow. The water depth is measured with an integral pressure transducer. When the sampler is activated a predefined amount of water is pumped to the sampling device and distributed to a bottle (Fig. N.3.2.). The sampling device consist of 24 bottles and the water sample is conserved using sulphuric acid. During low flow periods, in the summer, typically 1-2 samples a week is retrieved whereas during high flows at least one sample a day is taken. The sampling device can be accessed via a modem, meaning that the sampling status is remotely monitored and flow data can be retrieved at any time. A total of about 130 samples were collected from each flow-driven sampling station during the measurement period.

Figure N.3.2. Flow-driven sampling of phosphorus and nitrogen. Top left: Grillby site looking down-stream through 5 m wide bridge. The Doppler velocity device and inlet pipes are mounted on centre of the bottom. Note the historic water levels on the bridge wall. Top right: Box containing sampling device. Bottom left: Sampling device. The inside is covered with insulating material. The heater to keep temperature above 0° C is seen in the centre. Bottom right: Bottom of the sample container with 24 bottles. In the lower right corner of the picture, the top unit with the pump and electronics, is seen. Photos: Tony Persson, IVL.

Results and discussion

Hydrology

Flow-driven sampling of total phosphorus and nitrogen were performed from June/July 2007 to June 2008 at two stations located at the outlets of the streams that drain the Grillby and Sundbyholm catchments, respectively.

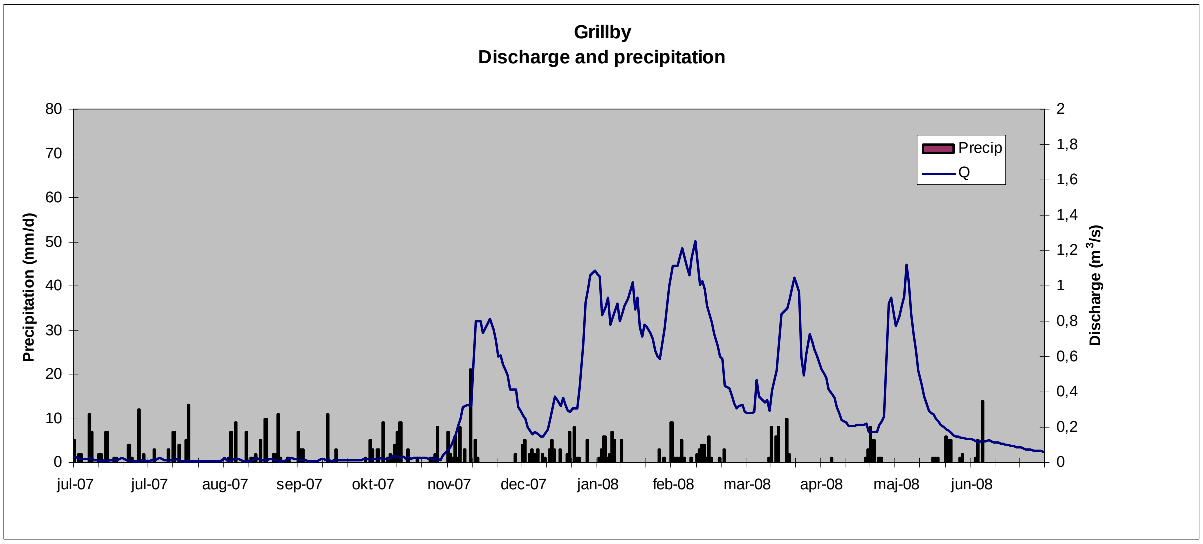


Figure N.3.3a. Discharge and precipitation at the flow-driven sampling station at Grillby.

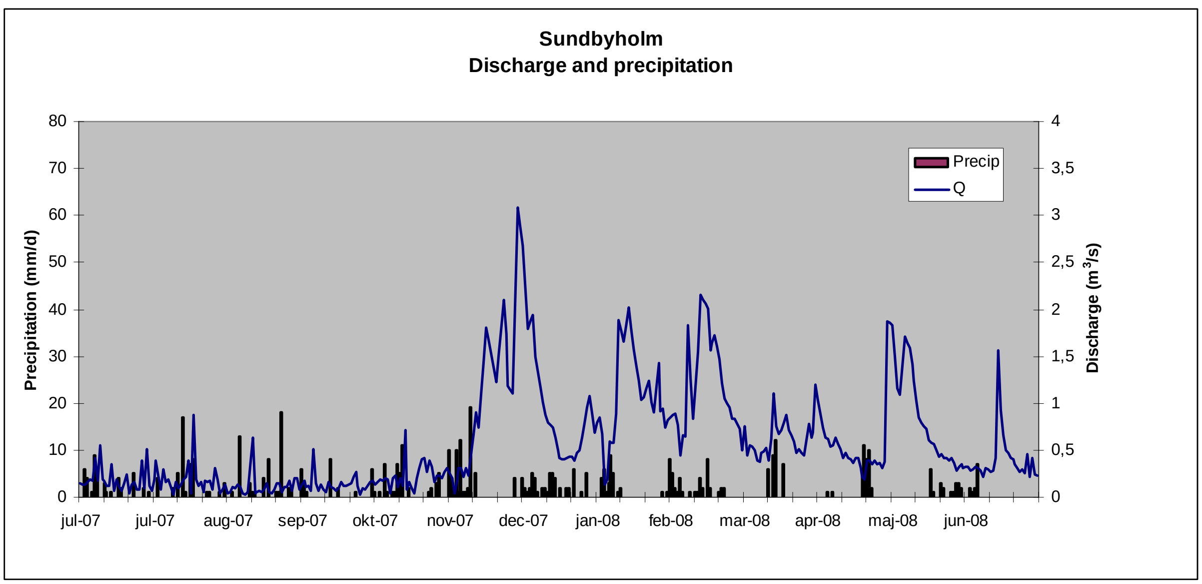


Figure N.3.3b. Discharge and precipitation at the flow-driven sampling station at Sundbyholm.

The observed discharge in both streams was low and steady with no significant peaks during the period from July through October 2007 (Fig. N.3.3a-b). The summer of 2007 was wet, but also relatively warm and most of the water from the catchments were lost to the atmosphere because of the high evapotranspiration rates. The flow rates were very low, typically about 10-20 l/s at Grillby and 50-100 l/s at Sundbyholm. The fall was warm and dry, especially the month of September, and moderate flow rates were maintained in both catchments. The precipitation that fell in November in combination with decreasing temperatures and low evapotranspiration saturated the agricultural soils and when a more intense rain episode occurred in the beginning of December 2007 the discharge increased dramatically in both streams (Fig. N.3.3a-b). The winter of 2007-2008 was warm and the number of days with maximum temperatures below 0 ºC were few and no lasting snow cover were built-up. The lack of a persistent snow-storage is reflected in the discharge as the streams respond quickly with distinct peaks when precipitation is falling as rain. The absence of a noticeable spring flood is also somewhat uncharacteristic for these latitudes. The difference in size and storage capacity between the catchments is mostly reflected in the summer discharge which is much higher in Sundbyholm. The latter catchment has also a more toothed hydrograph due to the larger differences in time of concentration of flow events and also to some extent it is due to the effects of non-uniform precipitation patterns over this larger catchment. A large flow peak in mid-June 2008 is recorded in Sundbyholm but absent in the Grillby hydrograph clearly illustrating the regional differences between these two catchments draining to the same large lake (Fig. N.3.3a-b).

Phosphorus

The measured phosphorus concentrations at the flow-driven sampling station in Grillby are very low during the five-month period from July through October 2007 and typical values are 10 µg/l (Fig. N.3.4a). As the first large peak flow occurs in the stream in the beginning of December the phosphorus concentrations rise dramatically up to values over 300 µg/l. The amount of phosphorus flushed-out of during this first peak flow event is a significant contribution to the annual load. After the initial rise the concentrations decreases proportionally more rapid than the river discharge and the concentrations then fall back to approximately the same levels as measured during the summer and fall period even though the flow is about 10 times larger than the summer flow. A small flow peak in the beginning of January 2008 does not show increased concentrations and the same is also observed for a small flow peak in the beginning of March. The four larger peaks flow events from January and onwards are associated with high concentrations of phosphorus although with somewhat lower peak values (about 200 µg/l) than compared with what was measured during the first flow peak of the winter season in December.

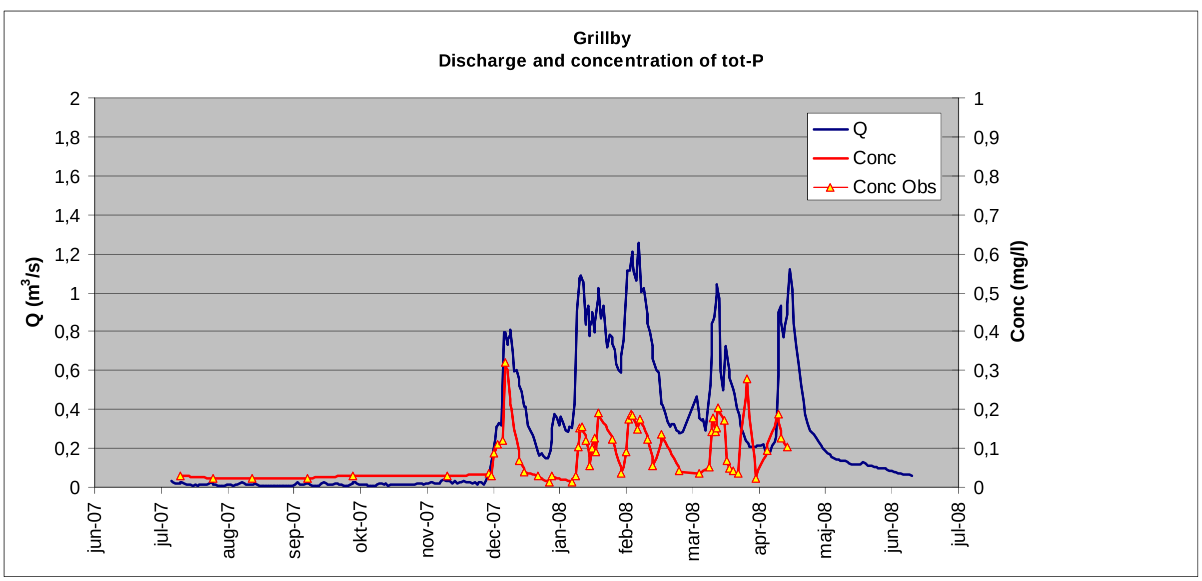


Figure N.3.4a. Discharge and concentration of total phosphorus at the flow-driven sampling station in the Grillby catchment.

For the Sundbyholm catchment the dynamics of phosphorus flush-out is showing a similar pattern as for Grillby and the most pronounced increase in concentrations is also here associated with the first peak flow event of the winter season in December 2007 (Fig. N.3.4b). This particular peak consists of two parts with a small decrease in both river discharge and phosphorus concentration in-between. The second part of the peak is higher both in terms of stream discharge and phosphorus flush-out and clearly illustrates the quick flow increase to relatively small amounts of precipitation when the soils are saturated (Fig. N.3.3b and N.3.4b). The peak concentrations of more than 500 µg/l are much higher in the Sundbyholm catchment than in Grillby. Small flow peaks does not give a significant increase in the phosphorus concentrations and this pattern was also observed in Grillby. An major difference between the two catchments are that the "background concentrations" during the winter period is proportionally higher in Sundbyholm than compared with Grillby and this might depend on several different factors or a combination of these such as differences in land use, soil type, crop type, location and area used for agriculture, fertilizing practices, livestock density etc.

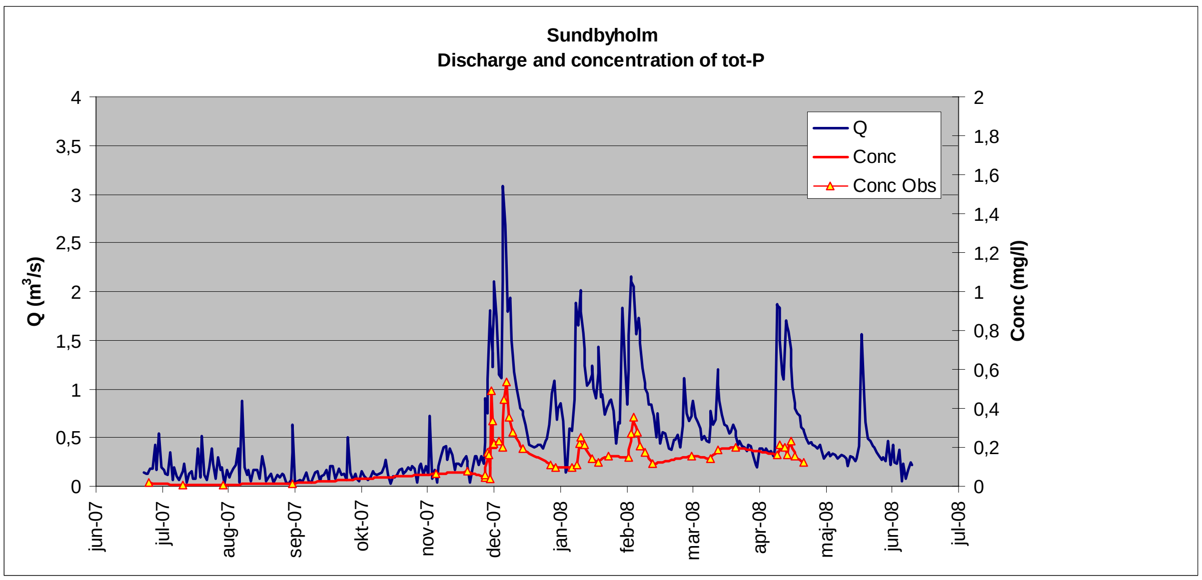


Figure N.3.4b. Discharge and concentration of total phosphorus at the flow-driven sampling station in the Sundbyholm catchment.

Although it was not analyzed separately it is likely to attribute particulate phosphorus to the very high peak concentrations during especially the first flow peaks of the winter season. This is due to the intense sediment transport in the streams that occurs when rain fall on already saturated soils (Fig. N.3.5).

Figure N.3.5. Sundbyholm. Left picture: June 2007. Right picture: January 2008. Photos: Tony Persson, IVL.

Nitrogen

In addition to the phosphorus measurements total nitrogen was also sampled but no detailed analysis will be presented here since the focus of the TWINLATIN research in the Norrström basin was on the quantification and dynamics of phosphorus losses for modelling purposes. The measured nitrogen concentration in the two catchments exhibits very different patterns. In Grillby the highest concentrations are found during the low flow period from July to November 2007 where the concentration is very high and typically around 10 mg/l whereas the concentrations drop to about 6-7 mg/l from January and onwards (Fig. N.3.6a). The lowest concentrations of about 5 mg/l were observed during the peak discharge events.

In Sundbyholm the nitrogen concentration during the low flow period until November 2007 is around 0,5 mg/l and the variation is very small (Fig. N.3.6b). From December 2007 the concentrations rises with a factor 10 to around 5 mg/l thus coinciding with the high flows during the winter season. For Sundbyholm there is also a weak indication of an increased flush-out of nitrogen during events with the highest peak flows. The differences between the catchments might depend on a combination of the same factors that accounts for the differences in phosphorus concentrations.

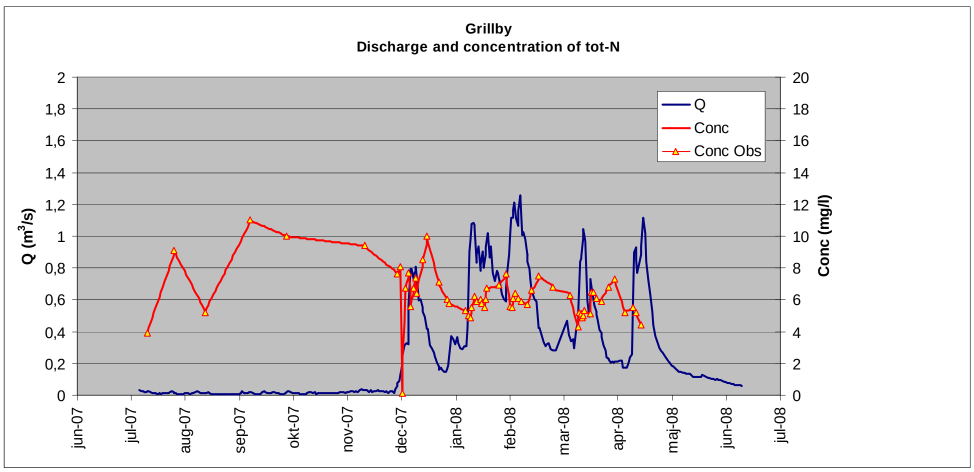


Figure N.3.6a. Discharge and concentration of total nitrogen at the flow-driven sampling station in the Grillby catchment.

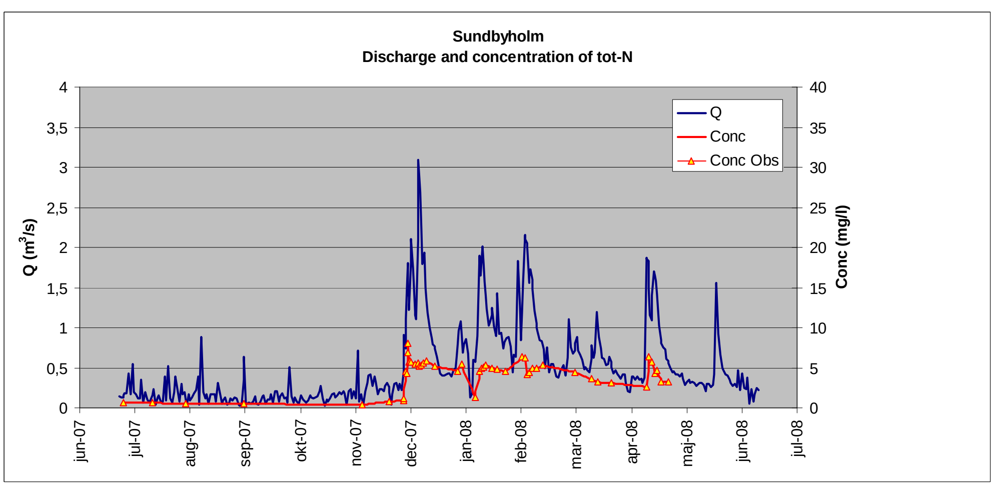


Figure N.3.6b. Discharge and concentration of total nitrogen at the flow-driven sampling station in the Sundbyholm catchment.

Total loss of phosphorus and nitrogen

The total loss of phosphorus and nitrogen from the Grillby and Sundbyholm catchments for the sampling period is presented in Table N3.1.

Table N.3.1. Total mass transport of phosporus and Nitrogen

Catchment	Measurement period	Phosphorus, tot-P (kg)	Nitrogen, tot-N (kg)
Grillby	2008-07-15 to 2008-04-11	585	32561
Sundbyholm	2008-06-15 to 2008-04-21	2117	50143

The areal loss per unit agricultural land from the Grillby catchment with a size of 40 km^2 and occupied with 66 % agricultural land was 0,22 kg/ha for the sampling period. From the Sundbyholm catchment with a size of 85 km^2 and with 52 % occupied by agricultural land the loss of phosphorus was 0,48 kg/ha for the sampling period. Based on these figures an estimate of the areal loss on an annual basis should be 0,3 kg/(ha*year) for Grillby and 0,6 kg/(ha*year) for Sundbyholm.

Conclusions

It is shown that flow-driven sampling of phosphorus (and nitrogen) is an efficient and reliable method for quantification of nutrient losses from agricultural watersheds since the total loads can be calculated with high accuracy and the complex dynamics of phosphorus losses is captured. A limited number of peak flow events during the winter and spring of 2007-2008 accounts for the majority of the annual loss of total phosphorous from the agricultural catchments of Grillby and Sundbyholm to Lake Mälaren in central Sweden. It is evident from both catchments that the first high flow event of the winter season exhibits the highest concentrations of phosphorus measured during the sampling period. This flush-out is attributed to high flow events occurring when rain fall on already saturated soils giving high sediment loads with an increased transport of particulate phosphorus.

Thames Basin

Identification of priority data needs

The current and future monitoring programmes in the Pang and Lambourn tributaries of the Thames are described in detail in a previous chapter of this report. This section focuses on the basin-wide monitoring programmes in the Thames, which are replicated in other basins across the UK.

Beginning with the Industrial Revolution, the Thames has had a history of pollution, particularly in the London area. The Thames Valley, a term referring to the lower part of the basin, is dominated by “knowledge-based” industries, particularly information technology firms, but also pharmaceuticals, specialist manufacturing and professional service industries. These are attracted to the good communication links, the skilled workforce and the attractive environment. Agriculture, both crops and livestock, is the main land use in the rural areas of the basin, and this also contributes pollution, predominantly as high nutrient runoff from the agricultural land.

Successive campaigns to clean up the environment have been aimed at improving water quality: firstly gross organic pollution and latterly nutrient enrichment. However, whilst river water quality may be improving, groundwater pollution is an progressively more important issue with nitrate concentrations in groundwater across the Thames basin continuing to increase slowly. The tidal Thames is now cleaner and healthier than it has been for nearly 200 years and supports a wide variety of wildlife including 119 species of fish, though through and downstream of London it is still particularly contaminated with pollutants.

The environment of the entire Thames basin is monitored by the Agency against a series of indicators, developed in discussions with a range of external organisations and presented in the annual Regional State of the Environment Report. The selection of key indicators is based on a number of criteria, including: the importance of the indicator in illustrating a key aspect of the environment in the Thames basin; its ability to record environmental change in a meaningful way; and the regularity with which the data for the indicator are updated. Many of the indicators are related to one another e.g. rainfall amounts affect river flows and the quality of groundwater, which in turn affect water quality. The Agency collects many of the data used to compile the indicators, though some are obtained from other organizations. The Agency is continually working to develop new tools and techniques for environmental monitoring.

A state-pressure-response framework (Figure T.3.1) is used the present the indicators.

- State indicators measure the quality and quantity of natural resources e.g. quantity of river flow, chemical river water quality (Table T.3.1).

  Assessing the state of the environment at a point in time is a very complex undertaking. Lack of any previous comprehensive or fully integrated means by which the state of the environment as a whole has been assessed is, in part, because many of the standards which apply to environmental materials have evolved independently to protect against specific risks. The different aspects of the state of the environment can be differentiated by distinguishing between the three environmental media: water, air and land.

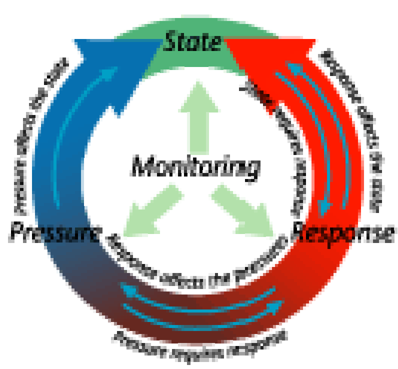


Figure T.3.1. State-pressure-response framework used by the Agency

- Pressure indicators measure the forces on the environment which are usually caused by human activities, but may include measures of pressure caused by natural processes e.g. long-term change in temperature, rate of water demand (Table T.3.2).

  The pressures on the environment arise from both controllable and non-controllable sources. Some pressures relate to geographical position, the nature of the countryside, population density and distribution. Some pressures arise directly from controlled releases of substances to the aquatic environment, to the atmosphere and into and onto land. Pressures also arise from the abstraction of materials from the environment, most notably that of water from both surface and groundwater sources.

- Response indicators assess the normally beneficial impacts of activities, which aim to address environmental problems e.g. technical reaction, management and policy response (Table T.3.3).

  The response indicators illustrate actions or activities intended to address the current state of the environment, or the pressures acting upon it.

The trend in these indicators over time is classified as: improving or positive progress; change uncertain or mixed; or deteriorating or no/unfavourable progress. The results to date, and the predicted future trends, illustrate the intense pressure that the basin's environment is under. The information is used to help formulate and update Local Environment Agency Local Plans (LEAPs) which are management plans for identifying, prioritizing and solving local environmental issues, and River Basin Management Plan (developed under the Water Framework Directive) to identify any changes in water quantity that are required to achieve a healthy aquatic ecosystem in the Thames basin.

Table T.3.1. State indicators

Key State Indicators			
No	**Name**	**Class**†	**Progress**
1	Area of urban land	L	unfavorable/none
2	Air quality: concentration of key pollutants	A	positive/improving
3	Quantity of rainfall	W	positive/improving
4	Number of heavy rainfall events	WL	uncertain/mixed
5	Quantity of river flows	W	positive/improving
6	Chemical river water quality	W	positive/improving
7	Biological river water quality	W	uncertain/mixed
8	Tidal Thames water quality: dissolved oxygen	W	uncertain/mixed
9	Radiation levels in the vicinity of nuclear sites	WAL	positive/improving
10	Quantity of groundwater	WL	positive/improving
11	Groundwater levels in London	WL	unfavorable/none
12	Groundwater quality: concentration of nitrates	WL	unfavorable/none
13	Numbers of salmon returning to the river Thames	W	uncertain/mixed
14	Distribution of key biodiversity species	WL	some positive/improving; some uncertain/mixed
15	Compliance with bathing water directive	W	positive/improving
16	Number of days when air pollution exceeds national objectives	A	uncertain/mixed
*	Area of contaminated land and number of major sites in the basin	L	
*	Area of floodplain developed	L	
*	Length of national fisheries classification scheme classes	W	

† State media is water W, air A and/or land L
* Potential indicator for future

Table T.3.2. Pressure indicators

Key Pressure Indicators

No	Name	Class‡	Progress
1	Long-term change in temperature	N	unfavorable/none
2	Rate of water leakage	S	positive/improving
3	Rate of water demand	S	positive/improving
4	Projected housing development	S	unfavorable/none
5	Number of planning applications	S	unfavorable/none
6	Passenger transport and vehicle traffic	S	unfavorable/none
7	Boat traffic on the non-tidal Thames	S	unfavorable/none
8	Volume of water abstraction and consumption	R	unfavorable/none
9	Demand for aggregates	R	uncertain/mixed
10	Number of sewage treatment works compliant with consent	U	positive/improving
11	Emissions to air from major industries	U	positive/improving
12	Waste production and management	D	unfavorable/none
13	Volume of waste to landfill	D	unfavorable/none
14	Number of water pollution incidents	I	unfavorable/none
15	Water levels in the river Thames	N	uncertain/mixed
*	Number of contacts that need to be made when a flood warning is issued	S	
*	Recreational use of the river Thames footpath	S	
*	Emissions of methane to air from landfill sites	U	
*	Emissions of CO_2 to air from Part A process	U	
*	Amount of waste transportation by mode	R	
*	Amount of sewage sludge produced	R	

‡ Pressure category is natural forces N, societal influences S, abstractions and removals R, uses, releases and discharges U, waste arisings and disposals D and/or illegal practices (accidents and non-compliance with regulations) I

*Potential indicator for future

Table T.3.3. Response indicators

Key Response Indicators			
No	**Name**	**Class**	**Progress**
1	Number of Thames barrier closures against tidal surges	T	unfavorable/none
2	Number of fluvial and tidal flood warnings issued	T	uncertain/mixed
3	Number of river reaches benefiting from environmental enhancements implemented by flood defence	T	uncertain/mixed
4	Amount of waste recovered	T	unfavorable/none
5	Use of Thames Bubbler and Vitality	T	unfavorable/none
6	Number of LEAPS completed	P	positive/improving
7	Proportion of river reaches receiving maintenance	P	uncertain/mixed
8	Number of Water Level Management Plans completed	P	positive/improving
9	Number of low flow rivers under study or remediated	P	positive/improving
10	Proportion of rivers for which a landscape assessment has been undertaken	P	positive/improving
*	Amount of waste minimization/ recovery by type	T	
*	Amount of landfill gas used for energy generation	T	
*	Area of restored landfill sites by use	T	
*	Reduction in releases from part A process	T	
*	Number of LEAP actions implemented	P	
*	Number of companies advised about waste management	E	
*	Number of pollution control visits	E	

‡ Response category is technical reaction T, management and policy response P, economic measures M and/or advice, education and enforcement E

* Potential indicator for future

Priority substances for monitoring

Table T.3.4. shows the number of sites from the whole of the UK reporting emissions of priority substances to controlled water at levels above and below the EC reporting thresholds (RT) and total annual emissions. The information is abstracted from the Agency's Pollution Inventory for 2001. The Agency has studied the emissions of some of these substances in detail, to seek an explanation and context for the emissions:

- Benzene – releases dominated by the chemical, fuel and power sectors. None of the main industrial releases were in the Thames basin.

- Cadmium – releases dominated by the chemical and metal industries. Transfers to sewers (and hence to controlled waters from sewage treatment works) were reported in the London area and elsewhere in the Thames basin.

- 1,2-dichloroethane – releases dominated by the chemical industry from processes involving halogens. None of the main industrial releases were in the Thames basin.

- Lead – releases dominated by chemical and metal industries. Transfers to sewers were reported in the London area and elsewhere in the Thames basin.

- Mercury – releases dominated by chemical and metal industries. Transfers to controlled waters and sewers were reported in the London area and elsewhere in the Thames basin.

- Naphthalene - releases dominated by chemical industry. Transfers to controlled waters were reported in the London area.

- Nickel - releases dominated by the chemical, fuel and power sectors. Transfers to controlled waters and sewers were reported in the Thames basin.

- Nonylphenols – releases dominated by the chemical industry. None of the main industrial releases were in the Thames basin.

- Octylphenols – releases dominated by the chemical industry. None of the main industrial releases were in the Thames basin.

- Tributyltin – the main release incident reported to controlled waters was from a ship repair site, most likely due to the stripping of old TBT coating. Releases to sewers occurred mainly from the paper and pulp, timber treatment, and treatment of animal and vegetable matter industries.

- Trichloromethane – releases dominated by the chemical industry from processes involving halogens. Some of the releases to sewers were in the Thames basin.

Table T.3.4. Numbers of sites reporting emissions of priority substances and total annual emissions

Substance	No of sites emitting above RT	No of sites emitting below RT	Total emissions from sites (kg)	No of STWs emitting above RT	No of STWs emitting below RT	Total emissions from STWs (kg)
Atrazine	2	14	0.324	43	75	156
Benzene	27	21	103000	13	56	157
Cadmium	36	194	996	89	75	862
Chlorfenvinphos	2	3	0.211	9	69	6.78
1,2-dichloroethane	10	26	2200	13	77	318
Endosulfan	2	12	0.0084	4	70	0.126
Hexachlorobenzene	4	18	2.68	5	86	11.7
Hexachlorobutadiene	4	14	2.68	0	70	0
Hexachlorocyclohexane	1	16	0.112	7	67	2.87
Lead	36	137	17400	122	56	24600
Mercury	53	195	217	133	40	1650
Naphthalene	4	13	500	3	65	4.90
Nickel	46	119	12200	154	26	55800

Nonylphenols	1	6	805	8	57	395
Octylphenols	2	4	0	0	58	0
Pentachlorophenol	11	8	11.9	135	22	644
Simazine	2	13	0.199	13	65	26.8
Tributyltin	2	19	0.0459	13	58	2.64
Trichlorobenzene	5	18	8.13	0	69	0
Trichloromethane	14	32	1390	96	56	32300
Trifluralin	0	14	0	17	81	4.94

Monitoring under TWINLATIN

No further monitoring will be done in the Thames basin as part of TWINLATIN.

Catamayo-Chira Basin

Identification of priority data needs

The Catamayo Chira is a river basin that has been intensely studied in its lower parts, because of the great hydraulic infrastructure existing as it is Poechos reservoir. In spite of this, there are gaps of quality information within the river basin and a lack of continuity in the registry of certain parameters, which they are exposed next.

Meteorological parameters

The meteorological station network is not sufficient for the river basin scope; in addition, many of the stations have discontinuous registries or have been removed from operation at some moment. There is an unavoidable need of a proper hydrometeorological binational information sharing. So far, Peruvian institutions dealing with water management in the Peruvian side don't have access to this information from the upper part of the Ecuadorian river basin.

Hydrological Parameters

It is an aspect that has a good level of registries by the operation of the reservoir, but there are only registered data at gauging points on times of avenues. Generally, in dry periods, the stations stop to operate and only the entrance to the reservoir is measured. On the other hand, in the high river basin there are no water gauge stations. With respect to the precipitation registries, these have the same characteristics that the meteorological parameters, and in general are very few stations equipped with rain gauges. There is no information on the types of predominant storms, or the intensities of these.

Sediments

On sediments, isolated measurements of the Peruvian part of the river basin are had, since the solid load in suspension have been registered during the previous years to the starting in operation of the reservoir, and after some studies were made in the Peruvian part, but from the Ecuadorian part there are no data. There is no information of the zones which contribute more with sediments, neither of the quality nor of the amount of them.

Biology of water bodies

Studies do not exist on the ecosystems of the water bodies of the river basins.

Hydrogeology

It is a subject which has never been studied in a systematic way. There are some isolated studies, of very small portions of the river basin and also some wells of underground water operation but there is no knowledge of the hydrogeologycal processes that occur in the basin.

Flooding limits

Modelling and flood zones studies exist under Poechos reservoir area but this information does not exist in the waters areas above the dam, in spite of the existence of vulnerable zones.

Water use

On the agricultural water use, there are global demands data, and established irrigation modules, but these data obey to calculations and/or inferences of the people in charge of distribution of the water. There are no real consumptions data, because of the lack of structures of gauging at field level. With regards to population use, there is no general inventory of the population supplies systems. The situation is more problematic in rural areas where, in general, the few supplying systems are only conductions from the sources to the towns which generally have no purification systems. The populations waste waters, do not count with treatment, reason why there is a constant pollution of the channels. There is no information of the spilled volumes, or of the source points.

Priority substances for monitoring

As long as in the Catamayo Chira River Basin, a systematic water quality monitoring program that fulfilled the requirements of the Peruvian and Ecuadorian water quality laws and regulations had never been done, the main objective of the Twinlatin water quality monitoring program was to monitor the substances that these laws identify. Some of these substances (physical and chemical, microbiologic, biochemical) were being monitored in some sites of the river basin by different institutions, but a periodic monitoring program with consented substances, technical protocols, time frames and frequencies was needed, for taking advantage of the existing efforts and offer a more global and systematic perspective of the actual water quality status.

Heavy metals had never been monitored (due to the lack of budget) by the responsible institutions. Thus, these were going to be priority substances for Twinlatin water quality monitoring program because, it was thought they supposed a potential problem for the area and it was suspected that the concentration of some of this substance could be exceeding the recommended maximum safety limits.

Although the participant institutions had equipped laboratories for carrying out the physical, chemical, biochemical and microbiological analysis, in the area there were no laboratories having quality certifications for carrying out the needed analysis. That’s why this task had to be commissioned to outsiders laboratories, from Lima, in Peru, and Cuenca, in Ecuador.

The details about these questions were negotiated with the participating institutions. An institutional work was done in both sides of the river basin since the beginning of the project, to get cooperation agreements with the institutions in order to cheapen the required analysis and support the sustainability of the program.

Monitoring under TWINLATIN

The primary goal of Catamayo Chira water quality monitoring program has been to provide information about the water quality condition of the river. This has allowed the establishment of a baseline of water quality, to use it as a reference point for the determination of the changes that might be occur to the water system in the future and to be taken into account by decision makers.
Specific objectives of the program were to:

- Monitor the condition of the water courses in the Catamayo Chira River;
- Identify problems related to source water quality;
- Evaluate the effectiveness of existing activities to prevent or remediate water contamination and
- Evaluate if applicable water-quality goals, standards and guidelines were being met.
- Increment the technical and technological capacities of the local competent institutions creating a binational structure around the topic of water quality of the basin for the experience and information transfer

Table CC.3.1 shows the sites monitored and its location. The number and distribution of the elected monitoring sites is shown in the Figure CC.3.1. Sites were chosen coming to a consensus with the Peruvian and Ecuadorian participating institutions. The list suffered changes along the timeframe of the project with the aim of improving representativeness of the sites.

Altogether, the Catamayo Chira Monitoring Program included 28 sites to be monitored. These sites were chosen in accordance to the following criteria:

- To use existing monitoring sites, with functional equipment to measure the river flow and with good accessibility all along the year
- To monitor every subbasin
- To establish a well distributed program taking into account the variability of climates, land use, population, human impacts and budget limitations.
- To identify the potential influences of activities on the surrounding land and water (mainly, to identify the influence of the punctual sources). Thereby, the Arenal site would monitor the contamination proceeding from the industrial, agrarian and urban area of Malacatos – Vilcabamba; Zapotillo site would monitor the contribution of the Catamayo to the Chira, in its final lot, downstream of an important area of artisan mining activity; Saucillo would measure the state of Alamor River, upstream of the confluence with the Chira, measuring the impact of the urban punctual sources of this river basin; Macará site would measure the contribution of Macará River to the Chira, also in an area of important artisan mining activity; monitoring sites 1 and 2 would indicate the influence of the agrarian and artisan mining activities occurring in Quiroz River Basin and would give information about its influence to the Chira River water quality; monitoring site at Chipillico main outlet, would measure the impacts of an important agrarian and piscicultural area; Puente Sullana, at Sullana city, would monitor the water quality of Chira System, downstream of the most important contaminating area, with urban and industrial

pollution. Monitoring site at Arenal would indicate the water state at the last lot of the river, in an important zone where drinkable water catchments are located.

Table CC.3.1. Catamayo Chira monitoring program sampling sites

Id	Hydric source	Sampling site	Parroquia / Distrito	Cantón / Provincia	Provincia/ Departamento
ESTACIONES ECUATORIANAS					
E-01	Rio Piscobamba	Puente de la Estación Meteorológica Moyococha	Vilcabamba	Loja	Loja
E-02	Rio Arenal	Estación Meteorológica Arenal - Puente Boquerón.	Tambo	Catamayo	Loja
E-03	Rio Catamayo	300 m. después de la unión con el río Guayabal. Estación Meteorológica Guayabal	La Vega	Catamayo	Loja
E-04	Rio Guayabal	2 Km aguas arriba del puente Guayabal.	Catamayo	Catamayo	Loja
E-05	Rio Pindo	Puente Lucero-Estación Meteorológica Chiriyacu	Lucero	Cariamanga	Loja
E-06	Rio Alamor	200 m. aguas arriba de estación Meteorológica Alamor en Saucillo	Zapotillo	Zapotillo	Loja
E-07	Rio Catamayo	Puente Santa Rosa	El Empalme	Celica	Loja
E-08	Rio Gualel	Rio Gualel			
E-09	Rio Espindola	Rio Espindola en zona Ecologica	Salado	Jinbura	Loja
E-10	Rio Alamor	Rio Alamor en Puente Internacional	Zapotillo	Zapotillo	Loja
ESTACIONES BINACIONALES					
B-01	Rio Espindola	Puente Internacional	Salado	Jimbura	Espindola
B-02	Rio Macará	Bocatoma del Canal de Irrigación Macara	Eloy Alfaro	Macará	Loja
B-02	Rio Calvas	Puente Remolino	Usaine	San Guillin	Calvas
B-03	Rio Macará	Puente Internacional		Macarà	Loja
B-04	Rio Chira	200 m. aguas abajo Estac. Meteorológica El Ciruelo	Zapotillo	Zapotillo	Loja
ESTACIONES PERUANAS					
P-01	Rio Aranza Palo Blanco	1 Km. De la localidad de Portachuelo de Yanta	Ayabaca	Ayabaca	Piura
P-02	Rio Portachuelo Tomayaca	100 m. de la localidad del Tambo	Ayabaca	Ayabaca	Piura
P-03	Rio Ramos o Sancay	Altura del Puente Parcochacas	Ayabaca	Ayabaca	Piura
P-04	Rio Santa Rosa San Pedro	1 Km. frente a la localidad de frejolito	Ayabaca	Ayabaca	Piura
P-05	Rio Quiroz	200 m. aguas arriba del Puente Jambur	Paimas	Ayabaca	Piura
P-06	Rio Quiroz	1 Km. de la desembocadura	Lancones	Sullana	Piura
P-07	Canal Daniel Escobar	Puente Chilaco	Lancones	Sullana	Piura
P-08	Rio Chipillico	Puente Chipillico	Lancones	Sullana	Piura
P-09	Rio Chira	300 m. aguas abajo captación Santa Victoria	Lancones	Sullana	Piura
P-10	Rio Chira	Puente Viejo Sullana	Sullana	Sullana	Piura
P-11	Rio Chira	Puente Sojo	Sullana	Sullana	Piura
P-12	Rio Chira	Pase a Pueblo Nuevo de Colàn	Vichayal	Paita	Piura
P-13	Rio Chira	Captación a la Planta de Tratamiento El Arenal	El Arenal	Paita	Piura
P-14	Rio Chipillico	50 m. de la Bocatoma de Chipillico	Las Lomas	Piura	Piura

Figure CC.3.1. Proposed Twinlatin monitoring sites

The parameters monitored in the Catamayo Chira Water Quality Monitoring Program were the following:

A. - Physical

- Temperature
- Hydrogen potential
- Dissolved solids
- Smell
- Colour
- Turbidity
- Floating material and foams
- Greases and oils
- Electric conductivity

B. – Chemical

- Dissolved Oxygen
- BOD_5
- Total Nitrogen
- Nitrates

- Nitrites
- Sulphates
- H_2S
- Relation Nitrogen - Organic Phosphorous
- Ammoniac
- Cyanide
- Chlorine
- Chloride
- Phenolic compounds
- H_2S

C. – Microbiological

- Total coliform
- Fecal coliform

D. - Heavy Metals

- Arsenic
- Barium
- Cadmium
- Magnesium
- Zinc
- Copper
- Iron
- Chromium
- Mercury
- Lead
- Manganese

The above was the final list consented by the Peruvian and Ecuadorian participant institutions. This list suffered changes during the project because it was adapted to the real needs of the program, depending on the results of the first monitoring campaigns. In the frame of Twinlatin project, seven quarterly samplings were done at every monitoring site.
In the frame of Twinlatin, seven monitoring campaigns were done, in the following dates:
First monitoring campaign: July – August, 2006
Second monitoring campaign: October, 2006
Third monitoring campaign: Mars, 2007
Forth monitoring campaign: August, 2007
Fifth monitoring campaign: November, 2007
Sixth monitoring campaign: Mars, 2008
Seventh monitoring campaign: June, 2008

Analysis and data processing procedures

In the Catamayo Chira River Basin, as a binational river basin, there was a need of developing a binational institutional structure related to water quality. Among other tasks, this institutional structure or committee should work for the homologation and uniformization of the water quality monitoring procedures, the organization of the monitoring campaigns, the transference of information and the sustainability of

actions. This would include the harmonization of the list of parameters, the sampling procedures, the analyzing protocols and the data processing activities.
The Catamayo Chira project, in the frame of Twinlatin, started this process and created a binational technical working group that conducted the monitoring work. The group was conformed by the following institutions:

- Dirección Regional de Salud Ambiental (DESA - Sullana). DESA is a decentralized organ of the Dirección General de Salud, the Wealth Peruvian Minister (DIGESA). Its functions are the authorization of every spill of waste waters in the river, the determination of limits of pollutant concentration in water and the vigilance and control of water quality of natural rivers.

- Subcomisión Ecuatoriana para el Aprovechamiento de las Cuencas Hidrográficas binacionales Puyango – Tumbes y Catamayo Chira (PREDESUR). It is responsible of the planning and execution of works for the promotion of integral development of sectors and subsectors of economy of the south region of Ecuador.

PREDESUR, DESA and DIGESA are institutions that have legal competences on the monitoring and data processing of water quality. In this process, the Peruvian part has leadered the water quality work and the Ecuadorian part has leadered the water quantity work, depending on the experience of every part. The analysis and data processing of the quality component of the monitoring has been conducted by the Peruvian team. In the process, the Ecuadorian institution has been trained. For that reason the Peruvian official standard procedures have been used in the process. These procedures are dictated, through national regulations, by DIGESA and publicize (in part) by INDECOPI, which is the Peruvian normalizing Institution.

Investment plan

The following table synthesizes the budget of the water quality monitoring program used in the frame of Twinlatin project by the different partners:

Table CC.3.2. Investment plan

	Twinlatin Project	PREDESUR	DESA Sullana	DIGESA
Infrastructure				
Equipment	6,000	5,000	2,000	0
Monitoring				
Materials	400	2,000	1,500	500
Field work	1,200	4,000	2,500	0
Analysis	3,000	500	15,000	21,000
Institutional enforcement				
Training	6,000	0	0	0
TOTAL	**16,600**	**11,500**	**21,000**	**21,500**

Efforts were done in order to, firstly, ensure that the program was developed by the institutions that had legal competencies on the topic (activities of sampling, analyzing and data processing). As this objective was got, the cost of monitoring decreased and all the resources oriented to water quality monitoring were maximized. The final goal was to pursue the creation of an institutional structure of donors and participants that supported the program to ensure the sustainability of the process.
The available Twinlatin budget was destined, initially, to complement the budgets of the water quality responsible institutions participating in the program. This allowed the monitoring of additional sites and parameters (as heavy metals) that normally were not reached because of budget limitations.

The rest of the budget was spent on institutional strengthen activities. This began with the development of an initial diagnose of the current institutional situation (at the level of capacities, knowledge, procedures, methods and infrastructure) for having an integral panorama of the existing problems and needs. Having this complete information, an institutional enforcement program was conducted. This included, basically, two components: infrastructure reinforcement (which consisted on getting a multiparameter for the field work) and capacity building. This second component included technical training courses (about sampling, analyzing procedures and data analysis, etc.) and public participation activities for constructing the desired binational institutional committee.

Results from the monitoring

UNIGECC Annex 1 (EXCEL file) contains the results of the parameters analyzed in field and in laboratory in the first five campaigns of the program. At the moment of writing this report (July, 2008), the results of the analysis corresponding to the sixth and seventh monitoring campaigns were not ready yet. These results will be incorporated to the database and to the following reports of the Binational Technical Group.
In general, the values of the parameters measured in the field (temperature, dissolved oxygen, electric conductivity and pH) correspond, with punctual exceptions, with normal values of water quality. The monitoring sites present well oxygenated waters and this fact shows a good ecological potential of the river and a good auto depuration capacity. Total solids values oscillate between normal ranks and increase downstream. This behaviour is shown by most parameters, as the waters of the river receive the effluents of human activities. In the case of electric conductivity, the increase of the value is proportional to the increase of dissolved solids and reflects the level of mineralization and the presence of salts. Values are especially important from P06 station until the main outlet of the river.

At some stations, the parameter dissolved oxygen presents alarming values, below 2 mg/L. This is due to the elevated concentration of organic mater in the river. The anoxia in these sites supposes a serious impact for the living conditions of aquatic flora and fauna of the river, and is a especial problem in the Puente Viejo of Sullana, where this situation is permanent.

Total solids and turbidity are closely related and measure the level of “clarity” of the river. These are important parameters because affect directly the uses of water, the treatments that the water will need for those uses and the aquatic life. The values of solids and turbidity increase downstream, as waters collect the sediments from the slopes of the basin and the dusts from pits and other areas where materials explorations near to rivers are done. These kinds of activities generate elevated punctual values that could limit some uses of water, as in the case of P-14, in the Chipillico river, and raise the price of the depuration treatments.

The presence of sulphates, nitrates and phosphates in water is due, probably, to the influence of human activity, principally to the agrarian and domestic activities (cleansing in the proper river and domestic effluents spills). The concentrations that appear in the results is lower than the legal maximum limit. Nevertheless, due to the agrarian character of the river basin and to the potential impacts that these substances could have, it is necessary to continue the monitoring of these parameters in the agrarian areas of the basin.

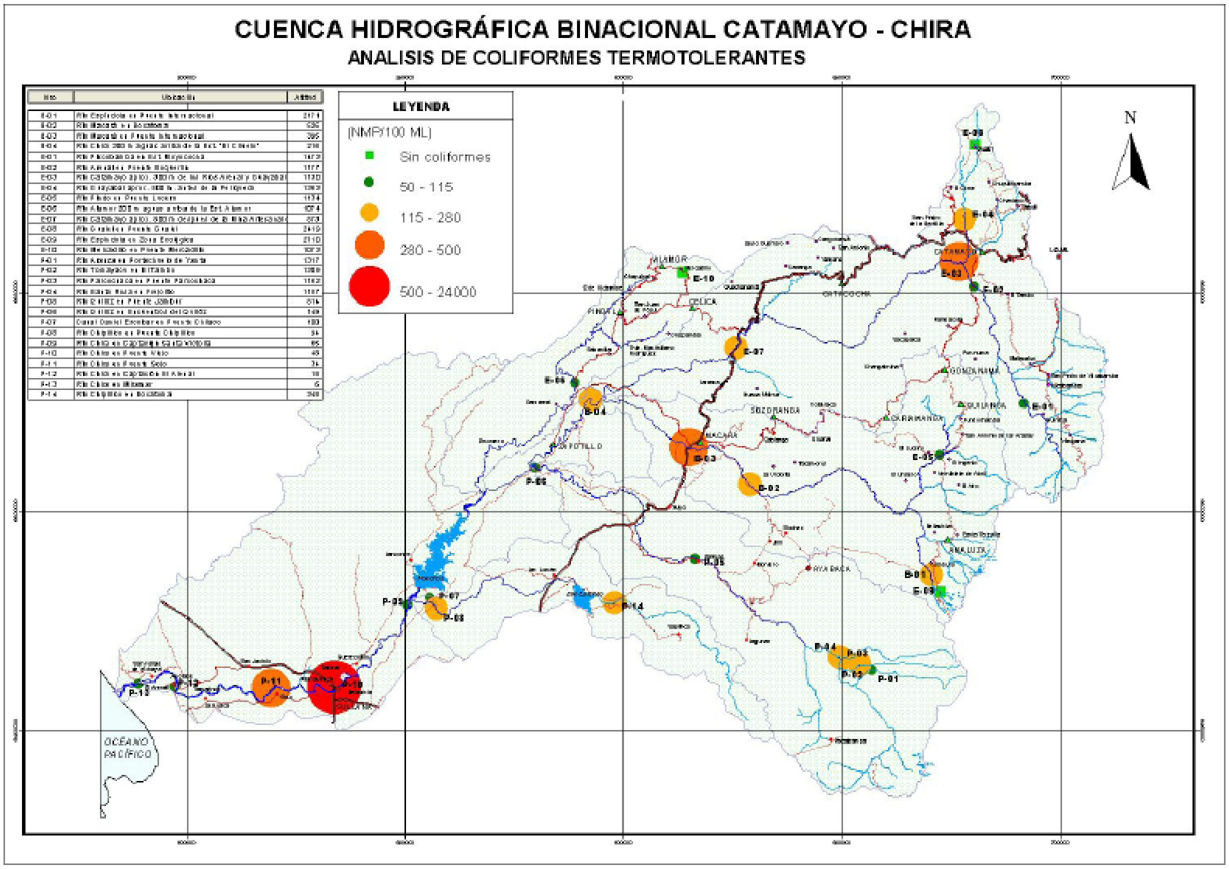


Figure CC.3.2. Results of coliform bacteria analyses

With regard to oils and greases, indicators of domestic human activity, their presence is significative in points with vehicular transit or accessible areas that population uses for diverse objectives as cleaning up.
Magnesium, manganese, iron and arsenic present small values that not represent risks for the uses of water. It is important to remind that because of the geological condition of the river basin, the water presents a tendency to have concentrations of salts and other chemical elements naturally. This is the case of Barium that presents values that deserve a further research. The probable cause of theses values is the presence of natural deposits of baritina that, by mineralization, can produce, in raining conditions, similar concentrations to those founded in some campaigns. The rest of heavy metals monitored don't present significant values.

The most significant parameter in the river basin is the microbiological. The presence of termotolerant coliforms shows clearly the occurrence of domestic sewerage spills, without any previous treatment, to the river. This is the principal problem related to water quality in the river basin and a risk for human and livestock health. Furthermore, this contamination of water presumes the existence of other infectious parasites for humans, case that will have to be studied with more detail. Diarrheic diseases, parasitosis, infantile malnutrition and other diseases of the dermis are some of the problems associated frequently to the direct ingest of this water that population do without any previous treatment. These risks are particularly dangerous to the health of children of less than five years. Next page presents a map that shows the distribution of the microbiologic results in the river basin.

Observations on the sustainability of an operational monitoring plan

Sustainability of operational monitoring was the main issue addressed to ensure the perdurability of Twinlatin water quality actions in the river basin. The sustainability of the desired Water Quality Monitoring Program in the Catamayo Chira River Basin was worked at the level of the folowing components:

Institutional component

The main objective of this component was to work for the constitution of a solid institutional structure related to the water quality issue of the river basin. This would take the form of a binational committee, representing the main institutions in both sides of the river basin, with legal competences in the water quality field.

The main aim of this water quality committee was to coordinate all the activities related to this topic in the basin, harmonizing existing monitoring activities, checking and analyzing the monitoring information that was generated and proposing actions and legal regulations for improving the water quality condition of the binational river. At the end, the result that is being looked for is the appropriation of the program by the local stakeholders.

This process started in both sides of the river basin, with the creation of two institutional thematic groups. The implied institutions where identified in the first steps (official presentations) of the project and a task of approaching the existing institutional initiatives related to the topic was been done.
After the formation of the binational technical group of water quality, the next activities consisted on strengthen this binational institutional structure by increasing local monitoring capacities (training and infrastructure improvement activities mentioned above).

Economical component

Initially, the activities of the water quality program were funded by Twinlatin budget, but, at the same time, an additional work of researching further economic supports to the program was developed. Some institutions, as Piura Regional Government or PREDESUR compromised an economic contribution to the program for the future. Furthermore, most of the activities were funded by DESA Sullana and PREDESUR, who have shown interest of following the binational work after the end of Twinlatin project. In the other hand, the activities of the program have been included in the second phase of the Catamayo Chira project and this ensure the continuity of actions in the following years.

Social component

Social component of the water quality monitoring program sustainability refers to the need of having a population concerned about the importance of the water quality and about the rights and responsibilities that inhabitants and institutions have in this theme. The main goal, in this field, would be then, to carry out social communication activities to increase this social alert.

In this sense, a set of social communication activities related to water quality in the river basin were planned and developed in the frame of Twinlatin. This was carried out participatorily with other related institutions and NGO's working on the same field and in the same area, to ensure the creation of synergies and to reach bigger objectives.

The activities carried out include the design of communication materials; the realization of an awareness rising campaign through the mass media (as radio spots, newspaper articles, etc.) and the developing of other activities oriented to specific social groups as women or farmers. These activities were grouped, planned and systematized in the Twinlatin social communication plan that was elaborated by the UNIGECC and that can be consulted at WP04 report.

Upper Cauca Basin

Identification of priority data needs

Many gauging variables can be included in a monitoring program. However, these variables shall meet specific needs. Therefore, the previously mentioned variables have been historically measured, as well as some others used in specific projects. These measurements have allowed the execution of important projects in the region, river flood prevention and establishing the management base line for the 2002 Regional Environmental Management Plan.

Priorities set by the Twin Latin Project framework have the following scope in terms of monitoring:

- ➢ Improvement in the quality of the water model through the establishment of constant kinetics in experimental form in the Cauca River.

- ➢ Establish the pilot projects of Erosion and integrated gestion of the Water Resource in the basins of Bugalagrande y Tuluá Rivers.

- ➢ Compliment the monitored sediments to improve the pilot projects of the erosion models and the quality of the water for the integrated management of the water resource, which is improved in the basins of the Bugalagrande and Tulua Rivers, sub basins of the Cauca River, located in the middle zone of Valle del Cauca. In these basins, there is high pressure of exploitation of river materials and water resource.

Monitoring activities include:

- Water quality monitoring from the upper part until to Salvajina, in order to have consolidated basin information.
- Sediment monitoring for the Bugalagrande and Tuluá River Basins.
- Monitoring of main basin discharge sources.
- Quality and Fog monitoring in the Tuluá River Basin.

The Cauca River basin covers jurisdictions under CVC and CRC, the environmental authorities. Therefore, information management and development of project priorities have to be defined by the two corporations.

Hydrology modeling and water quality work will continue being done in the sector corresponding to the valle of the Cauca River, between Salvajina and La Virginia, given the fact that Salvajina Dam has modified the regime.

River drag material overexploitation has been identified as a problem by CVC Management. Another problem encountered is the considerable demand of water quantity and quality at the higher part of the Upper Cauca sub-basins. These situations require the development of projects that improve mining zoning and available water usage in all its sources.

The priorities selected for these studies are the Bugalagrande and Tuluá Rivers, two important sub-basins of the Cauca River. River sediments will be monitored in the first basin. Results obtained on sediment production in the pilot Bugalagrande basin will be useful for erosion studies of difuse source contamination (WP06 work package). The quantity and quality of water present in the fog (horizontal precipitation) will be assessed in the second basin in order to study the possibility of implementing fog water collection systems for the better use of water resources in areas where water availability is scarce or none. The results of these studies can later be replicated at other sub-basins.

Priority substances for monitoring

Cauca River Critical Parameters. In 2003- CVC, with the support of Universidad del Valle, identified critical parameters for water quality monitoring. Results obtained in this study are a powerful tool for the selection of parameters to be more frequently monitored by CVC in order to evaluate water resources quality in a more representative manner. The Cauca River common and non-common parameters were defined as critical for the evaluated usages, being No. 1 the section having the largest amount of critical parameters (The section between the Hormiguero Bridge and Mediacanoa). These are the critical parameters identified:

- Dissolved Oxygen
- BOD_5
- DQO
- Suspended solids
- Turbidity
- Color
- Phosphates
- Ammonia nitrogen
- Iron
- Manganese
- Total coliforms
- Fecal coliforms

These critical parameters include those associated with water quality (DO, BOD_5, DQO), suspended materials (S.S.T), nutrients (Phosphates and Ammonia nitrogen), Metals (Iron and Manganese) and pathogens (Total and Fecal Coliforms).

Water demand satisfaction in the pilot basin was complemented by monitoring the quantity and quality of fog water. Horizontal precipitation information using fog measuring devices was collected in the highly foggy study zone. The following parameters were analyzed to determine the quality of water for human consumption: Turbidity, Color, Hardness, Total Iron, Nitrites, Sulphates, Total Coliforms, E-Coli, Fecal Coliforms and pH.

Monitoring under TWINLATIN

Considering the current status of the Cauca River Basin, it is important to continue with efforts being done by environmental entities in the study area.

Joint meetings were held between Corporación Autónoma Regional del Valle del Cauca CVC and Corporación Autónoma Regional del Cauca CRC, to determine monitoring activities to be implemented. As a result of the meetings, it was concluded that it is necessary to jointly monitor water quality in the study section to document river water quality information and to apply the water model application in the Bugalagrande and Tulua River Basins which have been chosen as pilot basins for scenario analyses within erosion modeling and integrated water resources management.

Monitoring sites

According to monitoring sites presently established by environmental entities, Table C.3.1 shows monitoring sites where physical-chemical water quality information is updated:

Table C.3.1 Monitoring sites

Station	Corporation	Status
Before the Vinagre River	CRC	Presently being monitored.
Before the Piedras River discharge	CRC	Presently being monitored.
Before the González settlement (before the entrance to Popayán)	CRC	Presently being monitored.
Julumito, exiting Popayán	CRC	Presently being monitored.
Entrance to Salvajina Dam	CRC	Presently being monitored.
Salvajina exit (vehicle bridge over the Cauca River on the road Morales – Suárez)	CRC	Presently being monitored.
La Balsa bridge	CRC	Presently being monitored.
Before the Palo River	CRC	Presently being monitored.
Hormiguero Bridge	CRC	Presently being monitored.
19 stations over the Cauca River	CVC	Presently being monitored.

Monitoring the main quantity and quality pressure sources:

Sediment monitoring in the Bugalagrande River basin in order to have data for the implementation of a layer erosion model is made on sites chosen for suspension sediments. These are El Placer station and site known as Puente Nuevo. Liquid and solid measurements were made during a 2 month period (May – June, 2008), taking samples every 2 days on average.

The horizontal precipitation monitoring project in the Tuluá River pilot basin includes the installation and operation of 6 fog measuring devices in the upper part of the basin. Figure C.3.1 shows the installation and arrangements of devices used to measure and use the water resource represented by fog in the zone.

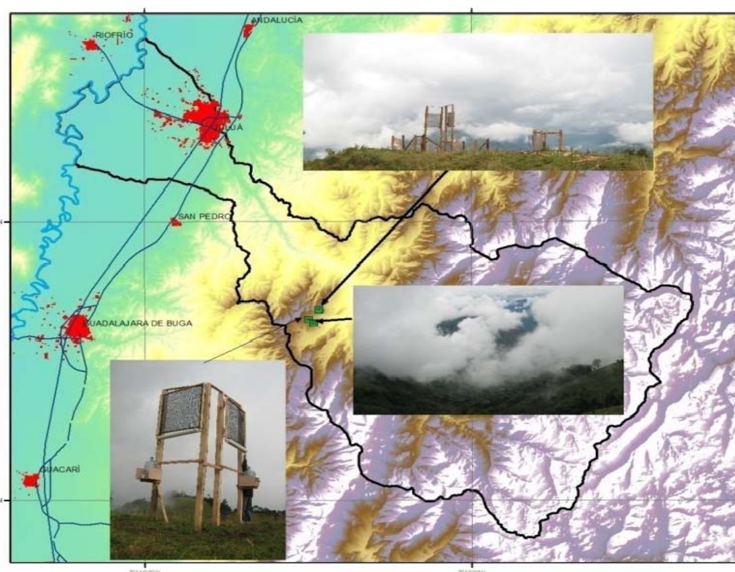


Figure C3.1. Location of fog measuring devices in the Tulua River Basin

Parameters monitored

Physical-Chemical and Bacteriological Quality. Measurements included in the proposed monitoring are those previously described as critical parameters. Of these parameters monitored by CRC, the following are not analyzed: Iron, Manganeso and Ammonia Nitrogen.

Sediments. Another component added is sampling of suspension sediments (Concentration of water sediments) in order to monitor erosion processes in the basins. The pilot basins used are the Bugalagrande and Tuluá River basins.

Data processing and analysis

Information processing on the physical-chemical and bacteriological Cauca River water quality, as well as the main pressure agents, will be used to optimize the Cauca River Water Quality Modeling.

CVC has been working on the integrated management of water resources project for the Cauca River basin. The representative basin is denominated Zone 2 in the geographic valley, considering the following criteria:

- This basin has historical hydroclimatologic information which is basic to reconsider location of new stations.
- The lower part of the basin has an intermediate population of more than 190,000 inhabitants and active agricultural practices that jointly generate pressure and conflict in water resources usage.
- Water resources production starts at an altitude of 4,000 meters above sea level (high barren plateau) until an elevation of 1,400 meters, where the last important tributary is located. That is the location of the hydrometric station of Tuluá-Mateguadua, which is in charge of characterizing natural regime flows.
- There is a hydrometric station located before the Cauca River mouth (Tuluá-La Rafaela station) that monitors intervened regime flows. This can also be considered a permanent water quality gauging station.
- In the mid lower part of the basin there was a meteorological station owned by IDEAM (Botanical Garden). This station can be refurbished for the new monitoring network.

In the framework of the water resources integrated management for the Tulúa River basin, it is required to optimize water distribution. In order to take advantage of fog as a water resource, fog metering devices will be installed to evaluate its availability in terms of quality and quantity.

On the other hand, in the pilot basins of the Tuluá and Bugalagrande Rivers, samples and analyses of suspended solids will be used for pilot erosion modeling.

Investment plan

The budget has been allocated for the proposed monitoring activities as shown in Table C3.2.

Table C3.2- Investment Plan for Basin Monitoring Budget

ACTIVITY	ENTITY/contributions	BUDGET (Colombian $)	BUDGET (Euros)
Complementation of water quality monitoring for the upper part of the basin through an agreement with CRC	Twin Latin Project (UE)	12,000,000	4,417
Monitoring of Cauca River water quality and pressure agents	CVC	209,000,000	76,925
Monitoring of sediments in the pilot basin station in the Bugalagrande River.	CVC	18,000,000	6,625
Monitoring fog water quantity and quality in the pilot basin of the Tuluá River	Twin Latin Project (UE)	9,000,000	3,313
Experimental study of kinetic constants for model quality optimization.	CVC	22,000,000	8,097

Cuareim/Quarai Basin

Identification of priority data needs

The identification of data needs were presented in TWINLATIN Working Package 1. Below follows a summary of the main points. Those in bold letters will be addressed in the Framework of TWINLATIN.

Some gaps to be addressed by the project implementation are: the gathering of all available information of the basin **in a unified and structured database**.

The existing monitoring data in the basin are: hydrometeorologic data, water quality data, and data of other environmental aspects.

The pluviometric monitoring network is not uniformly distributed in the basin and there is only one flow gauging station in the main stream. The quality of the available data varies.

There is no data of high flows during storm events in tributaries of the Cuareim river (there are only at one specific point at the Cuareim River). To achieve this, a DCP could be used (as the use of conventional measurements would require the presence of a bridge). Existing low-flow data are not reliable in some cases. **There is some difficulty to access some data due to the way they are archived (for example the precipitation data previous to 1971 is in hard copy format (paper) and need to be digitalized.**

With respect to real-time hydrometeorology data in the basin, there are gauging stations on the left margin (CTM) but not on the right one. It would be important to add real-time gauging stations on the right margin, especially upstream of Artigas and Quaraí cities, in order to improve the existing preliminary hydrological forecast system.

Some conflicts have arisen within the Uruguayan territory due to extra need of water (applications for more water-use rights or direct intakes without authorization), that have been resolved with the active participation of the DNH and the Irrigation Assessing Committees. **Currently, the water used for irrigation that returns back to the river is not taken into account when determining the water availability because of the lack of quantification of it.**

There is just a first and partial assessment of the basin's water-quality current condition. Some localized problems of poor water quality have been identified due to the effluents generated from the cities of Artigas/Quaraí. This information is just the result of two water quality campaigns, so that statement is no more than the situation at two specific moments in time. There are no systematic water quality measurements.

The consequences of the use of agrotoxics for growing crops in the water quality are not known on the left margin (Uruguay) (there is not enough field information to have a diagnosis of the basin in this respect). On the right margin (Brazil), the concentration of total phosphates is above accepted limits. It is important to pay attention to this issue, especially when the use of fertilizers is a common practice in the basin. It is believed that in the Uruguayan territory the problem could be similar, based on similar land uses and common production practices. With respect to metals, mercury and Cadmium have been found in the Brazilian territory with values higher than those allowed. It is likely that similar results would be obtained in the basin in Uruguayan territory.

During storm events, polluted urban runoff from the cities of Artigas/Quaraí is considerable. This phenomenon occurs with a return period of 2 years. On the other hand during droughts, there may be a considerable decrease in flow and therefore reduced capabilities of autodepuration.

There are planned monitoring networks to measure water quality data and other environmental data, but they have not been implemented neither in the left nor in the right margin. **There is a need for an extensive and systematic water quality monitoring program.** On the left margin (Uruguayan territory) no agrotoxic testing has been performed (in the Brazilian margin there are only localized measurements).

Priority substances for monitoring

As there is practically no information about water quality in the basin, the monitoring under the framework of TWINLATIN will be focused on the determination of: the general water quality (conductivity, dissolved oxygen, etc); dissolved salts; solids; organic matter; nutrients; microbiologic; and inorganic elements.

Monitoring under Twinlatin

1.1 WATER QUALITY MONITORING

DNH and IPH in the Framework of TWINLATIN agreed to carry out a joint monitoring program of the Cuareim River.

Objectives

- Get information on water quality of the Cuareim River

- Generate the necessary information for the establishment of a permanent monitoring and management plan for the Cuareim River's basin

1.2 WATER QUANTITY MONITORING

The Cuareim River basin is one of the basins in Uruguay in which there is an intensive use of the water resources, mainly for rice. Rice is grown in summer, and needs big volumes of water, so for basins that are far from water bodies the construction of irrigation systems capable to store water during the year and distribute it during the rice season is necessary.

There are also other systems, when closer to important streams of water, that withdraw water with pumps, directly from the river, and then the water is distributed.

In both cases, the water is transported (from the reservoir or from the pumping site) to the fields through excavated channels and it is distributed by them through lateral outlets.

In the case of small reservoirs, generally the fields are downstream, so that the distribution channels can transport the water by gravity without the need of additional pumping. Based on the inventory of the National Directorate of Hydrography (DNH), in 2002 the Cuareim River Basin had 92 reservoirs and 35 direct intakes.

The region has a big climate variability, being the deviation standard of the precipitation for each month higher than that of its mean value. There is also variability between humid and dry years. **Figure 1.2.1** shows that variability.

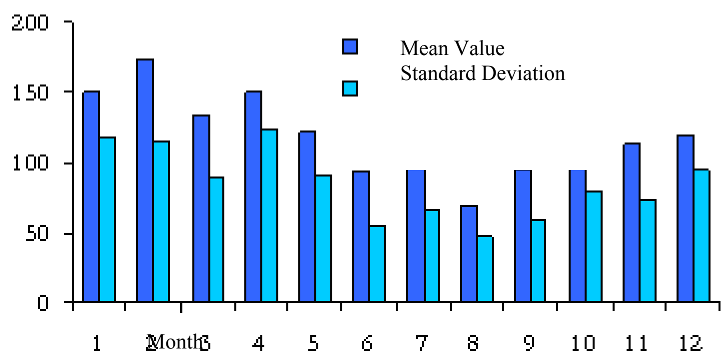


Figure 1.2.1 Variability of the mean precipitation (mm per month) for 1970-2005, at Artigas, operated by the National Directorate of Meteorology

Although the water permits are granted as a function of what the water is used for, the Management Agency of the water resources in Uruguay does not know neither the real demand of crops nor the effect of the irrigation system on the hydrologic cycle. In particular, in the Cuareim River basin there is the belief that the irrigation systems increase low flows, downstream of where they are.

Objectives

- To contribute to the knowledge on how rice irrigation systems work, so to use that information to optimize and improve the management of water resources in the Cuareim River Basin.
    - To determine low flows and their relationship to the area of installed rice fields in the Cuaró River subbasin of the Cuareim River basin

- To determine the flow and the volume of water that returns to the stream from an irrigated field at the Cuareim River basin

2. PLANNED MONITORING SITES

2.1 WATER QUALITY MONITORING

In the framework of TWINLATIN, four sampling stations were chosen (**Figure 2.1.1**):

Point 1: Source of the Cuareim River, located on Brazilian territory

Point 2: Upstream the Cities of Artigas-Quarai

Point 3: Downstream the Cities of Artigas-Quarai

Point 4: Paso Paypaso

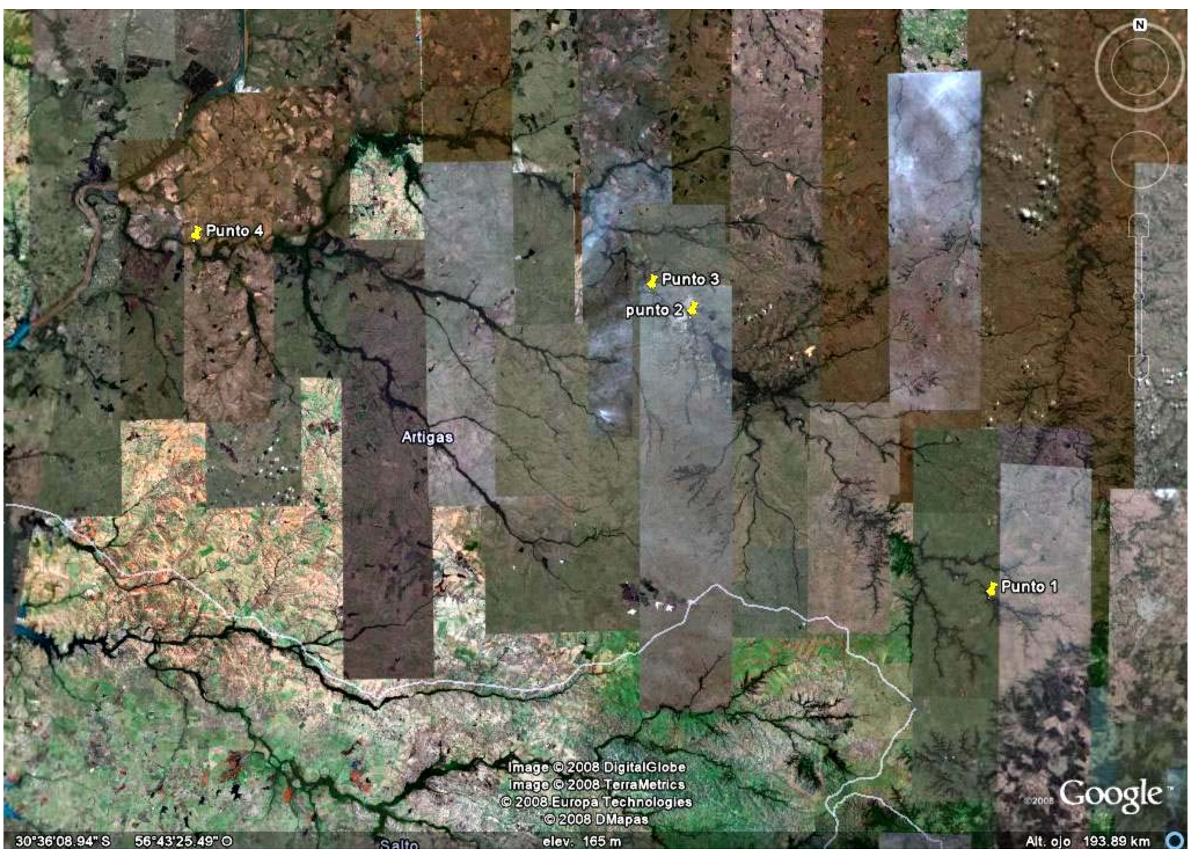


Figure 2.1.1 Location of the sampling stations (Points 1,2,3, and 4)

As point 4 is located on Brazilian territory, this point was monitored just by IPH. The other 3 points were monitored by both partners in parallel.

Even though a complete report about the state of the Cuareim River at the time of the monitoring campaigns is presented in **DNH ANNEX 3.1**, some information is included here to help interpret the water quality results.

During the time period October 2006 - February 2008, DINAMA and DNH (Uruguay) and IPH (Brazil) did 10 monitoring campaigns under the TWINLATIN framework. DNH-DINAMA participated on 9 of the 10 and are presented in **Table 2.1.1**. There was also local participation (teachers and technical personnel of the Municipality of Artigas) in various of the monitoring campaigns (TWINLATIN Working Package 4).

Table 2.1.2 shows the antecedent 15-day precipitation and average flows in Artigas.

Table 2.1.1 TWINLATIN sampling campaigns dates

N° of sampling campaign	Season	Dates
1	Spring	22-Nov-2006
2	Summer	3-Jan-2007
3	Summer	27-Feb-2007
4	Autumn	5-Jun-2007
5	Winter	7-Aug-2007
6	Spring	9-Oct-2007
7	Spring	7-Nov-2007
8	Summer	9-Jan-2008
9	Summer	26-Feb-2008

Table 2.1.2 Antecedent precipitation and average flows in Artigas

DATE of Monitoring	ACCUM. Precipitation	N° DAYS	FLOW (m^3/s)	
	(mm)	without precip.	during monitoring	15 antecedent days
03 TO 05/10/2006	28	6	3	8
21 TO 23/11/2006	153	4	23.9	188.5
03 TO 04/01/2007	137	9	35.2	87.6
27 TO 28/02/2007	193	1	38.8	76.8
05 TO 08/06/2007	6	15	1.1	1.4
09/10/2007	70	3	80.5	84.7
06 TO 07/11/2007	118	3	33.2	191.1
08 TO 09/01/2008	79	5	2.2	2.2
26 TO 27/02/2008	1	10	2.2	2.2

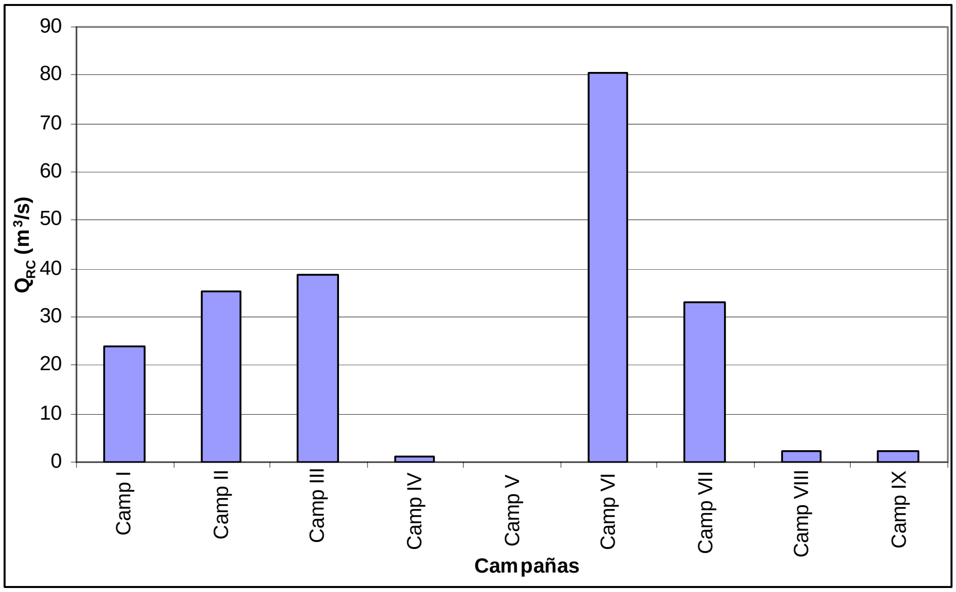


Figure 2.1.2 Flows registered during the different sampling campaigns in Artigas. Vertical axis: flow in m3/s. Horizontal axis: Monitoring Campaign

Figure 2.1.2 and Table 2.1.2 show an average flow of 23,9 m3/s. The maximum flow (80,5 m3/s) was reached in October 2007, and flows were below the average flow during 4 campaigns: Oct/06, Jun 07, Jan 08 and Feb 08.

2.2 WATER QUANTITY MONITORING

Based on the objectives stated previously, an irrigation system was chosen, where flow measurement instruments were installed. The pilot study was done for the rice seasons 2006-2007 and 2007-2008.

The rice sector had been recurrently expressing the need to determine the positive or negative effect of dams and irrigation systems on streams. The office of DNH in Artigas held many meetings with the directors and associates of the Association of Rice Growers of Artigas (ACA), to determine the water systems that could comply with the necessary technical requirements to do a water balance of a typical irrigation system in the region. With the backing of the ACA four ranches were visited and the one chosen is presented in **Figure 2.2.1**, on the Cuaró River basin. The owner of the irrigation system of the selected pilot study area allowed the installation of gauging structures, of monitoring instruments for data collection, and he also collaborated with personnel and machinery for the construction of the structures and to measure the precipitation in the area.

Figure 2.2.1 presents the principal components of the irrigation system: basin, reservoir (upstream), irrigation channel, and rice fields. In this system, not all the area upstream has been intervened by the dam. **Table 2.2.1** shows the area corresponding to each subbasin presented in **Figure 2.2.1**. **Figure 2.2.2** shows pictures of the system. **Figure 2.2.3** shows the location of this basin in the Cuareim River basin.

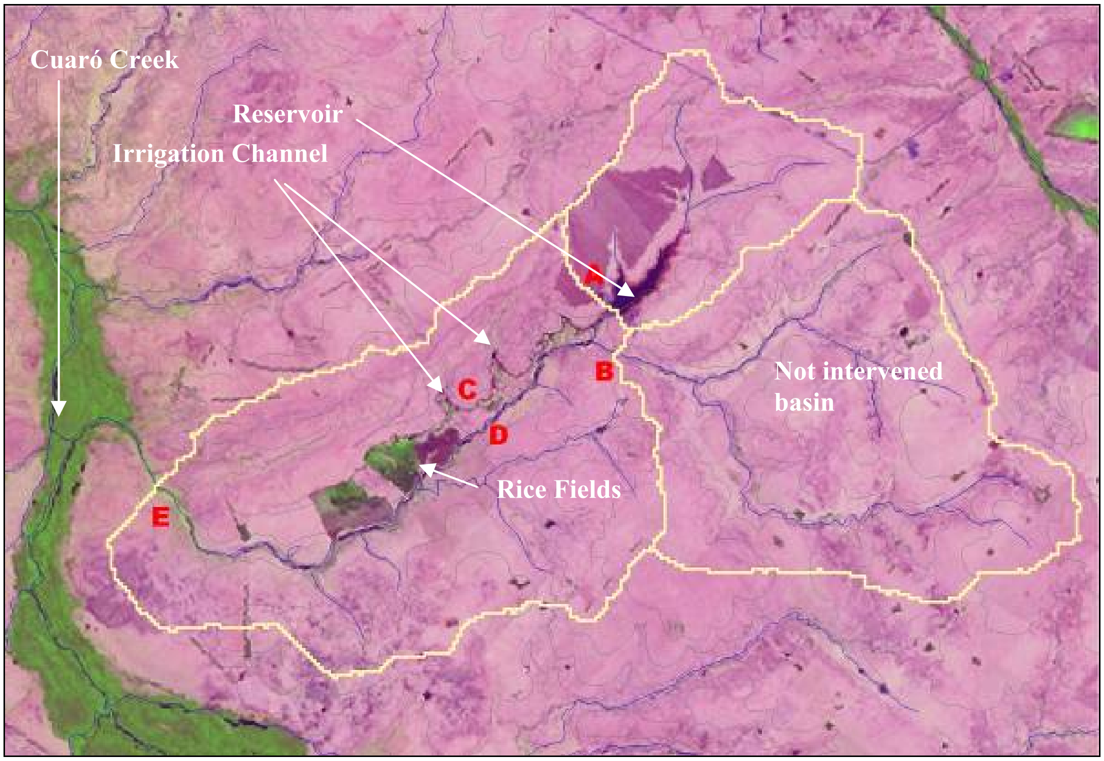


Figure 1.2.1 Chosen irrigation system and monitoring scheme on Landsat image

The chosen irrigation system withdraws water from the reservoir using a siphon, then this reservoir cannot let pass the required minimum flow of 0.4l/s/km^2 established by the authority, and it can be then concluded that during the two-year study the total runoff of the basin was stored.

Table 2.2.1 Basins' Areas

Basin	***Area (ha)***
Total of the irrigation system (point E)	5792
Reservoir's basin (point A)	877
Not intervened (point B)	2184

The soils present in the basin are Curtina unit, based on the soil map 1:1,000,000. That soil unit has a potential water availability of 78.9mm, and due to the presence of rocks and porosity the net potential water availability is 55.2mm, what is low (Molfino & Califra, 2001).

The areas planted in the studied rice seasons are presented in **Table 2.2.2.**

Table 2.2.2 Planted areas in the analyzed rice seasons

Rice Season	***Planted areas (hectare)***
2006 – 2007	88
2007 – 2008	202

The monitoring that was devised at the beginning of the work had 4 points of measurement (Figure 2):

- Point B - outlet of basin with no intervention
- Point C - at the irrigation channel, at the entrance of the rice field
- Point D - at the river channel before receiving the lateral contributions from the rice field

- Point E – at the outlet of the pilot study

This monitoring scheme to measure flows at points B and D, needed the construction of dikes and spillways. Unluckily, although these were constructed, they did not resist several precipitation events that occurred.

Siphon of the reservoir

Siphon outlet and beginning of the distribution channel

Siphon in operation, water entering the distribution channel

Distribution channel in operation, with lateral outlets to the fields

Figure 2.2.2 Photos of the irrigation system

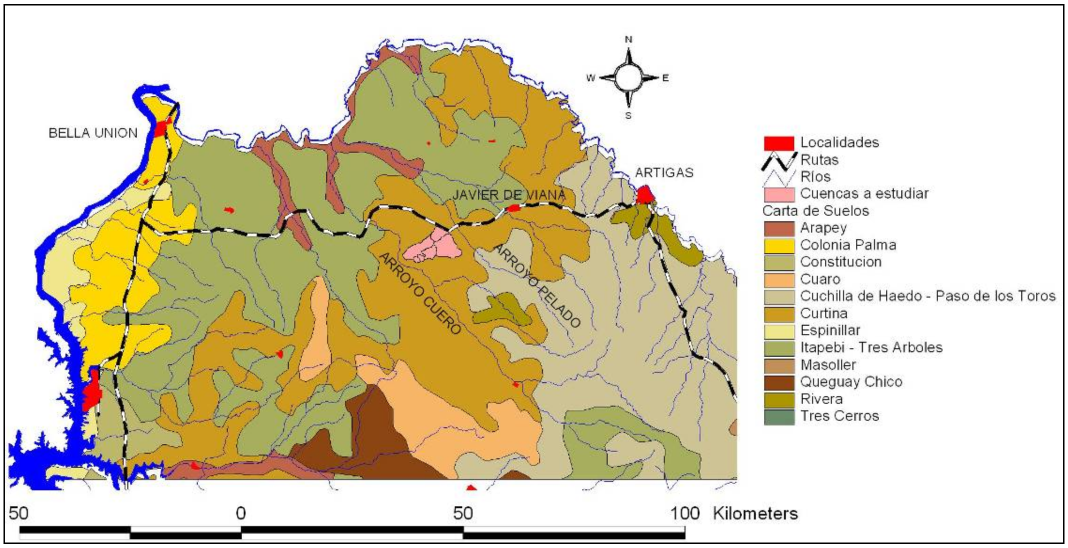


Figure 2.2.3 Location of the irrigation system under study and soils

3. PARAMETERS MONITORED, TIME FRAME & FREQUENCY

3.1 WATER QUALITY MONITORING

Sampling done by DINAMA (National Directorate of the Environment) and DNH (National Directorate of Hydrography) in Uruguay was done following the protocols that the Department of Water Quality Assessment (DECA) of DINAMA has. Those protocols are based on **the International Program of Environmental Global Monitoring System (Operating Guide GEMS Water, 3rd Ed, 94,1).** This is the mechanism of the United Nations (UN) to coordinating the monitoring activities and environmental evaluations done by specialized UN Agencies and by national and international institutions.

The variables that were monitored, grouped into categories according to GEMS Water Program are:

- **General Water Quality:** Temperature, Conductivity, pH, Dissolved Oxygen, % of Oxygen Saturation, Turbidity, and Total Suspended Solids
- **Dissolved salts:** Alkalinity
- **Nutrients:** Nitrate, Nitrite, Ammonium, Ammoniac, Total Nitrogen, Kjieldal Phosphates and Total Phosphorous
- **Organic matter:** Biochemical Oxygen Demand (BOD5)
- **Microbiologic contamination:** Fecal or Thermoresistant Coliforms
- **Inorganic contaminants:** Aluminum and Zinc

In addition, other variables not contemplated in the GEMS Water Program were measured:

- Chemical Oxygen Demand (COD)
- Total solids (TS), total fixed solids (TFS) and total volatile solids (TVS)
- Total Suspended Solids (TSS), Volatile Suspended Solids (VSS)
- Total Dissolved Solids (TDS), Fixed Dissolved Solids (FDS) and Volatile Dissolved Solids (VDS)

The analyses were done at the laboratory of the National Directorate of the Environment (DINAMA), Environmental Laboratory Department, following internationally validated methodologies, based on the Standard Method for the Examination of Water and Waste Water; 21st edition; 2005.

Quarterly monitoring campaigns were made to cover the possible seasonal variation for the different analyzed variables.

4. PLANNED ANALYSIS & DATA PROCESSING PROCEDURES

4.1 WATER QUALITY MONITORING

As many of the reported values are below their detection limits (DL) or quantification limits (QL), it was decided to use internationally-accepted statistical methodologies for their statistical handling.

As the group of values below QL is significant, in some cases 100%, it was decided to use DL or QL, or their average value, depending on the variable.

This strategy of data handling does not permit for any inference analysis (confidence intervals and hypothesis testing), when the proportion of replaced data is higher than 25% of the data (Australia New Zealand, 2000).

This handling of the data has a strong influence on the analysis, as it does not permit in the case of 100% replaced data to draw inferences from a given variable and its relationship with other variables, allowing only to reference them to typical values or quality standards.

Data were analyzed with no more handling than the previously mentioned, using statistical analysis for raw data in every case, getting correlations, box graphics, etc. Correlations were done among variables and stations, allowing spatial and temporal interpretation of the data.

5. INVESTMENT PLAN (INFRASTRUCTURE & FIELD WORK)

5. 1 WATER QUALITY MONITORING

5.1.1 Basic Hydrochemical Variables

5.1.1.1 In-situ measured variables

There are variables that because of their unstable nature are recommended to be measured *in situ*. These are: temperature, pH, electric conductivity, dissolved oxygen and turbidity.

These variables allow a fast characterization of the water quality conditions.

Water temperature is a variable highly dependent on the air temperature, so it has daily and seasonal cycles. It is an important variable for aquatic life, as it regulates the biological cycles, specially the metabolisms, the species present in the community, and the solubility of atmospheric gases, for example Oxygen.

The recorded temperature values show a clear seasonal variation, with values close to 10 °C in winter and 30 °C in summer (**Figure 5.1.1.1.1**).

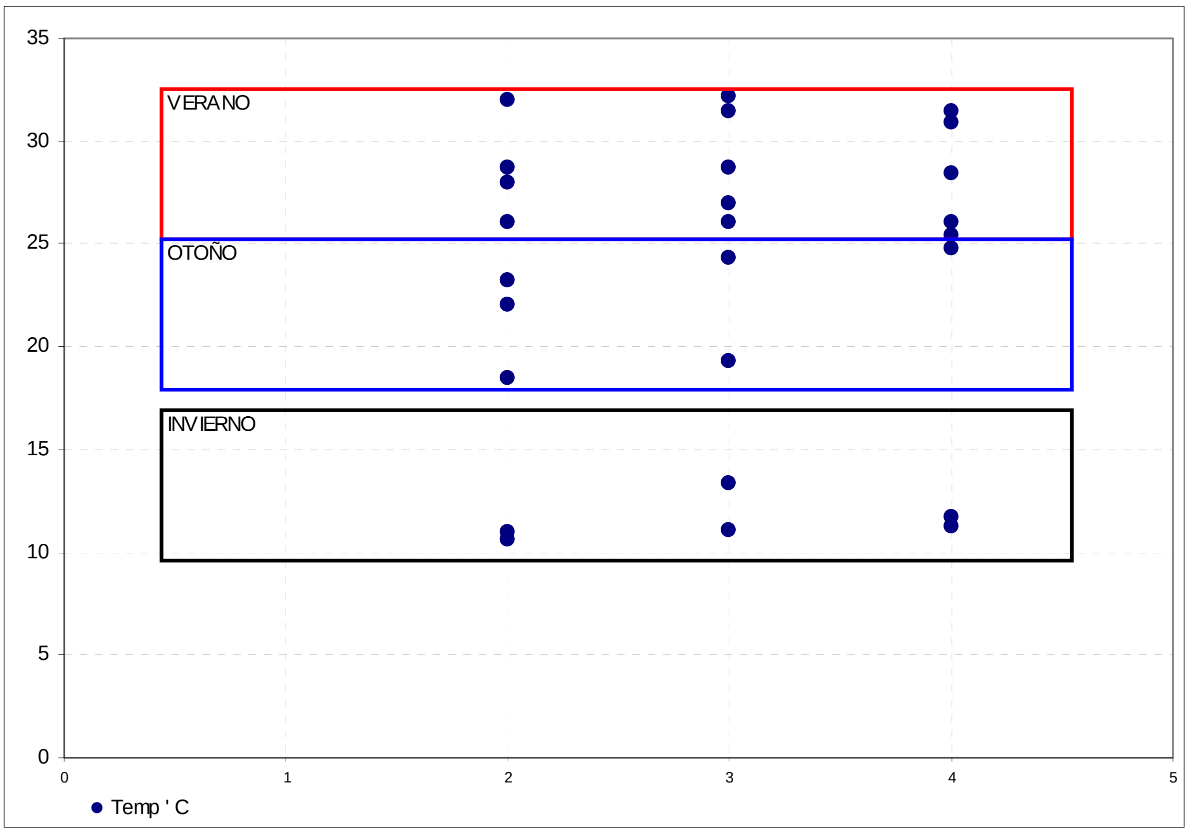


Figure 5.1.1.1.1 Variation of water temperature for the monitored points (Red box is summer, Blue box is fall and Black box is winter).

pH is defined as the negative logarithm of the concentration of free hydrogens in water. It is a measure of the degree of water acidity. In natural waters it is, in a way, determined by the geology of the basin, and is governed by the equilibrium of CO_2 - HCO_3 - CO_3. Therefore, it is a measure of the buffer capacity of the system. In natural conditions the pH is influenced by the presence of organic acids, biological processes (for instance photosynthesis), and physical processes (for instance, turbulence).

The concentration of hydrogen ions is an important factor in all chemical reactions associated to the formation, alteration, and dilution of minerals. The pH of the water affects the transformation processes among the different nutrient and metal forms and has influence on the toxicity of the contaminants formed by acids and bases due to the effect caused by the ionization in these compounds.

The pH values obtained during the sampling campaigns are within the limits of the Decree 253/79 and modifications for Class 3 (**Figure 5.1.1.1.2**). The average value varies between 6,6 at point 3 and 6,9 at point 2.

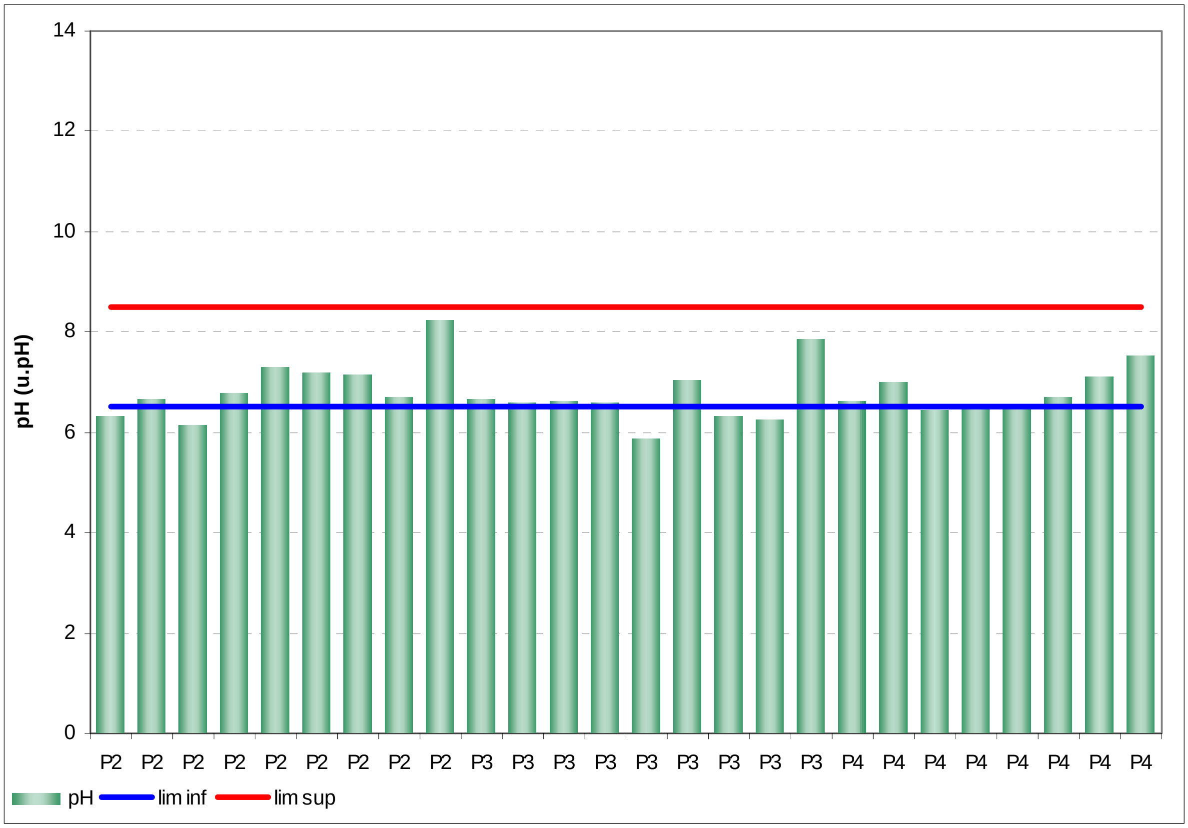


Figure 5.1.1.1.2 Variation of pH for the different samplings and for the different monitored points. In blue, Lowest limit, in red Highest Limit of the Decree 253/79 and modifications

Conductivity is a numerical expression of the capacity of an aqueous solution to conduct an electric current. This capacity depends on the presence of ions, on their concentration, mobility, valence, and on their relative concentrations, as well as on the temperature at which the measurements are taken. It is a conservative variable that based on its value a water body is characterized, or the mixture of two different water bodies.

This variable is not standardized in the Decree 253/79 and modifications. The conductivity in natural waters can vary between 50 and 1500 micro S/cm, so we can state that the recorded values along the River, are those characteristic of natural waters (average=108,3, max=241, min=53,8 micro S/cm).

It is important to say that during summer 2008 (shaded in **Figure 5.1.1.1.3**) the 2 conductivity values were high; this may be because the flows were 2,2 m3/s (**Table**

2.1.2 Antecedent precipitation and average flows in Artigas), the minimum flows recorded during all the samplings. During summer 2007 (shaded in figure 4,4) the flows recorded in both opportunities were significantly higher, 23.9 m3/s and 35.2 m3/s respectively, which allowed a bigger dilution of the ions, resulting in lower conductivity values. Even though precipitations wash away ionic components by runoff, higher volumes allow a higher dilution, reducing the conductivity values.

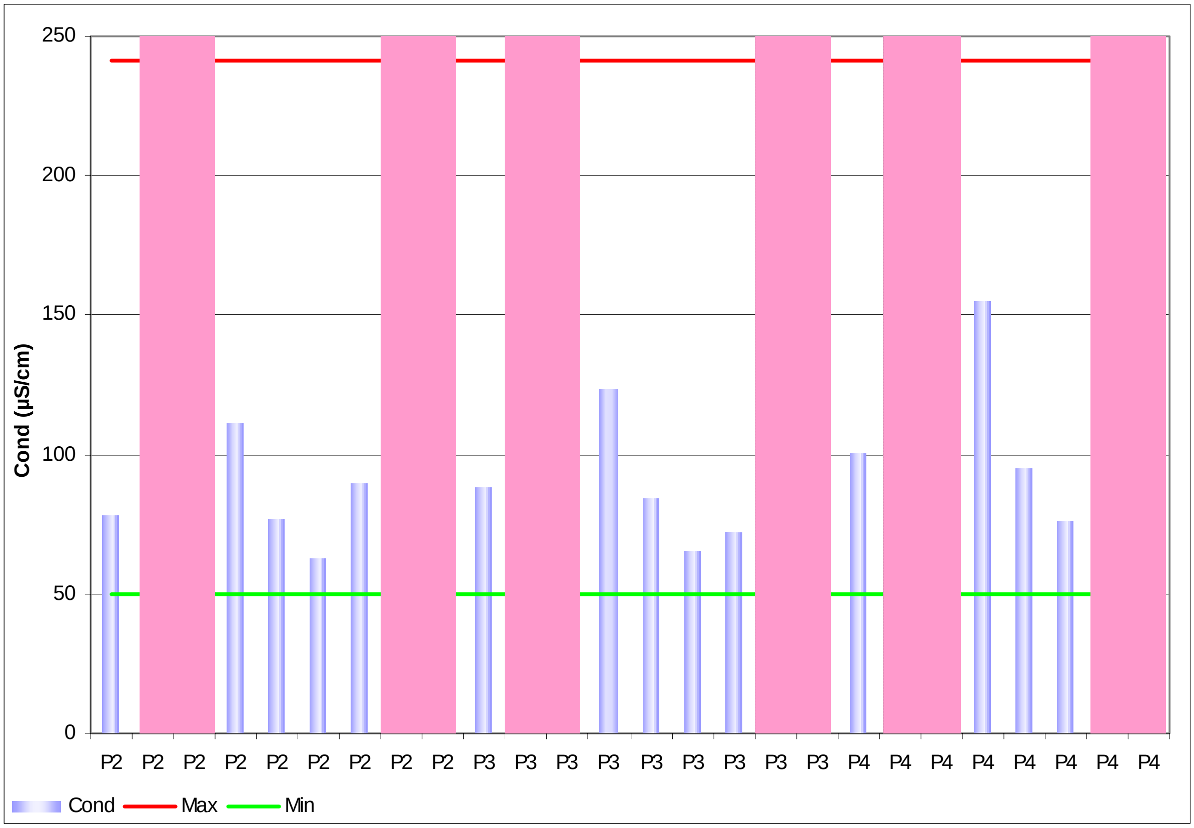


Figure 5.1.1.1.3 Variation of the conductivity among samples and monitored points (summers are shaded). In green, Lowest Limit, in red Highest Limit of the Decree 253/79 and modif. Conductivity: µS/cm Average = 108,3 Maximum = 241 Minimum = 53,8

The **dissolved oxygen (DO)** in surface waters comes principally from the atmosphere and from the photosynthetic activity of the algae and other water plants. Oxygen is moderately water-soluble. Its concentration varies daily and seasonally, depending on the phytoplankton species present in the water, the light penetration, the availability of nutrients, the temperature, the motion of the water, the partial pressure of the atmospheric dissolved oxygen, among other ones.

The concentration of dissolved oxygen is important to evaluate the quality of the surface water and to control the process of treatment of wastes. It is an essential compound for the aerobic respiration and it is a biological activity indicator.

In the Cuareim River (**Figure 5.1.1.1.4**) this variable complies 100 % with the Decree 253/79 and modifications.

It is interesting to note the seasonal variation of this variable, given that in winter with lower temperatures its dilution in water increases, and therefore its concentration increases, obtaining the highest values.

The percentage of oxygen saturation during the monitoring follows the same behavior than that of the DO.

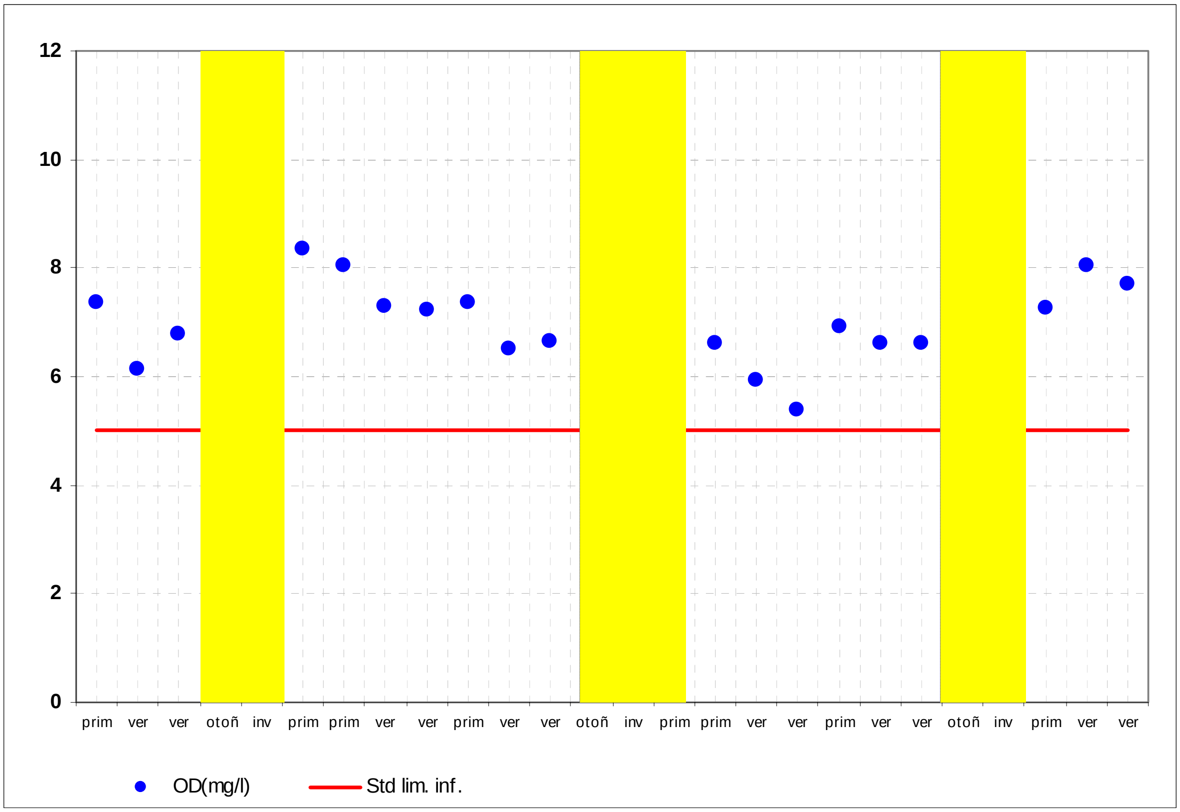


Figure 5.1.1.1.4 Dissolved oxygen at the different sampling stations and seasons (winters are shaded). Blue dots are dissolved oxygen. The red line is the standard's lowest limit of the Decree 253/79 and modifications

Turbidity is an expression of the water's optic property that causes the beams of light to be dispersed and absorbed instead of being transmitted in a straight line through it. It is a measure of the quantity of dissolved or colloidal substances present in the water body.

It is a characteristic of water bodies, that does not imply quality, but it is intimately related to soils washed away from the river bank and river bed. Generally it indicates the presence of organic substances of the type of humic and fulvic acids.

At the Cuareim River a mean value of 20 NTU is observed, with extreme values of 68 and 3 NTU.

This variable is regulated in the Decree 253/79 and modifications, being the standard value 50 NTU. Except for one value, all the measurements were below the limit (**Figure 5.1.1.1.5**).

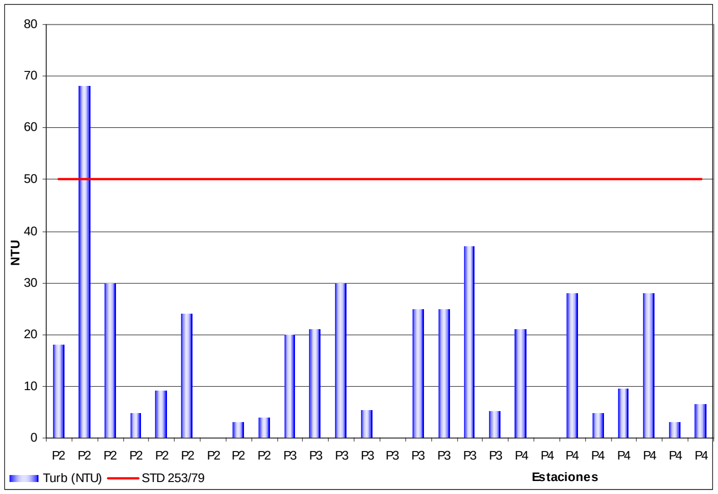


Figure 5.1.1.1.5 Behavior of the turbidity at the different sampling stations and seasons. In red, the limit of the Decree 253/79 and modifications

5.1.1.2 Alkalinity and total solids

The **alkalinity** of the water is a measure of the capacity of some of its components to accept protons. It regulates the changes in pH. Because of this, it is an important characteristic of the water bodies, as the pH has a direct effect on organisms and on the toxicity of certain contaminants. Also, the alkalinity plays an important role in the productivity of water bodies, being a back-up source for photosynthesis.

The compounds that contribute to alkalinity in the water bodies are carbonates, bicarbonates, phosphates, and hydroxides.

The alkalinity recorded at the Cuareim River has an average value of 53.3 mg $CaCO_3$/l, with a maximum value of 110 mg $CaCO_3$/l, and a minimum value of 27 mg $CaCO_3$/l (**Figure 5.1.1.2.1**).

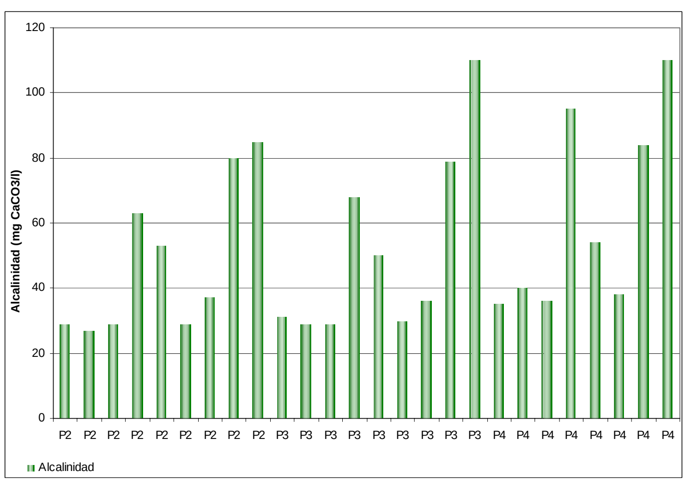


Figure 5.1.1.2.1 Behavior of the alkalinity at the different sampling stations and seasons Alkalinity: mg CaCO3/l Average = 53,3 Maximum = 110 Minimum = 27

The monitoring of **solids** (especially of suspended solids) is of vital importance in water quality studies. The distinction between dissolved and suspended solids is arbitrary, as there is not a physical discontinuity between the dissolved and solid states, which are linked by the colloidal state. The importance of monitoring suspended solids lies in that they are: carriers and storage-bodies of contaminants, contamination indicators, and records of contamination (when they sediment).

In the framework of the testing programmed for the Cuareim River, it was included the determination of total solids, suspended solids, and dissolved solids. However, the relationships found during the analysis of the data are not consistent enough to draw conclusions from them. Table II shows that the hydrological conditions at the moment of the different samplings were very dissimilar, what make these variables to change significantly, impeding the establishment of patterns in their behavior (**Figure 5.1.1.2.2**).

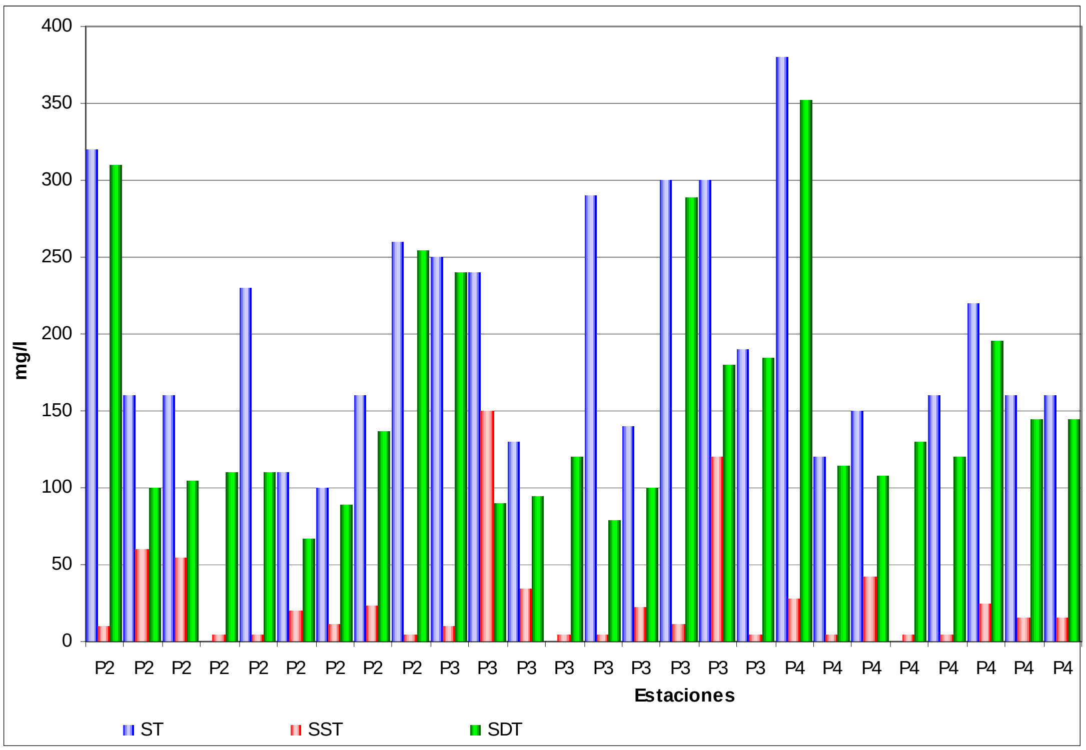


Figure 5.1.1.2.2 Distribution of total solids, total suspended solids, and total dissolved solids at the different sampling stations and seasons. In blue, total solids. In red, total suspended solids. In green, total dissolved solids.

5.1.1.3 Biochemical and chemical oxygen demand

The **Biochemical Oxygen Demand** (BOD5) is an empirical laboratory test to determine the relative requirements for oxygen of the water bodies. It is normally used as an approximation to the quantity of biochemically degradable organic matter in a sample.

The values found for the Cuareim River comply with the value established in the Decree 253/79 and modifications (10 mg/l). Even though most of the values are below the analytical quantification limit, some are above it. These quantifiable values were obtained when the river had very low flows (June 2007 and summer of 2008), but all the same they are below the limit set by the Decree (**Figure 5.1.1.3.1**).

The **Chemical Oxygen Demand** is an indirect measure of the equivalent oxygen of the organic matter content of a sample susceptible to be oxidized by a strong chemical oxidizer. It is measured with the objective of determining the characteristics of streams, sewage waters, industrial waste products, and effluents of treatment plants.

The values of the chemical oxygen demand (**Figure 5.1.1.3.1**) are always below the quantification limit that ranges between 11 mg O_2/l (DL) to 53 mg O_2/l (QL), so based on this variable the water quality is good.

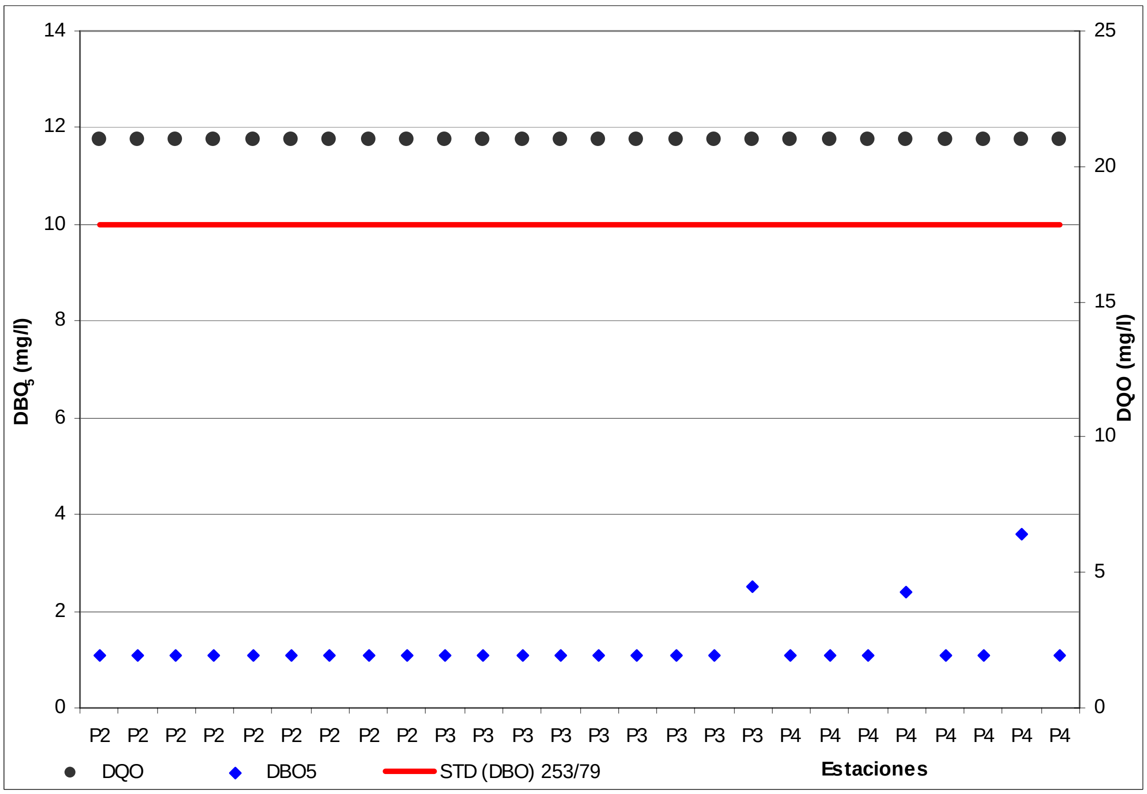


Figure 5.1.1.3.1 Distribution of BOD5 and COD at the different sampling stations and seasons. Left vertical axis, BOD5. Right vertical axis, COD. Blue dots correspond to BOD5 and black dots to COD. In red, the limit of the Decree 253/79 and modifications BOD → QL = 2,2 COD → QL = 53 y DL = 11

5.1.1.4 Nutrients

The importance of studying nutrients lies in that they are essential for the development and maintenance of aquatic life. Nutrients that are present in natural waters come from various origins: washed off lands, degradation of organic matter, or anthropogenic contributions from domestic or industrial effluents.

Dissolved inorganic salts and total nitrogen and phosphorous were monitored in this project.

Phosphates (PO_4) get to natural waters by the erosion of rocks. It is the oxidized form of the soluble phosphorous. They are biologically available, and are the available forms for the photosynthetic organisms.

Total Phosphorous (TP) represents and measures the organic and inorganic forms of phosphorous. It is an essential nutrient for the growth of the plants in fresh waters. Rarely, it is found in significant concentrations in surface waters. The monitoring of this parameter arises from the fact that it is normally the limiting nutrient, and anthropogenic contributions of phosphorus contribute to algae aquatic blooms.

Both compounds have anthropogenic origin, from effluents of domestic or industrial treatment plants, and from agriculture.

The Decree 253/79 and modifications limits the total phosphorus to 0,025 mg/l. **Figure 5.1.1.4.1** shows that none of the measures are below that limit.

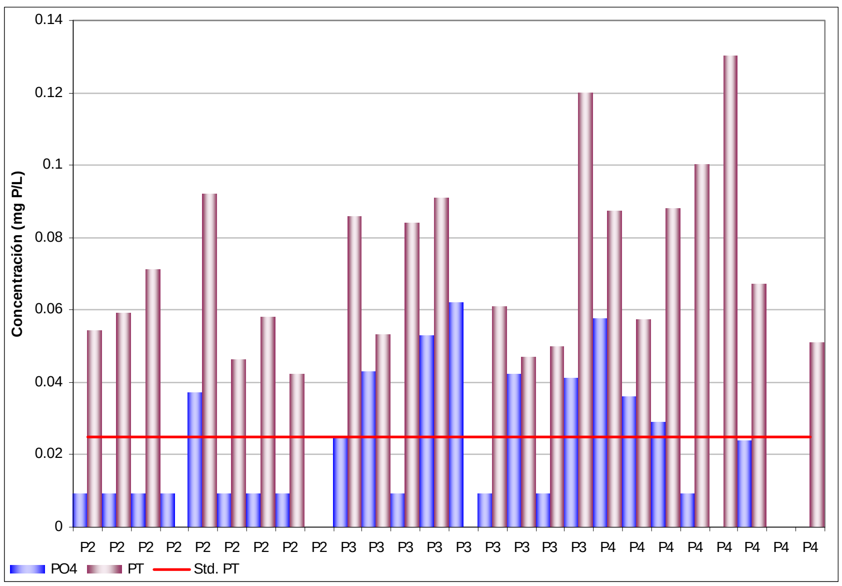


Figure 5.1.1.4.1 Distribution of PO4 and TP in the different sampling stations and seasons. Blue bars are PO4. Purple bars are Total Phosphorous. In red, the limit of the Decree 253/79 and modifications for TP. Fosfatos (PO4) y Fósforo Total (PT) : mg /l Std PT = 0,025 mg/l

Nitrates (NO_3) is the most oxidized and stable form of the nitrogen cycle, in a water body. It is the result of the complete oxidation of the nitrogen compounds. Its concentration can be expressed in micrograms or milligrams per liter, depending on the water body. The anthropogenic contribution of nitrates may be from effluents of domestic or industrial treatment plants, from agriculture, and from recreation.

They are important because they are the primary source of nitrogen used by the plants as nutrient, to stimulate their growth. Excess in their concentration may result in proliferations of phytoplankton or macrophites and be toxic for youngest stages.

Nitrites (**NO_2**) is the intermediate form in the nitrogen cycle. It is an unstable compound, which is rapidly oxidized to nitrate (nitrification) or reduced to gaseous nitrogen (denitrification). Its concentration can be expressed in micrograms or milligrams by liter, depending on the water body.

The anthropogenic contribution of nitrites is from urban and industrial effluents, agriculture production, and recreation.

Nitrites are also used as a nutrient source for plants, but they prove to be toxic for aquatic species in relative low concentrations.

The ammoniacal nitrogen includes the most reduced inorganic forms of nitrogen, that is dissolved ammoniac and ion ammonium. Even though ammoniac is a very small component of the nitrogen cycle, it contributes to the trophic state of water body. Its concentration on natural waters is expressed in micrograms and milligrams per liter. The importance of determining this parameter is that it contributes to the eutrofization of water bodies, favoring algae blooms which produce a deterioration of the water quality which impacts on the biota. Large concentrations of ammoniac are toxic for the aquatic life.

Figure 5.1.1.4.2 shows a predominance of the most oxidized and stable form (NO_3) in a water body. This makes evident the oxidation capacity of the system.

Ammoniac (NH_3) is the form that is regulated in the Decree 253/79 and modifications. All values were below that limit (**Figure 5.1.1.4.3**)

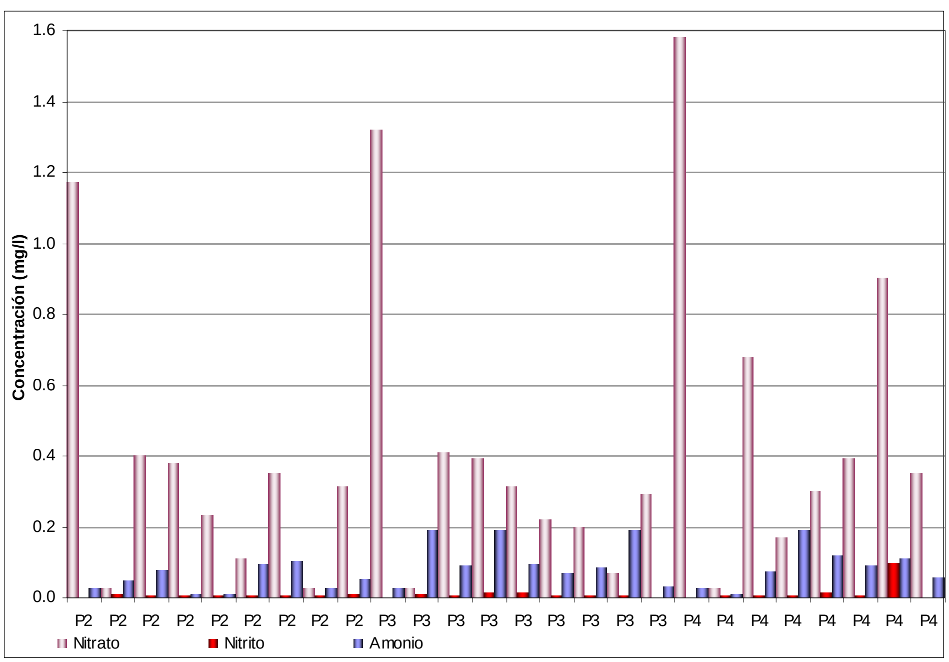


Figure 5.1.1.4.2 Distribution of NO3, NO2 and NH4 at the different sampling stations and seasons. Nitrate in purple. Nitrite in red. Ammonium in blue.

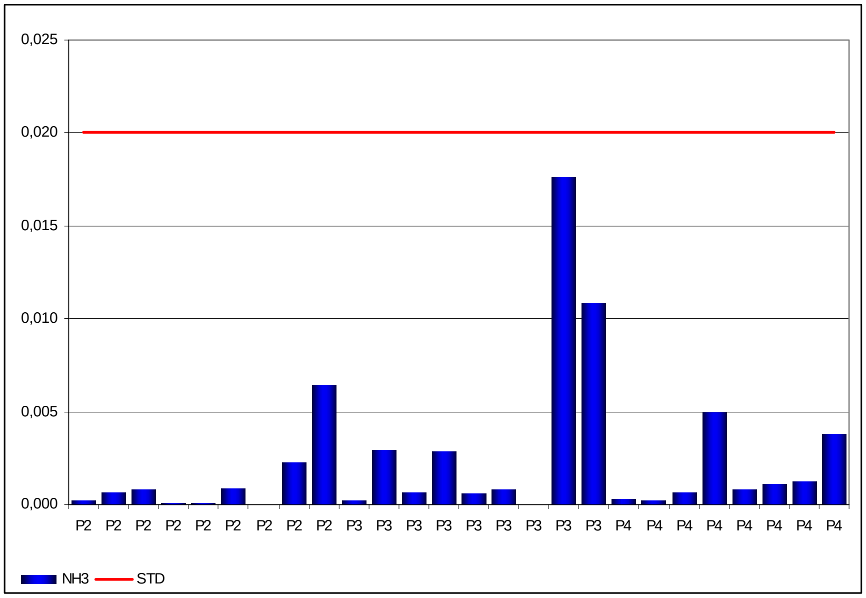


Figure 5.1.1.4.3 Distribution of ammoniac at the different sampling stations and seasons, and the limit for NH3 established in the Decree 253/79 and modifications in red

Kjeldal Total Nitrogen (KTN) is defined as the sum of the free ammoniac and the organic nitrogen compounds that turn into ammonium bisulfate in the course of digestion process of the sample.

The difference between KTN and free ammoniac gives the concentration of organic nitrogen of the environment. **Figure 5.1.1.4.4** shows its variation at different sampling stations and seasons.

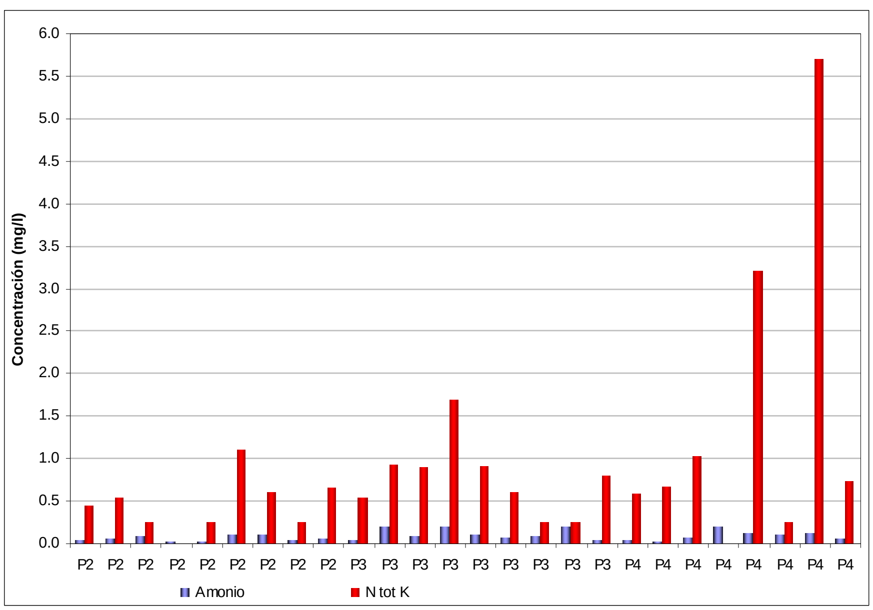


Figure 5.1.1.4.4 Distribution of ammonium and Kjeldhal Total Nitrogen (KTN) at the different sampling stations and seasons. In blue, ammonium. In red KTN

5.1.2 Inorganic compounds

5.1.2.1 Metals

Zinc is an element that abounds on rocks and minerals, but in natural waters is in low concentrations due to its low solubility (on the average 10 micro g/l).

It is an essential element for human nutrition, and generally it does provoke adverse effects if it is ingested in large quantities. It can be toxic for aquatic organisms, but the degree of toxicity varies a lot according to the characteristics of the water quality and that of the species under consideration (GEMS, 1994).

At the monitored locations, the zinc was in most cases below the limit required by the decree 253/79 (0.03 mg/l) (figure 5.1.2.1.1**). The values that are higher than the limit were obtained in the month of november with a flow of 33.3 m3/s that it is higher than the average of the flows recorded during all the samplings, but what it is important to note is that in the 15 previous days the biggest flow had been recorded (191.1 m3/s), which may have generated a contribution of zinc, washed off from the soil.**

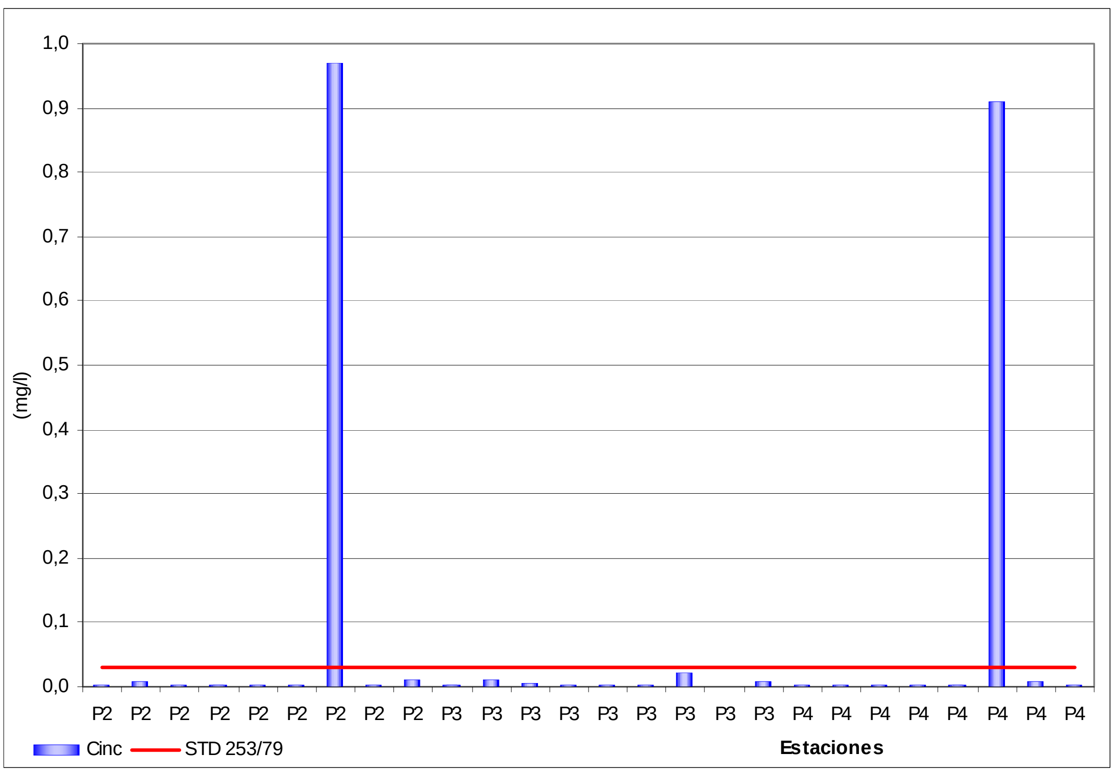


Figure 5.1.2.1.1 Distribution of zinc at the different sampling stations and seasons. In red, limit Decree 253/79 Zinc (Zn): mg /l Std = 0.03 mg /l

Aluminum is an element that abounds in nature, however low concentrations are found in the water. It is present in most rocks, minerals and clays that is why it is found in almost all waters on the planet.

The average concentration in fluvial waters is 0,24 mg/l with variations between 0,01 and 2,5 mg/l.

Figure 5.1.2.1.2 shows an average concentrations of 6,5 mg/l through points 2 to 4, which is higher than the reference average value mentioned by GEMS/W.

The value of November 2007, at point 4 does not seem to be an accurate record. It is possible that there was an analytical error or the antecedent flows (191,1 m3/s) must have washed off unexpected concentrations of that metal.

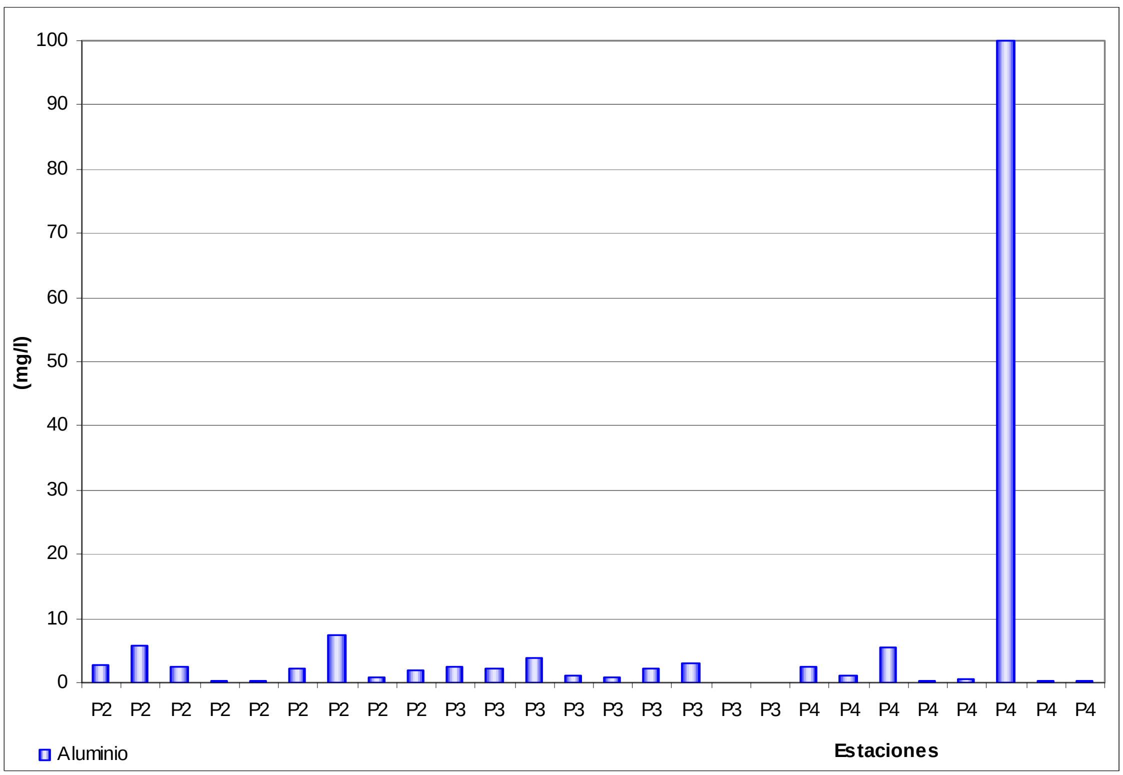


Figure 5.1.2.1.2 Aluminum's distribution at the different sampling stations and seasons. Aluminum (Al): mg /l Std = there is no standard

5.1.3 Microbiologic contaminants

Figure 5.1.3.1 shows the distribution at the different sampling stations and seasons of the Thermotolerant coliforms (Fecal coliforms). The limit established by the Decree 253/79 is 1000 UFC/100 ml. It can be observed that the monitored values are higher at Point 3, that is downstream the City of Artigas, being over the limit in two occasions. The limit was also surpassed in one campaign in Point 2.

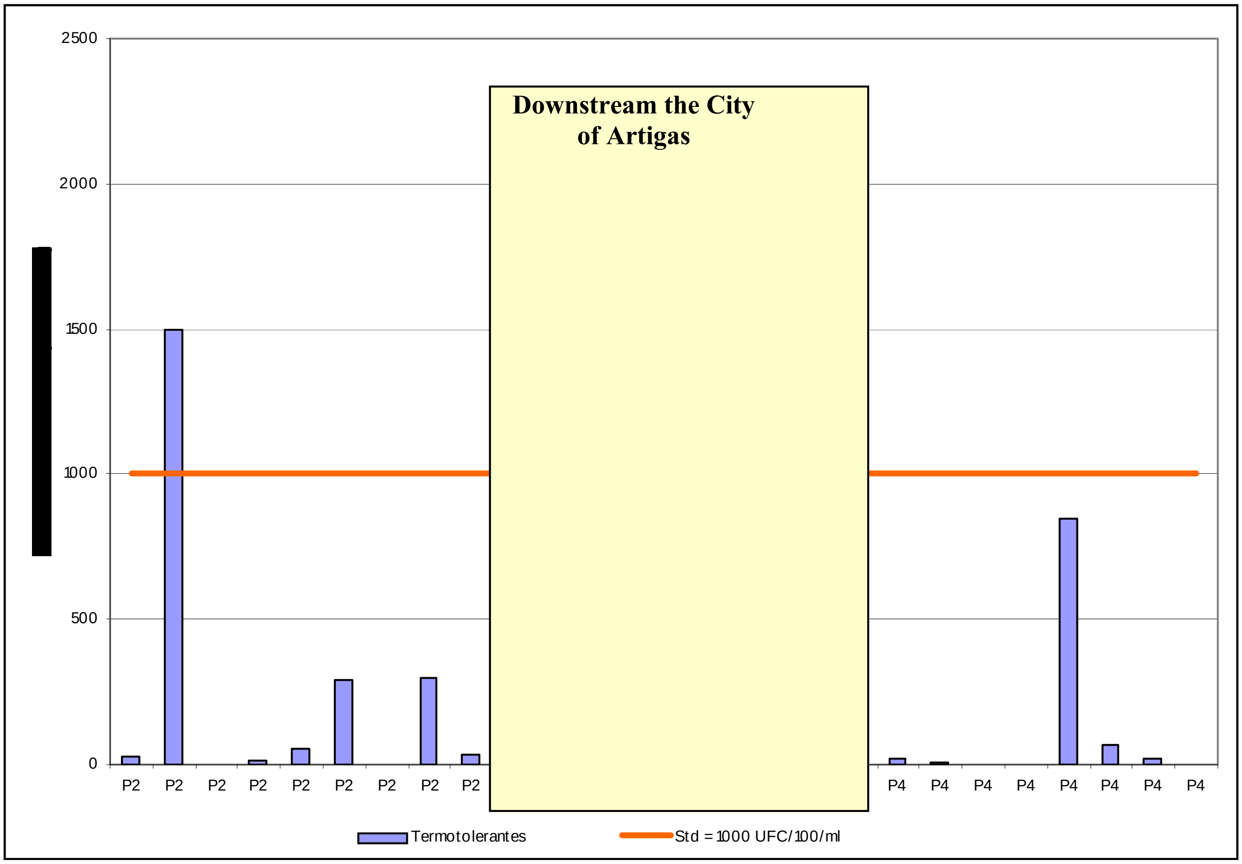


Figure 5.1.3.1 Thermotolerant coliforms (Fecal coliforms) distribution at the different sampling stations and seasons: UFC/100 ml Std = 1000 UFC/100 ml

5. 2 WATER QUANTITY

In general terms the methodology used was to devise and install a flow monitoring scheme, operated by DNH with the coordination of the IMFIA (Institute of Fluid Mechanics and Environmental Engineering of the University of the Republic of Uruguay), with the objective of getting the necessary data to quantify the water that returns to the creek from the irrigated rice fields and the irrigation demands in this pilot study.

The monitoring scheme that was built and installed will be described in **Table 5.2.1.**

Location (identified in **Figure 2.2.1** Chosen irrigation system and monitoring scheme on Landsat image)	**Flow measurement structure**	**Measured volumes**
C1	Venturi Channel **(ANNEX 3.2.1)**	Entrance to the fields
C2	Direct measurement in the channel **(ANNEX 3.2.2)**	Entrance to the fields
E	Flow measurement structure **(ANNEX 3.2.3)**	Total generated by the system

Table 5.2.1 Location, flow structures and objective

Two points C1 and C2 were needed as "entrance to the field", as the grower during the two rice seasons under study did not maintain the location of the rice fields, planting on the right margin in 2006-2007 and on the left margin in 2007-2008.

The precipitations were measured by the grower in the pilot study area and the potential evaporation used was the values calculated using the Penman method by INIA (National Institute of Agriculture Research) in the department of Salto (the closest evaporation data available to the area of study). The flow and precipitation values are presented in **Figures 5.2.1, 5.2.2, and 5.2.3**.

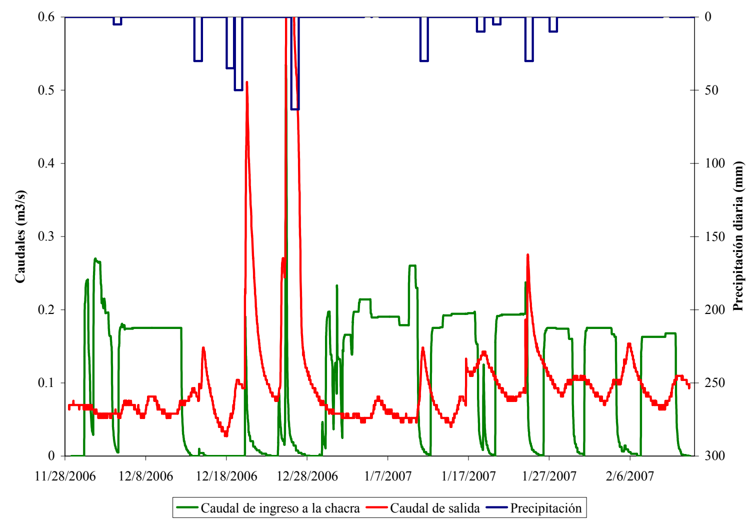


Figure 3.2.1 Monitoring that was done during the rice season 2006-2007. On the left axes flows are expressed in m3/s and on the right axes daily precipitation in mm. The green graph is the flow that enters the field, the red graph is the outlet flow, and the blue graph is the precipitation.

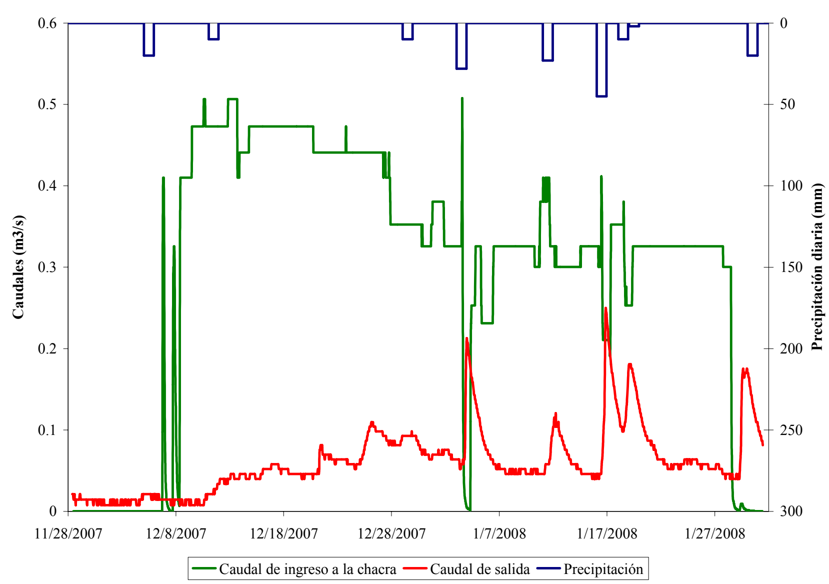


Figure 5.2.2 Monitoring that was done during the rice season 2007-2008. On the left axes flows are expressed in m3/s and on the right axes daily precipitation in mm. The green graph is the flow that enters the field, the red graph is the outlet flow, and the blue graph is the precipitation.

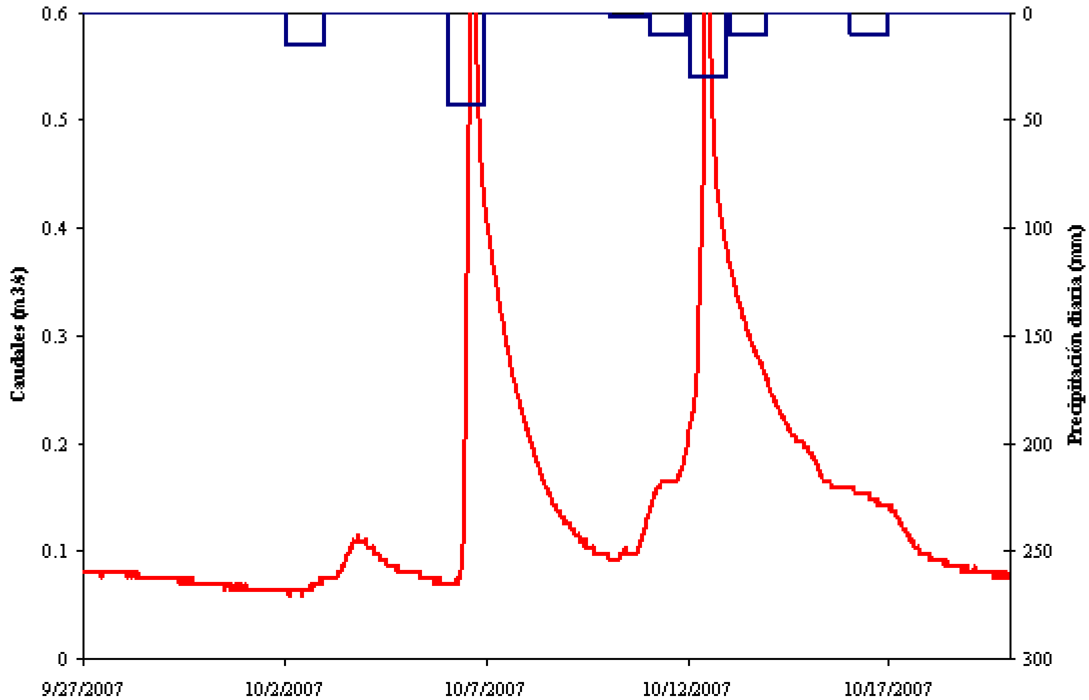


Figure 5.2.3 Monitoring that was done not during the rice season. On the left axes flows are expressed in m3/s and on the right axes daily precipitation in mm. The red graph is the flow at the outlet of the basin, the blue graph is the precipitation.

Although the initial methodology included just the measurement of flows to quantify the volume of water returning from the rice irrigated fields to the creek, the failure of some of the measuring structures mentioned before obliged to look for another way to quantify it.

Using the flows measured outside the rice season, during the period 27/09/2007 - 20/10/2007, a hydrologic model of continuous simulation and with daily-step precipitation was calibrated. It models the basin without the presence of the rice fields and the irrigation. The hypothesis that the portion of the basin with the presence of the reservoir does not participate in the hydrologic cycle was assumed, as during the study period the reservoir was not filled completely and therefore there were no spills. The model implemented (HEC-HMS) and its calibration are presented in **ANNEX 3.2.4.**

The methodology used to distinguish in the outlet flow of the system the portion of flow corresponding to the return of flow from the irrigated fields was to apply the model in the same period and compare the modeled and observed hydrograms together with the irrigation done and the precipitations that occurred. The periods with precipitation events were not considered, because during those periods the runoff is many orders higher than those during low flows. In all the cases, the antecedent conditions of soil humidity and water stored in ground reservoirs that the continuous simulation model generates itself after a warming time were used. It should be said that the calibration of the model was done in a visual way and from daily precipitation data, prioritizing a good fit of the recession curve and taking into account that the flow measuring structure cannot measure flows higher than 0.25 m^3/s. Not in all cases it made sense the measured precipitations and corresponding flows, and therefore it was assumed a deficiency in the measurement of the first one.

Finally, the flows returning from the fields to the creek were calculated as the difference between the modeled flow and the observed one in the periods without precipitation events and with irrigation.

The flow data used in the results are described in **Table 5.2.2** and in **Figures 5.2.4 and 5.2.5.**

Table 5.2.2 Available flow data

Monitoring point		***Beginning***	***End***
Entrance to the field and outlet of the basin	Rice Season 2006-2007	28/11/2006	13/02/2007
Entrance to the field and outlet of the basin	Rice Season 2007-2008	28/11/2007	31/01/2008
Outlet of the basin	Out of the rice season	27/09/2007	20/10/2007

In **Figure 5.2.4**, a high returning flow can be observed at the beginning of the rice season, accompanied by constant irrigation, then occurring precipitation events that increased the flows and affected the measurements. It is noted that the irrigation started days before than what can be seen in the graph. The weather continued rainy and it can be observed a new dry period from the 5-01-2007 on, when new flow-returns from the field to the creek occurred, accompanying the irrigation. It was decided not to consider the returns that came next, as they are associated to precipitations higher than those that were measured. These values would, furthermore, increase the return flow to 25% of the irrigated one.

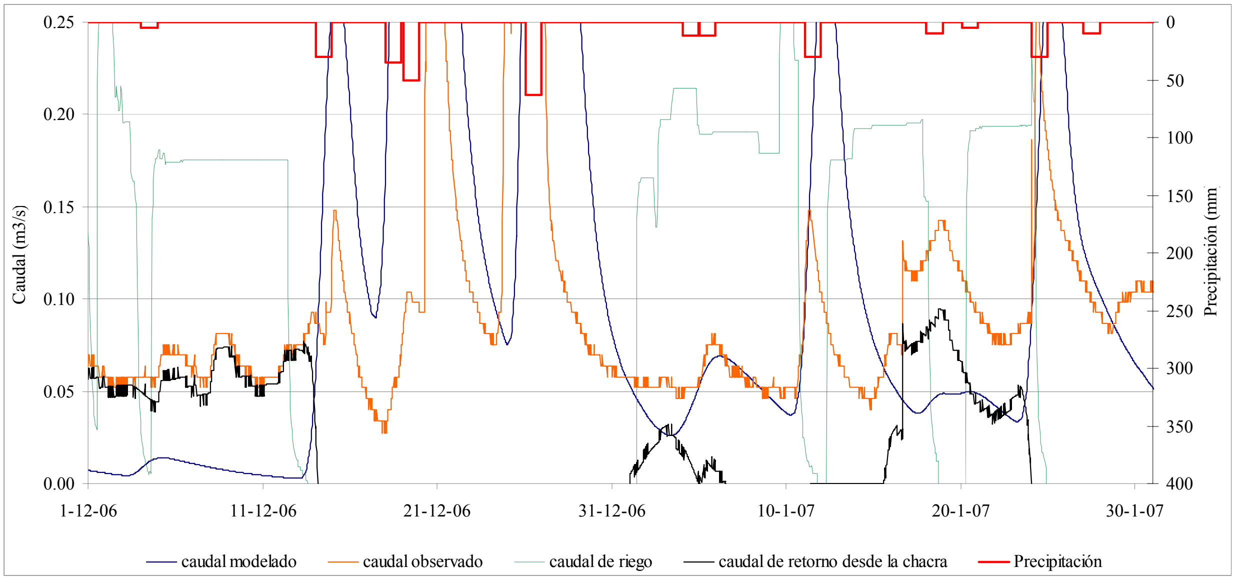


Figure 5.2.4 Results from the model and return flow from the field during the rice season 2006-2007. Left axes: flow in m3/s, Right axes: precipitation in mm. From left to right in the reference legend, we have: modeled flow, observed flow, irrigation flow, return flow from the field, and precipitation.

In **Figure 5.2.5**, it can be observed at the beginning of the rice season that the measured and observed hydrograms respond differently to the precipitation events. This difference may be due to the initial retention of the planted area at the outlet of the basin. From then, it can be observed that the flows that should decrease in a long period without rain, on the contrary increase, occuring an important flow return from the fields. Ahead, there are two more periods without rain, when new flow-returns occur.

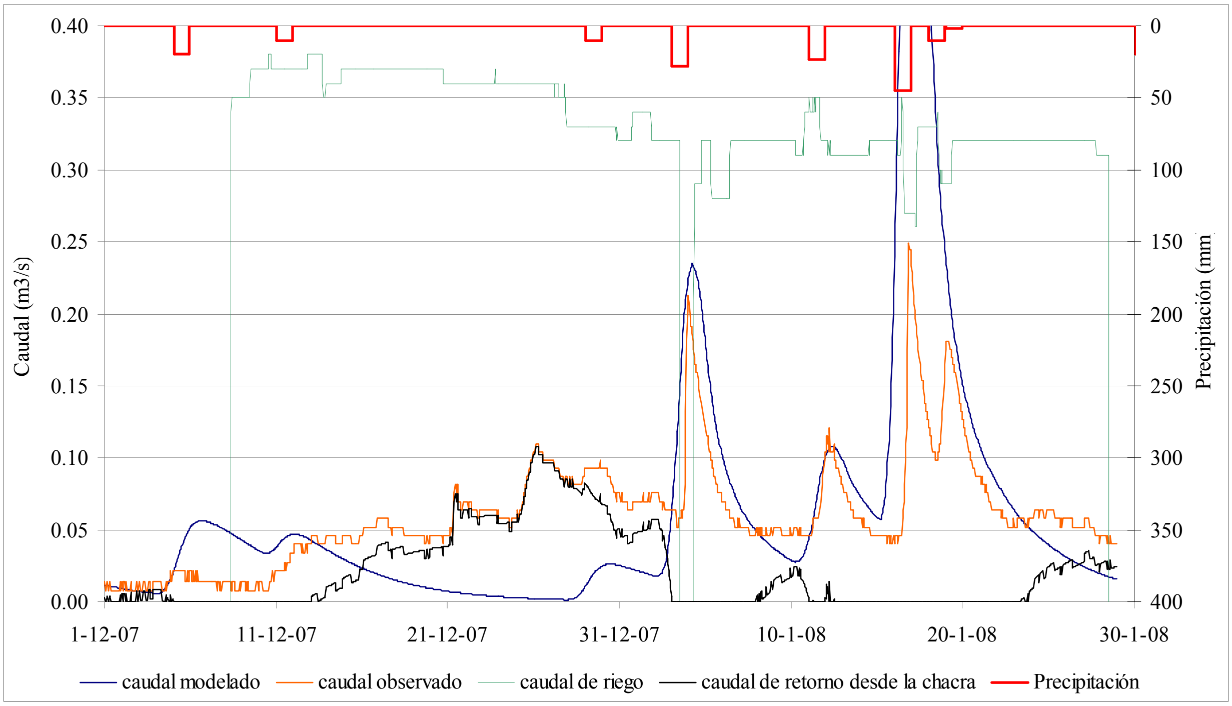


Figure 5.2.5 Results from the model and return flows from the field during the rice season 2007-2008. Left axes: flow in m3/s, Right axes: precipitation in mm. From left to right in the reference legend, we have: modeled flow, observed flow, irrigation flow, return flow from the field, and precipitation.

Finally in **Table 5.2.3**, the final results of the calculated return flows are presented, being 12% for the rice season 2006-2007 and 7% for 2007-2008. From that Table it can also be observed that the irrigation demand varies from 7700 to 7200 m3 per hectare, a lower value than the one generally used in irrigation projects (usually a demand of 14000 m3/ha is used).

Table 5.2.3 Results of the calculated return volumes

Season	***Planted (ha)***	***Irrigated total volume (*1000 m3)***	***Return volume (*1000m3)***	***Percentage***	**Applied irrigation per ha (1000m3/ha)**
2006-7	88	681	83	12%	7.7
2007-8	202	1461	107	7%	7.2

6. SUSTAINABILITY OF OPERATIONAL MONITORING PLAN

6.1 WATER QUALITY MONITORING

There is little knowledge about the water quality of the Cuareim River. TWINLATIN Monitoring Program has contributed to it but there is still a long way to go.

All the conclusions that can be drawn **are based on a low number of observations**, therefore the monitoring has to continue

- In general, the water quality of the Cuareim river is good
- Some variables show an increase of the relative concentrations closer to the mouth of the river
- Some variables show a strong association with the volume of water present at the time of the sampling

As a continuation of the work done in TWINLATIN, it is necessary to:

- Choose a greater number of monitoring stations, with a basin approach
- Modify the frequency of the sampling
- Monitor other variables such as majority ions that characterize water bodies, or biocides (chlorinated and phosphorated), Halogenated Organic Compounds, etc., in addition to those that have been monitored.
- Include sampling of sediments
- Continue with the monitoring to improve the data series of quantity and quality
- Relate biological data with environmental data
- Standardize the methodology of sampling and analysis of samples.

It is necessary to research on the contribution of nutrients from the basin to the water bodies, because the high levels of total phosphorous may be a natural characteristic of the basin or an anthropogenic impact.

Considering that it is a bi-national river, shared by Brazil and Uruguay, it is **essential to coordinate between the two countries**. It is a big challenge to be able to define and implement a monitoring program for the Cuareim River. During TWINLATIN, work was done in a coordinated, but parallel way. There is not yet real cooperation between the two countries to carry out a joint monitoring. Even though there are no clear signs of low water quality in the Cuareim River, it is the responsibility of both countries to maintain its quality, and if problems are detected they should be corrected in a shared and joint work. The important pressure that agriculture is having on water quantity will also be affecting the water quality.

In spite of the difficulties to carry out the monitoring during the project, it has to be said that for the first time both Brazil and Uruguay in the Cuareim River basin worked together in this issue, and many lessons have been learnt to devise a sustainable monitoring program.

6.2 WATER QUANTITY MONITORING

Monitoring of the uses of the water resources as the one presented in this pilot study in the framework of TWINLATIN requires important investments in the construction and maintenance of the structures used to do it. These investments and activities must be done with funds and equipment that today the Water Authority in charge of managing and controlling the use of the water resources and the university research centers do not have.

The measurement of flows in irrigation channels, the way it was done in this work, would be difficult for big flows associated to more that 300 ha of rice. It is recommended that the monitoring of flows of a channel be done by directly measuring flows and constructing the curve stage-flow that could be verified with hydrodynamic models.

The value of the return flow from the irrigated fields with the methodology used, can be estimated in 10% of the applied volume.

Lake Cocibolca Basin

Identification of priority data needs

Because the very low industrial activity around the basin the priority are the substances originated by agriculture, livestock, land use and domestic waste water. So nutrients, turbidity, dissolved oxygen and changes in land use would be the priority aspects to take in account in the monitoring program in the Lake Cocibolca.

Due to costs it is necessary to establish a methodology that in indirect way, the institutions and stakeholders can get an appraisal of the menace of pollution to waters of the Lake Cocibolca. This could be a valuable result of the project. For example, the use of free remote sensing (e.g. for evapotranspiration calculations) products can be interesting in this context (see also activities under WP03).

A state-pressure-response framework, like the one used for Thames basin, in dimensions according to the reality and needs in Lake Cocibolca basin, could be a tool for the management of the basin.

Monitoring under TWINLATIN

Since September 2006, through the Project TwinLatin Cocibolca, personnel of the Direction of Water Resources of INETER, every two or three months made measurements of liquid and solid flows on the main 6 rivers of the eastern side of the basin and on San Juan and Frio rivers too (see Table LC3.1). Samples of waters are collected and transported to CIEMA water quality laboratory to determine physical and chemical characteristics of that river waters.

Table LC.3.1. Rivers, station code and initial date of solid and liquid measurements

#	River	Measurement points	Code	First sampling date
1	San Juan	2	690102 690112	15-11-2006 14-11-2006
2	Malacatoya	1	690501	29-09-2006
3	Mayales	1	690801	28-09-2006
4	Acoyapa	1	691001	28-09-2006
5	Oyate	1	691201	26-09-2006
6	Tepenaguazapa	1	691302	27-09-2006
7	Camastro	1	6920009	29-09-2006
8	Frío	1	690114	14-11-2006
Total		9		

CIEMA has collected water quality data during the TWINLATIN Project, from records of drinking water wells, and rivers water samples collected by INETER during the measurements of flow and sediments. There are data from 89 wells, 17 river points, 3 creeks and 6 lake points. Figure LC.3.1. shows spatial distribution of these points and Table LC.3.2 indicates the date of first sampling.

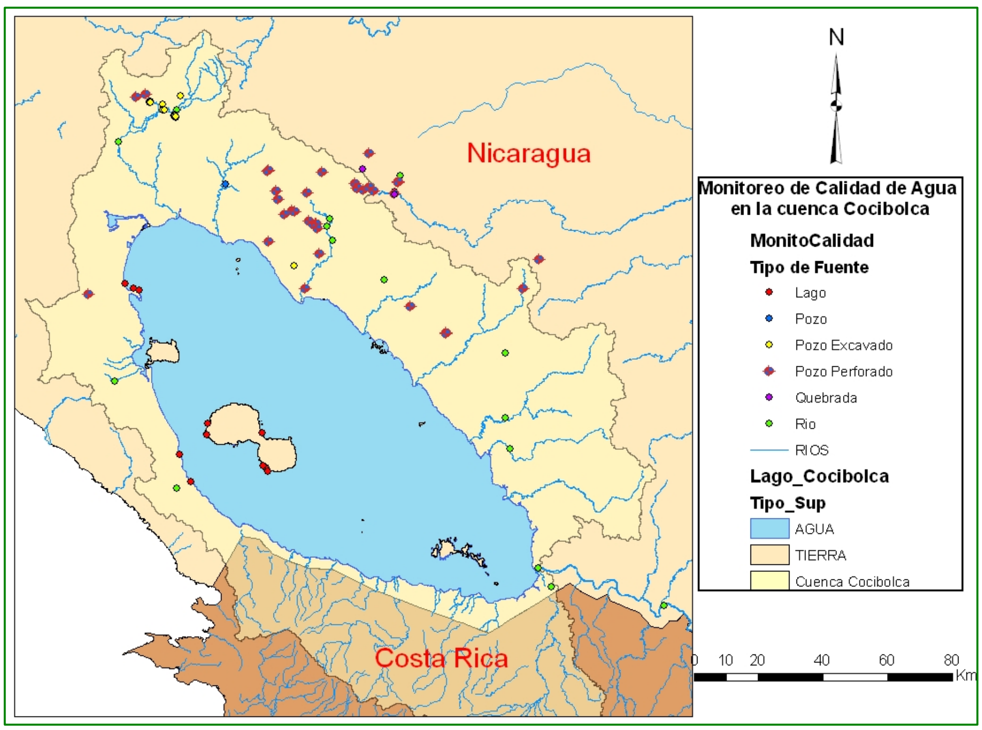


Figure LC.3.1. Physical Chemical water quality sampling points

Table LC.3.2. Number of sampling points and rivers sampled

#	River	Number of sampling points	Type of analysis	First sampling date
1	San Juan	2	FQ	14-11-2006
2	Malacatoya	2	FQ	18-11-2006
3	Mayales	3	FQ	08-06-2006

4	Ochomogo	1	FQ	01-05-2007
5	Acoyapa	1	FQ	28-09-2006
6	Oyate	1	FQ	26-09-2006
7	Tepenaguazapa	1	FQ	27-09-2006
8	San Miguel	2	FQ	16-03-2004
9	Kinuma	1	FQ	16-03-2004
10	Camastro	1	FQ	29-09-2006
11	Las Lajas	1	FQ	01-05-2007
12	Frío	1	FQ	14-11-2006
Total		17		

Table LC.3.3. shows a list of parameters measured in samples collected from different waters sources in different time periods by differents agents (CIEMA, NICANOR).

Table LC.3.3. Water quality parameters measured in samples

Parameter	Lake Cocibolca (CIEMA) (2006-07)	Rivers	Creek	Wells	Lake Cocibolca (NICANOR) (2004-07)
Total Arsenic (As)			X	X	
Carbon Dioxide	X				
pH		X			X
Conductivity		X			
Turbidity		X			
Color		X			
Alkalinity		X			
Bicarbonate		X			
Total Hardness		X			
Calcic Hardness		X			
Calcium		X			
Magnesium		X			
Chloride		X			
Ferrum		X			
Nitrite		X			X
Nitrate		X			X
Sulphate		X			
Sodium		X			
Potasium		X			
Fluoride		X			
Phosphorus		X			X
Nitrogen		X			X
Suspended Total Solids		X			
Total Solids		X			
Dissolved Oxigen					X
Chlorophyll					X
Temperature					X
BOD 5					X
Ammonium					X

In addition to this, through a twinning effort with EULA, a field campaign was conducted to obtain sediment cores for 210Pb from the Lake and the Las Canoas reservoir. Results from these cores (analysis to be conducted) will aid in the interpretation and validation of the results from the erosion modelling application conducted by means of the WATEM-SEDEM tool.

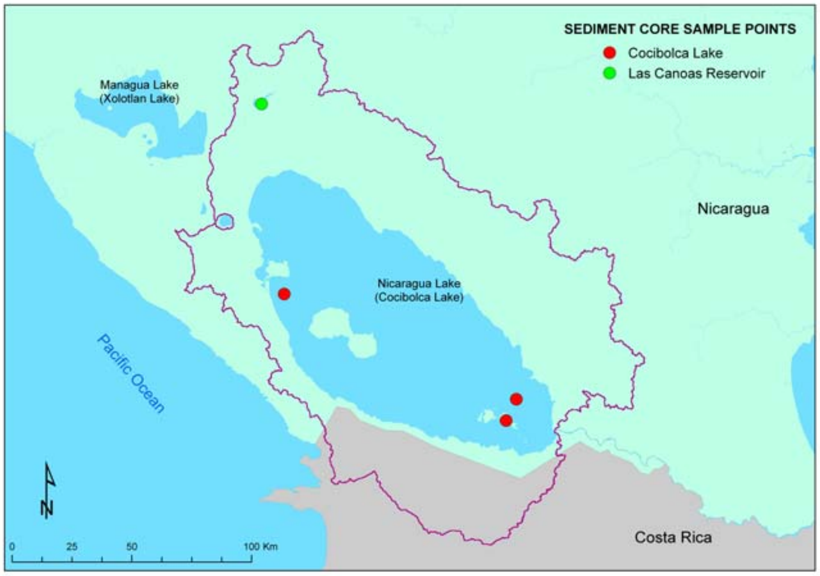


Figure LC3.2. Sites in the Cocibolca Lake Basin where the sediment cores have been taken

Results from all monitoring efforts were incorporated in the Georeferenced Environmental DataBase System for the Cocibolca Lake SIGACC, based on the ArcHydro time series model. Data has been made available to the water authority INETER for reference in future works on the Cocibolca Lake Basin. The information will also constitute a valuable input for the Nicaraguan "Country Environmental Assessment", to be conducted in the first half of 2009.

Baker Basin

As the TWINLATIN monitoring efforts in the Baker Basin are oriented - at least to a considerable extend - towards (i) a better understanding of ecosystem functioning, and (ii) the establishment of reference conditions, simultaneous work needed to be done on the establishment of a water body typology for the Basin (WP07; for this reason figures indicating (macro-invertebrate) monitoring sites are also given in the WP 7 report). Together with the results from the identification of pressure sources (WP06), this typology can be used in the future for further optimizing the design of the monitoring campaigns.

Monitoring during the Austral winter in the Baker Basin is logistically complicated. For this reason, the monitoring activities typically took place starting in Spring. In addition to the river monitoring, a special interest existed from the local water management and stakeholder community on the obtention of baseline information for both the river system and the adjacent transition zone (entrance of Baker in the "Baker canal" and connected fjord system. This is especially relevant with regard to potential impacts of damming on the Baker River (hydropower development), which might lead to considerable changes in the future sediment composition delivered by the Baker to this coastal zone ecosystem. Due to the relatively pristine characteristics of the area and the lack of available baseline information on the topic, and in agreement with the interests expressed by the local research centre CIEP and the water authorities, a lot of emphasis was also put on monitoring of biological/limnological variables in the Basin's lake and river network.

With regard to this last aspect, the following topics were identified as important for evaluation under TWINLATIN (reference for comprehension of ecosystem functioning and for future change monitoring):

- ✓ specific organic load problems of the aquatic systems.
- ✓ Abundance and biomass of bacteria, viruses, heterotrophic flagellates and zooplankton: Acquisition of the microbial eco-structure of the lake plankton which is representing the dominant protagonists for the conversion of substances and water quality in lakes. From this all so called "ecosystem services" (e.g. degradation of organic matter, biological productivity) emanate from.
- ✓ Radiochemical quantification of bacterial cell and biomass production rates: The bacterial production rates exhibit a key process for the degradation and the preservation of water quality. Ecological stability, carrying capacities and the capacities for organic conversion of substances can be derived. The quantification of microbial incorporation and respiration rates in respect to processing and eliminating the OM from the water column via CO2. As a result, the uptake of organic matter by bacteria is a major carbon–flow pathway, and its variability can change the overall patterns of carbon flux in the lake.
- ✓ Radiochemical quantification of primary production rates: Eutrophication processes can lead to an excess of phytoplankton primary production which then will affect the water quality adversely until the formation of dead zones. The quantification of the phytoplankton primary production rates reflect the eutrophication status and are a critical parameter, thus essential for monitoring programs.
- ✓ Microautoradiography (MAR – "double label technique") for identification of metabolically active bacteria: 3H–leucine: Using MAR we can quantify the share of active (metabolizing) bacteria / cells. With this we can relate conversions of substances specifically to the participated bacterial abundance and to trace the matter flow through the whole food web (e.g. processes like incorporation, transportation, grazing, and degradation of organic matter).

Monitoring under TWINLATIN

Freshwater biodiversity

During January 2006, an extensive freshwater biodiversity monitoring campaign was executed by researchers from EULA, in the framework of the initiation of the research activities of the Centre for Research on Patagonian Ecosystems CIEP. The campaign makes part of (Ph.D.) research at EULA, which is associated to both the TWINLATIN project as well as the small-grant DIUC project "Spatial Patterns of Freshwater Biodiversity in the Aysén Region".

General objectives of the monitoring are: **(1)** to characterize the diversity and distribution of the aquatic ecosystems in the Baker River Basin, as well as (**2**) the composition and patterns of spatial distribution of aquatic species (mainly macro-invertebrates); (**3**) to identify and to locate conservation objects (species, communities and ecological systems); and (**4**) to select the best examples of conservation objects that on the whole represent the complete diversity of the aquatic ecosystems of the region.

Objectives of the monitoring specifically with respect to the TWINLATIN project are: (**1**) to characterize the diversity and distribution of water body types (this includes an aggregation of the most similar aquatic ecosystems, in order to provide information for checking compliance of future environmental standards based on water body typology – in case it works); (**2**) the identification of reference conditions at different water bodies (and see if there is a relation with theoretically derived water body typology; (**3**) the identification of water bodies currently under pressure; (**4**) the incorporation of biological parameters/reference data in future water quality standards for the Baker River Basin ; **(5)** providing information for the establishment of the Secondary Water Quality Standard for the Baker river.

More than 50 stations were sampled during this January 2006 campaign. Besides the biological parameters (benthonic macro invertebrates, periphyton and bird fauna (field observations)), the following physicochemical parameters were measured: Conductivity, pH, Dissolved Oxygen, Temperature, visual Turbidity, Turbidity and Color. Measurements of depth and speed were also carried out.

Whenever practically feasible, for the selection of future monitoring stations the results from the establishment of a theoretical water body typology were taken into account (GIS exercise, WP07).

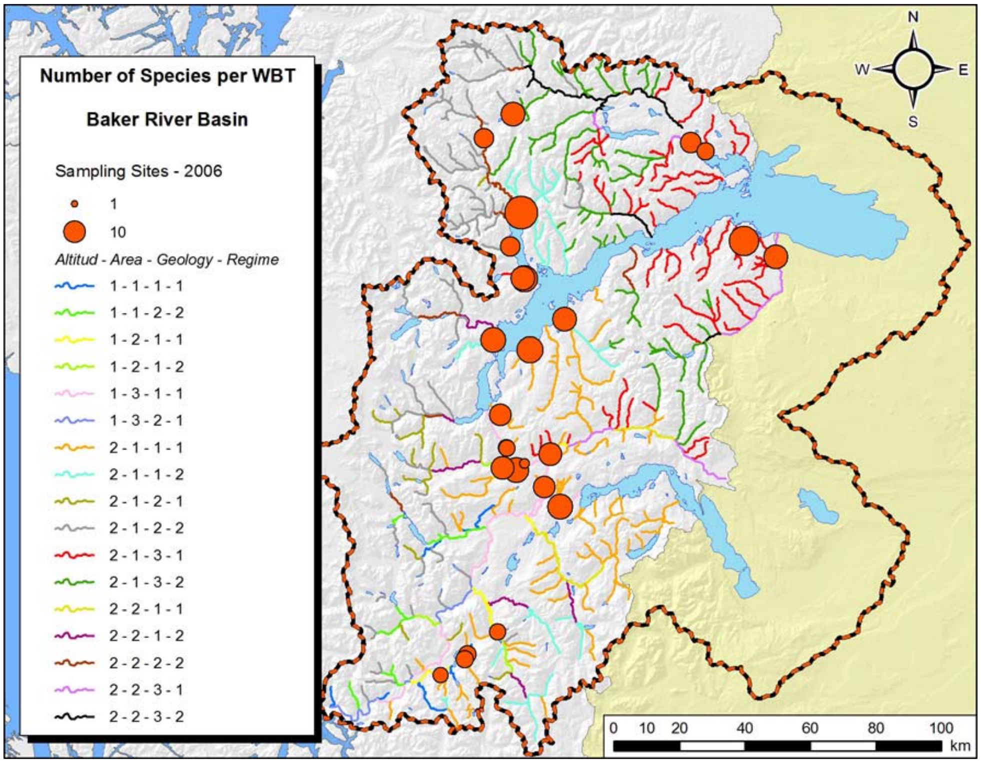


Figure B.3.1. Species richness at selected sampling stations from the 2006 campaign

Additionally, a limited amount of monitoring on the presence of native fish species in lake ecosystems is being executed in the framework of a collaboration with a DIUC project entitled "Spatial & Temporal Patterns of the Native and Non-native Lacustrine Fish Fauna of the Aysén Region: an Approach based on Community and Population Levels", which is also associated to the EULA, CIEP & TWINLATIN research activities on the Baker River Basin and wider Aysén Region. At the community level, it focuses on spatial & temporal distribution patterns, species diversity and taxonomic distinctness, and their relationship with physical and ecological variables. At the population level, it will examine morphological and life history variation among galaxids in lake systems of the Aysén Region, and the relationship with physical and ecological variables. On a practical level, the information on species distribution is useful for setting reference conditions and interpreting disturbance levels for a limited number of Baker River Basin lakes. Figure B.3.1. shows the stations within the Baker Basin that were sampled during the first field campaign, executed in January 2006.

Sedimentometric Stations

In the context of TWINLATIN, the General Water Directorate DGA of the Aysén Region was capable – through the support of EULA – to install 2 turbidimeters with data logger in the Baker River basin. The information obtained from these instruments is currently subject to a validation process by part of central DGA (in the city of Santiago) and is expected to be available for use and for incorporation in the Basin databases.

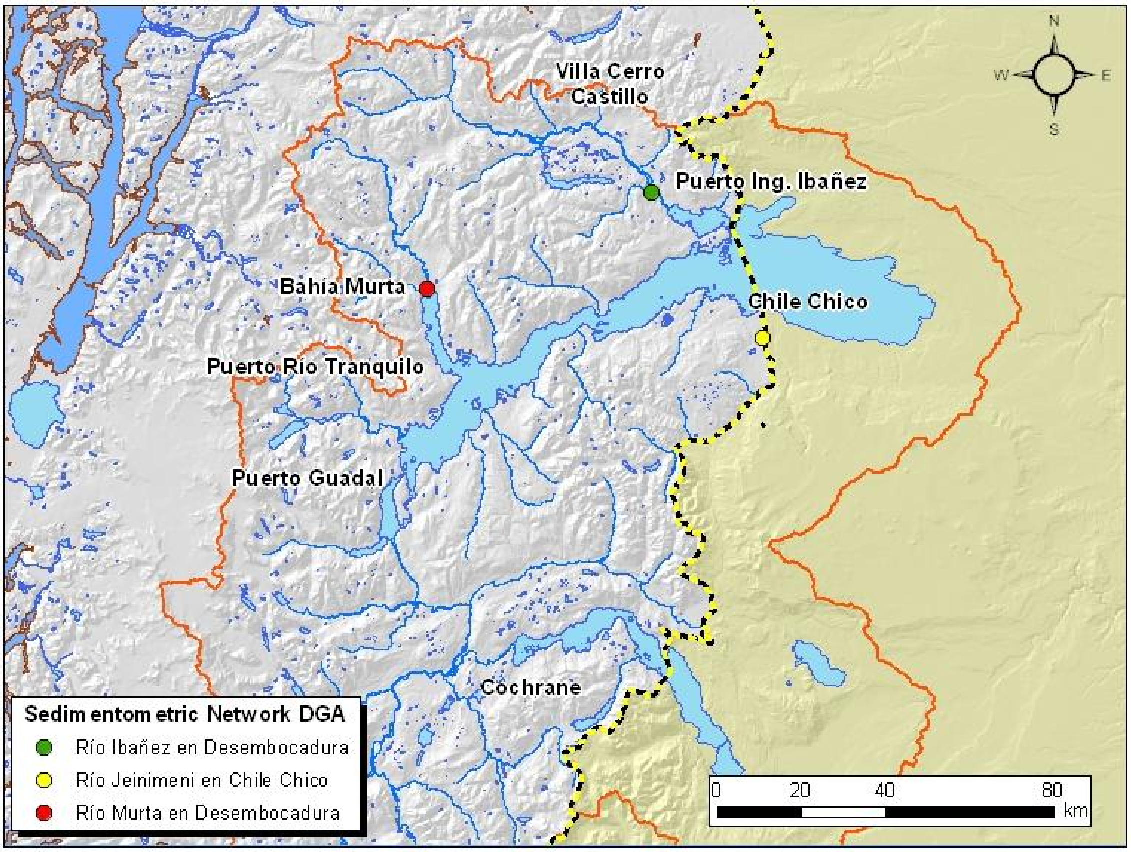


Figure B.3.2. Sedimentometric Network DGA

Monitoring about the origin of organic material in a continuous lake-river-fjord and exterior canals

In collaboration with the CIMAR 14 campaign of the CIMAR-Fjord Program of the National Oceanographic Committee (CONA), samples were taken on board of the investigative ship AGOR Vidal Gormáz, in the zone near Caleta Tortel (mouth of the Baker River), Baker Canal, Mitchell Fjord, until the most exposed zone of the Messier Canal. In each one of these stations, water samples were taken, which were filtered in GF/F filters (4-5 hours, at 400 ºC) for isotopic analysis of the δ13C and fatty acids composition in the particulate fraction of the organic material. In a complimentary form, this analysis of δ13C and fatty acids, as well as of δ15N in mesozooplankton organisms (mainly copepods and anphipods) collected through casts with Tucker Trawl plankton nets of 500 m of mesh were carried out, with the objective being able to establish until which point the alochtoneous/terrigeneous materials transported by the Baker River are reflected in the organic carbon assimilated by marine organisms through the consumption of detritus contributed by this river. In compliment to this study, samples were taken at four points along the Baker River itself: 1) General Carrera Lake, 2) The beginning of the Baker River in

Puerto Bertrand, 3) halfway point of the river, and 4) close to 12 km from the mouth of the river in Tortel Cove.

Together with this analysis of isotopes and the analysis of fatty acids composition in the particulate organic material, samples were taken, both in the river as well as in parts of the canals and fjords for nutrient analysis (i.e. nitrate, nitrite, phosphate and silicates), pH, and alkalinity which were carried out in a complementary way by the Biogeochemical Laboratory at the P. Universidad Católica de Valparaíso, under the charge of Dr. Nelson Silva.

Finally, water samples for analysis from the community pico-, nano-, y microplanktonic were taken at the mouth of the Baker River, Baker Canal, Messier Canal, and nearby fjords.

This study was co-financed by the CIMAR 14 Program, with TWINLATIN support for the the isotopic analysis and fatty acids analysis in the river and of the fjord ecosystem. This is the first study in our country that analyzes, through a geochemical organic focus (isotopes and fatty acids), the destiny that the organic material has contributed by the rivers, in an ecosystem of canals and fjords in the Chilean Patagonia. We hope the study allows us to understand the pivotal role that the contribution fresh water, organic material, and nutrients from the Baker River play, in the operation of an adjacent marine ecosystem. The study acquires special relevance in the light of the planned hydropower development on the Baker River, which has led to (inter-)national controversy.

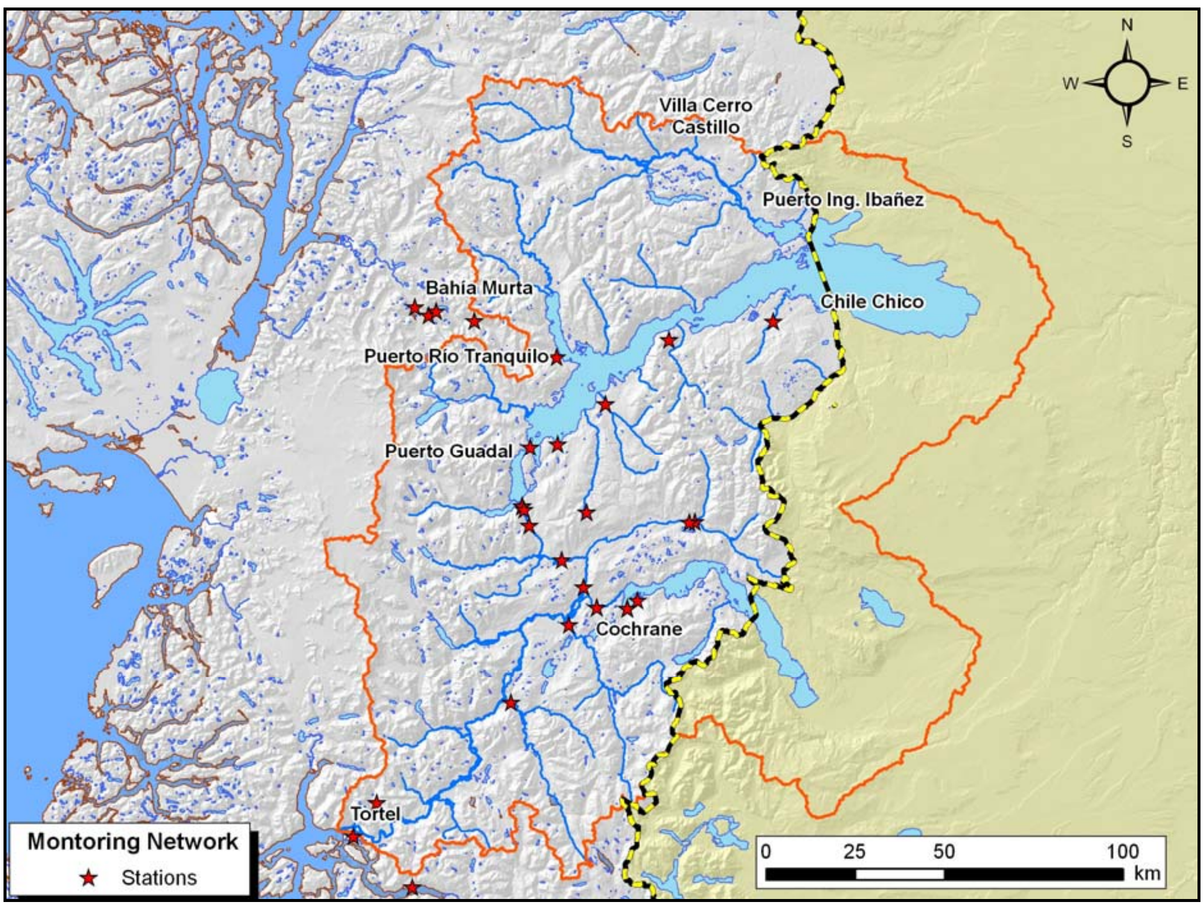


Figure B.3.3. Location of the stations sampled

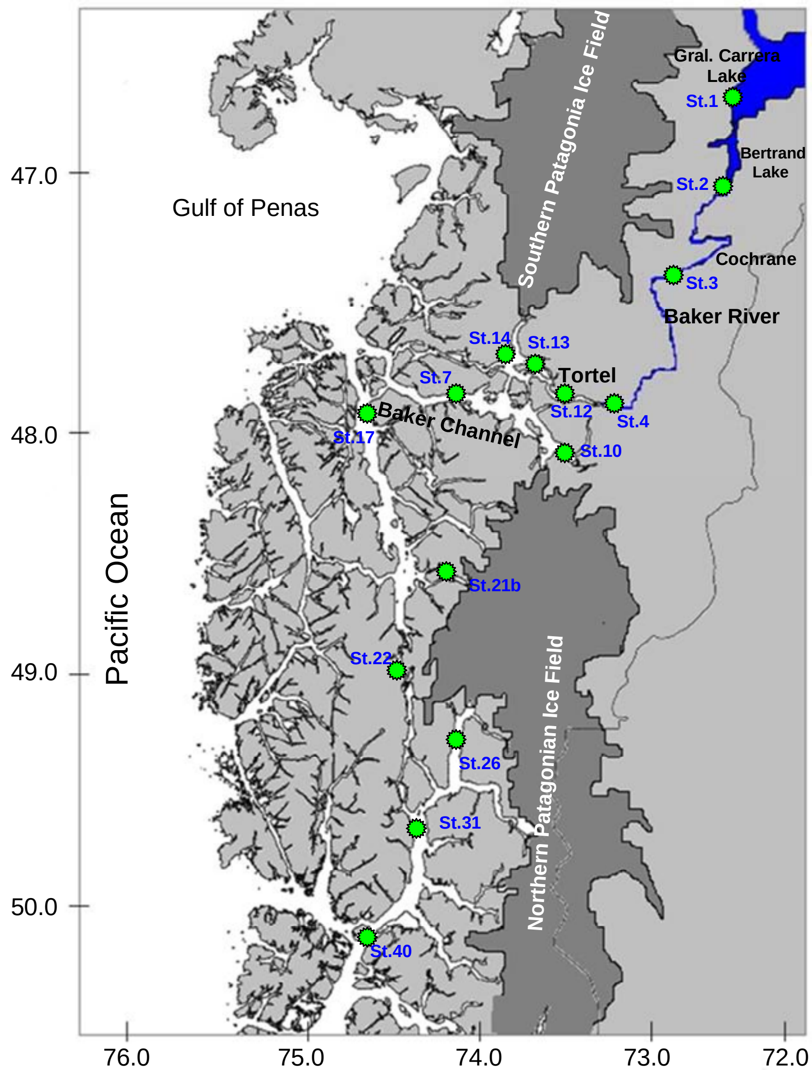


Figure B.3.4. Study Area of the CIMAR Fjord 14 Cruise in the area of Baker Canal, Steffen and Messier, and stations along the Baker River during the study

Paleolimnologic Monitoring of the Baker Basin lakes

In general terms, the sample of each lake involved the determination of depth through bathymetric tracks carried out with an echo sound/GPS Garmin 176C, that in addition to depth turned in the geographic location of each point. With this basic information collection of sediment samples in the most appropriate sector of the lake continued. For this, an Uwitec brand gravity sample with a hammer action system was used, which allows obtaining a column of sediment up 1.5 m long. Part of the samples was selected on land at intervals of 0.5 – 1cm, and packed appropriately for their transport to the laboratory and corresponding analysis. Another part of the samples, those of greater length, were stored in PVC tubes that were sealed and sent for analysis to Woods Hole Oceanographic Institution, USA, and to the Geology Department of the University of Liege, Belgium. In the laboratories of these institutions they are developing ITRAX analysis core scanning and mineralogical analysis. The analysis and parameters specified to carry out and/or sample during the execution of this monitoring is detailed here:

Table B.3.1. Paleolimnologic monitoring

Laguna Larga				
Sampling date:	19/01/2008	Latitude:	47º27'50,4"	
Depth:	24 m	Longitude:	72º48'01.9"	
Altitude:	275 m			
Cores retrieved	**Analyses**	**Core length**	**Sampled**	**Stored**
A	SCP	40 cm	37 cm	EULA
B	POPS	42 cm	38 cm	EULA
C	210Pb	38 cm	34 cm	EULA (UCL)
D	Long	80 cm		EULA
E	Long	73 cm		EULA
F	Long	89 cm		ULG

Laguna Cisnes				
Sampling date:	20/01/2008	Latitude:	47º06'50,6"	
Depth:	18 m (A to E) 8-10 m (F to G)	Longitude:	72º27'02.2"	
Altitude:	447 m			
Cores retrieved	**Analyses**	**Core length**	**Sampled**	**Stored**
A	210Pb	53 cm	41 cm?	EULA (UCL)
B	Bio	53 cm	51 cm	EULA
C	POPS	60 cm	41 cm	EULA
D	Long	77 cm	71 cm	EULA
E	No samples			
F	210Pb		47 cm	EULA
G			44 cm	EULA

Lago Negro				
Sampling date:	21/01/2008	Latitude:	46º54'14,6"	
Depth:	92 m	Longitude:	72º47'32.5"	
Altitude:	218 m			
Cores retrieved	**Analyses**	**Core length**	**Sampled**	**Stored**
A	X-ray	34 cm	30 cm	EULA
B	Bio	?	21 cm	EULA
C	POPs	?	22 cm	EULA
D	210Pb	?	23 cm	EULA (UCL)

Lago Sitting Bull				
Sampling date:	22/01/2008	Latitude:	46º42'49.1"	
Depth:	24 m	Longitude:	72º41'58.9"	
Altitude:	208 m			
Cores retrieved	**Analyses**	**Core length**	**Sampled**	**Stored**
A	210Pb	35 cm	25 cm!!	EULA (UCL)
B	Bio	37 cm	37 cm	EULA
C	POPs	29 cm	27 cm	EULA
D	Long	100 cm		EULA
E	Long	135 cm		ULG
F	Long	149 cm		WHOI

Lago Alto				
Sampling date:	24/01/2008	Latitude:	45º31'50.2"	
Depth:	58 m	Longitude:	72º42'24.1"	
Altitude:	95 m			
Cores retrieved	**Analyses**	**Core length**	**Sampled**	**Stored**
A	210Pb	59 cm	58 cm	EULA (UCL)
B	POPs	57 cm	53 cm	EULA
C	Bio	55 cm	50 cm	EULA
D	X-ray?	??		EULA

Lago Thompson				
Sampling date:	25/01/2008	Latitude:	45º38'26.7"	
Depth:	15 m	Longitude:	71º47'07.0"	
Altitude:	750 m			
Cores retrieved	**Analyses**	**Core length**	**Sampled**	**Stored**
A	Bio	41 cm	45 cm	EULA
B	POPs	31 cm	31 cm	EULA
C	Pigments	wrapped		EULA
D	210Pb	49 cm	41 cm	EULA (UCL)
E	Long	140 cm	45 cm	WHOI
F	Long	126 cm		ULG

Once the analysis are completed (task for on-going post-twinlatin research at EULA), a better idea will be obtained on the influence of important historical pressures (forest fires, overgrazing) on the past and current status of these lake ecosystems, and on background and perturbed erosion rates in these parts of the Baker Basin.

Paleolimnological Sample. January 2008 Campaign

In Figure B.3.5. some preliminary obtained results of the Burgos Lake sediments are presented. Specifically, the values of radioisotopes ^{210}Pb and ^{137}Cs have been determined, for the establishment of the chronology of the sediments. According to these estimations, the first 32 cm of the column cover the temporal range of the last 92 years; nevertheless, due to the preliminary characteristic of these estimations, the final dating of the sediments can present some differences, so final conclusions are not yet made at this time.
Regarding the activity of the ^{210}Pb, this isotope presents important variations during the profile, but generally one can observe that towards the upper part of the column, the activity of this isotope tends to increase, presenting a tendency similar to the theoretical profile of the exponential malaise (Crickmore et al. 1990). On the other hand, the activity of the ^{137}Cs does not present a peak of activity that could clearly associate itself to the period of greater quantity of nuclear tests, whose reflection in the sediments has been determined around 1965 for the Southern Hemisphere (Arnaud et al., 2006). Nevertheless, in spite of these inconveniences in the radioisotope data, an age profile vs. coherent depth was obtained, in which the deepest centimeters of the column are the oldest. Based on this information, it was possible to obtain an estimation of the sedimentation rate of the Burgos Lagoon, observing a clear tendency to increase towards the upper centimeters of the column, clearly identifying two peaks around the years 1970 and 1999. Obviously this increase in sedimentation is associated with the erosion from the basin, for which in a more detailed analysis these results should be integrated with the historic evolution of the changes in land use.

Up to the moment only the particle size of the sediments and the activity of the radioisotopes ^{210}Pb and ^{137}Cs for the Cisnes Lagoon (Figure B.3.6.) have been determined, in order to obtain the geochronology. The particle size parameters, such as average size and selection, do not present variations of importance during the range studied, which allows inferring that there would not be changes of great magnitude in the precipitation pattern in the study area. Regarding the ^{210}Pb activity, this does not present a clear tendency in increasing towards the upper part of the sedimentary nucleus, while there are important variations in the activity in the lower stratums of the nucleus. For its part the ^{137}Cs, unlike the profile observed in Burgos Lagoon, presents a clear activity peak around 4 cm, for which this depth should correspond approximately to 1965. If this is true, it means that this lake would have a very low sedimentation rate, close to 0.1 cm year^{-1}. But again, these data should be confirmed.

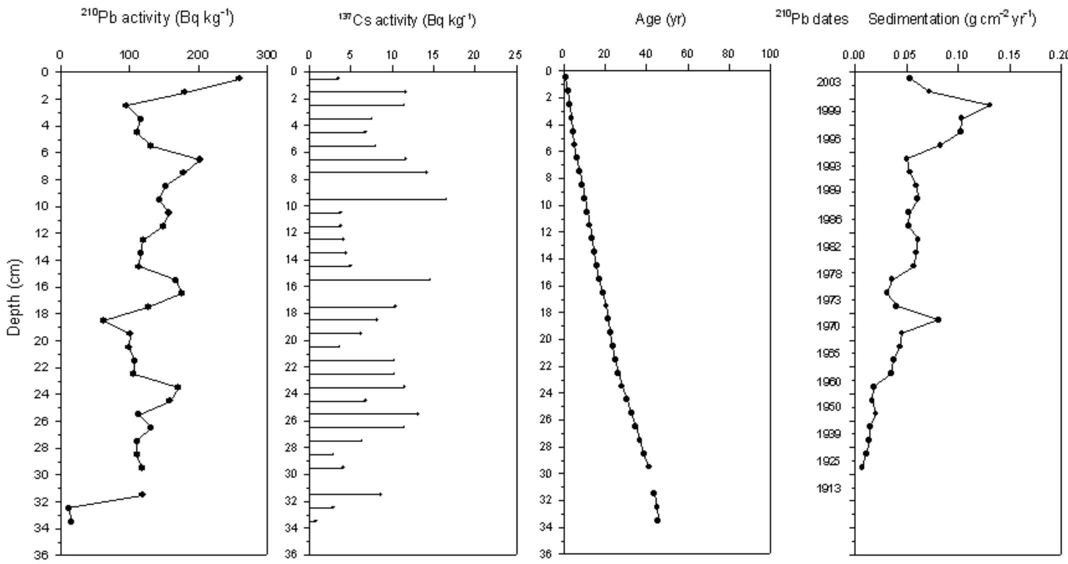


Figure B.3.5. Preliminary Dating of the sediments of Burgos Lagoon.

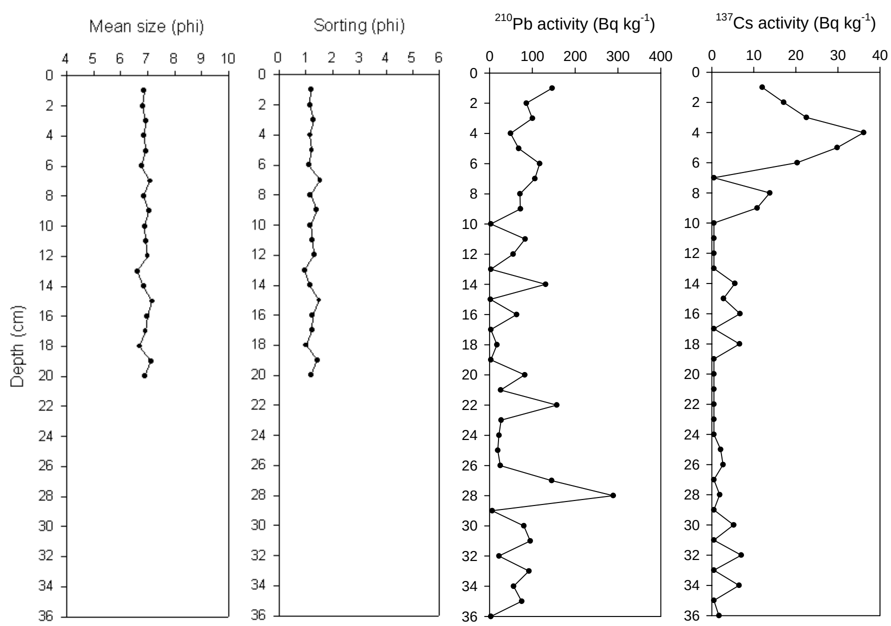


Figure B.3.6.. Sedimentology Parameters and Isotopic Activity of the Sediments of the Cisnes Lagoon.

Macro-invertebrate Sampling: extending the 2006 and 2007 campaigns

Characterization of the river habitat

At each sample sight the following variables were determined *in situ*: (b) physical-chemical parameters of the water column, such as: electric conductivity (μ/s), temperature (C°), Turbidity (UTM), pH and dissolved oxygen (mg/l) and in a complimentary way, suspended solids (ppm) in the summer of 2007; (b)

Physical parameters of the river: The slope was visually estimated and classified into four categories (very high, high, moderate and low). A visual characterization of the substrate bottom was carried out, characterizing them in: a) boulders (>20 cm), b) gravel (0.2 – 20 cm) y c) sands and mud (<0.2 cm).

Benthic Macro-Invertebrates

The samples of benthic macro-invertebrates (>500 µm), carried out in the stations covered a sample area of 0.6 m^2 with six samples per sight. The samples were stored in alcohol at 75%, and then translated to the laboratory for the subsequent separation and identification of the organisms up to the lowest possible taxonomical level, using a stereo-microscope.

Below we present some general results from the campaigns conducted during 2006 and 2007. For more details on the monitoring results, we refer to the Tables and Figures that have been incorporated in the Work Package 7 report.

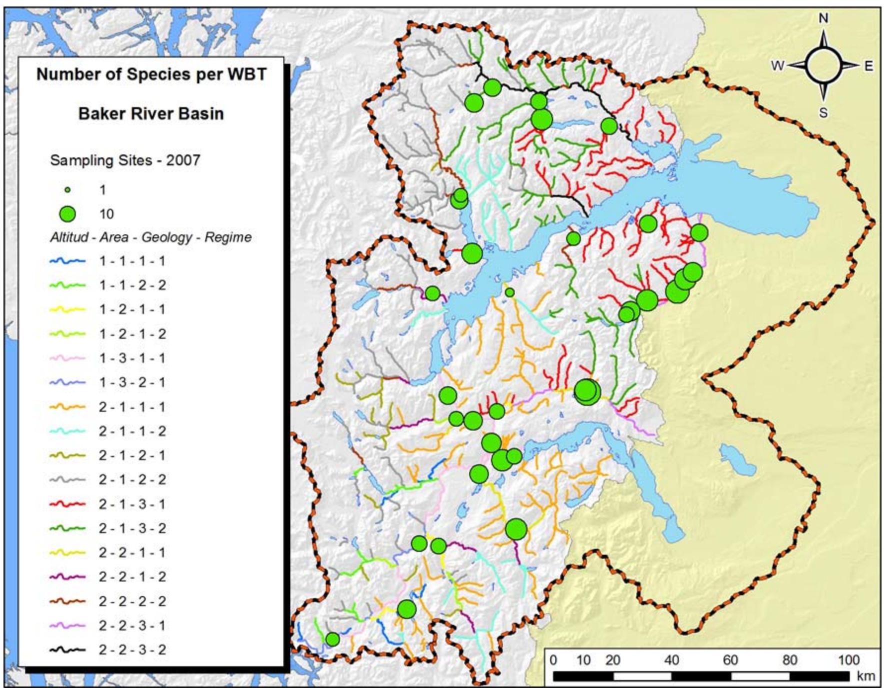


Figure B.3.7. Species richness at the different sampling sites. Background shows the water body typology determined under Work Package 7

Table B.3.2. Environmental features of the 50 sites of the hydro-graphic basin of the Baker River sampled in January 2006. (Med) medium, (M high) medium high, (Mod) moderate.

Site Number	River/Estuary	Water Temperature (°C)	Conductivity (µs/cm)	pH	Dissolved Oxygen (mg/l)	Turbidity (UTM)
1	**Quebrada s/n**	11.1	248	7.4	8	0.3
2	**Quebrada s/n**	-	-	-	-	-
3	**La Tranquera Estuary**	12	42.2	6.4	11.1	0

4	**Quebrada**	-	-	-	-	-
5	**Baker at Tortel**	11.9	1034	7.2	9.51	135
6	**Baker River**	11.9	65.7	5.1	10.3	0
7	**No-name River**	10	22.2	6.44	11.6	0
8	**Quebrada**	4	18.1	6.7	10.0	0
9	**El Encuentro Estuary**	10.9	12.1	6.1	10.9	6.97
10	**Vargas Lake Estuary**	10.3	23.3	7.2	9.12	168
11	**Los Ñadis River**	10.7	41.3	7.1	9.23	110
12	**Quebrada s/n**	9	33.9	7	9.7	1.3
13	**Quebrada s/n**	9.3	30.3	7.1	10.8	0
14	**del Salto River**	11.2	44.7	7.1	9.7	52
15	**Cochrane River**	15.2	157.3	7.1	10.4	0.4
16	**Baker River in raft**	11.9	52.3	7.3	11.9	37.38
17	**Chacabuco River**	9.9	90.6	7	12.1	14.85
18	**Quebrada s/n**	10.9	114	7.1	11.9	0
19	**Baker River narrowness**	12.4	56.9	6.9	10.44	22.15
20	**Baker River**	14.2	56.5	7.71	11.1	0
21	**Pato Raro Estuary**	13.3	97.2	6.9	11.4	0
22	**Maiten River**	13.3	45.1	7.9	11.6	0
23	**El Molino Estuary**	13	178.2	6.8	11.1	0.96
24	**Bertrand River**	12.6	60.4	6.7	10.6	0
25	**El sapo Estuary**	13.2	120	6.9	11.7	0
26	**Quebrada s/n**	7.5	57.5	6.53	12.1	0
27	**Santa Teresa Estuary**	9.1	50.5	6.6	10.4	0
28	**Quebrada s/n**	10.6	44.9	7.72	10.93	0
29	**Quebrada s/n**	10.7	78.8	6.9	11	0
30	**Los Maitenes River**	12.9	56	6.9	11	0
31	**Las Duna River**	12.9	38.6	7.5	10.5	0
32	**los Maqui River**	11.5	23.9	6	9.8	0
33	**El Cañal River**	12	40.3	6.9	11.2	24.45

34	**Meliquina River**	14.3	27.2	7	10.8	0
35	**El Leon River**	13.4	26.9	6.6	12.4	45.79
36	**Quebrada s/n**	13	43.3	68	11.8	0
37	**Chirifo Estuary**	13.8	37.5	7.2	9.5	13.1
38	**Tranquilo River**	18	72.8	7.3	11.9	0
39	**Pérez Estuary**	13.8	42.1	6.87	11.08	0
40	**Quebrada s/n**	14.1	19	7.23	11.3	0
41	**Resbalón River**	11.3	45.1	6.99	11.1	0
42	**Murta River**	13.8	42.1	6.87	11.1	0
43	**La Huemula**	10.5	42.7	6.94	11.8	0
44	**Ibáñez River**	12.6	52.2	6.9	13.1	47.65
45	**Lechoso Estuary**	11.3	124.1	6.8	9.5	0
46	**Las Horquetas Estuary**	10.9	130.3	7.6	9.9	0
47	**El Baño Estuary**	9.7	105.7	7.3	9.51	0
48	**Los Burgo Estuary**	14.1	284	7.56	9.06	0
49	**Jeinimeni River**	12.1	84.5	7.5	9.04	0
50	**Jeinimeni River**	13.9	81.8	7.25	9.31	0

Table B.3.3. Environmental Features of the 50 sites of the hydro-graphic basin of the Baker River sampled in March 2007. (Med) medium, (M high) medium high, (Mod) moderate.

Sight Num ber	**River/Estuary**	**Water Temperature (°C)**	**Conduct. (µs/cm)**	**pH**	**Dissolved Oxygen (mg/l)**	**Suspend. Solids (ppm)**	**Turbidity(UTM)**
1	**No Name Estuary**	13.4	19	7.55	8.95	10	0
2	**No Name Estuary**	12.7	16	7.55	9.20	7	4.23
3	**Jeinimeni River**	10,2	42	8,50	10,29	21	0
4	**Las Vacas**	10.1	68	8.65	10.55	34	0.43
5	**Sucio River**	8.6	103	8.65	10.63	52	0.65
6	**No Name Estuary at break**	8.1	108	8.98	10.69	54	1.49
7	**No Name Estuary**	8.6	105	8.97	10.54	52	13.79

8	**Estuary at the bridge break**	9.3	117	8.88	10,45	60	0.58
9	**Possible Canal**	9.8	72	9.73	10.84	36	0
10	**Chacabuco River before the ranch**	12.6	105	8.5	10.4	52	1.81

4. RELEVANT GLOBAL OR REGIONAL DATA SETS

Several partners have provided information on global or other existing data sets that may be useful for the partner basin, or for similar work in other basins around the world.

Some Latin-American data sources that may be of use to TWINLATIN partners include:

LACHYCIS (Sistema de informacion del Ciclo Hidrologico y las Actividades en recursos Hidricos de America latina) which provides an information system on hydrology and water resources in Latin American and Caribbbean countries.
Website: http://gcmd.nasa.gov/records/GCMD_LACHYSIS.html

LBA-HydroNET which aims to establish and test a prototype version of a web-based, regional hydrometeorological data bank to support water sciences and water resource assessment in South America, Central America, and the Caribbean, using joint pan-American scientific and monitoring station information resources.
Website: http://www.lba-hydronet.sr.unh.edu/

Some sources particularly relevant to Chile include:

NOAA data rescue scanned images of yearbooks which contain climatological data for Chile Chico (46º36S, 71º43W, 382 m.a.s.l) and Cochrane (47º14S, 72º33W, 181.5 m.a.s.l).
Website: http://docs.lib.noaa.gov/rescue/data_rescue_home.html

The annual precipitation map in Figure T.5.1. appears in Sugden *et al.* (2002a; 2002b).

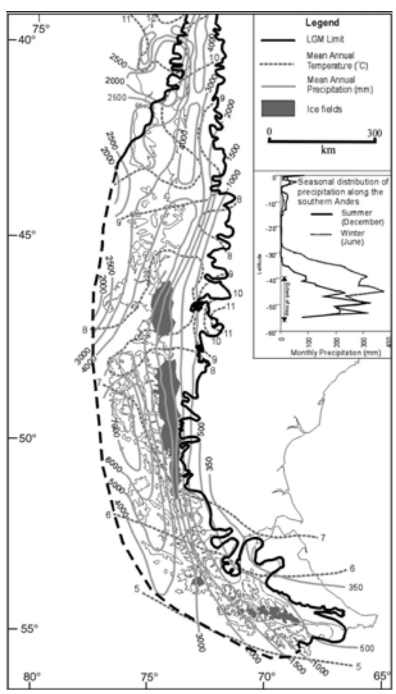


Figure T.5.1. Standard average annual rainfall for Southern Chile

For modelling hydrology and assessing water resource availability on a global/regional or catchment scale, CEH uses the GWAVA (**G**lobal **W**ater **AV**ailability **A**ssessment) model. GWAVA was developed and applied to Eastern and Southern Africa in a DFID funded project encompassing 20 countries (Meigh *et al*., 1999). Since then it has been applied to the Volga basin in Asia for which a new large reservoir component was developed, West Africa to explore impacts of climate and land use change within the region, Swaziland as part of the Southern Africa FRIEND project (UNESCO, 2004b). More recently, it has been applied to the Okavango basin in Southern Africa as part of TWINBAS to investigate impacts of development such as hydropower development and climate change on streamflows entering the Okavango delta (work package 4, in press), and to the Ganges, Brahmaputra and Megna basins in the Himalayas, for which a new glacial model was developed. However, GWAVA is more than simply a hydrological model, its strengths including:

- Providing an assessment of water availability on a spatial basis (GIS);
- Giving an assessment in terms of indices of water supply versus water demand;
- Enabling a consistent methodology to be applied across a region and over cross-boundary basins;
- Enabling impacts of climate change and population changes to be investigated (it has also been used to look at land-use change impacts and development of hydropower schemes);
- Moderate data requirement which draws upon freely available global datasets.

GWAVA's data requirements are set out in Table T.5.1., which indicates the source, type, spatial and temporal resolution, website and accessibility of each data item.

Table T.5.1. Potential sources of global data sets useful for GWAVA

Data type	Source & description	Point/ polygon/ grid	Spatial extent and/or resolution	Temporal extent and/or resolution	Website	Access*
Hydrological						
Observed streamflow	Global Runoff Data Centre (GRDC).	point		Daily/ monthly	http://grdc.bafg.de/servlet/is/987/	**?
Meteorological						
Min, max & mean temperature, precipitation, raindays & climatic variables (vapour pressure, relative humidity, cloud cover, etc)	Climatic Research Unit (CRU). High resolution datasets including long term monthly gridded temperature, precipitation & other climatological parameters.	grid	0.1º 0.5º	Monthly 1901–2001; CRU TS2.1 (Mitchell *et al.*, 2003)	http://www.cru.uea.ac.uk/cru/data/hrg.htm	*
Temperature & precipitation	WMO Global Historical Climate Network (GHCN). Restricted access although some data are available at KNMI Climate Explorer website.	point	n/a	Monthly/ daily(?)	Climate Explorer http://climexp.knmi.nl/start.cgi?someone@somewhere	*
Mean monthly temperature & precipitation	WorldClim.	grid	30”, 2.5’, 5’ & 10’	Monthly means	http://www.worldclim.org/	*
Various	UK Meteorological Office Library catalogue.				http://www.met-office.gov.uk/corporate/library/catalogue.html	?
Physical – elevation, soils, land cover, glacial extents						
Elevation	USGS Global DEM (GTOPO30).	grid			http://eros.usgs.gov/products/elevation.html	*
River network & basin delineation	USGS HYDRO1k derived river network & basins.	line - grid	n/a	n/a	http://edc.usgs.gov/products/elevation/gtopo30/hydro/index.html	*
Digitised river network		line - vector				
Lakes and wetlands		polygon				
Soils	FAO-UNESCO Soil Map of the World.	polygon	n/a	n/a		*
Land cover	USGS Global Land Characterisation Dataset.	grid	1km	n/a	http://edcsns17.cr.usgs.gov/glcc/	*

Glacial extents	ESRI Digital Chart of the World (DNNET layer).	polygon	n/a		Available on a per country basis from: http://www.maproom.psu.edu/dcw/	*
Water demands/users						
Population (totals & density)	UNEP-GRID Latin America & Caribbean Population Distribution database for the years 1960,70,80,90 & 2000.	grid	2.5’		http://grid2.cr.usgs.gov/datasets/datalist.php3	*
Population projections	UN World Population Projects database. Various demographic data including national total, urban & rural actual & projected populations.		National	1950-2050	http://esa.un.org/unpp/	*
Livestock distributions	(1)FAO - Global Livestock Production and Health Atlas (GLiPHa); and (2) the FAO Gridded Livestock Atlas of the world.		(1) National (2) 0.05º		http://www.fao.org/ag/aga/glipha/index.jsp http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGAInfo/resources/en/glw/default.html	*
Livestock populations	Country level populations of sheep, goats & cattle.		National		http://faostat.fao.org/	*
Irrigation	FAO – AQUASTAT & FAO Stat. Have information on irrigated areas and crop types.		National		http://www.fao.org/AG/AGL/aglw/aquastat/main/index.stm interactive map: http://www.fao.org/ag/agl/aglw/aquastat/irrigationmap/index5.stm http://faostat.fao.org/	*
Industrial water use	WRI Earth Trends database.		National		http://www.wri.org/	
Climate change scenarios						
Global climate model (GCM) outputs	IPCC Data Distribution Centre. Various GCM data outputs.	grid			http://ipcc-ddc.cru.uea.ac.uk/	*
Regional Climate Model (PRECIS)	Data from the UK Met Office’s Regional Climate Model (PRECIS). May also be available upon request. See PRECIS website for more details.	grid			http://www.precis.org.uk/	**?

* **Access**: * Freely available for download & use; ** Data may be available upon request; *** Charges apply/ restricted use

The web pages that are presented below contain geographical information with a global interest. However, these web pages have its limitations due to the used scale and the restriction in the access to the source of information.

Table CC.5.5. Global GIS information

SOURCE	INFORMATION	WEB
GOOGLE EARTH	Satellital images with different resolution	http://earth.google.com
NASA	Satellital images	http://worldwind.arc.nasa.gov/download.html
FAO SD Dimensions	Global data in digital format	http://www.fao.org/sd/spdirect/gis/EIgis000.htm

MODIS (Moderate Resolution Imaging Spectroradiometer) is an instrument on board of the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra Modis and Aqua Modis have a complete vision of the earth over a period of between 1 and 2 days, acquiring data in 36 spectral bands. Spatial resolution of the images is 250 m (bands 1 - 2), 500 m (bands 3 - 7) and 1000 m (bands 8 – 36). MODIS started operating in the year 2000.

The MODIS project also delivers several derived products, such as:

- Earth temperature and emissivity (LST/E), with a spatial resolution of 1 km to 5 km, and a temporal resolution from 1 to 8 days.
- Land cover (annual scale, 1km or 0.05 DEG CMG) and land cover dynamics (annual; 1 km)
- Two vegetation indices (VI); one is the NDVI and the other one is the EVI; both are complementary for global vegetation assessments. Time scale ranges from 16 días (250 m, 500 m or 1 km spatial resolution) to monthly (1 km resolution).
- “Snow” products (NDSI), global coverage; 8 days temporal resolution; spatial resolution 500 m or 0.5°. 6 types of product in this series (see Table B.5.2.)

Availability and more information on the MODIS products can be found on http://edcdaac.usgs.gov/modis/dataproducts.asp#mod12 y http://modis.gsfc.nasa.gov/index.php. Products can be downloaded free of cost from http://edcimswww.cr.usgs.gov/pub/imswelcome/

Table B.5.2. Diferent "Snow" products from the MODIS project

Tipo de Dato (ESDT)	**Nivel del Producto**	**Dimensión nominal**	**Resolución espacial**	**Resolución temporal**	**Proyeccion**
MOD10_L2	L2	1354 km x 2000 km	500m	swath (scene)	Ninguna. (lat,lon referenced)
MOD10L2G	L2G	1200km x 1200km	500m	Día de multiples swaths coincidentes	Sinusoidal
MOD10A1	L3	1200km x 1200km	500m	día	Sinusoidal
MOD10A2	L3	1200km x 1200km	500m	Ocho días	Sinusoidal
MOD10C1	L3	360° x 180° (global)	0.05° x 0.05°	día	Geographica
MOD10C2	L3	360° x 180° (global)	0.05° x 0.05°	Ocho días	Geographica

Orthorectified LANDSAT images can be downloaded for free from: http://www.eogeo.org/Members/adoyle/ad-news-05/orthorectified-landsat (1 scene per day)

The "Digital soil map of the world and derived properties" (Version 3.6, January 2003) is available at EULA (acquired in the framework of the TWINBAS project). This product is derived from the "FAO/UNESCO Soil map of the World" (original scale 1:5000000).

An SRTM-based data gap-free DEM (90m resolution) as well as derived hydrological products is available for the whole of South-America from a collaborative efforts between a series of institutions, including WWF and USGS. http://www.worldwildlife.org/freshwater/hydrosheds.cfm

A global set of monthly climatology data in raster format (1km resolution) is available from: **http://www.worldclim.org/** This is just one of several global sets which are available through the internet.

5. IMPLEMENTATION OF ENVIRONMENTAL DATABASE(S)

In what follows, selected partners comment on their experiencies with regard to the implementation of environmental database systems previous to and/or under TWINLATIN. These contributions are given as a reference for the other partner basin, and/or interested groups outside of the TWINLATIN Consortium.

Thames Basin

In the UK, organizations responsible for collecting data are also responsible for storing those data. The result is a myriad of different databases storing different information. Assembly of these data may require substantial effort in terms of negotiation and data transfer, as they are often not freely available. Many of the datasets require end-users to sign expensive licence agreements on an individual basis, and even this generally covers only research use. Other data may be held at the private offices of contractors, consultants and researchers, who have collected it, and these will not be widely known of or generally available.

CEH has three databases that may be of interest to other TWINLATIN partners: one archive database, called the National Water Archive, and two operational databases also incorporating analytical techniques, called HYDATA and LowFlows-2000.

The National Water Archive (see reference list) is an ORACLE-based UK database comprising:

- the National River Flow Archive (15 million daily flow values from 1300 catchments, including both gauged and naturalised flows for some catchments);
- the National Groundwater Level Archive (operated by BGS);
- the Flood Peak database (88000 instantaneous peaks from 1000 catchments);
- the Flood Event database (4000 events (rain, soil moisture, flow) from 300 catchments);
- various spatial data including the UK digital terrain model, the UK 1:50000 digitised river network, the UK Hydrology Of Soil Types map, and the UK Flood Risk Map.

The Archive staff are responsible for collating, quality controlling, storing and disseminating the data, as publications, through research applications and decision support systems, and through the website. In addition to daily gauged and naturalised flow data for the gauging stations, outputs and retrievals include a register of stations and station summary sheets, monthly hydrological summaries and annual hydrological reviews, assessments of hydrological variability and trends, and selected spatial data. Figure 8 shows the summary retrieval for the Thames at Kingston. The National Water Archive 5-yearly Hydrometric Register and Statistics (latest 1996-2000) gives an invaluable catalogue of river flow gauging stations and observation boreholes together with summary hydrometric statistics.

The CEH HYDATA database system (IH, 1999; CEH, 2001) is a freely available hydrometeorological data processing and analysis system which has been used in more than 50 countries world-wide, and is the national database system for surface water data in more than 20 countries, primarily in Africa. In the UK, HYDATA is used by the Agency's sister organisation British Waterways, who are responsible for the UK's extensive canal network, part of which falls within the Thames basin. HYDATA stores the types of time series data most commonly required in water resources studies, including river levels and flows, reservoir, dam and lake levels and storages, rainfall and other meteorological data. HYDATA also includes facilities for developing rating curves relating river levels to flows and reservoir, dam and lake levels to storages. Output is provided in the form of "yearbook" style tabulations and graphs, and there are also powerful data transfer facilities. Options are provided for routine hydrological analyses, such as the derivation of flow duration curves and calculation of low flow statistics

The CEH LowFlows 2000 system (Young *et al.*, 2003) is used in every Environment Agency region in the UK, at both gauged and ungauged sites, for making natural river flow assessments, monitoring the effects of existing licensed abstractions on river flows, and making water allocation decisions. For example, when an application for a new abstraction is made, the system provides an estimate of the natural low flow and of the effects on key low flow statistics of the existing artificial influences and the new abstraction. The database includes many data sets including spatial data, flows and artificial influences. LowFlows 2000 forms a component of the Agency's move towards IWRM through the development of both scientific methods for low flow estimation and software tools to provide managers with the ability to make water resources assessments and to manage water use data. Pilot application have been developed for part of Malawi, and part of Nepal under the UNESCO Southern Africa FRIEND and Hindu Kush-Himalayan FRIEND projects, respectively, demonstrating its potential to be modified for other countries.

Catamayo-Chira Basin

Prior to TWINLATIN a centralized environmental database of the River Basin doesn't exist, even if most of the needed information already has been created. This information is available on digital format by the project. Besides, the related institutions operate relevant environmental information that could be useful for the desired environmental database. This information, sometimes, has access restrictions. When diffused, this is done by different means, as publicizing it in Internet. Other way of accessing it is directly in the institution, by presenting a formal solicitude, which is proportioned in a printed or digital format.

The implementation of an environmental platform should include a multiplicity of data, themes and formats that have to be collected and considered for its integration and starting up. For these purposes, the establishment of the necessary relations and agreements with the competent institutions (institutions that generate and manage the information) will be needed, taking into account that these institutions will be in future in charge of the updating and complementation of this database.

A crucial aspect on the analysis of the Catamayo Chira River Basin is its binationality. This fact complicates the establishment and maintenance of a unique centralized database for the river basin. Therefore, there is a need of administrating the database from both sides of the river basin, defining clearly the parameters that will be included, the measurement units, the updating timetables, and other aspects that allow having a database with standardised information and consolidated operative structures in both countries. Furthermore, there is a need of surpassing the institutional obstacles and strengthening the institutional internal synergies for initiate the consolidation of a binational relation between both data administrators, between institutions and forward the starting up of the database.

In the Peruvian case, two initiatives related to spatial data infrastructure are being developed. One of them is being developed at a national level and the other is being developed at a regional level (administered by the Regional Government of Piura). In this later case, the Regional Government has created a GIS office (regional GIS) that has a physical infrastructure, hardware, software and a technical team, whose capacity is feasible of being used in the Twinlatin scope.

In the Ecuadorian case there are two initiatives related to spatial data infrastructures, at a national level. At the local level, the Catamayo Chira project is working on the implementation of a GIS structure for the south region and for the Loja province with institutions as PREDESUR and the Regional Government. These institutions have the technical capacities and manage environmental and social information, so, they could manage the desired environmental database of the River Basin. For this purpose, a participatory institutional work is to be done in the same way as in the Peruvian case.

Structure of environmental database

A data model called ArcHydro has been implemented in the frame of Twinlatin as a proposal for the development of a water resources database for the Catamayo Chira Binational River Basin. ArcHydro consists on the creation of a geographic database (geodatabase) which contains spatial information and alphanumerical data. Additionally permits access to hydrological information for different models. ArcHydro has been developed by the Center for Research of Water Resources (CRWR) at the University of Texas (Austin) and is distributed by ESRI freely. It works only with ArcGIS of ESRI software with the ArcInfo license and the Spatial Analysis extension.

The spatial and alphanumerical information considered for the ArcHydro input data includes:

Elevation Model

- Hydric network (HydroEdge)

- Subbasin limit (Watershed)

- Monitoring stations (MonitoringPoint)

- Dams and water bodies (WaterBody)

- Meteorological and hydrometric stations data

A major problem found was related with the inappropriate management and use of the information. Information normally is hard to collect and out of date even this from the institutions related with the basin management.

Catamayo Chira Project made a great effort to compile the data related with the basin. However, a lot of information needed for the Twinlatin's work packages, like Hydrological modelling, was obtained in different formats, wasn't included in any database, it was impossible to know exactly the type and amount of information available and in some cases temporal information wasn't related with spatial information. Moreover, the binationality of the basin increases the difficulties as neither Peru nor Ecuador have an institution charged to compile and keep this kind of information and there is no metadata generated that allows a major reliability and accuracy of the information used.

The first step for the model implementation was to compile all the information available. This information was not enough for the needs of the Model. For this reason, a great effort was done in order to obtain all the hydrometeorological data needed and in a digital format, since all information of the Peruvian part of the basin was in an analogical format. Though, a long digitalisation process started with the relevant data for the Model.

Once the digitalisation process was done, an analysis about the quality of the daily and monthly meteorological and hydrological data registered in 24 Ecuadorian and 19 Peruvian stations was undertaken with the support of the Hydrological area UGC-SIG of the *Universidad Técnica Particular de Loja*. With statistical procedures, a homogenisation process of the registers was carried out in order to obtain the parameters needed for the characterisation and implementation of the SWAT and Watem/Sedem models.

A quality control process of the spatial data was made; to generate the MDE the available contour lines were at 200 meters, at scale 1:250,000. To increase the accuracy of the MDE, the improvement of the scale of the source map was needed. For this reason a topographic data compilation at a scale 1:50,000 with contour lines every 40 meters was completed for the Ecuadorian side and at a scale 1:100,000 with contour lines every 50 meters for the Peruvian side. The compatibility process of the topographic information was made with Arcview SIG using interpolation techniques.

Besides, the hydric network was edited taking into account the consistency with the basin topography. During this process some inconsistencies were found, especially in the Ecuadorian part, like rivers crossing above contour lines, cuttings or disconnection of river parts with the network.

Another part of the ArcHydro data is the monitoring points, which correspond to the place were the variables of the water resources are measured, the stations. In this case, the data obtained was from hydrometric and meteorological stations.

The data of the hydrometric and meteorological time series was prepared in the required format of the ArcHydro Model. This format corresponds with 5 columns with information about:

- date
- Featureid (station identification code)
- TSTypeid (type of variable code: rain, temperature solar radiation, etc.)
- Mean value
- Additional column for the station's name (Table 1.0)

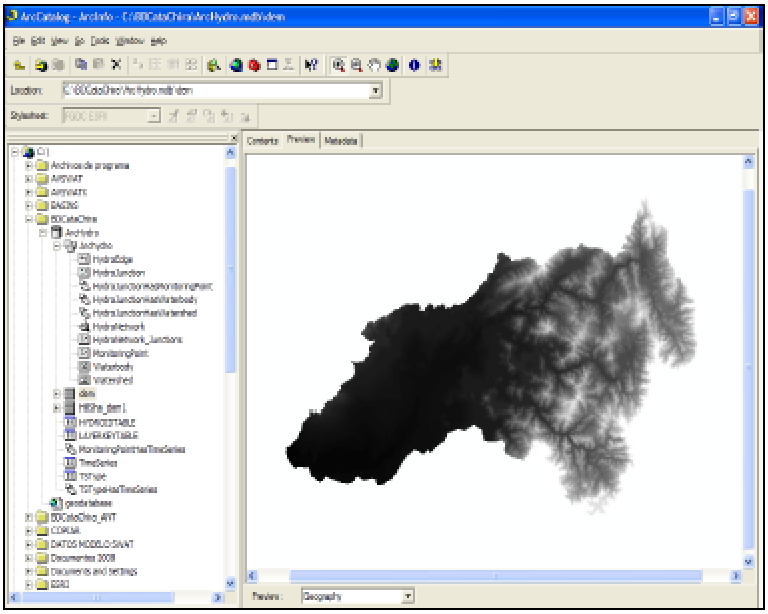


Table 1.0: monitoring stations data adapted to the ArcHydro format

FeatureID	TSTypeID	TSDatetime	TSValue	HydroCode
36	7	01/10/1985	1.4	Amaluza
36	7	01/11/1985	1.2	Amaluza
36	7	01/12/1985	0.9	Amaluza
36	7	01/01/1986	0.9	Amaluza
36	7	01/02/1986	0.9	Amaluza
36	7	01/03/1986	1.4	Amaluza
36	7	01/04/1986	1.1	Amaluza
36	7	01/05/1986	1.3	Amaluza
36	7	01/06/1986	1.5	Amaluza
36	7	01/07/1986	1.4	Amaluza
36	7	01/08/1986	1.9	Amaluza
36	7	01/09/1986	1.5	Amaluza
36	7	01/10/1986	1.3	Amaluza
36	7	01/11/1986	1.5	Amaluza
36	7	01/12/1986	1.5	Amaluza
36	7	01/01/1987	1.5	Amaluza
36	7	01/02/1987	1.6	Amaluza
36	7	01/03/1987	1.5	Amaluza
36	7	01/04/1987	1.1	Amaluza
36	7	01/05/1987	1.5	Amaluza
36	7	01/06/1987	1.4	Amaluza
36	7	01/07/1987	1.5	Amaluza
36	7	01/08/1987	1.3	Amaluza
36	7	01/09/1987	1.4	Amaluza

Figure CC.5.1. Viewing and generation of graphics and reports of the Geodatabase with "ArcHydro Ts Viewer"

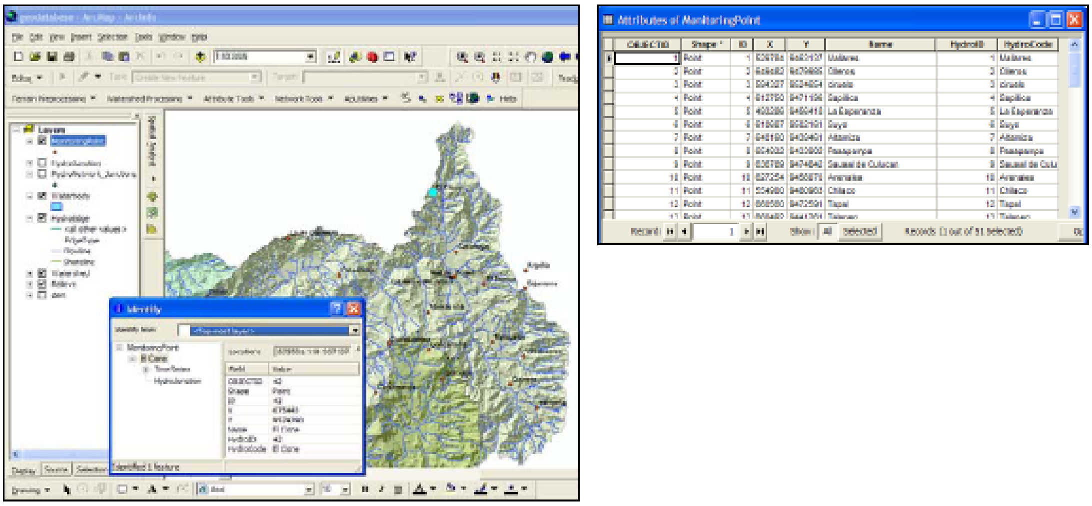


Figure CC.5.2. Attribute data (monitoring results) associated at monitoring stations in ArcHydro

*The source of the alphanumerical data is from the Peruvian and Ecuadorian institutions. In Peru: Proyecto Especial Chira Piura and Servicio Nacional de Hidrológica y Meteorología de Piura (SENAMHI). In Ecuador: Programa de Desarrollo del Sur (PREDESUR) and Instituto Nacional de Meteorología e Hidrológica (INAMHI). The spatial data is from Proyecto Binacional Catamayo Chira, at a scale 1/250 000. The coordinates system used was Universal Transversal Mercator (UTM), datum WGS84, which is being standardized in both countries.

Results

A geographic database is available in Access format and with de ArcHydro Model structure. This database has been adapted to an application called "ArcHydro Ts Viewer" *(Figura 1.2)*, which permits the visualisation of the data without ArcGis and is useful for all institutions without a ArcGis-Arcinfo licences and also for the sustainability of this tool, as it is the way to be updated for everyone.

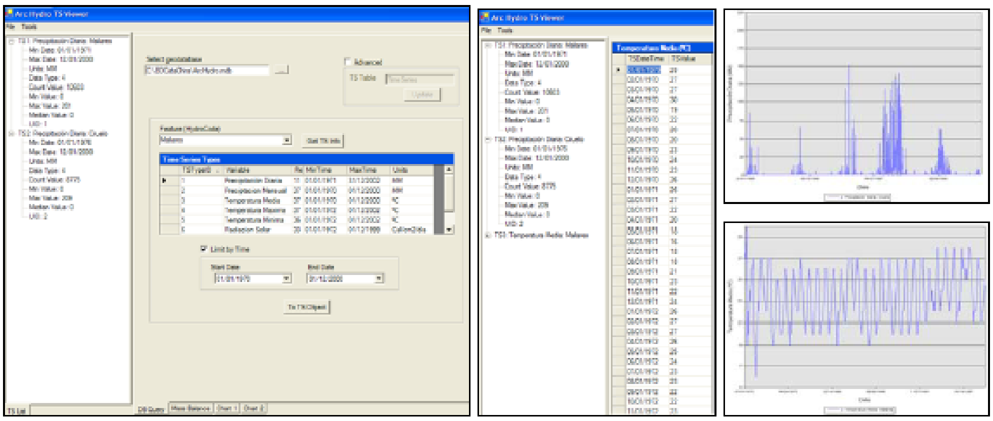


Figure CC.5.3. Time series management in ArcHydro GIS

The implementation of the ArcHydro Model allowed the link between the alphanumerical information and the spatial data contained in the Geodatabase. These links allow the realization of queries of the stations with the data related to them.

Upper Cauca Basin

Currently there is no data base containing all environmental information available. Presently there are information systems located in the different areas elaborated through diverse calculation methodologies and tools, such as:

- Patrimony system: SIPA
- Water resources system: SIGRH
- Hydroclimatologic monitoring system
- Water quality monitoring system
- Deep wells and underground water information
- Information systems for the administrative, financial and human resources management areas (SABS y SIGEC)
- Other regional branches systems

Taking this into consideration, it is necessary to coordinate experiences, existing data and the information storage structure through a corporate geographical information system including systems such as:

- Spatial meta-data
- Statial information storage
- Spatial data capturing and its flow in the organization
- Primary, intermediate and final spatial products
- Spatial data forms
- Spatial data exchange forms
- Cartography-related standards.

CVC currently has some information systems based on an Oracle 9i database that can possibly be upgraded to Oracle 10g. The following application analysis, design and construction tools have been implemented:

- Designer 9i
- Developer 6i
- Developer 10g
- Oracle Web tools.

GIS available data corresponds to the study zone cartography classification and to the analysis results which have provided broad information on the study zone:

- Soil usage conflict
- South and North geological profiles
- Municipalities and rural areas political division
- Slope degree
- Erosion levels
- Humidity
- General erosion
- Foothill line
- Structural geology (faults and folds)

- Thermal floors
- Geology
- Natural reserves
- Geomorphology
- Salinity
- Isoyetas Curves
- Soils
- Micro-basins and morphometry
- Actual use
- Life zones
- Biophysical landscape units
- Digital land model
- Potential use
- Shadow model

In the work done to develop the Twin Latin Project, the different coverage organizations existing in the Upper Cauca River basin were developed to establish a GIS on the study zone to facilitate the development of GIS activities within the different Project packages.
Figure C5.1 shows a system screen based on ArcGIS 9.x.

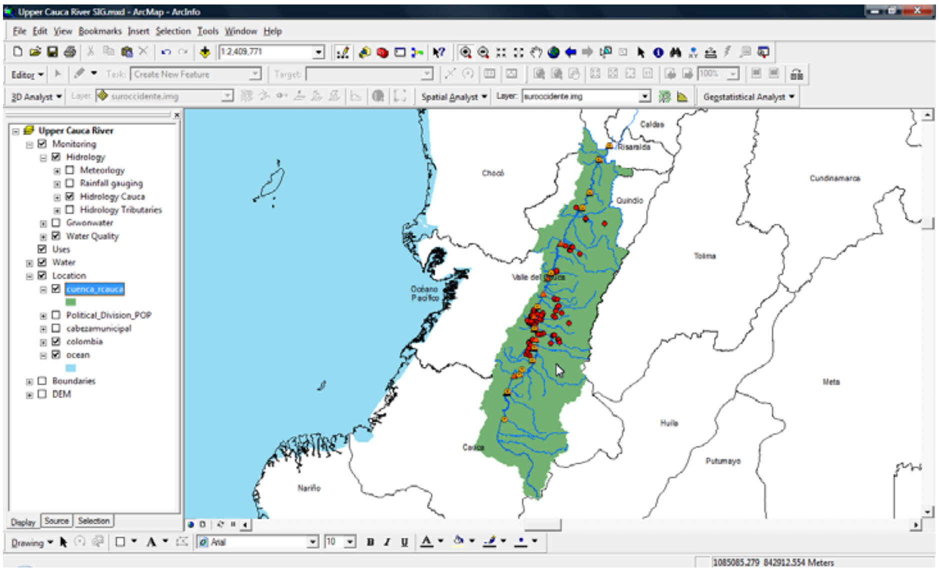


Figure C5.1. Upper Cauca River SIG

Cuareim/Quarai Basin

A **binational geodatabase** for the Cuareim River Basin was developed in the framework of TWINLATIN, used and updated during the whole project. This database was the base for the development of all TWINLATIN Working Packages.

Summarizing, the characteristics of the developed database worth to stand out are:

- **Binational Database**, implemented **for the whole basin**. All information was shared between the two partners IPH (Brazil) and DNH (Uruguay) to create a database for the whole basin.
- **Georeferenced database, ESRI Geographic Information System (GIS) environment**. All information is spatially associated. For example time series data of monitoring meteorologic and hydrologic stations are associated to monitoring points that at the same time are associated to a river and the river to a catchment.
- **ArcHydro Database Structure** – Adopted by all TWINLATIN partners. The principal characteristics of ArcHydro are (Maidment, 2002):
  - "it is a geospatial and temporal data model for water resources that operates within ArcGIS"
  - "ArcHydro has an associated tool that populates attributes of the features in the data framework, interconnect features, and support hydrologic analysis"
  - "it provides systematic and efficient project execution and the potential to reuse data on subsequent projects in the same area"
- **Metadata associated to the data**

The projected coordinate system chosen was **the Universal Transverse Mercator (UTM) 21 S, datum WGS 84,** projection that had been adopted by the international Guarani Aquifer Project in which both Brazil and Uruguay participated, so both IPH and DNH opted for the same one for TWINLATIN.

Using the ArcHydro tool and starting from a Digital Elevation Model (DEM) for the basin, a river feature class was generated (HydroEdge). The DEM was downloaded from HydroSheds, USGS, with a 90m resolution. HydroSheds is based on high-resolution elevation data obtained from NASA's Shuttle Radar Topography Mission (SRTM). This DEM was reconditioned with an existing river layer, a result of the international Guarani Aquifer project that put together the best available information of Brazil and Uruguay. The river data used for Uruguay to recondition the DEM was at a 1:50.000 scale. With the HydroEdge and HydroJunctions feature classes (HydroJunctions area a set of junctions located at the end of the river segments and at strategic locations (in this case, monitoring points)), a HydroNetwork was built (HydroEdges and Hydrojunctions became therefore topologically connected). The threshold used for beginning a stream of water was 5 km2. Using ArcHydro a flow direction grid was created and drainage areas were delineated as necessary. All historical meteorologic data that was only available in paper was digitalized in the framework of TWINLATIN, therefore the database has all the historical pluviometric and hydrometric records in the basin.

Lake Cocibolca Basin

For the storage of the information generated for the Cocibolca Lake Basin under TWINLATIN, a Georeferenced Environmental Information System for the Cocibolca Basin called **SIGACC**[5] was constructed. With this database, the information resources related to the case study area – with their spatial, thematic and temporal components- are structured and stored on a physical

[5] *SIGACC stands for "Sistema de Información Geográfica-Ambiental para la Cuenca del Cocibolca"*

unit (harddisk). For structuring and implementing this database, the **ArcHydro** data model was used as a reference.

The SIGACC and the ArcHydro data model

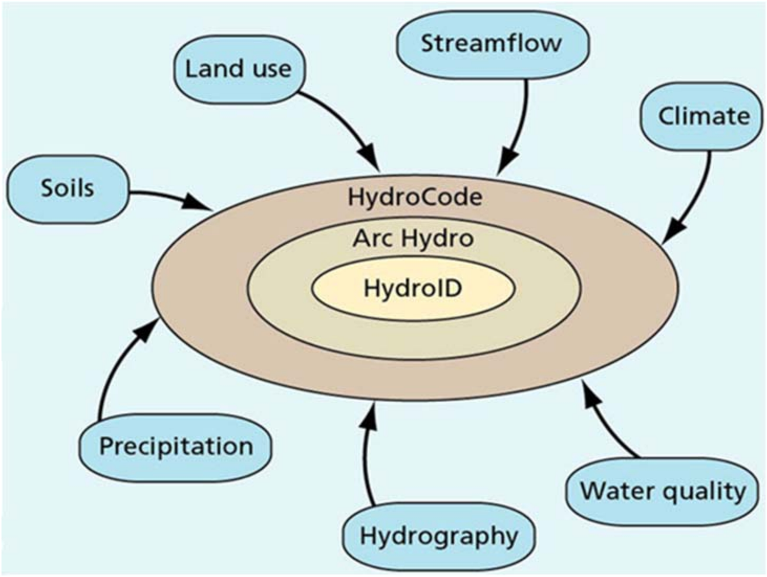


Figure LC.5.1. The ArcHydro data model, linking different kinds of thematic information to the Basin's hydrographic network

The ArcHydro data model allows the user to link different data sets –including their thematic, spatial and time components- to the basic information layers that represent the hydrography of the Cocibolca Lake Basin; by this means, the database structure facilitates the different types of analyses required for water resources management studies. Through the **HydroID**, ArcHydro is capable of establishing relationships between the individual objects in the thematic data sets - together with their spatial and temporal descriptions- and the different hydrographic features in the Cocibolca Lake Basin: from individual river reaches or lakes, to micro- and subbasins, etc.

As part of the Twinning efforts under TWINLATIN, the ArcHydro data model was proposed as an adequate model for setting up the geographical/thematic databases for the different case study basins. The basic aspects of the ArcHydro concept were effectively implemented in several of the TWINLATIN case study basins, among which the Cocibolca Lake. Twinning on the implementation of ArcHydro was particularly strong between the Cocibolca Lake Basin (Nicaragua) and the Baker River Basin (Chile). Basic training sessions on the initial steps for setting up the ArcHydro data model have been held at the Nicaraguan Institute for Territorial Studies INETER ("*Instituto Nicaraguënse de Estudios Territoriales*"), as a result of the intensive collaboration efforts with -and further channelled through- its Water Resources Division ("*Dirección de Recursos Hídircos*"). INETER is the Nicaraguan institution which holds the responsibility over the generation, storage and distribution of many of the basic data sets (eg. hydrometeorological time series) required for the study & management of the country's water resources. During the last phase of the execution of TWINLATIN, together with INETER additional training needs and a further extension on the implementation of more advanced aspects of the ArcHydro data model have been identified.[6]

[6] *Opportunities are currently being sought to give continuity to the work started under TWINLATIN, and to assure the sustainability of the obtained progress & results*

Baker Basin

A similar approach was used as explained under Cocibolca Lake Basin (the implementation in Cocibolca occurred through intensive EULA Twinning support). A Guidance document based on the same principles was simultaneously developed for the Baker River and the Cocibolca Lake Basins (available in Spanish; made for local water authorities)

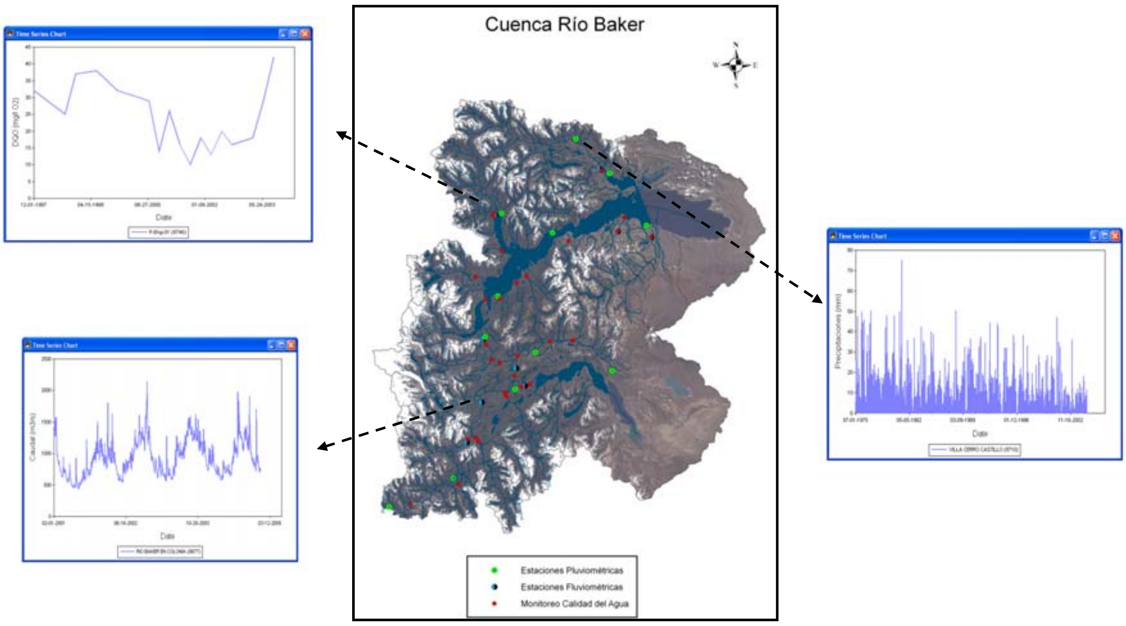


Figure B.5.1. Georeferenced Environmental Database for the Baker Basin based on the ArcHydro data model (integration of hydrography, subbasin and station representation with time series data sets)

6. DATA QUALITY & METADATA ISSUES

Selected partners comment on the issues of data quality and metadata generation. The contributions to this chapter with regard to the proposal for selection of a metadata standard and profile for future work in the Latin-American case study basins were mainly prepared at EULA/CIEMA, with support from DNH. DNH prepared a methodological guidance document for the generation of metadata based on the ISO standard (NEM profile), which is provided as annex to this report.

More details on methodological approaches that have been applied for issues related to quality control (e.g. gap filling of time series for the Cocibolca Lake Basin) can also be found in other work package reports (e.g. on the hydrological modeling - WP03).

CEH

In the UK, all hydrometerological time series data are managed according to the periodically updated British Standards Institution (BSi) Guide to Hydrometric Data Management BSi 7898 (1997), which interested partners or readers can purchase from the BSi website (see reference list). This sets out the principles of data management before turning to specific issues relating to precipitation data, water level data, discharge and volume data, and stage-discharge relationships. The MetOffice publishes its own guidelines on climatological data, called Rules for Rainfall Observers and Making Weather Observations, both of which are available from the MetOffice website (see references).

The Agency produces annual “State of the Environment” reports for the regions, and DEFRA (see references) produces annual statistics on the environment and on sustainable development indicators.

EULA/CIEMA/DNH

The discussion on data quality and metadata issues which is given below mainly originates from the problems encountered during the construction of the environmental database, and the use of the data sets in the work for the different work packages in the case of the Nicaraguan study basin (Cocibolca Lake). However, as similar problems occur in many other river basins, or can even be considered to be universal, we feel it is of general interest in the context of the reporting on the TWINLATIN activities, and with regard to the outreach of the project results to include this discussion here.

Data quality

A considerable problem encountered during the construction of the georeferenced environmental database for the Cocibolca Basin (the so-called “SIGACC”), as well as during the execution of the different research activities under TWINLATIN, was the inexistence of, or the lack of readily available, good and high-quality input data sets covering the entire study area.

It should be noted, however, that over the past decades a considerable amount of information and data has been generated on the Cocibolca Basin, as a result of different projects and initiatives that have taken place. These have studied or addressed different aspects of the Cocibolca Lake Basin. The spatial coverage of these studies varied widely from case to case: certain projects addressed the Basin as a whole, others focused only on the Nicaraguan part, or just a certain sub- or microbasin; some did not even directly focus on the Cocibolca Basin or its water resources, but even so provided input information with potential usefulness for TWINLATIN or other initiatives on the basin.

Nonetheless, for these existing data sets, the following **major quality problems** should be reported here:

- obtaining certain potentially (highly) useful datasets has been difficult and extremely time consuming (or even impossible in some cases): useful information is spread out over a number of institutions, universities, or even (with)held by private consultants, individual researchers or research groups; certain information sources are available within the country of Nicaragua, other sources of information (e.g. on the Costa Rican part of the bi-national Cocibolca Lake Basin) can only be obtained outside of the country[7]
- integration of the different data sources is further complicated due to the ***heterogeneity in scales, spatial extent, nomenclatures, thematic descriptions and associated attributes (orthography / orthographic errors / inconsistent use of case letters / used character symbol sets,...), analytical techniques and quality criteria & control measures used***, as well as due to the different basic input layers and/or multiple versions that have been used for generating or deriving secondary-source data sets; information is often repeated or many different versions may exist
- spatial and/or temporal gaps, slivers, duplicated features,..., and serious quality problems related to many of the data sets; lack of descriptive information on the origin & quality of the individual data sets which would allow for a fast evaluation of their usefulness, and for evaluating the preference of one data set above the other(s); (>90% of collected data came without any, or with only very limited metadata)
- unequal spatial distribution and spatial/temporal coverage of monitoring stations and associated time series data sets
- ***serious lack of integration*** between the different past, ongoing and/or future initiatives

The need for metadata – an introduction

The experiences from the TWINLATIN work on the Cocibolca Basin clearly show how the lack of readily available and consistently structured documentation for the existing datasets (**metadata**) has complicated the advances during the project execution towards the achievement and delivery of durable, high-quality results from research for which a broad acceptance by a wide group of stakeholders can easily be guaranteed, and which therefore can serve for real-world decision-making.

Therefore, during the execution of TWINLATIN, at EULA-Chile/CIEMA-UNI an analysis has been made of the literature with regard to the creation of documentation for geographic/thematic data sets, as well as with regard to related standards, data profiles and available tools. Additional twinning between EULA/CIEMA and DNH also provided input with regard to the use and interoperability of selected metadata generation tools. In what follows we provide the reader with both a basic introduction and the most important conclusions obtained from this research.

Metadata are commonly defined as: "data about data". They describe the content, quality, format, etc. associated to a resource, and constitute a mechanism for characterizing data and services in such a way that users (and applications) can locate and obtain access to those data sets that best serve their specific purposes.

Metadata provide an answer to questions of the following type:

---

[7] *with regard to this last aspect, it is important to point out that currently official collaborative efforts between Nicaragua and Costa Rica on the Cocibolca Lake are hampered to a certain extent due to the International Dispute between both nations on the San Juan River (which drains the lake)*

· **what is the data set about:** name and description of the data set
· **when:** when were the data created; what time period does the reality they represent correspond to; when have the data last been updated, etc.
· **who:** who created the data sets; who distributes the data set
· **where:** what geographic area do they correspond to
· **how:** how was the data set created; what methods have been used; which limitations are associated to its creation and further use; under which format are they available, etc.
…

According to the **Federal Geographic Data Committee** (FGDC, USA), the generation of metadata should pursue 3 main objectives:

- **Organize and maintain the investment an organization has made in its datasets**
- **Make people aware of the existence of geographic information through the creation and use of catalogue systems**
- **Provide information that will facilitate data transfer and use**

In the literature, different recommendations can be found with regard to the creation of metadata; these recommendations aim at providing a hierarchic and well-defined structure which allows for an exhaustive description of the different characteristics of a geographic/thematic data set. These recommendations have typically been created and approved by standardization organizations, and are based on the opinions of national/international experts. They have been made available under the format of different standards and schemes. More recently, the following international standard has been established:

<u>ISO 19115:2003 – Geographic Information Metadata</u>

"Digital geographic data pretend to model and describe the real world for its later analysis and visualization by diverse means. Their principal characteristics as well as their limitations must be completely documented by means of metadata." With the aim of providing a structure that serves for the description of geographic data the international standard **ISO 19115:2003-** ***Geographic Information Metadata*** was created. In 1996 a first draft was available; in 2003 the final text was approved as the International Standard for Metadata which was adopted as the European Standard by CEN/TC 287 in 2005.

The ISO 19115:2003 standard is a very complex standard and includes an extensive series of metadata elements, some of them obligatory, others optional. The document consists of 140 pages and includes a total of 409 items and defines 27 lists which control entries for certain metadata fields. More recently, the standard has been extended (***ISO 19115- 2 "Geographic Information- Metadata for imagery and gridded data"***) as to specifically address metadata needs for geographic raster and image data sets; the target publication date of ISO 19115-2 is 15/05/2009. A previous standard, the Dublin Core metadata standard **ISO 15836,** already addressed the issue of metadata in a more general way; it differs from the ISO 19115 in that the latter specifically addresses the matter of metadata for data sets of the geographic type (i.e., with a geographic component).

The complexity of the general model proposed by ISO19115:2003 implies that in many organizations its direct use as a guide for the generation of metadata will be very difficult. For this reason, **regions**, **countries** or **organizations** may recur to the establishment of **metadata profiles** for the ISO 19115. These profiles adhere to the specific rules of the international standard, but simplify the general model, typically as a function of the specific national, regional or thematic conditions and needs. As a consequence of the publication of ISO 19115, Canada and the US plan to develop and file a joint common profile in agreement with this standard, the **NAP** (North American metadata profile of ISO 19115:2003; FGDC), which will substitute the existing Content Standard for Digital Geospatial Metadata (**CSDGM** version 2; FGDC-STD-001-1998). At the European level, the **INSPIRE**[8] and **WISE**[9] metadata profile have been introduced, whereas the profile "Núcleo Español de Metadatos – **NEM** was published in Spain. In Latin-America, a draft proposal for both a Metadata Profile for the Nations of the Andean Community **CAN** as well as a Latin-American Metadata Profile (**LAMP**) has been made.

Analysis of metadata standards, profiles and editing tools under TWINLATIN

As a conclusion from the work conducted under TWINLATIN, we highly recommend the **systematic generation of metadata in all future efforts** in the twinned (and other) river basins. For this purpose, the **ISO 19.115** international standard needs to be the reference. We currently recommend the practical implementation of this standard for the data sets for the Cocibolca Lake Basin (and other TWINLATIN basins) by means of the Spanish Data Profile **NEM ("*Nucleo Español de Metadatos*").** The NEM profile offers several distinct advantages for implementation in the water resources management sector in Latin-America: ***(i)*** documentation and a user guide are available in Spanish; ***(ii)*** the profile incorporates elements from ISO 19115 as well as from the Dublin core, and also includes additional elements from the WISE profile (Water Framework Directive); ***(iii)*** its implementation is perceived as being more realistic than the analyzed version of LAMP (LAMP being a draft and apparently more complex and therefore potentially overly ambitious in the current context: *realistic aims need to be set especially in an initial phase, as most organizations in the Latin-American region will not count with human resources or financial means specifically designated for the generation of metadata*).

An additional advantage of NEM is that metadata in accordance to the NEM Data Profile can be generated by using the freeware tool **CatMDEdit** (downloadable from the internet); CatMDEdit is a versatile tool as it also allows for the generation of metadata in accordance with different profiles based on ISO 19115 (NEM, Core, INSPIRE and WISE). Alternatively information for the most important elements corresponding to the NEM can also be edited directly in **ArcCatalog**, by means of the embedded **Metadata Editor**.

Generation of metadata – an issue for ongoing work

Whereas an exhaustive analysis of standards, profiles and tools for the generation of metadata could be conducted under TWINLATIN, unfortunately due to time and logistical constraints the production of metadata for the generated datasets for the Cocibolca (and other partner) basin(s) could only be started in the last phase and should therefore urgently be continued in the ongoing post-TWINLATIN efforts. The following figure shows the different metadata elements that should be included in a data source's description, according to the NEM (figure in Spanish).

[8] **INSPIRE** stands for Infrastructure for Spatial Information in Europe

[9] This profile has been customized to meet the guidelines for metadata in the implementation of the Water Framework Directive (**WFD**) and the development of the Water Information System for Europe **WISE**

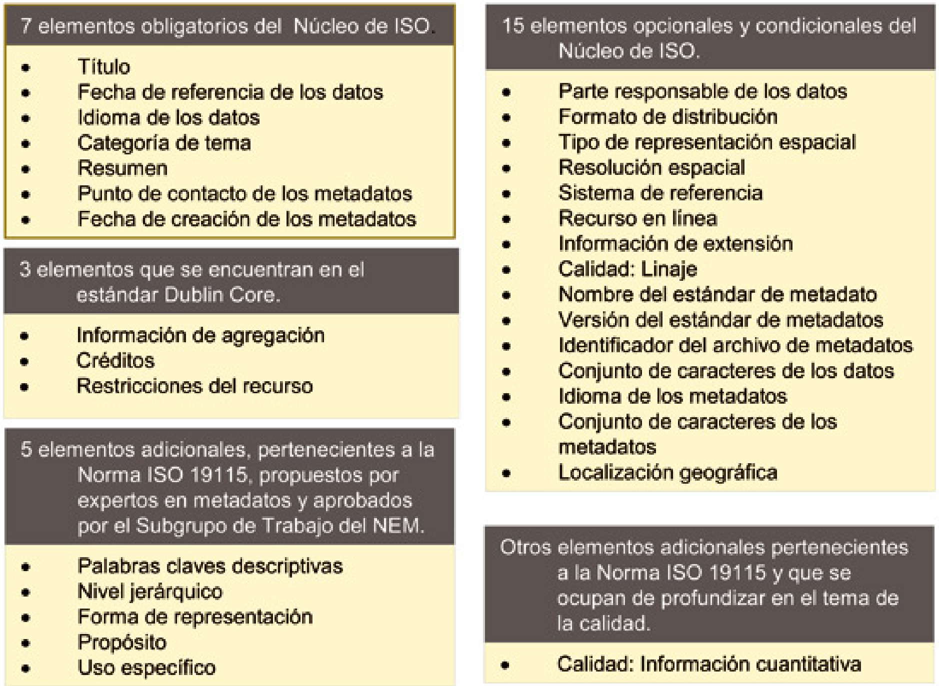


Figure . Elements to be included in the metadata according to the Spanish Metadata Profile NEM (“*Nucleo Español de Metadatos*”)

DNH

Metadata is defined as **“data about data”**. They describe **the content, the quality, the format** and other **characteristics associated to a resource**. It is a way to characterize data so that users can localize them, access them and know the best way to use them. They give answers to questions like: **What, When, Who, Where, How**. The concept of metadata has become a necessary tool for those who work with spatial information.

OBJECTIVES OF METADATA

- **To organize and maintain the investment in data done by an organization**: metadata aim to promote the reuse of data without the need of the person who created it. Even though the creation of metadata could be seen as an additional cost, in the long term the value of the data depends on how well they are documented.
- **Make public the existence of geographic information through catalog systems**: with the publication of geographic information with the use of a catalog, the organizations can find: data to use; other organizations to share data and maintenance efforts; and clients for that data. In general, they allow users to use data in a more efficient way, determining whether they will be useful to them or not.
- **To give information so to help to transfer data:** metadata always have to accompany the data. They make easier the steps to take to access the data, to acquire them, and how to better use them, permitting inter-operational use when they come from different sources. Metadata help users or organizations to process, interpret, and store the data in internal repositories.

Recommendations have been defined for the creation of metadata, with the goal to provide a **“hierarchical and concrete”** structure to describe exhaustively each of the data to which they refer to. They have been created and approved by standardization organisms, in the form of standards or metadata schemes. Therefore there are different alternatives to use: **FGDC, Dublin**

Core, ISO 19915. The main problem is how tedious and challenging to generate them under those standards is, that is why, specially the Spanish speaking countries, have started to create what they called “profiles”, that are a synthesis of those standards containing the minimum information needed to comply with the objectives mentioned before.

In Uruguay, collections of metadata exist under the FGDC and ISO 19115 standards (being the latter a generalization of the former). Currently, the Interinstitutional Group that is working in the IDE (Uruguayan Spatial Data Infrastructure) is assessing, and it is practically a fact, the adoption of the NEM profile (Núcleo Español de Metadatos - Spaniard Nucleus Metadata), which is a synthesis of the ISO19115 standard, and by transitivity will be transparent to the FGDC format.

In the framework of TWINLATIN, we will work with the **NEM profile, so to comply with the ISO standard** and at the same time, we will enrich it with the **FGDC format, that is the one adopted by ESRI tools** (GIS environment in which the geographic information has been managed in a geodatabase in this project. As part of the project, a setp-by-step methodology has been created for the preparation of metadata and it is presented in **ANNEX 3.3** as well as metadata was created for the feature classes, rasters and tables included in the Cuareim River Basin Geodatabase:

Geodatabase Twinlatin_Cuareim River Basin
Feature Dataset Base Map
Feature Classes

- Roads
- Towns
- Rivers
- Reservoirs
- Direct intakes
- Soils

Satellite images
Digital elevation model

Feature Dataset ArcHydro
Feature Classes

- HydroEdge
- HydroJunction
- HydroNetwork_Junctions
- MonitoringPoints

Tables:

- TimeSeries
- TSDataType
- TSIntervalType
- TSOrigins
- TSType

LayersArcHydro

- agreedem
- cat
- fac
- fdr
- fil
- lnk
- str

7. TWINNING NEEDS WITH RESPECT TO MONITORING & DATABASE CONSTRUCTION

As part of the Twinning efforts under TWINLATIN, the ArcHydro data model has been proposed as an adequate model for setting up the geographical/thematic databases for the different case study basins. Many partners have decided to implement (at least) the basic aspects of the ArcHydro concept in their case study basin. Twinning on the implementation of ArcHydro was particularly strong between the Baker Basin (Chile) and the Cocibolca Lake Basin (Nicaragua). But also other partners have realized intensive twinning activities in this context, and in the first phase of the project a general twinning workshop on the implementation of ArcHydro was held with participation of almost all partners at Porto Alegre, Brazil.

In what follows, and as an example, a description is given of the reasoning behind, and the content of the important work on database construction for the Cocibolca Lake.

Database construction – Cocibolca Lake

Previous experience with regard to the construction of environmental databases or the use of Geographic Information Systems (GIS) for environmental analyses was not present at the Nicaraguan partner institution CIEMA-UNI at the start of the TWINLATIN project. In general, as the centre is one of the main Nicaraguan research centers dedicated to the study of the environment, an urgent need was perceived here for the training of (*ideally permanent*) staff members on the use of spatial analysis and modeling techniques, as well as on the construction and maintenance of environmental databases.

From a sustainability point-of-view, however, several problems may arise: environmental modeling or analysis and database construction was (is) not an established research line at CIEMA-UNI, and the current configuration of permanent staff does not include experts on this matter. Junior personnel specifically contracted for the TWINLATIN project execution may not be able to continue their activities at the Centre as the resource flux which allowed conducting such work under TWINLATIN will cease to exist once the project ends. Under such a scenario, the constructed database may lack further updating and therefore rapidly become outdated and obsolete. Also, the risk exists that the acquired knowledge is lost as resources for maintaining the trained project staff members within the institution may not longer be available (unless a long-term strategy is implemented by the Direction of the centre, aiming at knowledge transfer to permanent staff members or incorporation of the trained staff itself as permanent staff).

Under TWINLATIN, in order to guarantee to the maximum possible extent the durability of project outcome and results, it was therefore important that the final environmental database was transferred, installed and maintained at the corresponding department(s) of one or several (government) institutions which hold responsibility over water resources management, and which have as part of their institutional tasks the generation, maintenance and distribution of environmental datasets.

It is from this sustainability perspective that a double approach has been implemented under TWINLATIN:

- training on GIS, ArcHydro and analysis techniques has been provided to CIEMA-UNI (and associated) staff, and research activities have been largely conducted at the Centre itself
- intensive interaction has taken place throughout the project's execution with the Nicaraguan Institute for Territorial Studies INETER, and both knowledge and the database itself have been transferred to INETER's Water Resources Directorate

Twinning between other project partners and CIEMA-UNI and INETER on the topics of database construction & monitoring has been implemented through the following actions:

- long-term stationing of an expert from EULA-Chile at the CIEMA-UNI Centre, with frequent visits to INETER (second & third year of execution of the TWINLATIN project)
- training workshops on the ArcHydro data model implementation for the construction of the environmental database, and on water balance modeling/calculations, organized at IVL (Sweden) and at/for INETER by EULA-Chile, IVL (Sweden) and CIEMA-UNI (this also included invitation of other Nicaraguan stakeholders such as e.g. the CIRA aquatic resources research centre)
- long-distance and on-site twinning on metadata generation with EULA-Chile and DNH (Uruguay)

Monitoring – Cocibolca Lake

Due to priority setting as a consequence of time and logistical constraints, the twinning on monitoring itself has been limited to a joint field trip to the Cocibolca Lake Basin conducted by CIEMA-UNI and EULA-Chile staff members, in which sediment cores have been obtained from the Cocibolca Lake and the Las Canoas reservoir (objective: determination of historical sedimentation rates through ^{210}Pb dating).

Rather than focusing the twinning on the monitoring itself, the twinning attention has been focused on collecting and improving the existing monitoring data sets (time series), as we consider that a good overview of what already exists is a first step that needs to be addressed before ambitious new monitoring plans are being developed and implemented. The results from this work have been documented throughout this work package report. Work has been realized through an intensive twinning effort between EULA-Chile, IVL (Sweden), CIEMA-UNI, INETER, the Nicaraguan Ministry of the Environment MARENA and the National System for Environmental Information SINIA, and the Agriculture and Forestry Ministry MAGFOR.

DNH participated in several TWINNING activities in relation to Database construction:

- ArcHydro Training Course in Porto Alegre IPH (Brazil) May 2006, organized by IVL and supported by EULA
- DNH gave a course of ArcGIS in Porto Alegre IPH, September 2006
- Modeling and ArcHydro applications, Stockholm IVL April 2007

8. CONCLUSIONS AND RECOMMENDATIONS

UNIGECC

The presented work on the Catamayo-Chira Basin is the result of three years of conduction of the "Programa de Monitoreo de la Calidad del Agua de la Cuenca Binacional Catamayo – Chira", initiated in July of 2006 in the frame of Twinlatin Project, with the objective of establishing a base line of information that allows the characterization of the water quality of the river basin and the rigorous and systematic analysis of the evolution of the physical, chemical and microbiological characteristics, using as reference the binational legislation of environment quality.

In this period, almost 35 parameters were monitored, with a trimester periodicity, in almost 28 monitoring sites of the river basin. The sampling were done following the criteria of the "Protocolo de Monitoreo de la Calidad Sanitaria de los Recursos Hídricos Superficiales", of the sanitarian Peruvian authority - DIGESA.

We can conclude that in the main stream of the basin and in its effluents, water quality deteriorates downstream, due to the more demographic density in the lower parts of the river basin. The activity that most influence the water quality in the basin are sewages from villages and cities that are spilled to the river without any previous treatment. The effluents of agrarian drainages are also a potential threat to water quality. Deterioration of water quality in the basin is due to the demographic explosion of the last years, the negative effect of the incorrect or non treatment of sewages.

However, in the basin, there are acceptable levels of water quality at almost all monitoring sites and most of the water is suitable for conventional treatments, for agrarian uses and biota conservation. There are points that have presented problems with salts and other compounds that request the development of more monitoring campaigns to have more information to analyse trends and develop further study.

Due to the socioeconomic situation of the river basin, the generalized existence of microbiological contamination in the water, poses a great risk for the human health, especially children. For that reason is urgent to take action in those places where population drinks water directly from the river, without any previous treatment.

Data obtained in this period allows the establishment of a baseline information, that has been created systematically, following the protocols established in the Peruvian legislation. However, the following recommendations are concluded order to improve the future work.

- Incorporate the monitoring activities in the second phase of the Catamayo Chira Project, for ensuring the continuity of the enforcement work to the local institutions and the sustainability of the monitoring program.

- Incorporate to the monitoring program, the analysis of parameters that could be representatives as parasites, dissolved soils and hydrocarbures (in binational points) and extract those that don't result of special interest in the monitoring campaigns done.

- Work on increasing the quality of the obtained information, training and enforcing the technical team and preparing field manuals and technical's proceedings of the monitoring and analysis process.

- Promote complementary research that bring more knowledge about the processes related to the water quality in the basin, as the inventory of the pollutant focus, a indispensable tool for increasing the knowledge of the characteristics of the water pollutants of the river basin.

- Work for the further implication of the local institutions and local organizations, for their participation in the water quality management, through activities of monitoring and control that ensure the sustainability of actions.

With respect to the database ArcHydro we can conclude:

- ArcHydro Model is a useful tool to maintain both spatial and alphanumerical data in the same deposit (Geodatabase). For this reason, following studies, projects or other kind of work of the basin will have all data organised, accessible and friendly for all users.

- It is necessary to support the institutions in charge of this data with the use of these tools in order to solve the problem of the Basin hydrological information's management

- The implementation and updating of the ArcHydro Model should continue with a good coordination among institutions.

- A main problem detected is that most of the institutions are not users of ArcGis nor they haven't a software license. This is basic in order to continue the data introduction and the upgrade of the Geodatabase of ArcHydro. In this sense, it is desirable to encourage the institutions to upgrade its GIS software.

EULA (GENERAL CONCLUSIONS)

Based on the activities and reporting conducted under TWINLATIN Work Package 2, some very general short comments and recommendations are formulated:

Monitoring

- Under TWINLATIN, a high heterogeneity of monitoring efforts have been conducted, serving multiple purposes. Instead of entering into detail on each one of these efforts, besides the typical issues such as quality of data and analyses, we would also like to project the following important keywords: **baseline - complementarity** – **sustainability/continuity:**
- **Baseline:** in most Latin-American case study basins under Twinlatin, very limited baseline information was available; Twinlatin has in this sense provided an important means for the acquisition of more baseline information for these basins, which –when making this available to future users- can certainly positively contribute to improved future management in these river basins
- **Complementarity**: as can be seen, in most of the basins, different monitoring efforts are being undertaken by different organizations. In addition to this, projects start and projects end, and for such reason certain monitoring efforts will be intermittent in time, or only "punctual" or temporal. Complementarity of different efforts can best be achieved by starting the monitoring work with an inventority on previously existing data sets, as was done under Twinlatin. From this departure point, better

complementarity of past, ongoing and future efforts can be achieved. In addition to this, the incorporation of monitoring data in a structured database as is suggested under the following paragraph will also facilitate future inventories of what is really available.

- **Sustainability**: monitoring is expensive, and monitoring programs often benefit from temporarily available resources, which frequently leads to discontinuous or just occasional monitoring efforts. Here again, the incorporation of monitoring data in structured databases may make it easier to continue, or restart activities from the past, and as such give added value to the obtained extended data sets; the combination of monitoring data from Twinlatin with the results from work under the other work packages may further also contribute to the achievement of better insights in the processes and problems in the different river basins, and as such enable more efficient and cost-effective future monitoring efforts, which is particularly relevant in conditions of limited availability of financial resources. In the different river basins, Twinlatin has thus delivered a very important contribution in this context.

Database, ArcHydro, metada – recommendations for future work

- Many partner recognized **ArcHydro** to be a very interesting data model for structuring information on a river basin. However, due to time and logistical constraints, the work under TWINBAS has often been focused on the basic implementation of this data model (basin delineation, creation of time series databases, etc.). ArcHydro offers however much more, as it is an important tool kit for water management whose multiple potential uses will only be limited by the creativity of the user. Further training and twinning on the ArcHydro data model in a post-Twinlatin context would allow to reach further than the initial phase of database construction and allow for the implementation of more advanced applications such as the practical database use for environmental assessments and decision-making (many applications of this already existed in Twinlatin, but this can be further extended); a general recommendation for partners and other interested institutions in the region would thus be to keep on looking for further possibilities for cooperation on this topic.
- The development of a methodology and protocol for bi-directional **data exchange** between the Basin Georeferenced **Environmental Database** (incl. **monitoring data**) and **environmental modeling tools** and applications would further contribute to the continuous updating and optimized use of the database
- In many case study basins, the formation of **inter-institutional committees** for the development of a **shared data base** with well-defined and commonly agreed structure will be necessary in order to avoid duplicate work; commonly agreed-upon, clear and non-overlapping assignation of **institutional responsibilities** with regard to the collection, quality control, updating, and distribution of the Basin-related data sets will therefore be needed, as wel as a common **protocol for inter-institutional data exchange**
- A protocol for the **systematic generation of metadata** for geographic data sets for the basins, in accordance with the ISO 19115 and ISO 19115-2 standards (ISO 19139/TS XML schema implementation) and (our proposal:) the NEM metadata profile should be developed and agreed upon between the different institutions (see also the guidance materials provided by DNH in the Annex)

9. BIBLIOGRAPHY

BIBLIOGRAPHY (CVC)

CVC – Environmental Technical Direction, Water Resources Group (2000). Balance demand – water availability, municipalities of Valle del Cauca. Santiago de Cali

CVC –Universidad del Valle, School of Engineering – Natural resources and Environmental Inter-Administrative Agreement 0168 dated November 27, 2002 (2002). Cauca River mathematical modeling and characterization - PMC phase II, volume IX, identification of critical parameters in the Cauca River and its main tributaries in the section between Salvajina and La Virginia. Santiago de Cali

CVC – Environmental Technical Direction, Environmental Information Systems Group (2005). CVC Hydrometeorological Bulletin. Santiago de Cali

CVC – CVC Planning Direction, Environmental Information Systems Group (2006). Professional and technical staff oral interviews. Santiago de Cali

CVC – CVC Planning Direction, Environmental Information Systems Group (2005). Geographical Information System of the Tuluá River basin. Santiago de Cali

CVC - Environmental Technical Direction, Environmental Information Systems Group (2005). Hydrometeorological measurements, dissemination material prepared by Ramón López. Santiago de Cali

CVC. Environmental Management Direction, Infrastructure Group (1999). Flooded areas, February –March, 1999, prepared by Freide Guzmán G and José Antonio Sierra C. Santiago de Cali

CVC – Environmental Technical Direction, Underground Water Group (2000). Importance and Perspectives of Underground Water of Valle del Cauca – prepared by Gloria Isabel Páez**.** Santiago de Cali.

CVC, Environmental laboratory data base on water quality and discharge sources monitoring**.** Santiago de Cali.

Soto,C- Arias G- “Regionalization of streaming media flows superficales tributaries to the river Cauca between Salvajina and Cartago”. Degree thesis. June 2000 . Santiago de Cali.

BIBLIOGRAPHY (DNH)

WATER QUALITY MONITORING

GEMS/Agua. 1994. Guía operativa. 3ª Edición. PNUD-OMS-UNESCO-OMM

IMFIA. 2004. Plan de Monitoreo de la cuenca del Río Cuareim, margen izquierda. Informe técnico realizado para la Comisión del Río Cuareim.

Plan de Monitoreo de la Cuenca del Río Cuareim – Margen Izquierda – CRC – IMFIA; 2004

Australian and New Zeland Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zeland. 2000. Australian Guidelines for Water Quality Monitoring and Reporting- Summary

METADATA / DATABASE

Maidment, D. 2002. Arc Hydro GIS for Water Resources

10. ANNEXES

ANNEX UNIGECC – see additional Excel file

ANNEX CVC

Water quality assessment based on Water Quality Indexes (ICA) and Contamination Indexes (ICO) is done through the analysis of physical-chemical and microbiological parameters converted into a sole figure, generally ranging between 0 (very poor quality) and 100 (excellent quality) in case of ICA and between 0 (very low contamination level) and 1 (very high contamination level) in case of ICO. These indexes define the quality or contamination level of the water body expressing their adequacy for the determined use.

- **ICA NSF (National Sanitation Foundation according to the English acronysm – "NSF" in the United States):** Uses the following physical-chemical and microbiological parameters to be taken into consideration for indexes calculation:

1. Biological Oxygen Demand (BOD_5, in mg/l).
2. Dissolved Oxygen, (DO, in saturation %).
3. Hydrogen Potential (pH, in units).
4. Turbidity (Turb, in UNT).
5. Phosphates (PO_4^{-3}, in mg/l).
6. Nitrates (NO_3^{-2}, in mg/l).
7. Temperature (T), expressed as T deviation from balance (ΔT).
8. Fecal coliforms (F. Coli., in NMP/100 ml).
9. Total Solids (TS, in mg/l).

Although the Water Quality Index (ICA-NSF) was created according to North American rivers' characteristics, its generalized application converts it into a practical guide for the determination of water quality in surface waters.

- **Water Quality Index Customized by CETESB (2002):** Another customization of ICA-NSF for tropical area rivers was done by the Environmental Sanitation Technology Corporation of Brazil – CETESB (2002). This company proposed a modification to the NSF multiplicative ICA, adjusting it to specific conditions of rivers in the State of Sao Paulo. Such modification consisted on changing Nitrate and Phosphate parameters by Total Nitrogen and Total Phosphorus, respectively, maintaining the same subindexes function and specific weighing for each ICA-NSF established parameter. Additionally, CETESB modified the river water quality classification according to the index value obtained, considering the destination of water for human consumtion.

- **Water Quality Index Proposed by Dinius (1987):** Another general usage ICA was developed by Dinius (1987). Dinius created a multiplication type index with 12 physical-chemical and microbiological parameters, establishing limit values or advisable ICA measurements, according to the water resource use. Results of such procedure allowed to select the following physical-chemical and microbiological parameters to be taken into consideration for index calculation:

1. Biological Oxygen Demand (BOD_5 , in mg/l).
2. Dissolved Oxygen, (DO, in saturation %).
3. Hydrogen Potential (pH, in units).
4. Nitrates (NO_3^{-2} in mg/l).
5. Temperature, expressed as T deviation from balance (□T).
6. Fecal Coliforms (Coli. F in NMP/100 ml).
7. Total Coliforms (F. Coli. in NMP/100 ml).
8. Alcalinity (mg/l).
9. Hardness (mg/l).
10. Chlorides (Cl^- mg/l).
11. Conductivity (□s/cm).
12. Color (UPC).

- **Contamination Indexes (ICO):** ICOs are assessment criteria to determine water contamination levels developed in Colombia by Ramírez, A. and Viña, G. (1998) based on "Main Component Analysis" (ACP), applied to a significant amount of physical-chemical information resulting from different limnological studies related to the oil industry. Based on such information, physical-chemical variables were defined, expressing the same environmental condition. Some of the most representative or easy to determine variables were selected to participate in contamination indexes (ICO).

Four contamination indexes were defined in this study, through which it is possible to draw conclusions on data such as mineralization, organic matter, suspended solids and trophic level. These indexes define the contamination level of a water body using a figure ranging between 0 (very low contamintation level) and 1 (very high contamination level).

Mineralization Contamination Index (ICOMI): This contamination is expressed based on Conductivity (as a consequence of dissolved solids), hardness (gathering calcium and magnesium cations) and alkalinity (gathering carbonate and bicarbonate anions).

Organic Matter Contamination Index (ICOMO): Represents contamination variables such as ammonia nitrogen, nitrites, phosphorus, oxygen, BOD_5, DQO and total and fecal coliforms. This index was defined based on BOD_5, total coliforms and oxygen saturation percentage. The first two reflect diverse sources of organic contamination, and the third one expresses the environmental response of the water body to this type of pollution.

Suspended Solids Contamination Index (ICOSUS): Suspended solids reflect a condition different from that of disolved solids and do not relate with minineralization variables. It is mainly caused by erosion and extraction processes, and its main effect is decreased light penetration. Turbidity is another expression of this variable, but not a direct measurement.

Trophic Contamination Index (ICOTRO): ICOTRO is based in total phosphorus concentration. Due to the fact that it is generally the limiting nutrient, it defines water ecosystems euthrophication. Even though this phenomenon is most important in lentic waters, it is also frequently expressed in lotic waters, especially in slow flow rivers and still waters.

ANNEXES DNH

3.1. WATER QUALITY - CHARACTERIZATION OF THE STATE OF THE CUAREIM RIVER DURING TWINLATIN'S WATER QUALITY MONITORING

The objective was to establish a **characterization of the state of the Cuareim River at the time of each water quality sampling**. Two monitoring points are close to the City of Artigas and one is in the area known as Pay-Paso, a section approximately 27 km away from the mouth of the Cuareim River on the Uruguay River.

The information used is from the Hydrologic Service of the Water Resources Division of the National Directorate of Hydrography. There is flow and stage data from the stations: N° 84.1 (Puente Concordia) and N° 28.0 (Bella Unión). The data of the latter were taken as a reference for the case there existed influence of the Uruguay River on the Cuareim River at Pay-Paso, as close to this section there are no direct observations.

3.1.1 State of the Cuareim River during the water quality campaigns

Table 3.1.1 shows the daily average water-level readings at station N° 84.1 and N° 28.0, the days of the TWINLATIN monitoring campaigns, with the corresponding frequencies for the period 2001-2007 (**Figures 3.1.2.10 and 3.1.2.11**). Values in red correspond to values above the general average for each station.

It can be concluded that in general the monitoring was done with the Cuareim River at water-levels below the average one. When the level of the Cuareim river corresponded to a frequency less than 50% in station N° 84.1 (09/10/2007 and 06 to 07/11/2007 campaigns), the Uruguay River in Bella Unión was at higher levels than the average one.

During the 05 to 08/06/2007 campaign, the Cuareim River was at low levels while the Uruguay River was somewhat high (approximately 50% frequency), what could be relevant in terms of the influence of the Uruguay River in the flows at Pay-Paso.

Table 3.1.1 MONITORING CAMPAIGNS AT THE CUAREIM RIVER

ARTIGAS	BELLA UNIÓN

DATE	LEVEL (m)	FREQ. (%)	LEVEL (m)	FREQ. (%)
03/10/2006	1.40	*80*	1.40	*75*
04/10/2006	1.38	*80*	1.40	*75*
05/10/2006	1.45	*72*	1.44	*72*
21/11/2006	1.92	*32*	2.29	*52*
22/11/2006	1.83	*38*	***2.66***	***43***
23/11/2006	1.76	*45*	***3.51***	***26***
03/01/2007	***2.01***	***28***	***2.94***	***37***
04/01/2007	1.92	*32*	***2.77***	***41***
27/02/2007	***2.08***	***24***	2.13	*55*
28/02/2007	1.95	*31*	2.14	*55*
05/06/2007	1.29	*97*	***2.64***	***44***
06/06/2007	1.29	*97*	2.32	*51*
07/06/2007	1.29	*97*	2.09	*57*
08/06/2007	1.29	*97*	1.87	*63*
09/10/2007	***2.31***	***17***	***3.27***	***30***
06/11/2007	***2.02***	***28***	***4.88***	***9***
07/11/2007	1.89	*35*	***5.14***	***8***
08/01/2008	1.38	*80*	1.22	*78*
09/01/2008	1.38	*80*	1.02	*84*
26/02/2008	1.38	*80*	0.56	*93*
27/02/2008	1.38	*80*	0.64	*92*

3.1.2 Antecedent Conditions

Apart from the state of the river the very same days of the monitoring campaigns it is of interest to have a reference of its evolution in the previous days, as they could have an influence on the analysis of the results of the samplings. Indeed, it is not the same a relatively stable and prolonged situation of levels and flows, than a situation immediately after important rainfalls, even for the same level of river.

That is why the daily average precipitation for the department of Artigas was gathered from the Meteorological Service, for the 15 days prior to each monitoring campaign. **Table 3.1.2** shows the accumulated precipitation for those 15 days (departmental averages); the days that went by from the last precipitation until the beginning of the monitoring; the average flow in monitoring station N° 84.1 when the monitoring was done; and the average flow for the previous 15 days.

The estimation of the flows at Pay-Paso is not possible with the available data at the Hydrologic Service. If it were accepted the proportionality of flows with respect to the respective basins, the values measured at station N° 84.1, should be multiplied by a factor of 3,5.

Table 3.1.2 ANTECEDENT PRECIPITATION AND AVERAGE FLOW IN ARTIGAS

	ACCUM. PRECIPITATION	**N° OF DAYS**	**FLOW (m^3/s)**	
CAMPAIGN	**(mm)**	**With no Precipitation**	**campaigns**	**15 antecedent days**
03 AL 05/10/2006	28	6	3.0	8.0
21 AL 23/11/2006	153	4	23.9	188.5
03 AL 04/01/2007	137	9	35.2	87.6
27 AL 28/02/2007	193	1	38.8	76.8
05 AL 08/06/2007	6	15	1.1	1.4
09/10/2007	70	3	80.5	84.7
06 AL 07/11/2007	118	3	33.2	191.1
08 AL 09/01/2008	79	5	2.2	2.2
26 AL 27/02/2008	1	10	2.2	2.2

Graphs in **Figures 3.1.2.1 to 3.1.2.9** represent the evolution of the levels of the Cuareim River (station N° 84.1) and at the Uruguay river (Station N° 28.0) during the monitoring days and the antecedent ones, with the precipitation events registered in those periods. In those graphs it can be seen for each case if the river was stable when the monitoring campaign took place or if the sampling or measurements took place with the influence of close-previous precipitation events.

To be able to present the data of both stations simultaneously, it was used a dimensionless value that is calculated in relation to their respective average, maximum and minimum values in the same period of data. The expression is as follows:

$$H_{a\,\text{dim.}} = \frac{(h - H_{med})}{(H_{máx} - H_{mín})}$$

Figure 3.1.2.1 Level of the river and precipitations - Campaign N°1

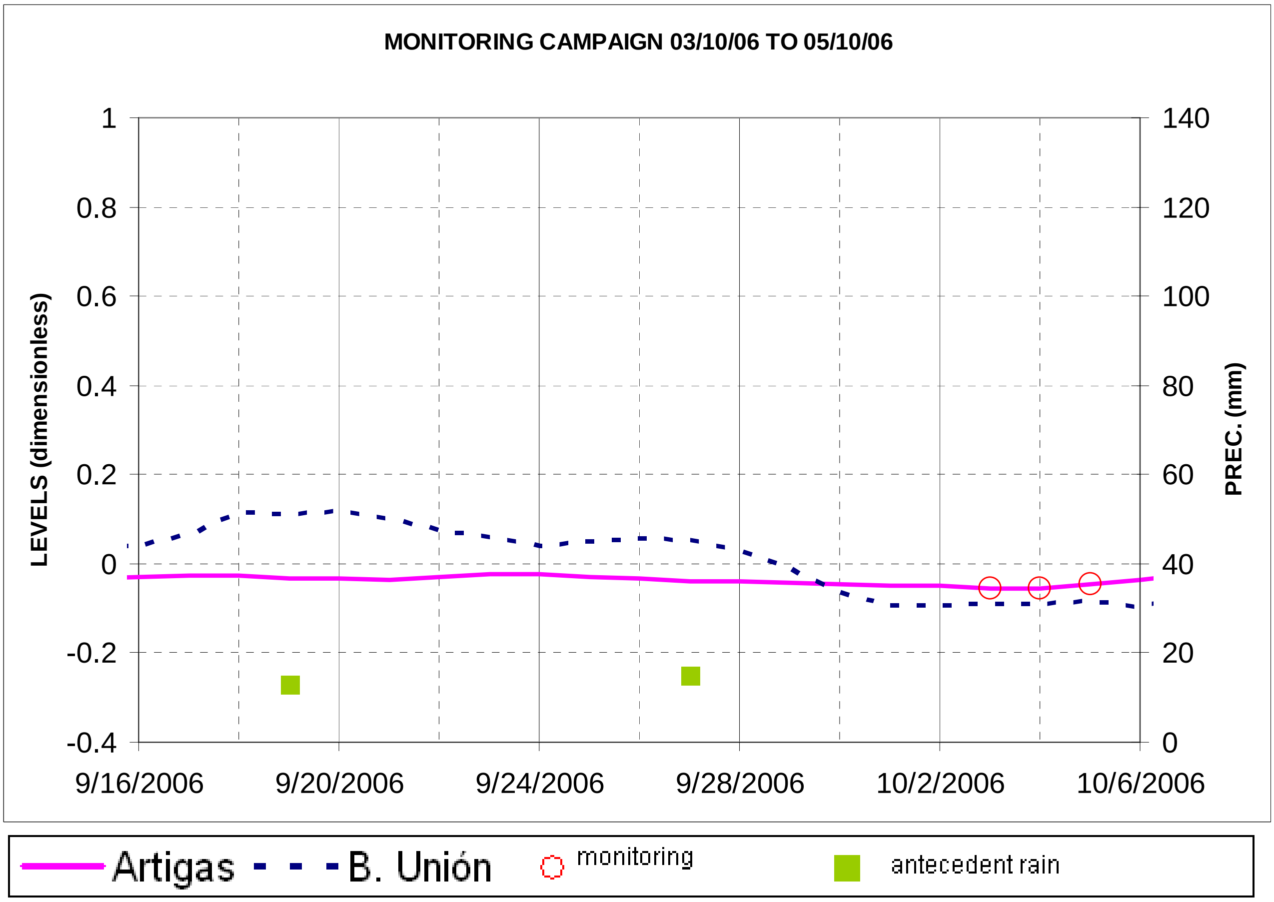


Figure 3.1.2.2 Level of the river and precipitations - Campaign N°2

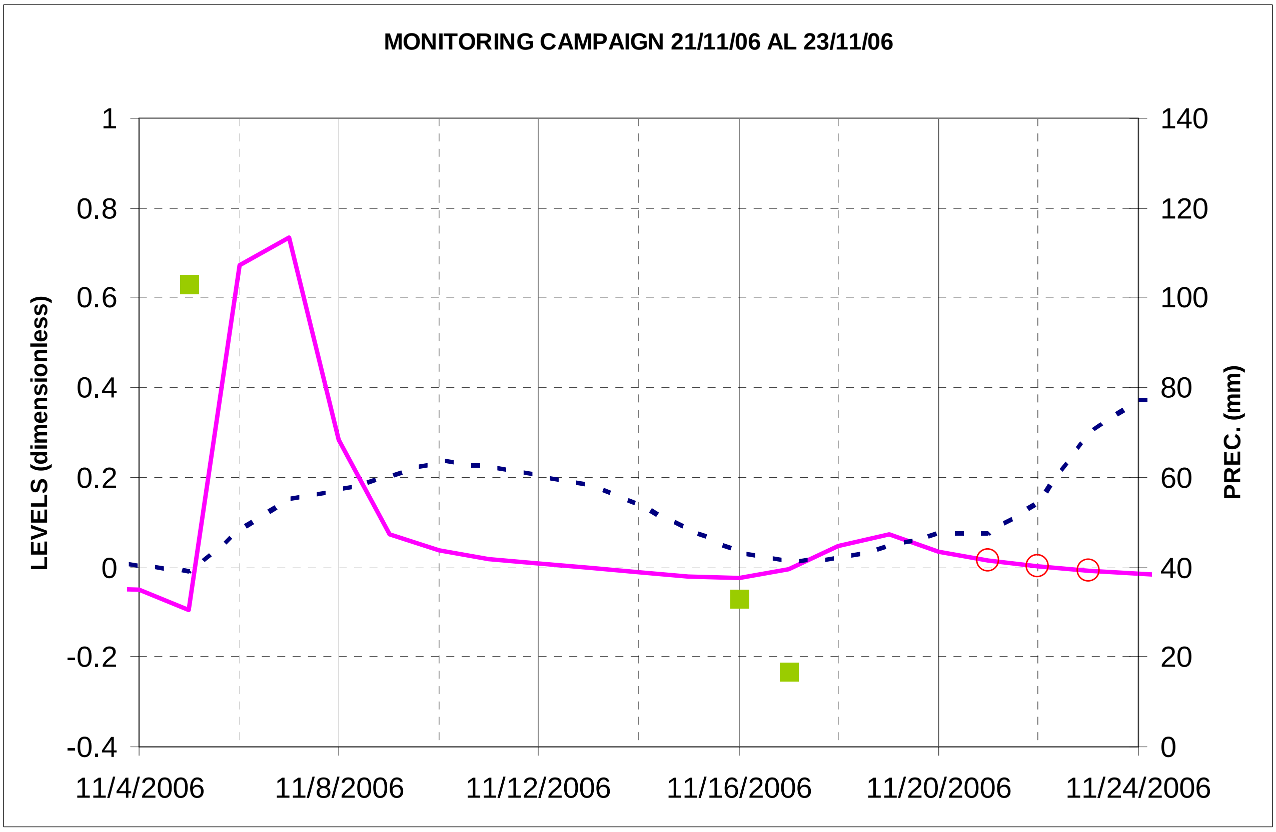


Figure 3.1.2.3 Level of the river and precipitations - Campaign N°3

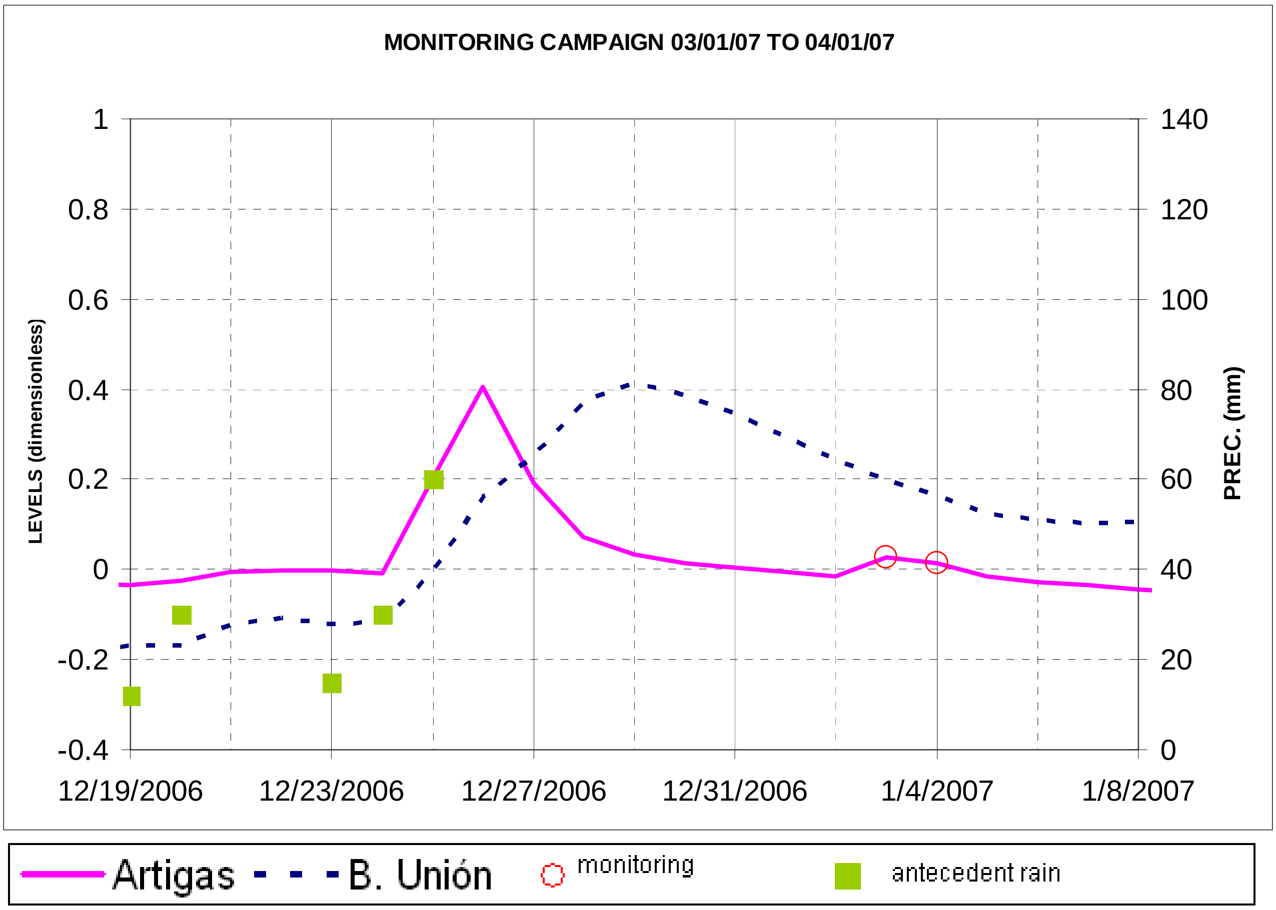


Figure 3.1.2.4 Level of the river and precipitations - Campaign 4

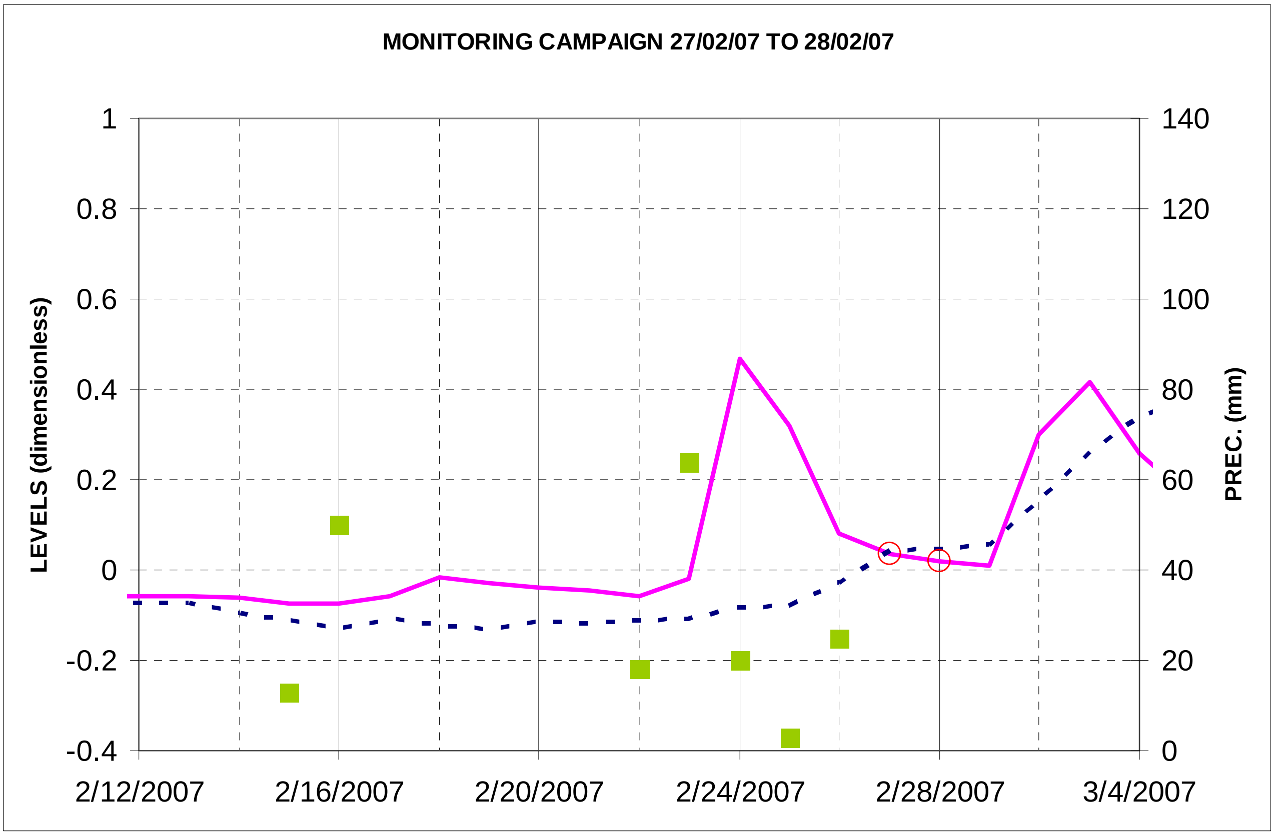


Figure 3.1.2.5 Level of the river and precipitations - Campaign 5

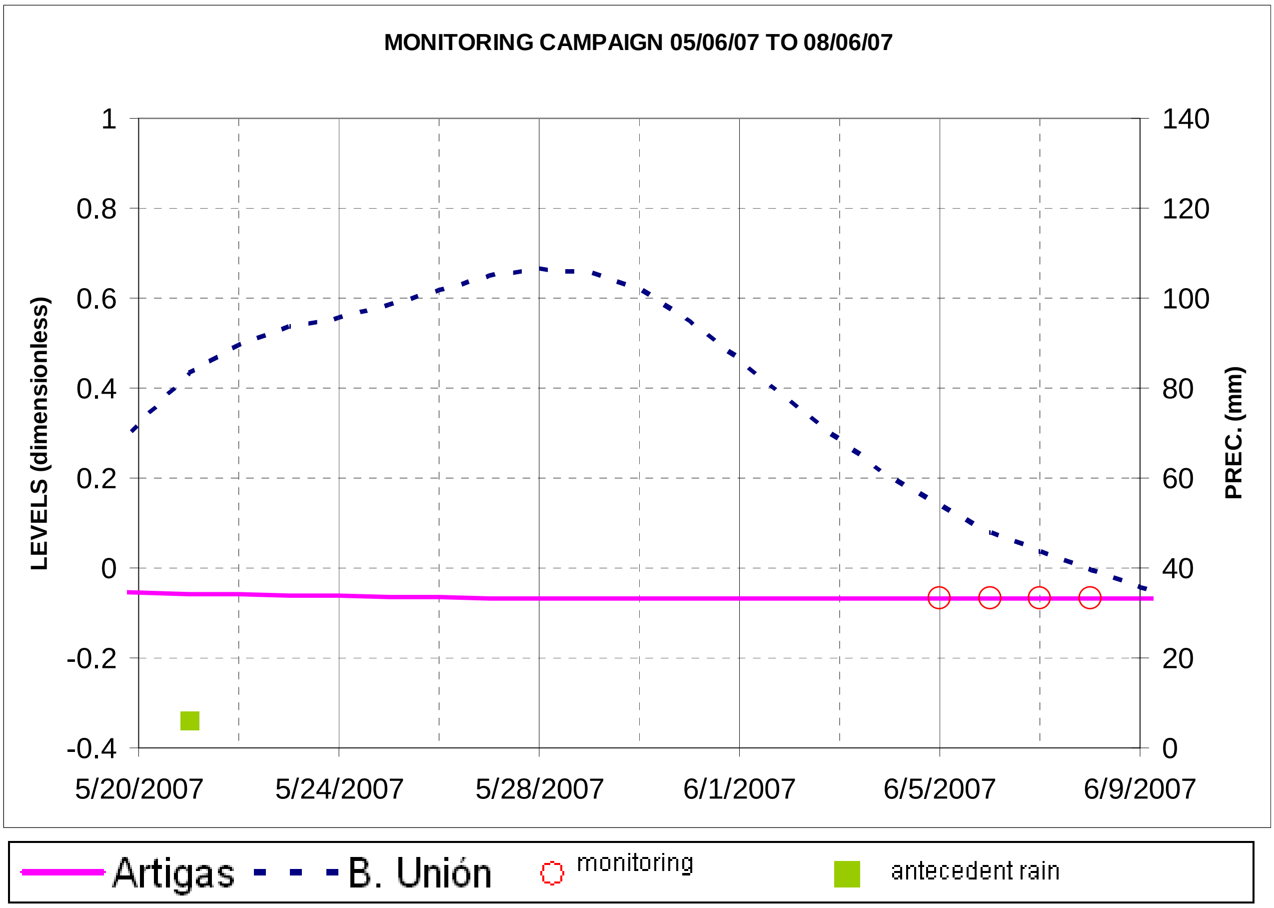


Figure 3.1.2.6 Level of the river and precipitations - Campaign 6

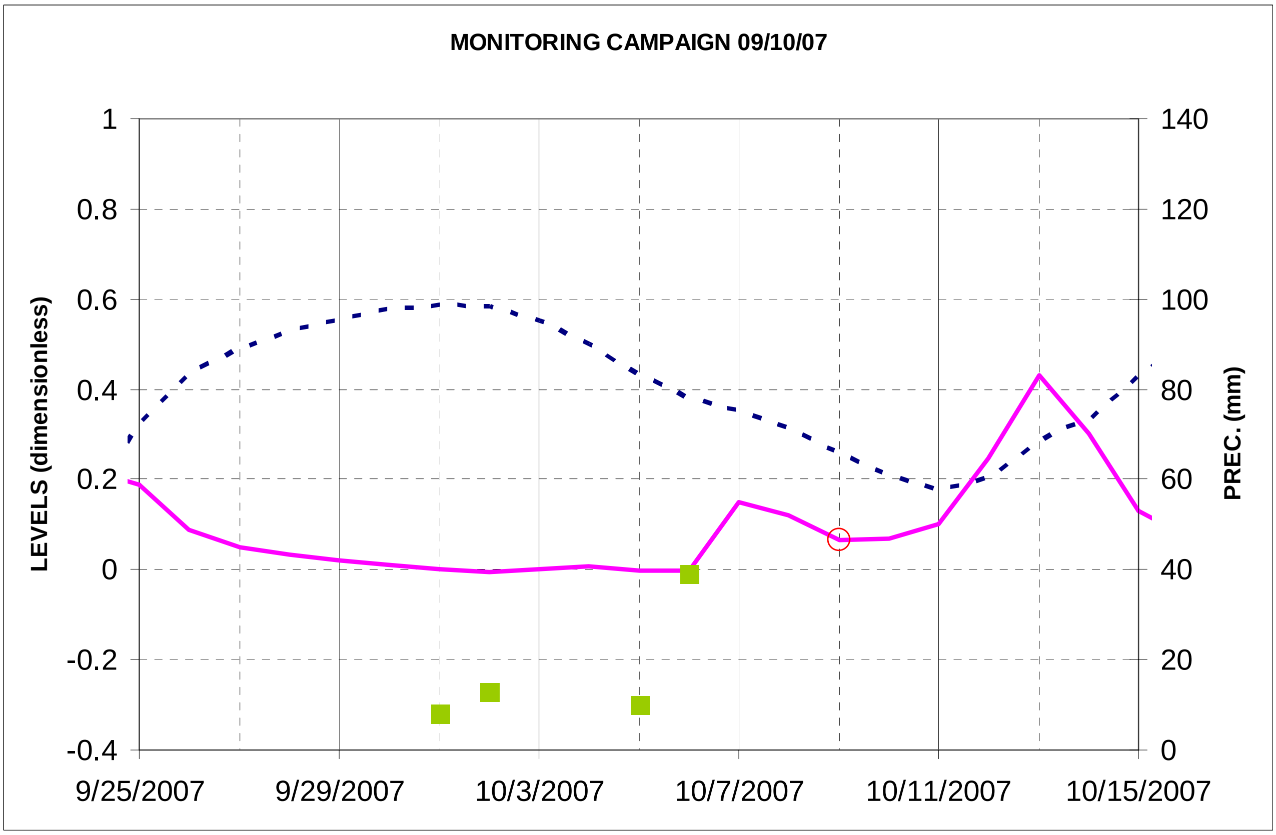


Figure 3.1.2.7 Level of the river and precipitations - Campaign 7

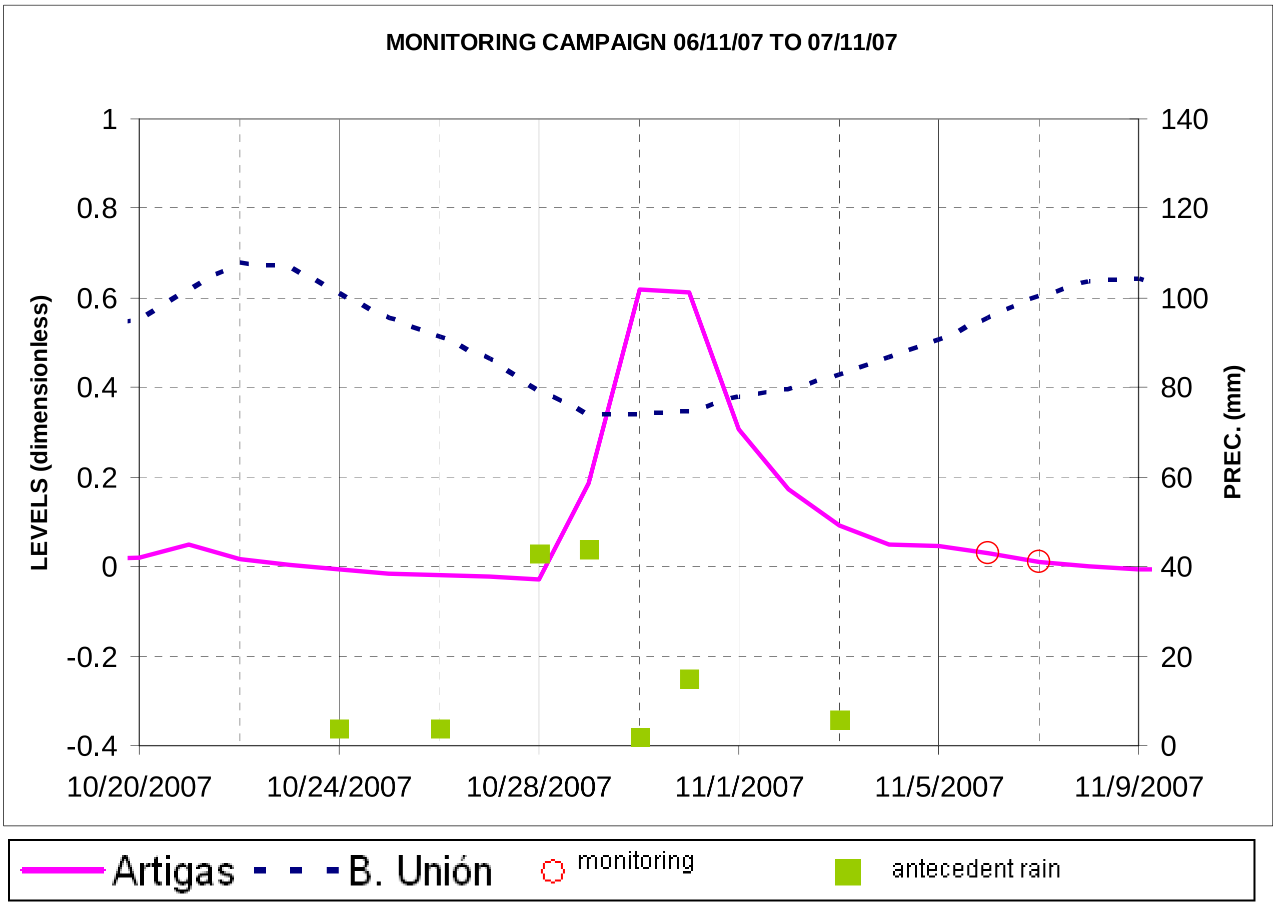


Figure 3.1.2.8 Level of the river and precipitations - Campaign 8

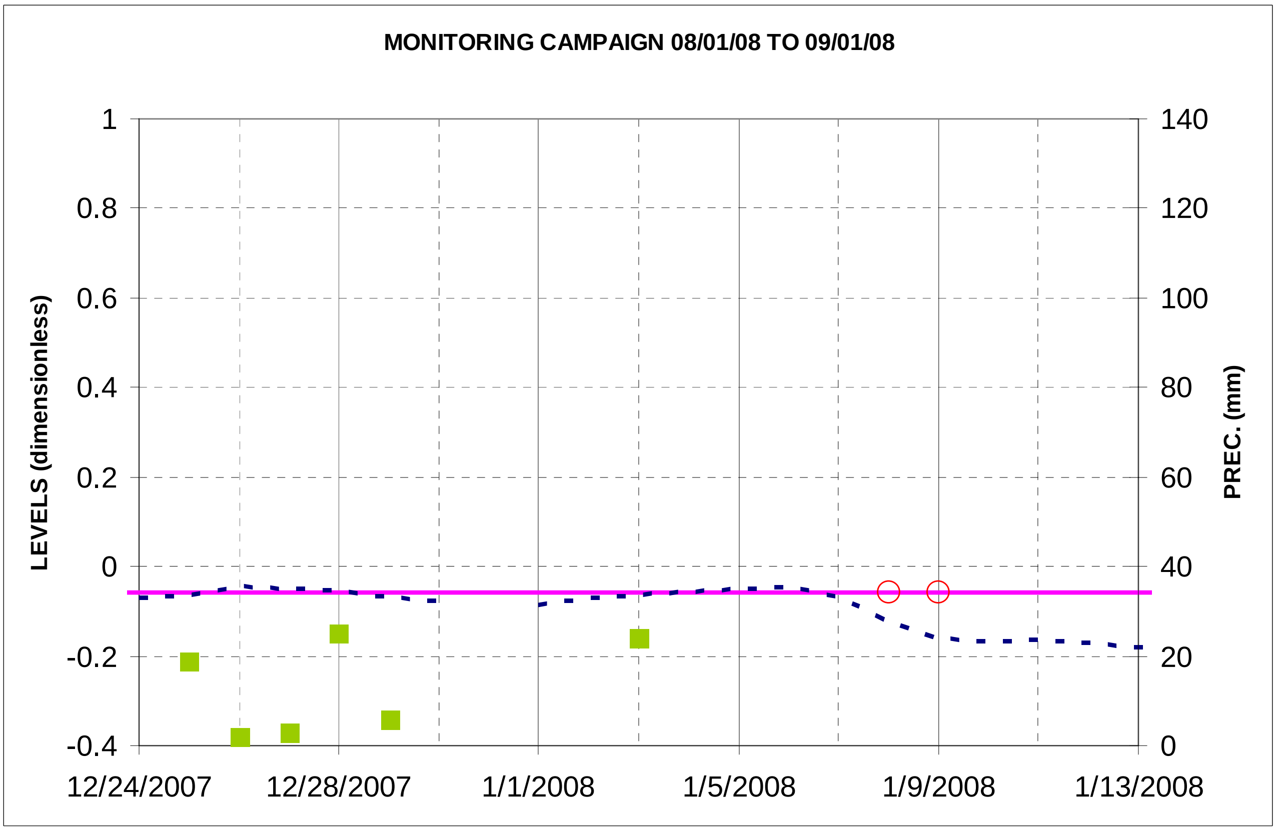


Figure 3.1.2.9 Level of the river and precipitations - Campaign 9

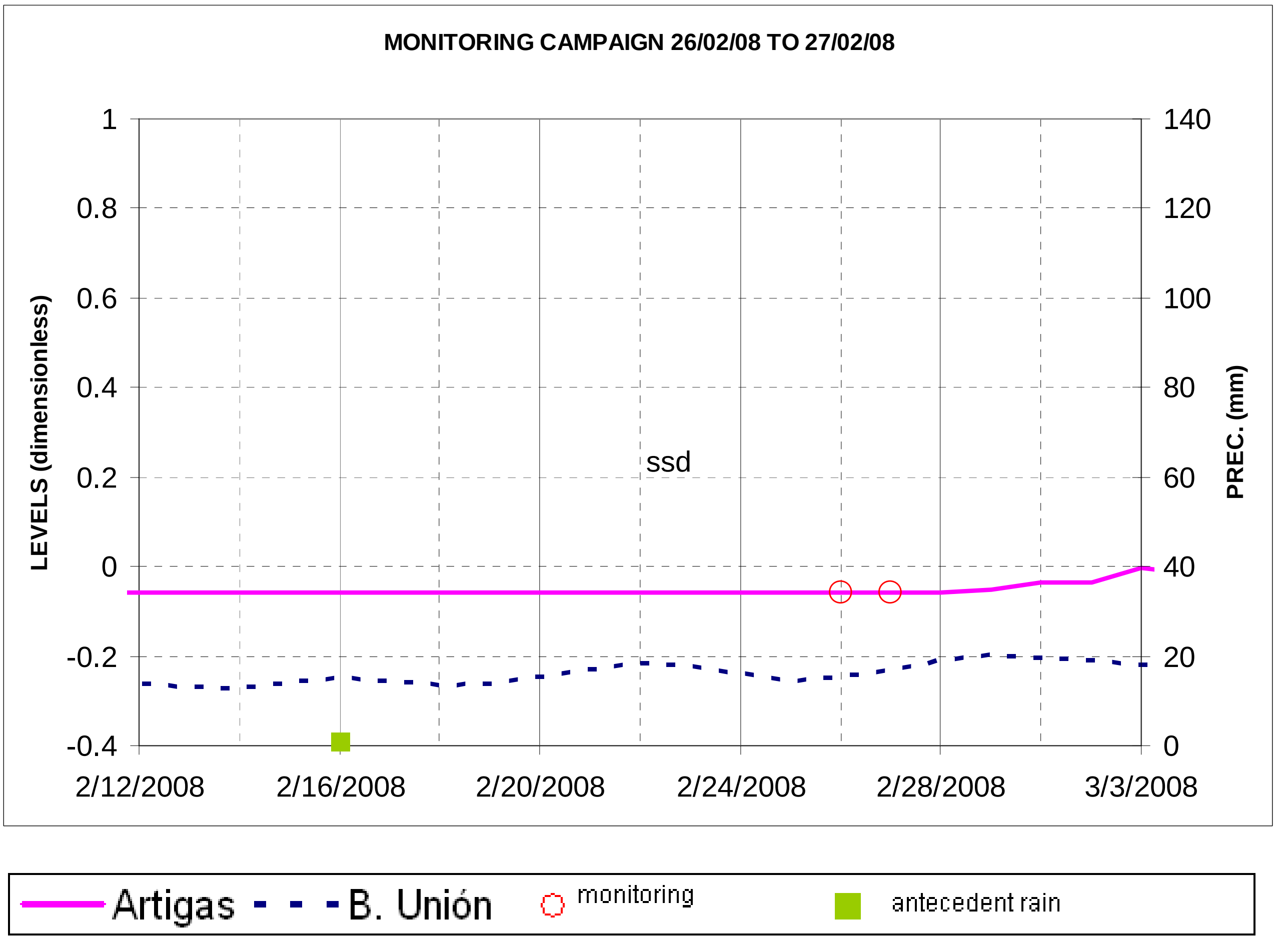

MONITORING CAMPAIGN 26/02/08 TO 27/02/08
LEVELS (dimensionless)
PREC. (mm)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
140
120
100
80
60
40
20
0
ssd
2/12/2008
2/16/2008
2/20/2008
2/24/2008
2/28/2008
3/3/2008
Artigas
B. Unión
monitoring
antecedent rain

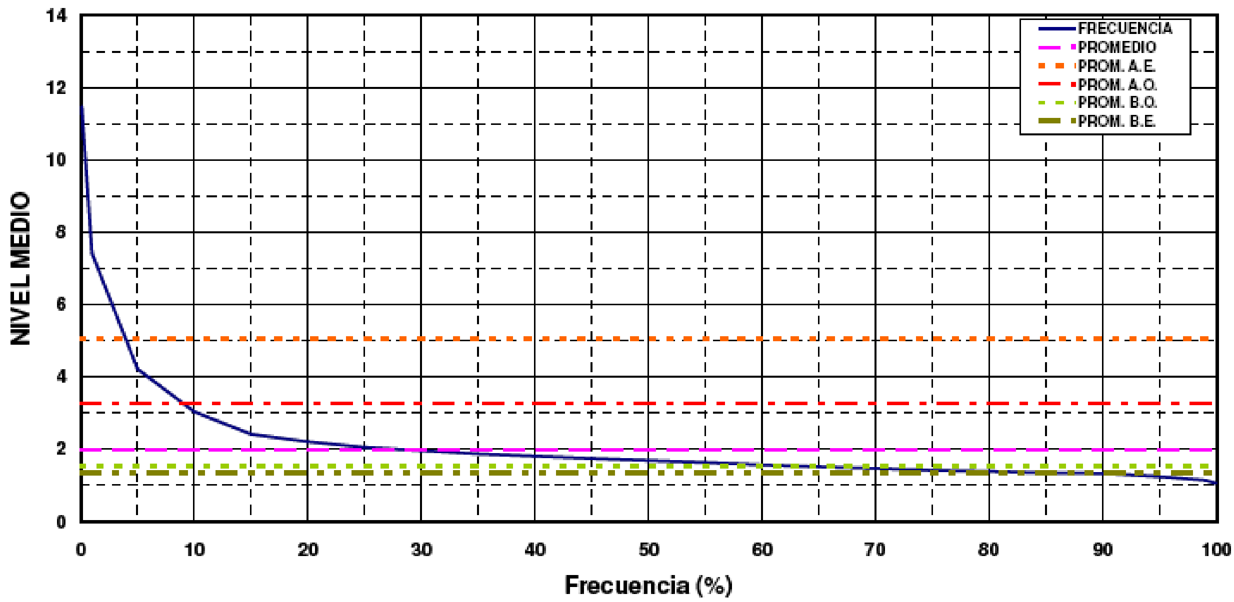
Figure 3.1.2.10 Frequency of daily data for Station 84.1 – Artigas- Puente Concordia

DIVISIÓN RECURSOS HÍDRICOS DEPARTAMENTO DE HIDROLOGÍA

FREQUENCY OF DAILY DATA

AVERAGE LEVEL
PERIOD 2001-2007

Station	: 84.1 Artigas - Puente Concordia	**Scale Zero:**	88.16 Wharton
Water Body	: Río Cuareim	**Area of Basin:**	4501 km2
Basin	: Río Uruguay		



Frequency
Average
Average Extraordinary Highs
Average Ordinary Highs
Average Ordinary Lows
Average Extraordinary Lows

Maximum daily average (m) = 11.81 03/09/2001
Minimum daily average (m) = 1.05 04/02/2003
Average Extraordinary Highs (m) = 5.08 (*)
Average Ordinary Highs (m) = 3.28 (*)
Average Ordinary Lows (m) = 1.55
Average Extraordinary Lows (m) = 1.37

Frequency (%)	Level (m)
0.1	11.48
1	7.42
5	4.23
10	3.04
15	2.42
20	2.21
25	2.06
30	1.97
35	1.88
40	1.81
45	1.75
50	1.69

Frequency (%)	Level (m)
55	1.64
60	1.58
65	1.52
70	1.48
75	1.42
80	1.39
85	1.35
90	1.34
95	1.25
99	1.15
99.9	1.07

Water Code, art. 36
(1) It will be determined the average level of the waters with at least 12 years of observations
(2) It will be determined the average of ordinary high waters, that is the average of all the water levels above the average level
(3) The average of all the water levels above the level determined in (2), will correspond to the average

Figure 3.1.2.11 Frequency of daily data for Station 28.0 – Bella Unión

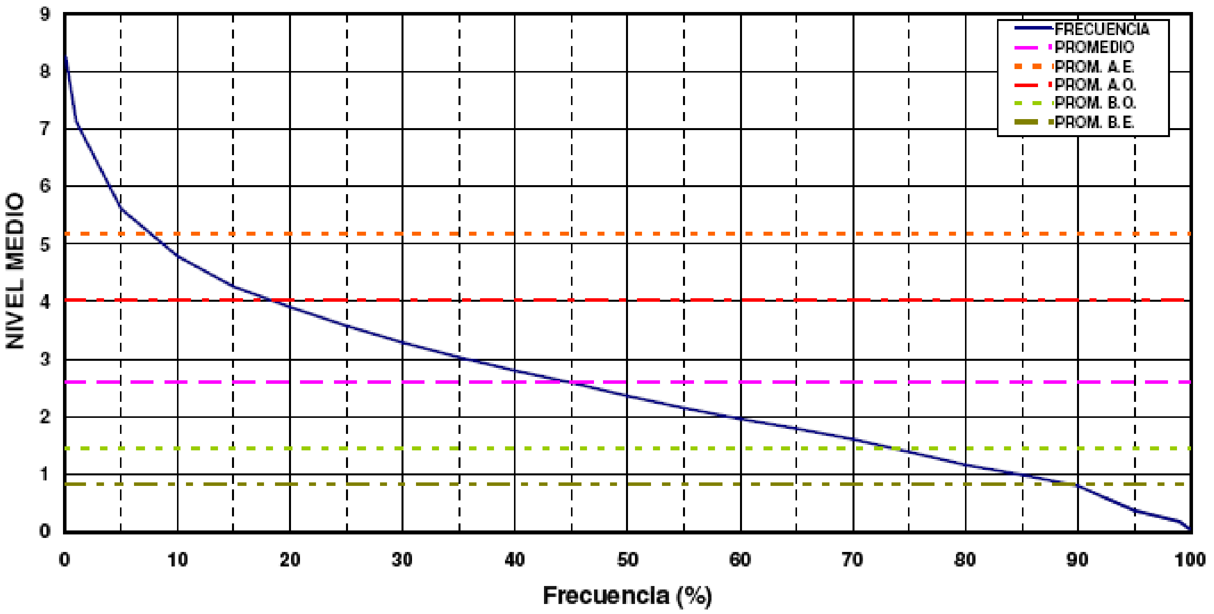
DIVISIÓN RECURSOS HÍDRICOS

DEPARTAMENTO DE HIDROLOGÍA

FREQUENCY OF DAILY DATA

AVERAGE LEVEL
PERIOD 2001-2007

Station	: 28.0 Bella Unión	**Scale Zero:**	33.57 Wharton
Water Body	: Río Uruguay	**Area of Basin:**	220700 km2
Basin	: Río Uruguay		



Frequency
Average
Average Extraordinary Highs
Average Ordinary Highs
Average Ordinary Lows
Average Extraordinary Lows

Average (m) = 2.6

Maximum daily average (m) = 8.35 17/10/2002
Minimum daily average (m) = 0.02 11/03/2005
Average Extraordinary Highs (m) = 5.18 (*)
Average Ordinary Highs (m) = 4.04 (*)
Average Ordinary Lows (m) = 1.45
Average Extraordinary Lows (m) = 0.84

Frequency (%)	Level (m)
0.1	11.48
1	7.42
5	4.23
10	3.04
15	2.42
20	2.21
25	2.06
30	1.97
35	1.88
40	1.81
45	1.75
50	1.69

Frequency (%)	Level (m)
55	1.64
60	1.58
65	1.52
70	1.48
75	1.42
80	1.39
85	1.35
90	1.34
95	1.25
99	1.15
99.9	1.07

Water Code, art. 36
(1) It will be determined the average level of the waters with at least 12 years of observations
(2) It will be determined the average of ordinary high waters, that is the average of all the water levels above the average level
(3) The average of all the water levels above the level determined in (2), will correspond to the average of all the extraordinary highs

3.2 ANNEX - WATER QUANTITY MONITORING

3.2.1 FLOW MEASUREMENT at the irrigation channel FOR RICE SEASON 2006-2007

To measure the flows in the rice season 2006-2007, a Venturi flume was used built according to the standard ISO 1438 "Liquid flow measurement in open channels using thin-plate weirs and Venturi flumes". The equation that relates flow and head is:

$$Q = (2/3)^{3/2} \cdot C_v \cdot C_e \cdot \sqrt{g} \cdot b \cdot h^{3/2}$$

where:

- Q is flow
- Cv is the velocity coefficient, that depends on the approximation velocity to the channel
- Ce is the discharge coefficient that depends on the loss of head due to friction and turbulence
- g is the acceleration due to gravity
- b is the throat width
- h is the head with respect to the base of the throat (measured in the chamber of calm waters, as shown in the picture)

The velocity and discharge coefficients are given by the following equations:

$$\left(\frac{2}{3\sqrt{3}} \cdot \frac{b}{B}\right) \cdot C_v^2 - C_v^{2/3} + 1 = 0 \qquad \text{y} \qquad C_e = \left(\frac{b}{b + 0.004 \cdot I}\right)^{3/2} \cdot \left(\frac{h - .003I}{I}\right)^{3/2}$$

Figure 3.2.1.1 presents a plant view of the Venturi Flume that was constructed and **Figure 3.2.1.2** pictures of it.

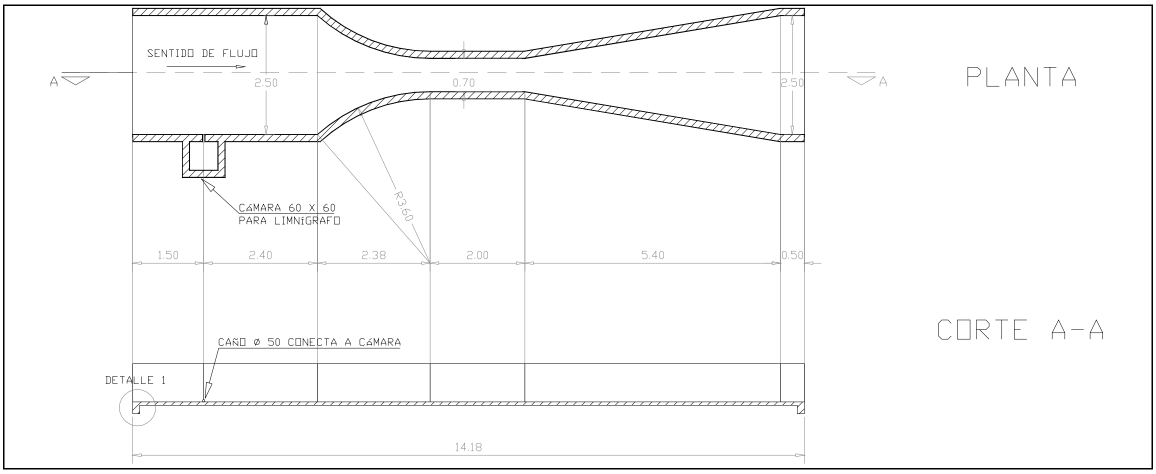


Figure 3.2.1.1 Plant view of the Venturi Flume built

Figure 3.2.1.2 Photos of the Venturi Flume built and of the installed limnigraph

Figure 3.2.1.3 presents the flow-head curve, and also dots that correspond to flow and head measurements done to verify and validate the theoretic relationship described before.

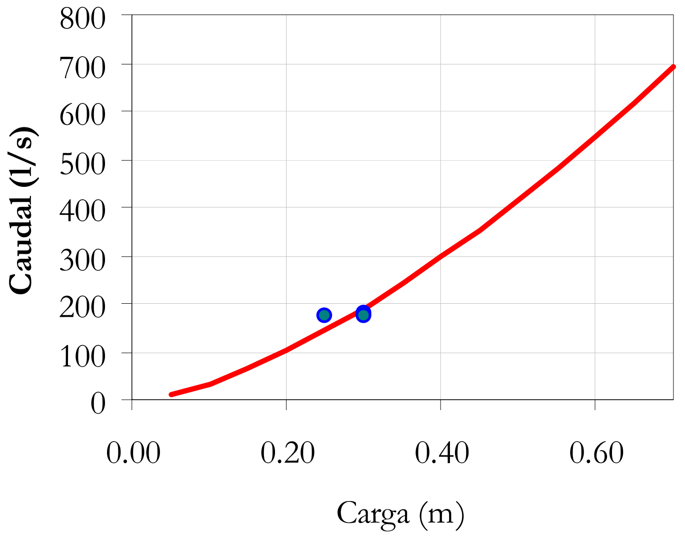


Figure 3.2.1.3 Relationship between head and flow in the channel using the Venturi Flume. Vertical axis: Flow (l/s). Horizontal axis: Head (m).

3.2.2 FLOW MEASUREMENT at the irrigation channel FOR RICE 2007-2008

Direct measurements of flows were taken for the rice season 2007-2008, measuring heights with a limnigraph and transforming them into flows with a rating curve. This one was made with specific measurements and a hydrodynamic model that allowed the validation and the extension of the curve to all the range.

The measurements taken were:

- Flow measurement of the channel with a stage of 0.30, the flow resulting in 262 l/s and an average speed of 0.22 m/s. This flow measurement was done by DNH personnel in coordination with the IMFIA

- Head loss in the piped channel span that crosses the creek. This head loss was 0.82m in a horizontal pipe, built with tin, 245 m long and with a diameter of 600mm

Sections of the channel were also measured (**Figure 3.2.2.1**), what made possible the implementation of a hydrodynamic model in the proximity of the section where the stages were measured.

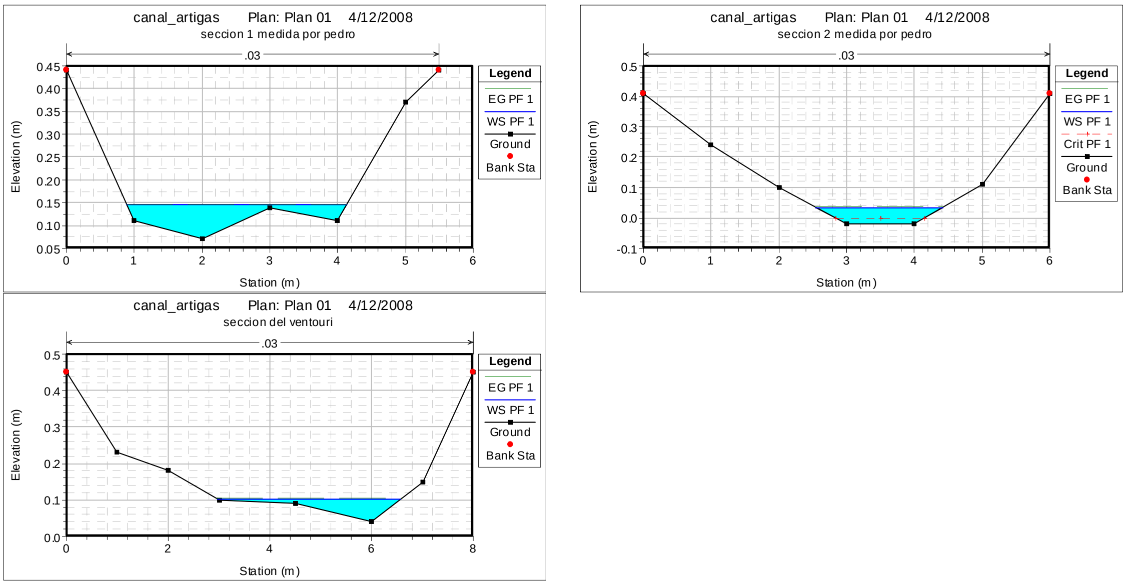


Figure 3.2.2.1 Sections used in the hydrodynamic model

From a range of manning values recommended in the literature for the channel, the flow-stage curves were determined and are presented in **Figure 3.2.2.2**. It was decided to choose the value of 0.03, with which was determined the flow-stage curve presented in **Figure 3.2.2.3**.

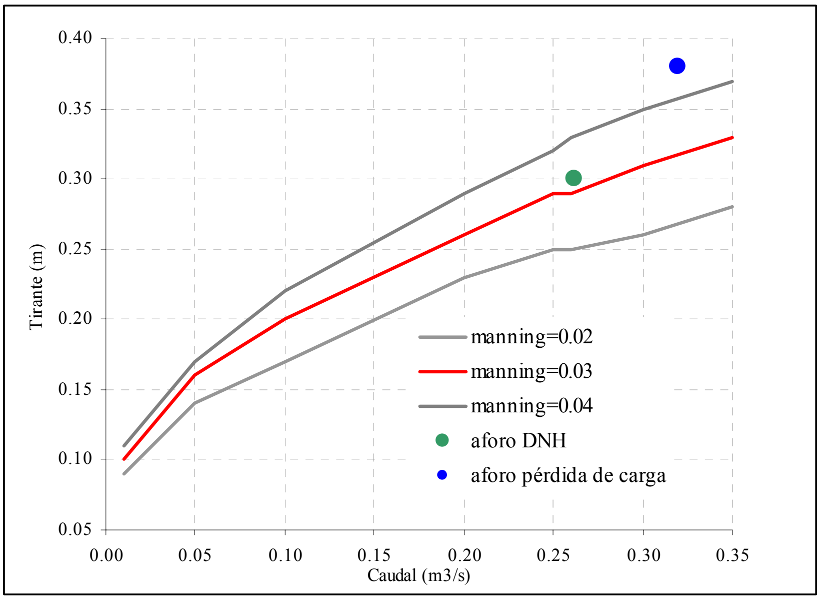


Figure 3.2.2.2 Flow-stage curve for the irrigation channel, rice season 2007-2008. Vertical axes: stage (m), Horizontal axes, flow (m3/s). Green dot is the flow measured by DNH. Blue dot is flow loss of head

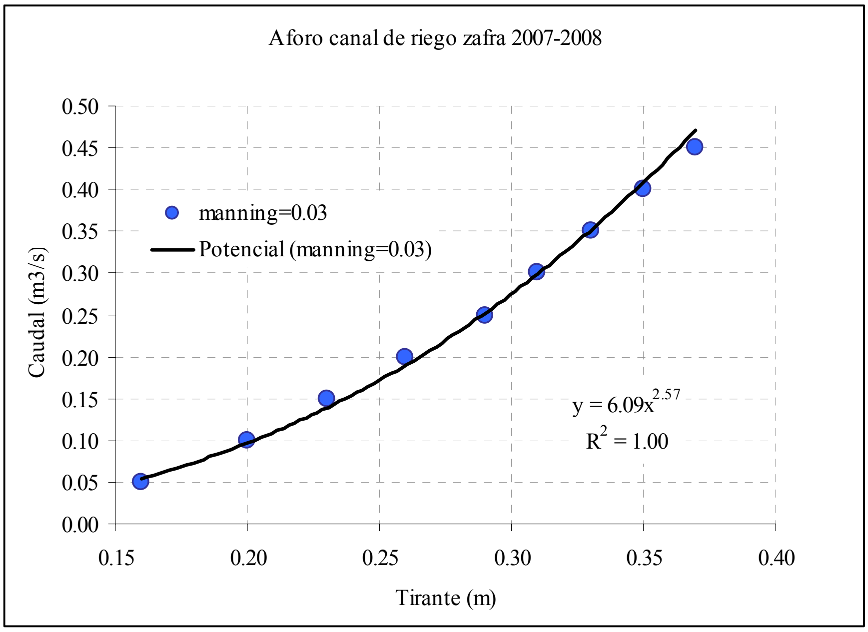


Figure 3.2.2.3 Flow-stage curve of the irrigation channel for rice season 2007-2008. Vertical axes: flow (m3/s), Horizontal axes, Stage (m).

The resulting equation to determine the flows as a function of the stage is:

$$Q(m^3/s) = 6.09 \cdot h(m)^{2.57}$$

3.2.3 FLOW MEASUREMENT at structure at point e (outlet)

A U-form concrete structure was built, with lateral small embankments to make all the water to run through the U. With that structure (**Figure 3.2.3.1**) the flow measurements presented in **Table 3.2.3.1** were taken.

Figure 3.2.3.1 Flow measuring campaign

Table 3.2.3.1 Flow measurements done at the U structure at the outlet of the basin

Dates of Flow Measurement	Stage (m)	Flow (m3/s)
31/03/07	0.02	0.014
24/03/07	0.16	0.083
31/03/07	0.22	0.137
26/02/07	0.24	0.130
17/03/07	0.24	0.157

Based on these flow measurements was fit the curve presented in **Figure 3.2.3.2**.

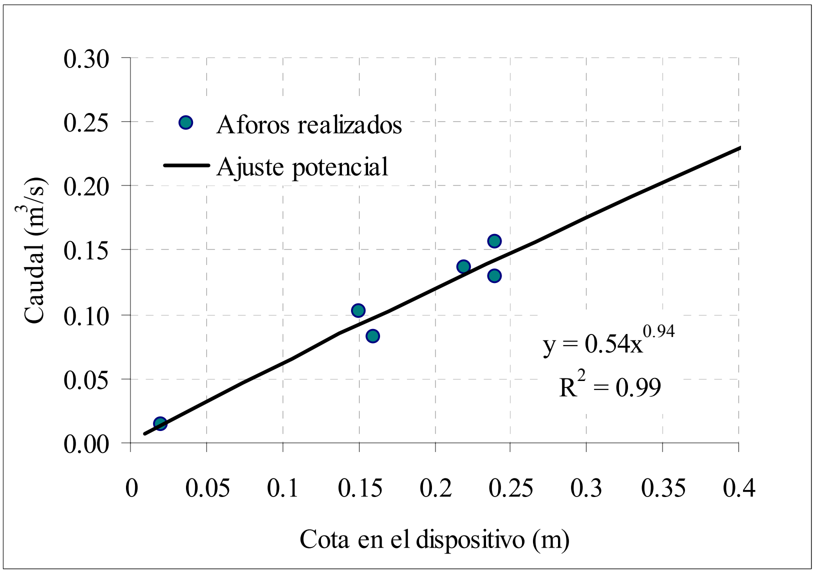


Figure 3.2.3.2 Fit flow-stage curve at the outlet of the basin (Point E). Vertical axes: Flow (m3/s), Horizontal axes: Stage in structure (m). Blue dots are measurements taken.

3.2.4 Calibrated precipitation-flow model

Using the software HEC-HMS, it was implemented a precipitation-runoff model for the basin, that as stated before did not include the portion of the basin controlled by the reservoir. It was used the algorithm of continuous simulation (SMA) included in HEC-HMS and for propagation the SCS unit hydrogram. The parameters used are presented in **Figure 3.2.4.1**.

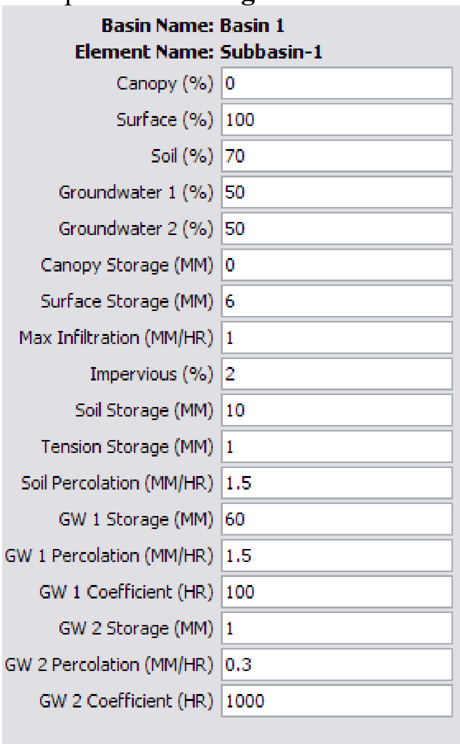


Figure 3.2.4.1 Parameters of the implemented hydrologic model

The observed and calculated flows by the model are presented in **Figure 3.2.4.2.**

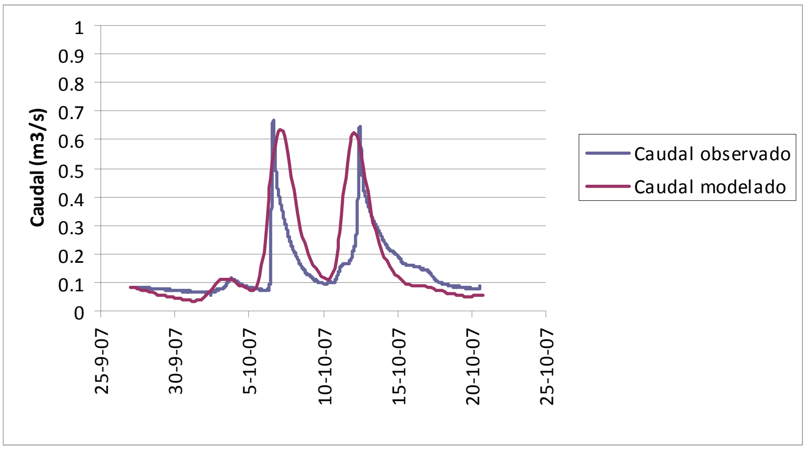
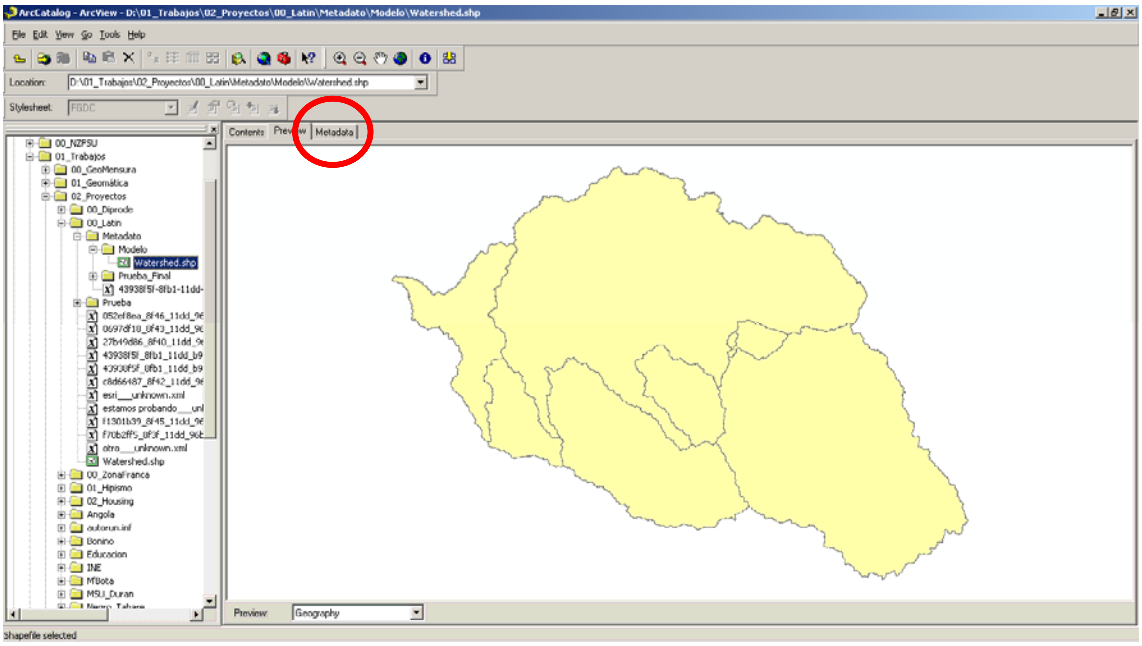


Figure 3.2.4.2 Calculated and observed flows. Vertical axes: Flow (m3/s). Blue graph: observed flow. Red graph: Modeled flow.

3.3 ANNEX - METADATA

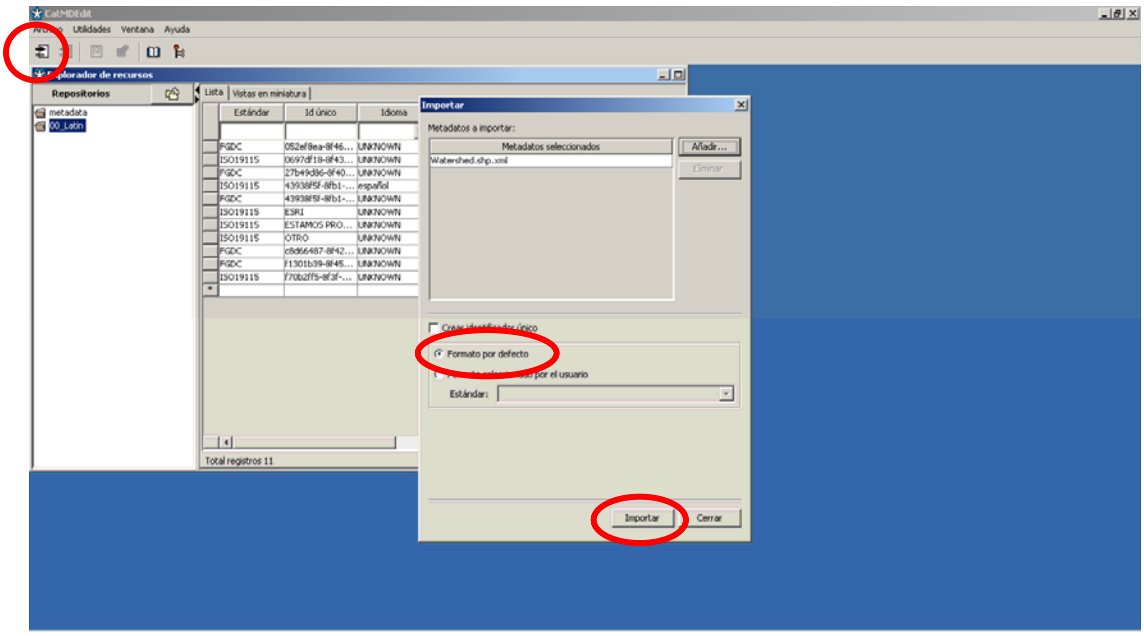
3.3.1 Step-by-step methodology for the creation of Metadata

STEP 1.

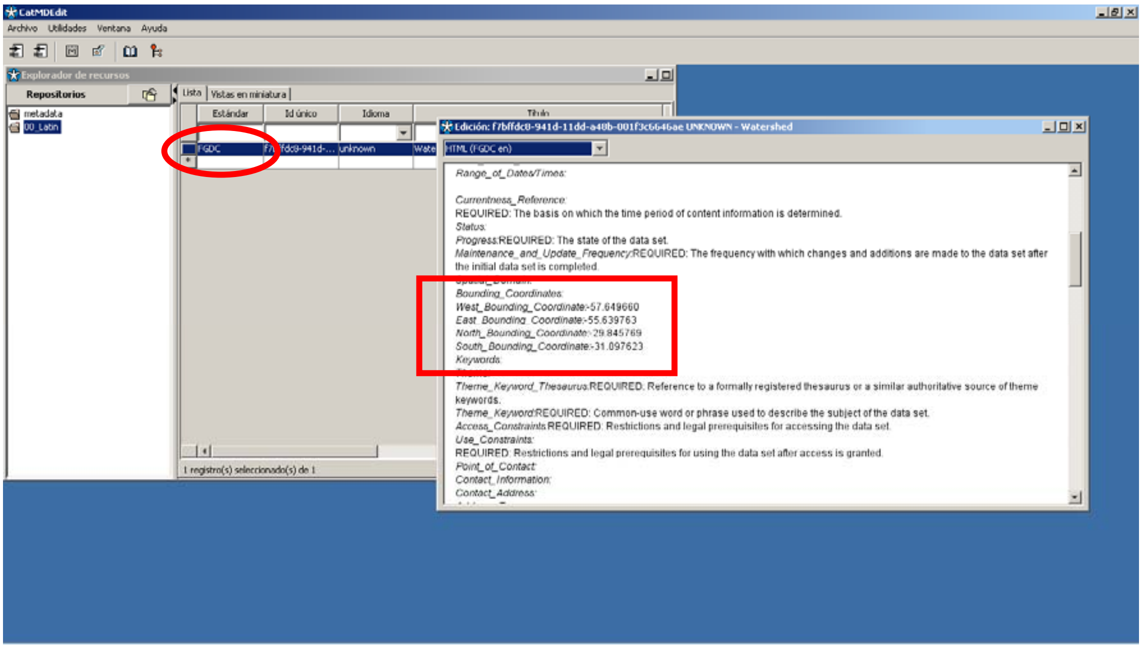


In **Arc Catalog - ArcGIS** environment:
Load the level of information of interest (set of data) or open the geodatabase to generate the first set of metadata.
Using the Export Metadata button in the Metadata toolbar, **export the file to xml** (for example xxx.shp to xxx..shp.xml).

STEP 2.

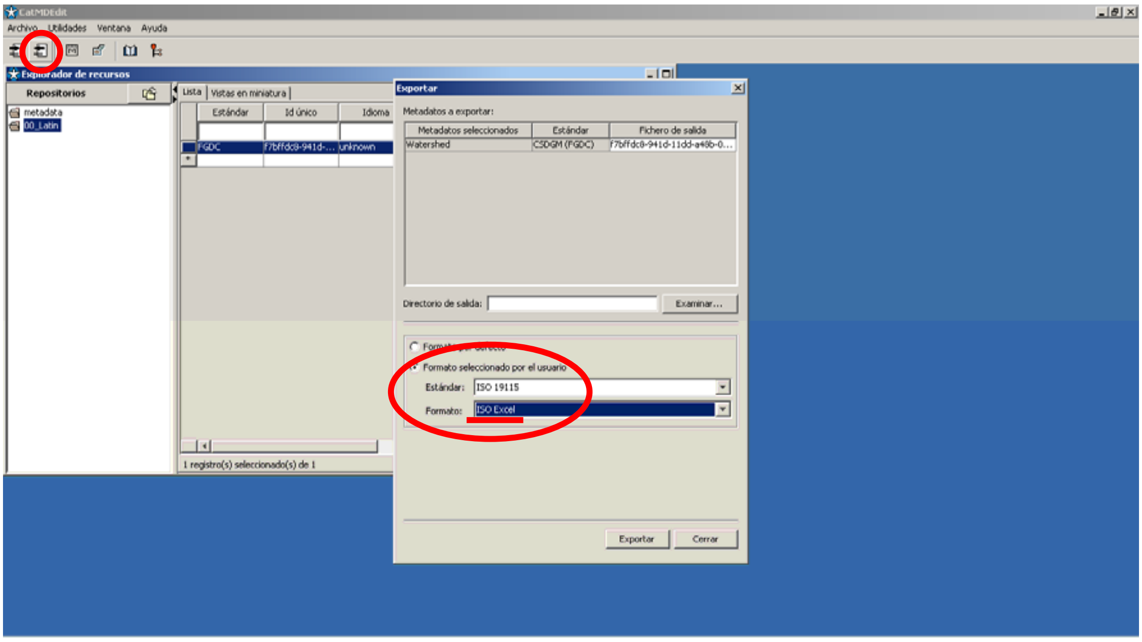


In **CatMDEdit** environment:
Import the xml file generated before.
As the information was extracted from the ESRI environment, it will recognize **automatically that the model used for the metadata is FGDC.** In that metadata it will already be available and loaded the geometry and geographic information.



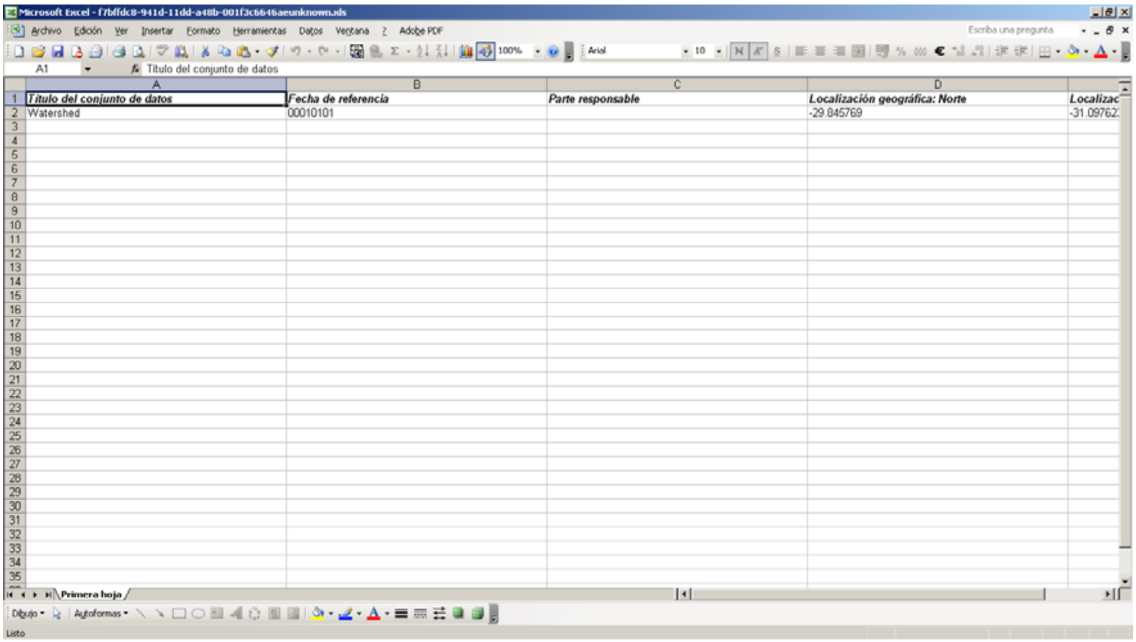
Visualize the first version obtained of the metadata that is being created.
It can be checked that the geometry information has been loaded.

STEP 3.



Transformation to **ISO 19115 format**
Continuing in the CatMDEdit environment, export that format into an excel file using the export tool. We need to specify the path where the files will be saved, obtaining a XXX.xls file.

STEP 4.



Completing the **ISO 19115 NEM** standard.

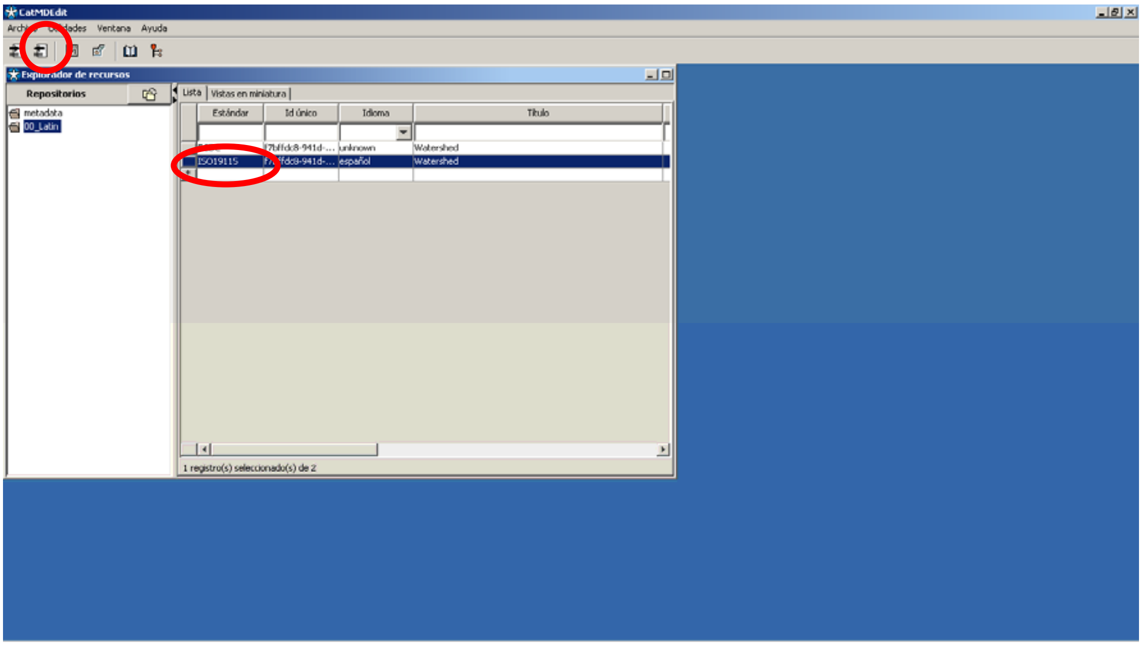
We continue working on the Excel environment, filling out all the columns of the sheet. Each cell will be completed based on the answers collected previously, using a questionnaire that has to be answered by the people responsible for the generation and/or administration of the different datasets.

The fields in the table are:
A – Title of the data set (completed) **Text chain** *For ex.. Basins*
B – Date (completed) **Date (yyyymmdd)** *20081112*
C –Accountable party of the data set **Chain text** *For ex. TwinLatin Project*
D – Geographic location: North latitude limit (completed) **Real (decimals with point)** *-35.5*
E – Geographic location: South latitude limit (completed) **Real (decimals with point)** *-36.5*
F – Geographic location: East longitude limit (completed) **Real (decimals with point)** *-55.5*
G – Geographic location: West longitude limit (completed) **Real (decimals with point)** *-56.5*
H – Language of the data set **Text chain** *Language (it can be loaded in the standard way "es", "en", etc. Or it can be corrected later on in CatMDEdit)*
I – Set of characters of the data set **Text chain** *Specify the type (for ex. utf-8)*
J – Category of the subject **Text chain** *Hydrography*
K – Spatial Resolution **Text chain** *It is related to precision (the numeric value has to be expressed, for ex. 50)*
L – Descriptive summary **Chain text** *Description of the process to obtain the datum, as exhaustive or simplified as wanted. Comment*
M – Distribution format **Text chain** *Which is the distribution mechanism, SHP, ASCII, DWG, RASTER (img, tif, jpg)*
N – Extension's Additional Information: **Minimum value Real** *(decimals with point)* Which is the absolute minimum to be represented, for ex. Minimum altimetric level
O – Extension's Additional Information: **Maximum value Real** *(decimals with point)* Which is the absolute maximum to be represented, for ex. Maximum altimetric level
P – Extension's Additional Information: unit of measure **Text chain** *Name of the work unit*
Q – Extension's Additional Information: Initial date **Date (aaaammddd)** *20080101*
R – Extension's Additional Information: End date **Date (aaaammdd)** *20091231*
S – Type of spatial representation (completed) **Text chain** *Vector, Grid, Raster*

T –Reference System **Text chain** *Specifications of the Reference Framework and Projection System. In CatMDEdit edition, it can be coded.*
U – Lineage: Step in the process date **Date (aaaammdd)** *Date in which the data were produced to use for the generation of new data*
V – Lineage: Step in the process processor **Text chain** *Data of the person responsible for the generation of data, organism, person, etc.*
W – Lineage: Step in the process description **Text chain** *Historical description on how data were obtained and how they were used afterwards*
X – Resource on line **Text chain** *URL where the data or information can be obtained, for ex. http://www.proyecto.org*
Y – Identifier of the metadata file (completed) **Text chain** *name identifying the file*
Z – Name of the metadata standard (completed) **Text chain** *ISO 19115 Geographic Information-Metadata o FGDC Content Standards for Digital Geospatial Metadata*
AA – Metadata standard version (completed) **Text chain** *2008*
AB – Language of the metadata (completed) **Text chain** *Language (it can be loaded in standard format “es”, “en”, etc. Or be corrected afterwards in CatMDEdit)*
AC – Set of characters of the metadata **Text chain** *Specify the type (for ex. utf-8)*
AD – Contact for metadata **Text chain** *Accountable party for the generation, organism*
AE – Date of creation of the metadata (completed) **Date (aaaammdd)** *20081112*
AF – Credits **Text chain** *Who generated the metadata*
AG – Information of aggregation: Type of association **Text chain** *With what or which set of data it relates to, for ex. The Project or principal work environment*
AH – Information of aggregation: Identifier of the aggregated set of data **Text chain** *Which is the code to identify the set of data, for ex. CH1.0*
AI –Information of aggregation: Title of the set of the aggregated data **Text chain** *With what name the set of data is known. Hydrographic basins 1:50.000*
AJ – Purpose **Text chain** *Why were that data generated*
AK – Constrictions of access **Text chain** *Requirements for access to them*
AL – Constrictions of use **Text chain** *Requirements for the use of data*
AM – Constrictions of other type **Text chain** *Any additional requirement (for ex. To be required to cite the source of the data in any publication where they are used)*

When it says “completed” it is because after the export process, those cells are already filled out automatically, so it is not necessary to load them and they can be left the way they are or may be edited to improve the information.

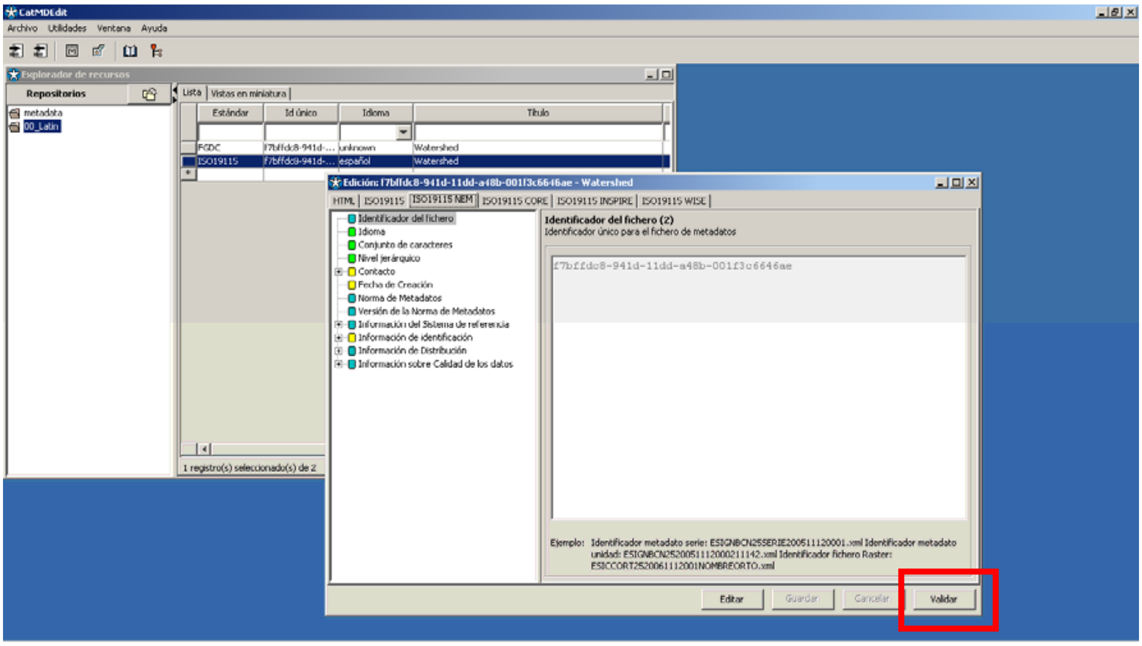
STEP 5.



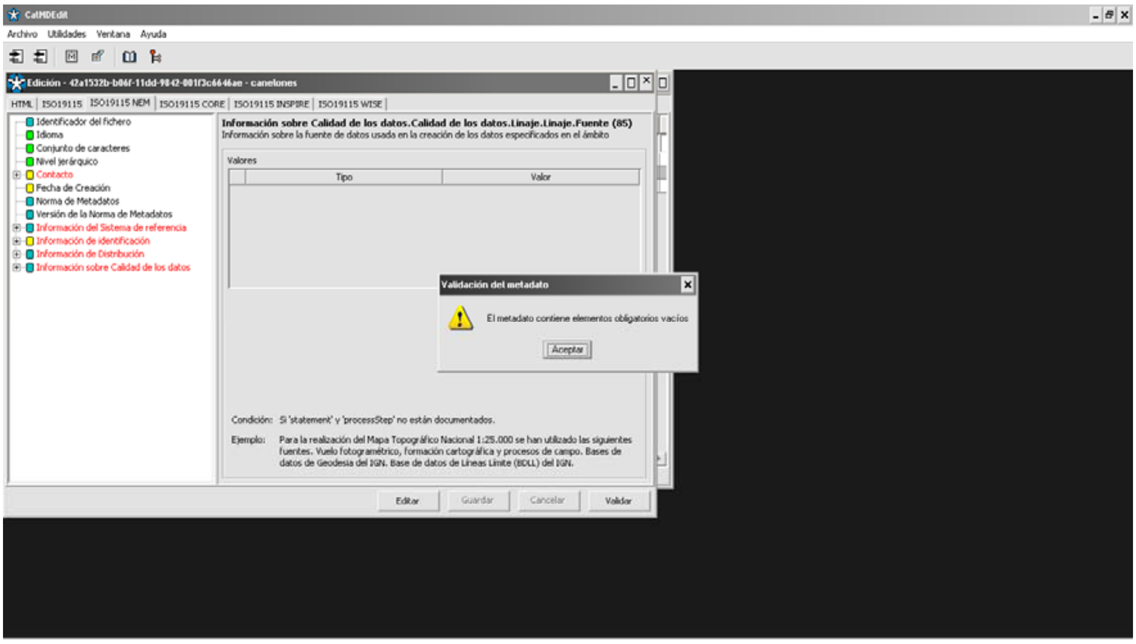
Now, we go back to the CatMDEdit environment.

Once the excel sheet is completely filled out, we save the file and we import it into the CatMedit environment. To do that, in the import task, I need to choose that I will import an excel sheet.

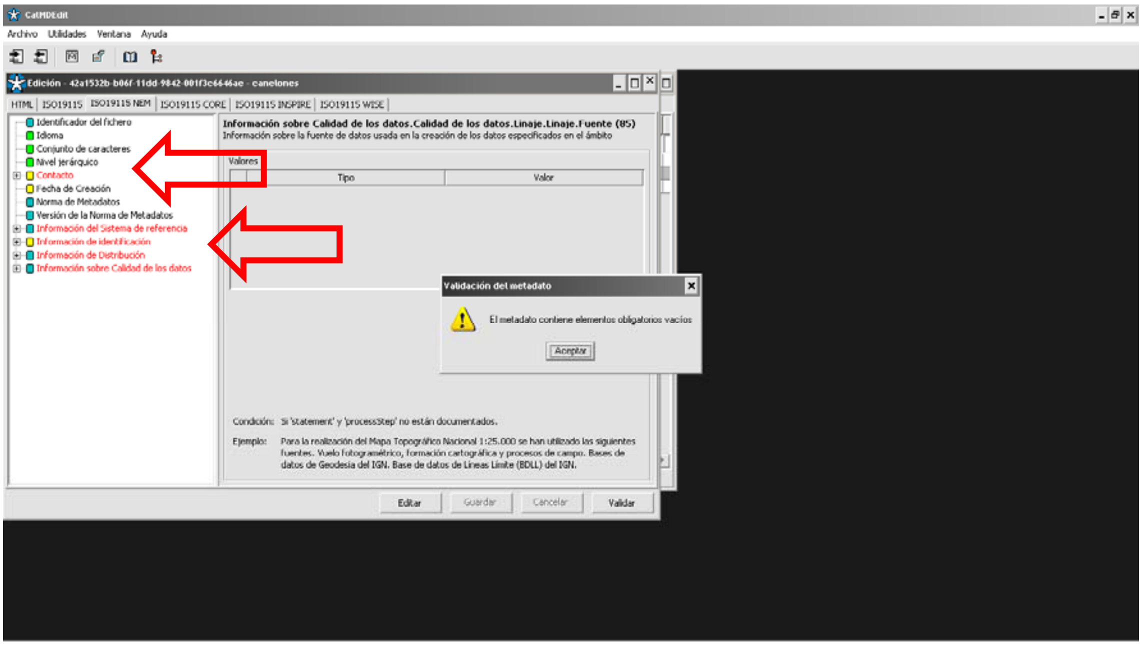
STEP 6.

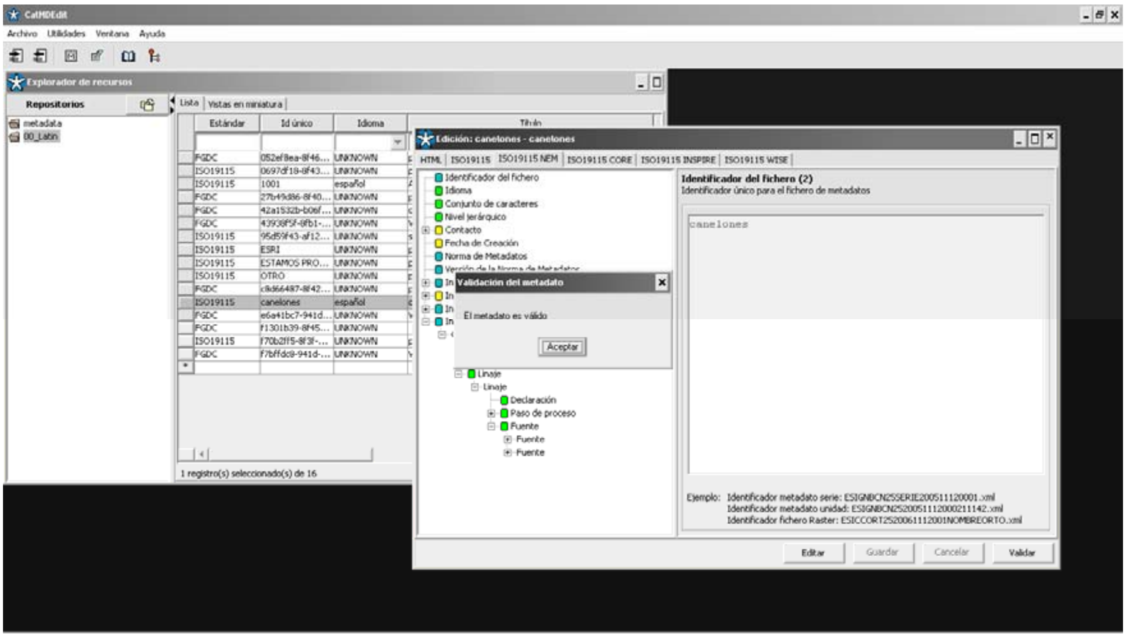


Now, opening this metadata. The first thing to do is to run “Validate”.



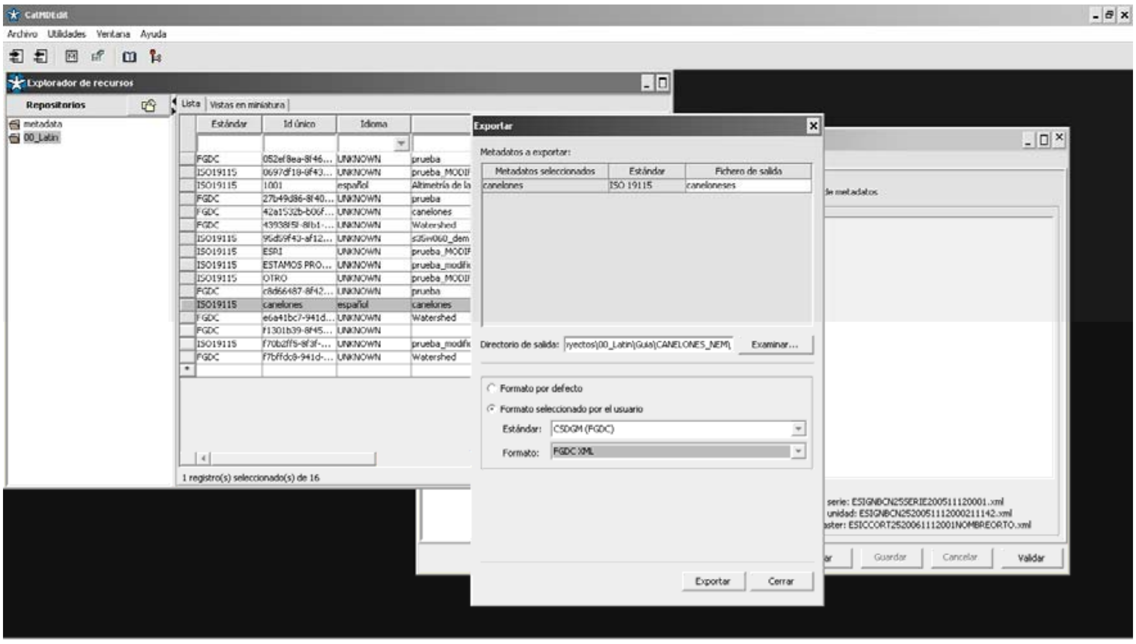
In red all the items that have not yet been completed and that are required to comply with the standard will be highlighted. I will do an edition task until all the requirements for ISO 19115 NEM are completed. Although we could just stay with the information input until now, we need to respect the requirements of the standards, if we are to generate homogeneous and standardized metadata.
The edition will be done this time in the CatMDEdit environment.





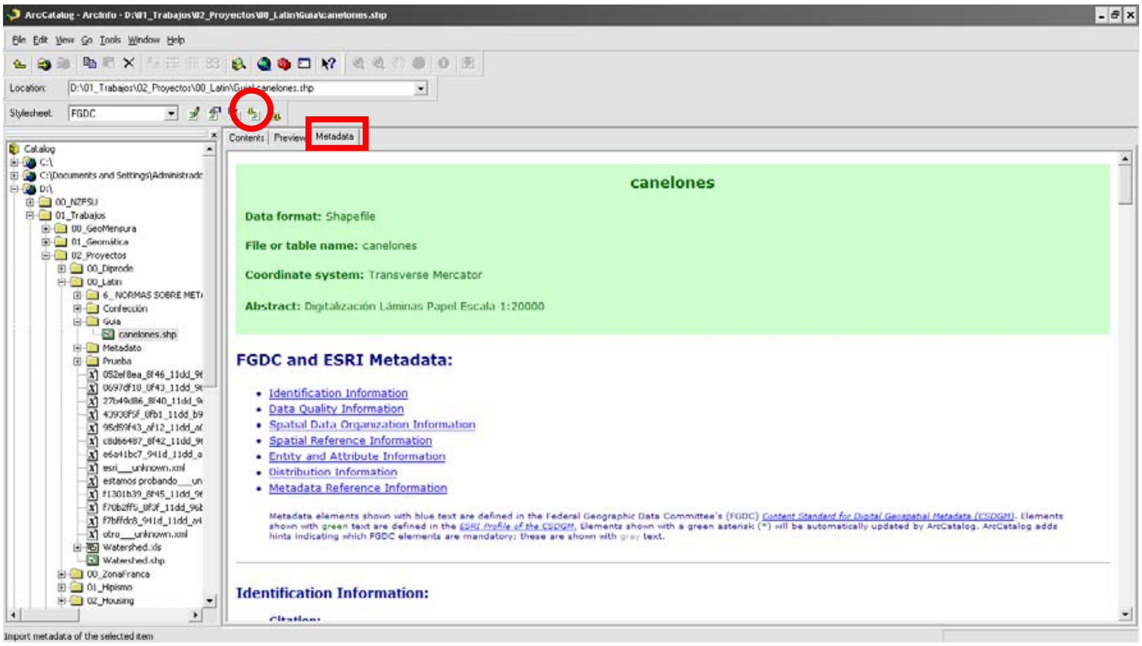
Validation ISO 19115 NEM Profile
After having completed the requirements that appeared incomplete, when choosing again Validation, we will receive the message "The metada is valid".

STEP 7.



Exporting into FGDC format for ESRI GIS environment
Using the export tool and after choosing the path where we want to save the file, we will get it according to the FGDC standard, under the XML format.

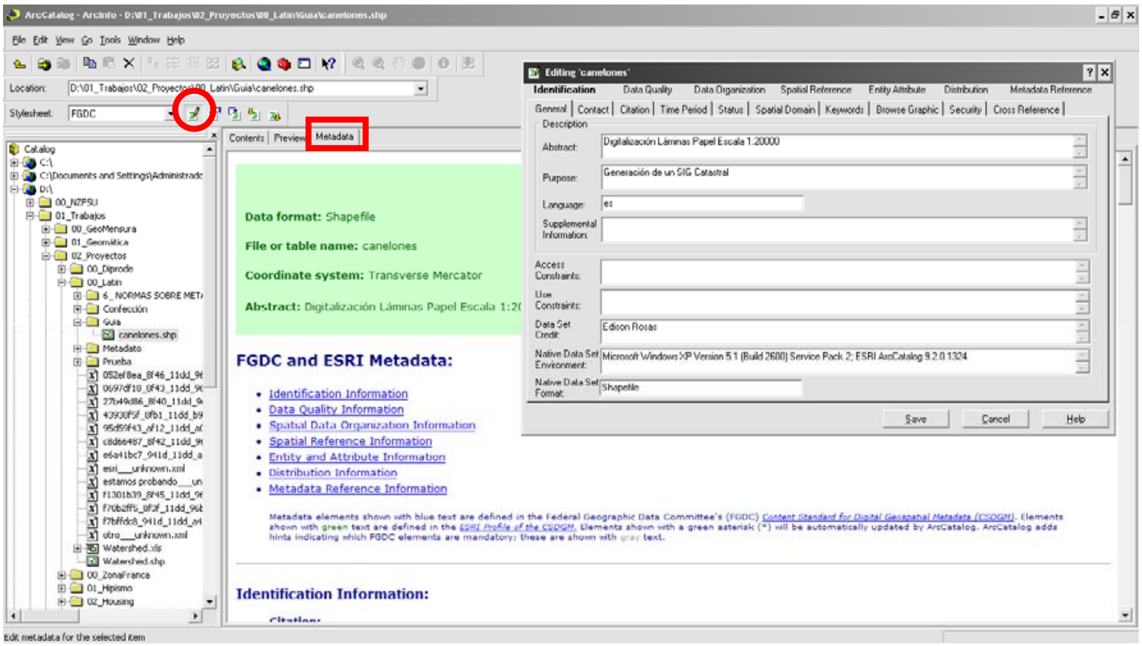
STEP 8.



Again, in **Arc Catalog – ArcGIS environment**:
Having selected the level of information we are interested in (set of data), or by default, within the Gedodatabase, choosing the corresponding feature, we import the last file.

In the GeoDataBase, the metadata has been updated. Initially it only had the geometric information. Now it complies with NEM ISO 19115 and also with FGDC standard associated to the GDB.

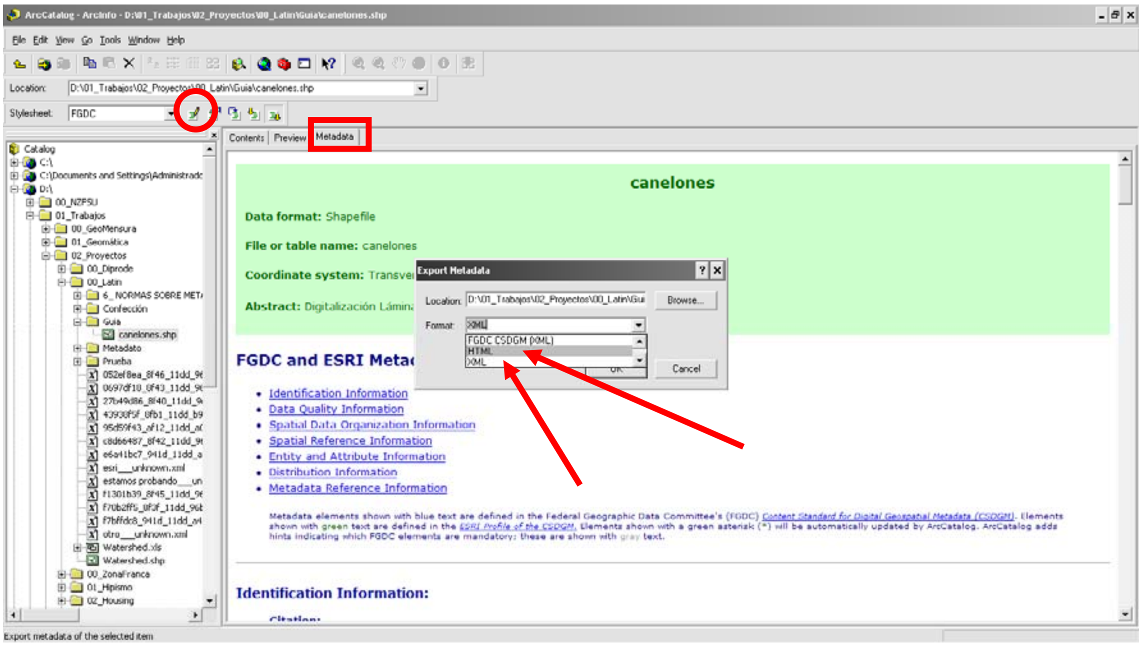
STEP 9.

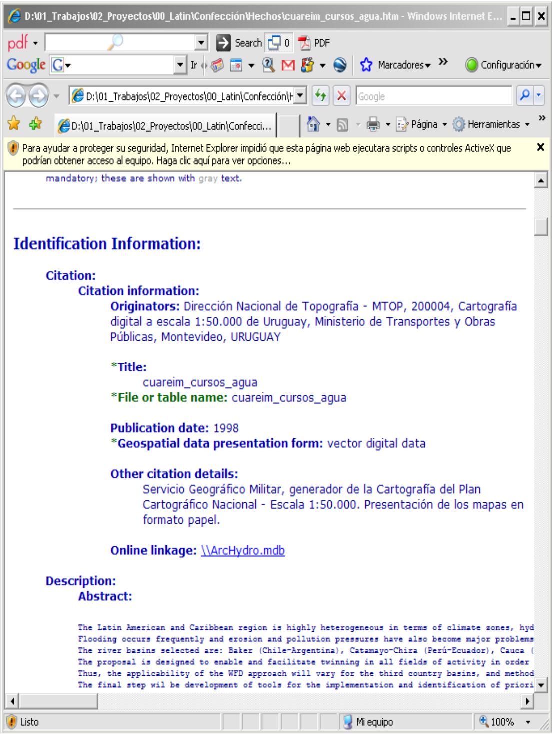


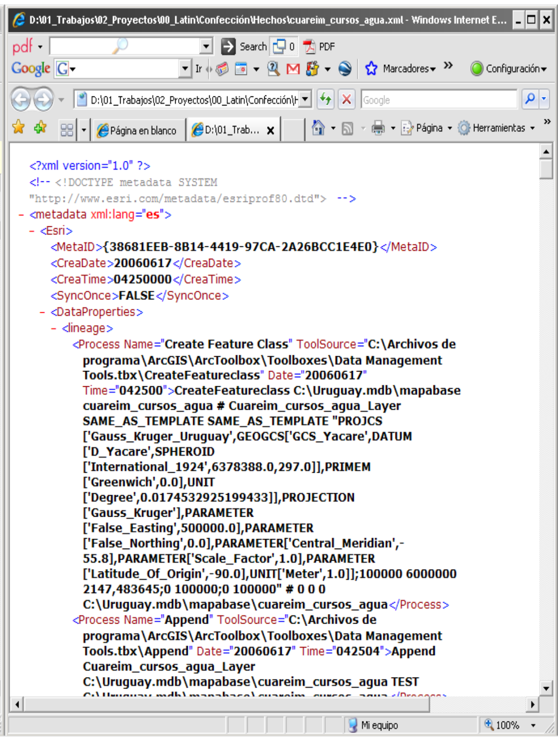
Edition in **Arc Catalog - ArcGIS** environment and completeness of the **FGDC standard.**
If it is of interest and there is additional information, we can within ArcCatalog, continue editing the metadata with the Edition tool. We could add information on: Identification, quality, accountable organization, Spatial reference, Attribute entities, Distribution, and references of the metadata.

STEP 10.

Files to publish on the **Web.**
Finally, in ArcCatalog-ArcGIS environment, using the export tool, we can generate the metadata in HTML or in the standardized exchange version, XML.







HTML file **XML file**

3.3.2 EXAMPLE OF THE INFORMATION NECESSARY TO BE GATHERED TO GENERATE A VALID METADATA

The minimum information to be gathered for the creation of a valid metadata is presented below. It can be used as a pattern to question those people that have generated or administrated a set of data.

C1. DATE – Creation of the data, publication of them
C2. ACCOUNTABLE PARTY – Data of the Project, data of the institution that provided the data
C3. LANGUAGE General Data– Language in which data are presented
C4. SET – Type of elements that describe the data
C5. THEMATIQUE CATEGORY– To what level of information corresponds the set of data. If there is a classification, add it.
C6. RESOLUTION – Description of the precision of the data (it may be relative)
C7. PROCESSING – Brief description of the process or processes needed to get the final product
C8. FORMAT – Description of the format typologies in which the data can be obtained. Identify their version.
C9. EXTENTION – Minimum and maximum unit to be able to use in the data set (degree of desaggregation). Units to measure those data.
C10. CREATION – Beginning and final date of the data, with the processing finished
C11. REFERENCE SYSTEM – Used projected system and datum.
C12. HISTORY – Brief description of the state of the set and its historical process to date
C13. GENERATOR – Organisms involved in the creation, maintenance and updating of the data
C14. METADATA LANGUAGE– Language of the metadata
C15. METADATA ACCOUNTABLE PARTY – Data of who is responsible for the edition and publishing of the metadata
C16. CREDITS – Compulsory citation of agents involved in the management of the data and metadata
C17. AGREGATION – Relationship between this set of data with others that have been of use for their generation and/or modification and identification (identification code, collection names, version for the case of data with updates)
C18. OBJECTIVE – Why the set of data was generated
C19. ACCESS – Description of possibilities and limitations to access and availability
C20. USE – Description of limitations for their use
C21. OTHER – Other comments necessary to clarify the management of the data responsibilities, certainty, etc.
C22. HIERARCHY – Typology of the dataset. In our case, it is applicable: set of data, attributes or tables, set of non-geographic data, series
C23. CONTACT – All the information necessary to get from the institutions and people that make decisions about the data contained in each set
C24. IDENTIFICATION – Dates corresponding to the creation, publication, updating, if that is established. If not, it will be unknown

EXAMPLE:

C1. DATE – Creation of the data **01/01/2000**, publication of them **01/01/2020**
C2. ACCOUNTABLE PARTY – Data of the Project **URUGUAY Project**, data of the institution that provided the data **DNU, Street 2000, Telephone 900.00.00, mail puydnu@dnu.gub.uy.**
C3. LANGUAGE General Data– Language in which data are presented **Spanish**
C4. SET – Type of elements that describe the data **Vector PL**
C5. THEMATIQUE CATEGORY– At what level of information corresponds the set of data **General Limit**. If there is classification, add it **Political Division**
C6. RESOLUTION – Description of the precision of the data (it may be relative) **1m**
C7. PROCESSING – Brief description of the process or processes needed to get the final product **Digitalization**

C8. FORMAT – Description of the format typologies in which the data can be obtained. Identify their version **DWG, SHP**
C9. EXTENSION – Minimum and maximum unit to be able to use in the data set (degree of desaggregation). Units to measure those data **0,1 meter**
C10. CREATION – Beginning date of the data and final, with the processing finished **01/01/2010 – 01/01/2015**
C11. REFERENCE SYSTEM – Used projected system and datum. **GK**
C12. HISTORY – Brief description of the state of the set and its historical process to date **Paper Maps, GPS, Digitalization and Georeferencing**
C13. GENERATOR – Organisms involved in the creation, maintenance and updating of the data **DNU, IG, URUGUAY Project**
C14. METADATA LANGUAGE – Language of the metadata **Spanish**
C15. ACCOUNTABLE PARTY MetaData – Data of who is responsible for the edition and publishing of the metadata **José Pérez, URUGUAY Project, Farolito 1000, 900.00.01, puyjperez@dnu.gub.uy**
C16. CREDITS – Compulsory citation of agents involved in the management of the data and metadata. **IG, Rinconada 1500, 900.00.02 – Used paper maps**
C17. AGREGATION – Relationship between this set of data with others that have been of use for their generation and/or modification and identification (identification code, collection names, version for the case of data with updates) **Uruguay Maps Paper, UY001.3.5**
C18. OBJECTIVE – Why the set of data was generated **Study Project, Creation of Uruguay**
C19. ACCESS – Description of possibilities and limitations to access and availability **Total availability, accessibility with written authorization of the project**
C20. USE – Description of limitations for their use **Compulsory to cite the source of the original data**
C21. OTHER – Other comments necessary to clarify the management of the data responsibilities, certainty, etc. **Data source, originated at IG and DNU**
C22. HIERARCHY – Typology of the dataset. In our case, it is applicable: set of data, attributes or tables, set of non-geographic data, series **Data Set**
C23. CONTACT – All the information necessary to get to the institutions and people that make decisions about the data contained in each set **URUGUAY Project – Pepitito, Rua 1400, 900.00.02, puypepitito@dnu.gub.uy**
DNU – Sigfredo, Pantaleón 1300, 900.00.03 dnupanta@dnu.gub.uy
IG – Calandria, Nido 1200, 900.00.04 igcalan@ig.gub.uy
C24. IDENTIFICATION – Dates corresponding to the creation, publication, updating, if that is established. If not, it will be unknown **Unknown**

How to transfer the information from the questionnaire to the excel sheet generated in CatMDEdit is presented below.

The content of each cell would be as follows:

A – Title of the set of data **Text chain** Uruguay
B – Date of reference **Date (yyyymmdd)** 20100101
C – Accountable party of the data set **Text chain** URUGUAY Project
D – Geographic location: North latitude limit (completed) **Real (decimals with point)** -30066031
E – Geographic location: South latitude limit (completed) **Real (decimals with point)** -34.976909
F – Geographic location: East longitude limit (completed) **Real (decimals with point)** -52.789895
G – Geographic location: West longitude limit (completed) **Real (decimals with point)** -58.158733
H – Language of data set **Text chain** es
I – Set of characters of the data set **Text chain** utf-8
J – Category of the subject **Text chain** Borders-Political Division
K – Spatial Resolution **Text chain** 1
L – Descriptive summary **Text chain** Paper Maps, GPS survey, digitalization and georeference
M – Distribution format **Text chain** DWG, SHP

N – Extension's Additional Information: Minimum value **Real** 0.1
O – Extension's Additional Information: Maximum value **Real** 2551961.7
P – Extension's Additional Information: unit of measure **Text chain** Meter
Q – Extension's Additional Information: Initial date **Date (aaaammddd)** 20100101
R – Extension's Additional Information: End date **Date (aaaammdd)** 20150101
S – Type of spatial representation (completed) **Text chain** Vector, PL
T –Reference System **Text chain** Gauss Krugger, Datum Yacaré I, Central Meridian -55,8, False Easting 500.000, False Northing 0, Scale factor1
U – Lineage: Step in the process date **Date (aaaammdd)** 20000101
V – Lineage: Step in the process processor **Text chain** URUGUAY Project – Pepitito, Rua 1400, 900.00.02, puypepitito@dnu.gub.uy, DNU – Sigfredo, Pantaleón 1300, 900.00.03 dnupanta@dnu.gub.uy, IG – Calandria, Nido 1200, 900.00.04 igcalan@ig.gub.uy
W – Lineage: Step in the process description **Text chain** Paper format and digitalization
X – Resource on line **Text chain** Not applicable
Y – Identifier of the metadata file (completed) **Text chain** Uruguay_metadata
Z – Name of the metadata standard (completed) **Text chain** ISO 19115 Geographic Information-Metadata
AA – Metadata standard version (completed) **Text chain** http://metadata.dgiwg.org/ISO19115/ISO19115_v0_7.htm
AB – Language of the metadata (completed) **Text chain** es
AC – Set of characters of the metadata **Text chain** utf-8
AD – Contact for metadata **Text chain** José Pérez, URUGUAY Project, Farolito 1000, 900.00.01, puyjperez@dnu.gub.uy
AE – Date of creation of the metadata (completed) **Date (aaaammdd)** 20081228
AF – Credits **Text chain** URUGUAY Project
AG – Information of aggregation: Type of association **Text chain** Uruguay Cartography Paper
AH – Information of aggregation: Identifier of the aggregated set of data **Text chain** UY001.3.5
AI –Information of aggregation: Title of the set of aggregated data **Text chain** Borders of Uruguay
AJ – Purpose **Text chain** Study project Creation of Uruguay
AK – Constrictions of access **Text chain** Total availability
AL – Constrictions of use **Text chain** Access with written authorization of the Project
AM – Constrictions of other type **Text chain** Compulsory to cite the source of the original data