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ECOMANAGE

Integrated Ecological Coastal Zone Management System

Deliverable 2.7

Diagnosis of the Reference Situation and Definition a Target Situation related to Groundwater Bahía Blanca Estuary

Study developed for the European Commission DG Research INCO-CT Programme under contract number INCO-CT2004-003715
Study developed within the framework of LNEC Research Plan 2005-2008, referring to the study “Prevenção da poluição e reabilitação da qualidade das águas subterrâneas”

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Núcleo de Águas Subterrâneas

Universidad Nacional del Sur

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DIAGNOSIS OF THE REFERENCE SITUATION AND DEFINITION A TARGET SITUATION RELATED TO GROUNDWATER

Deliverable 2.7 – Bahía Blanca Estuary

ABSTRACT

This report is the Deliverable 2.7 component for Bahía Blanca Estuary, and concerns the diagnosis of the reference situation and the definition a target situation related to groundwater.

Deliverable 2.7 aims the characterization of the inland waters, which contribute to the water quality of the Bahía Blanca estuary. The contribution is presented in two main parts: (1) assessing main existing Pressures, and (2) analysing the State of surface and groundwater quality. Based on this characterization, a future monitoring plan is suggested with the purpose of filing up existing gaps between drivers, pressures and state.

The report is structured is several sections that present: a general characterization of the study area, the main existing pressures, the geology and soils, the geomorphology and tectonics, the hydrology, the hydrogeology and the water quality.

DIAGNÓSTICO DA SITUAÇÃO DE REFERÊNCIA E DEFINIÇÃO DA SITUAÇÃO OBJECTIVO EM RELAÇÃO ÀS ÁGUAS SUBTERRÂNEAS

Deliverable 2.7 – Estuário de Bahía Blanca

RESUMO

Este relatório é a componente da *Deliverable 2.7* para o caso de estudo de Bahía Blanca e é relativo ao diagnóstico da situação de referência e definição da situação objectivo para as águas subterrâneas.

A *Deliverable 2.7* tem como principal objectivo caracterizar as águas interiores e sua potencial influência para a qualidade das águas no estuário de Bahía Blanca. A contribuição é apresentada em duas partes principais: (1) avaliação das principais Pressões e (2) análise do eStado de qualidade das águas de superfície e subterrâneas. Com base nessa caracterização, sugere-se um plano de monitorização futuro que tem como objectivo completar as lacunas de informação entre as forças motrizes, respectivas pressões e alterações causadas no estado de qualidade das águas.

O relatório está estruturado em diversas secções que apresentam: uma caracterização geral da área de estudo, principais pressões na área, geologia e solos, hidrologia, hidrogeologia, meteorologia e qualidade das águas.

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DIAGNOSIS OF THE REFERENCE SITUATION AND DEFINITION A TARGET SITUATION RELATED TO GROUNDWATER

Deliverable 2.7 – Bahía Blanca Estuary

1 OBJECTIVES

One of the three key purposes of ECOMANAGE project is "the consideration that a coastal zone depends on local pressures, but also on pressures originated in the drainage basin, transported mostly by rivers and by groundwater ...". For that objective, there is a need to analyse the contributions from the watershed upgradient to the coastal area, in terms of quantity and quality. This report contributes to the latter.

In the context of the above referred, the aim of the study at Bahía Blanca is:

- To analyse the contributions of existing "pressures", via surface and groundwater, to the Bahía Blanca estuary water quality.
- "To estimate the influence of anthropogenic activities (*i.e.* domestic and industrial sewage discharge, dredging, and waste land filings) on the equilibrium of the mentioned estuary cycles" via the watershed and regional aquifers of the region.

In this report, an analysis of the existing main pressures is made as well as a diagnosis of the reference situation in what concerns the surface water and groundwater quality that can potentially contribute to the estuary. This report will be complemented with the analysis of the quantity of water reaching the estuary.

2 GENERAL CHARACTERIZATION OF THE STUDY AREA

The region under study is located in the Buenos Aires districts of Puan, Tornquist and Villarino, Bahía Blanca and Coronel Rosales (Fig. 1). In the north, the Ventana ridge system represents the higher relief of the province, with Tres Picos Mountain (1243 m), where a series of rivers is originated, flowing afterwards to the estuary or to endorreic basins.

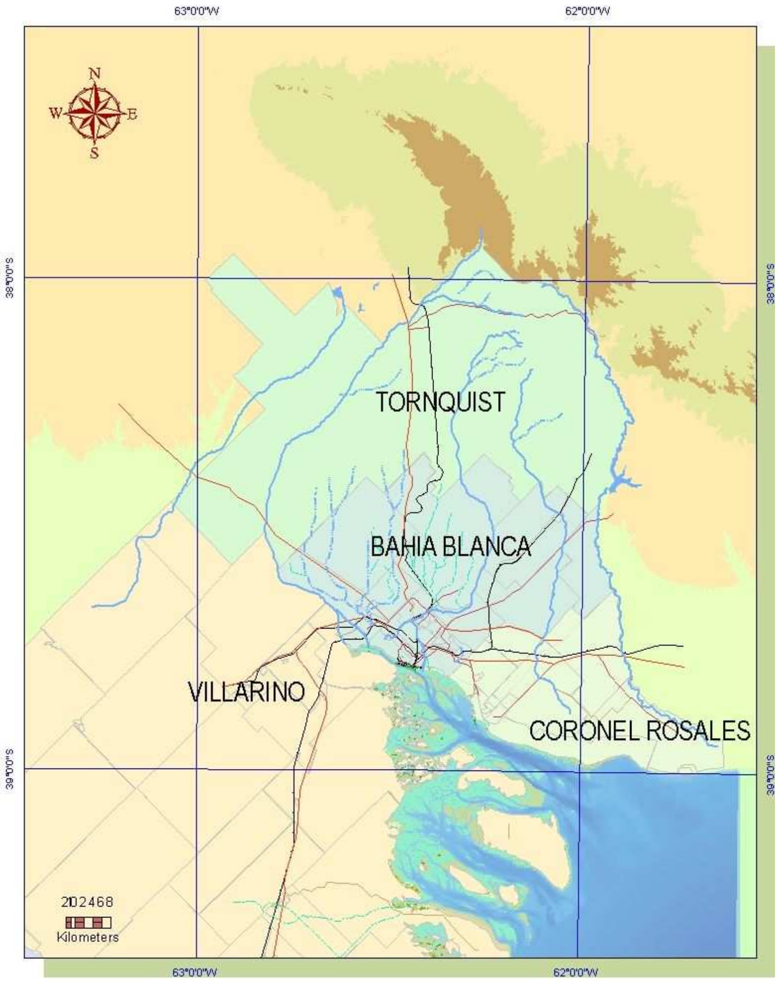


Fig. 1 - Bahía Blanca estuary region

The continental domain of Bahía Blanca estuary is represented by the region of the southeast of the La Pampa province and a part of the southwest of Buenos Aires province (Cammarata, 1982). In the north, the pampean plain contacts the Ventana ridge system, a 175 km large and 50 km wide ridge developed in the southwest Buenos Aires province, along a NW-SE direction. In the south and southwest the austral limit is defined by the Colorado river. To the west, this plain is interrupted by a sequence of depressions represented by lagoons and sabkhas. The most outstanding lagoons are Colorada Grande, Colorada Chica, Blanca Grande, Callaquéo lagoons and Salitral Negro. These units are distributed from north to south and some of them are aligned, following the depression formed by the Chasicó lagoon and the Salinas Chicas sabkha.

The axis formed by the Chasicó lagoon and the Vidriera sabkha also defines an area of morphologic transition between the north and the south of this region. The absence of large perennial water courses with a regional source constitutes the main feature, standing out only the Colorado river, which constitutes the area limit. Also, another similar transition is observed in the lagoon formations, since to the east of Bahía Blanca they are not observed. However, to the west, the magnitude of some allows them to be industrially exploited.

From a climatic point of view, the study area is included in the temperate climate zone. In this area two different air masses meet: one maritime, warm and wet from the South Atlantic; and the other cold, coming from the South Pacific, that becomes dry when it passes through the Patagonian region (Bróndolo and Bazan, 2000).

Air masses circulation defines the climate of the southwest as a transition type between the warm and humid climate of the east of Buenos Aires province and the cold and dry climate that predominates in the Patagonia (Bróndolo *et al.*, 1994). Thus, a transition climate in the east of the region is determined, identifying a wet climate subtype towards Bahía Blanca. However, the diminution of precipitations in the sense NE-SW articulates with the characteristics of the soils, being an essential agent for their formation (Casagrande and Conti, 1980), determining for this region transition features not limited by the climatic aspect exclusively.

The annual precipitation averages vary remarkably from west to east. In the west, the annual average precipitation oscillates between 200 and 300 millimeters, whereas in the east the values range between 600 and 700 millimeters. In Villarino the average precipitation observed is 448 mm and in Bahía Blanca 614 mm (Campos and de Steffens, 2000). In the last locality, the soil moisture is exhausted from the end of October until December and since then until March there is a deficit (Campos *et al.*, 2000).

Due to its climatic characteristics, Bahía Blanca is defined as a region of diverse transitions. In terms of vegetation, three geographic provinces converge: Spinal, Mountain and Pampean, being the last one of greater predominance (Bróndolo *et al.*, 1994). The border area is located in the central place of Bahía Blanca, Tornquist and Puan districts.

Toward the west of the study area, Bruniard (1997) indicates that the long winter drought, which is not favourable to the herbaceous vegetation, and the greater penetration of the humidity in the short summer, would create the conditions for an open xerophilous forest with deep roots. This situation is favoured by the presence of sandy soils that facilitate the penetration of water, which is concentrated in topographies of basins where arboreal specimens are grouped. Whereas to the east, in the surrounding area to Bahía Blanca, the more balanced regime of rains favours a discontinuous vegetal cover of xerophilous with roots laterally developed (Bruniard, 1997).

During the last century the natural species were devastated on a significant surface area and they were replaced by crops and pastures. This fact turns difficult the visual reconnaissance of the transition, and these species only appear in large slope areas, as they were not extracted due to the little development of the soils in those zones. Nowadays the climatic transition is observed indirectly in the annual production yield of the agricultural activity, which decreases towards the west.

3 MAIN PRESSURES: SOURCES OF DIFFUSE AND POINT POLLUTION

3.1 Urban

The main sources of point pollution in the study area are located in the urban areas of Bahía Blanca and Coronel Rosales districts (Fig. 2).

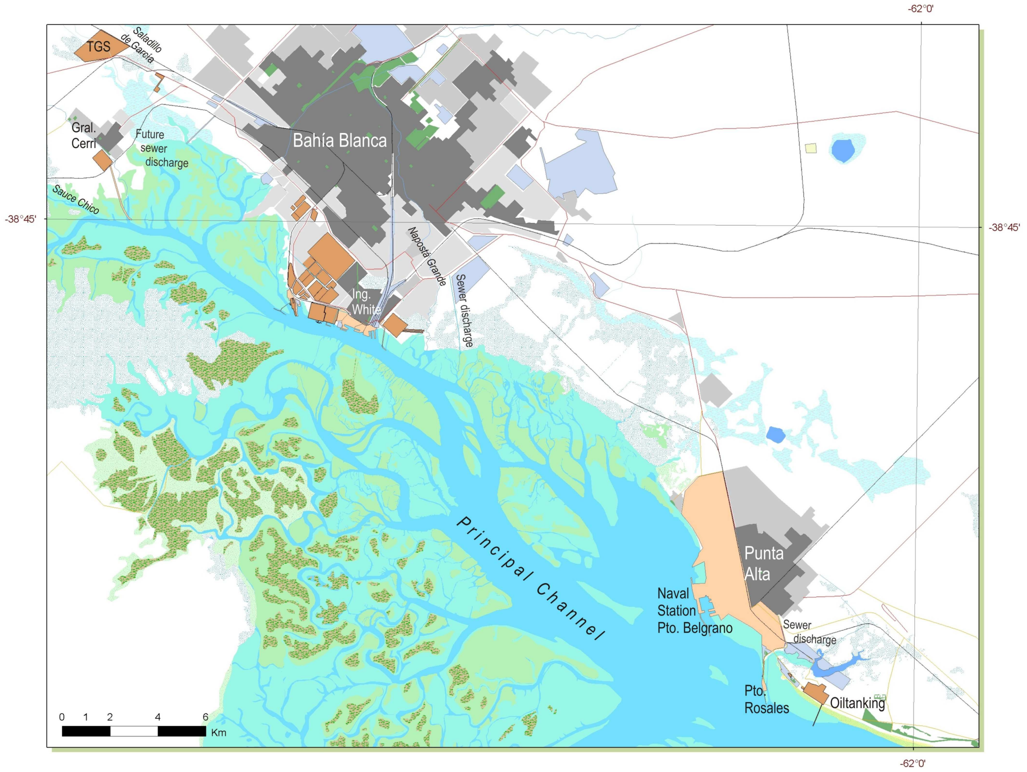


Fig. 2 - Location of the urban areas

At present, the principal sources of discharges to the estuary at Bahía Blanca district are: the sewage treatment plant of Bahía Blanca city; the sewer of Ingeniero White town; the Saladillo river, which receives the discharges of both a near slaughterhouse and one gas company; the Sauce Chico and Napostá Grande rivers contributions, with their potential charge of organic contaminants originated in agricultural activities of the region; the Maldonado Channel, receiving the Napostá Grande overflowing; and the effluents spills of several companies which are placed in the industrial and petrochemical pole near the Ingeniero White harbor zone. In summer, Maldonado Resort Area (Balneario Maldonado) can also be considered a pollution source.

Cloacae system at General Cerri is nowadays under development. At the present only a little sector of this town has a sewer network which discharges to Saladillo river.

Concerning Coronel Rosales district, the main sources of pollution are: the sewage discharges of Punta Alta city, done through a deactivated purifying plant; the spills originated by the oil ships operations at a buoy pertaining to the Oiltanking-Ebytem Company near Puerto Rosales (low volume of 55 m^3; and the activities of the Puerto Belgrano Naval Station.

3.2 Industry

With reference to the industrial discharges, they concern mainly the harbor area of Bahía Blanca (Fig. 3). The industrial and petrochemical pole located in this zone occupy an area of approximately 3.000 m^2 and it lodges the following companies: Petroquímica Bahía Blanca (PBB), Indupa, Polisur, Air Liquide, Mega and Profértil, one refinery of Petrobras company and the fuel storage plants of Shell, YPF and TGS companies.

There is a terminal specialized in cereal handling of the Oleaginosa Moreno Company and another sector for inflammable material management, located at Puerto Galván. They have the purpose of isolating the dangerous loads from the rest of the harbor facilities. Between both zones it is located a petrochemical floating plant, a property of Polisur.

Within Ingeniero White harbor, according to the type of products operated, two differentiated areas can be distinguished. The first area is designed for cereal load, with specialized terminals that manage the companies Platestiba, Terminal Bahía Blanca and Cargill. The other area is designed to store general merchandise. Also the harbor has a dock for coastal fishing boats and port services ships. Finally, in the lower area of the harbor, the Terminal Glencore –Toepfer operates for cereals handling and for the reception of fuel oil for the thermoelectric power plant Luis Piedrabuena.

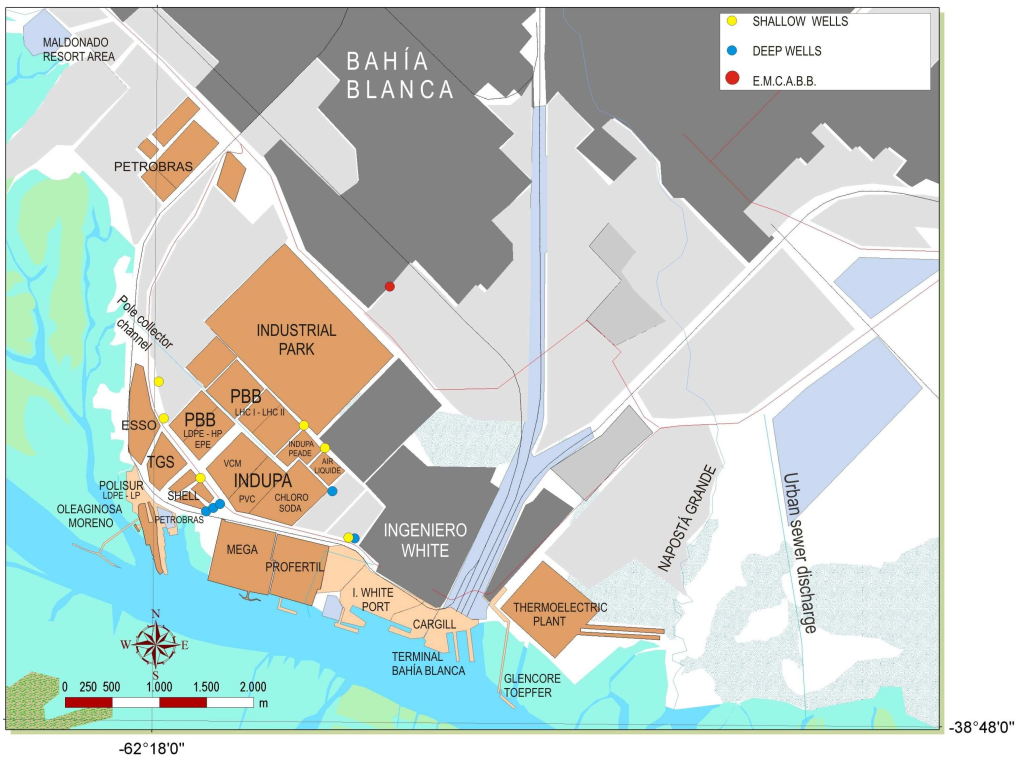


Fig. 3 - Sources of industrial pollution in the harbour area of Bahía Blanca

In this context, according to their receiving bodies, four groups of industrial effluents discharges can be differentiated:

1. Discharges to the unified collector channel of the Petrochemical Pole;
2. Spills to Saladillo de García river;
3. Direct releases to the Main Channel;
4. Discharges to the cloacae network.

These discharges are further detailed above and summarized in Table 1.

1. Discharges to the Petrochemical Pole Channel

The collector channel receives effluents from the following companies:

- Petroquímica Bahía Blanca (PBB) - Polisur
    - Diverse plants of ethylene cracking (LHC I and LHC II), expanded polyethylene (EPE), low and high-density polyethylene production.
    - LHC I and II, which have a common treatment plant for oil effluents discharging its spills to the chamber of LHC I. The effluents of LHC II are discharged to the collector, the cooling towers purges and non oil compounds.
    - Spills contain mainly contaminants like sulphides and heavy metals.

- Solvay-Indupa
    - Production plants of polyvinyl chloride (PVC), chlorine-soda and vinyl chloride monomer (VCM).
    - Effluents arising from the treatment plant carry out organic compounds, sulphides and heavy metals, especially mercury (Table 2).

2. Spills to Saladillo de García river

The plant of TGS - Gral.Cerri (Transportadora Gas del Sur) is the only company of CTE discharging their waste water to the Saladillo de García river. It is a discontinuous spill and it arises from a facultative lagoon of the treatment plant effluents. This effluent contains high levels of organic matter, iron and zinc.

Although official data are not available, it is known that Saladillo river also receives the discharges of a near slaughterhouse (Frigorífico Siracusa).

3. Direct releases to the Main Channel

The main channel receives the direct effluents of following companies:

- Petrobras
    - The company is dedicated mainly to the refinement, distribution and commercialization of lubricants and asphaltic membranes through its national

    - and regional network.
    - Liquids effluents, which are taken for a treatment plant, contain mainly hydrocarbons, phenols, sulphides and heavy metals.

- Mega
    - Its industrial goal is the recovery and division of the heavy components of the natural gas with production of ethane, propane, butane and gasoline.
    - Their waste waters, which receive a treatment before being rejected, include mainly some metals like iron and zinc.

- Profértil
    - Its plant counts on facilities to produce, store and ship granulated urea and liquid ammonia via marine or terrestrial route.
    - Their spills carry nitrogen compounds, particularly ammoniacal nitrogen, and heavy metals (Table 2).

4. <u>Discharges to the cloacae network</u>

The companies which directly spill their effluents to the cloacae network are:

- Cargill
    - This company, being dedicated to cereals handling, has a treatment plant for its waste water.
    - The effluent contains high levels of organic matter and nitrogen compounds.

- Air Liquide
    - The company is specialized in industrial gases and gas technology as well as cryogenic liquid hydrogen covering all aspects of storage, handling and safety. Its activities cover steel, chemicals and petrochemicals in the main industrial areas, different processing industries (metals, glass, food, laboratories….) as well as healthcare, both in hospital and in patient's homes. The company supplies industrial gases, including oxygen, hydrogen, nitrogen and other products to the steel, oil refining, chemical, glass, electronics, paper, metallurgy, food-processing, health care and aerospace industries.
    - Liquid effluents, after passing through a treatment plant, contain low levels of iron and zinc.

A summary of the main sources of diffuse and point pollution is showed in the table 1.

Table 1 - Sources of diffuse and point pollution and their main associated pollutants

Emission source		**Contaminants**		
		Gaseous	**Liquids**	**Solids**
PETROBRAS		SO_2 (predominant), SO_3, SH_2, NO_X, CO_2, CO	Hydrocarbons	Muds with heavy hydrocarbon fractions
ESEBA Thermoelectric Plant		SO_2, NO_X, CO_2, CO	Hot water discharge (35°C)	-
PETROQUIMICA BAHIA BLANCA		CO, CO_2, SH_2, ethane	-	Smoke
INDUPA S.A.I.C.	Chlorine Plant	Cl_2 (predominant), HCl, $Hg_{(g)}$, diethyl-ethane	Mercury waters (predominant), brines	Mercury muds, Hg, HgOH
	Vinyl Chloride Monomer Plant	Dichloro ethane (predominant), HCl, SO_2, CO_2, CO, Vinyl Chloride Monomer	EDC (predominant), chloroform, dichloroethylenes, chloroethanes, chlorinated organic compounds	Smoke
	Polyvinyl Chloride Plant	Vinyl Chloride Monomer	-	-
POLISUR		Ethylene	Plants and laboratory wash waters	Particulate Polyvinyl Chloride, zinc rich muds
MEGA - TGS		SO_2, NO_X, CO_2, CO, methyl mercaptans	Plants and laboratory wash waters	-
PROFERTIL		NH_3	Plants and laboratory wash waters	Particulate urea
CARGILL		Odor	Plants and laboratory wash waters	Sunflower pellets, smoke
INGENIERO WHITE PORT		-	-	Cereal powder
OIL TANKING (EBYTEM)		-	Crude oil	-
SEWERS	Bahía Blanca	-	Cloacae liquids with primary treatment	-
	Punta Alta			
	General Cerri			
	Ingeniero White			
STREAMS	Sauce Chico	-	Organic matter, nutrients, pesticides, bacteries	-
	Napostá Grande			
	Saladillo			

Table 2 - Pollutants in two main industries

Parameter	MIN	MAX	AVE
		PROFERTIL	
Total Nitrogen ($mg.L^{-1}$)	-	52.5	-
Ammonium ($mg.L^{-1}$)	45	9,300	2,858
Iron ($mg.L^{-1}$)	0.03	0.19	0.07
Chromium ($mg.L^{-1}$)	0.01	0.10	0.04
Zinc ($mg.L^{-1}$)	< 0.04	< 0.04	< 0.04
		SOLVAY-INDUPA	
Mercury ($mg.L^{-1}$)	< 0.001	0.011	< 0.004
Dichloro ethane ($mg.L^{-1}$)	< 0.1	500	< 80

The Comité Técnico Ejecutivo (CTE - Executive Technical Committee) of Bahía Blanca Municipality, in collaboration with the Universidad Nacional Del Sur (UNS - National University of South) and the Instituto Argentino de Oceanografía (IADO - Argentinean Institute of Oceanography), have implemented during the last years an Integral Monitoring Program of the Bahía Blanca estuary. The daily water contributions to the estuary have been evaluated from the mouth of Sauce Chico river to Puerto Belgrano inclusively, as either sewer or industrial discharges or via groundwater and surface water. The results obtained are of public access and can be consulted in the web through the official site of the Bahía Blanca Municipality (http://www.bahiablanca.gov.ar/cte).

Table 2 presents a compendium of the liquid effluents analyses, according to the monitoring carried out in the Industrial Park and the Petrochemical Pole of Bahía Blanca, as well as in Cargill and TGS companies by the CTE during year 2006 (http://www.bahiablanca.gov.ar/cte/Septima_Auditoria.pdf). Additional information can be obtained at http://www.bahiablanca.gov.ar/turismo/puertos.html.

The samples were taken from the common collector channel of the Petrochemical Pole and in the treatment plants spills for every single company. The displayed results are the maximum and the average values obtained for five to eight samples, according to the company information.

The maximum allowed levels assigned for each parameter are established by the Buenos Aires Provincial Law 5965 336/03. This law does not establish values for turbidity; those are settled by the Municipal Regulation 8862. Some parameters have differentiated maximum allowed levels in accordance with the company activity. More specifications can be obtained from the original report.

Table 3 - Synthesis of the liquid effluents physico-chemical properties of the effluents from the Industrial Park and the Petrochemical site at Bahía Blanca, according to CTE 2006

Parameter	**POLO CHANNEL**		**PBB-POLISUR**										**SOLVAY-INDUPA**		**PETROBRAS**		**MEGA**		**TGS**		**CARGILL**		**PROFERTIL**		Maximum Allowed level
			HDPE		**LHCI**		**LDPE**		**LHCII**		**EPE**														
	MAX	AVE	MAX	AVE	AVE	AVE	MAX	AVE	MAX	AVE	MAX	AVE	MAX	AVE	MAX	AVE	MAX	AVE	MAX	AVE	MAX	AVE	MAX	AVE	
Flow rate ($m^3.h^{-1}$)	-	-	-	-	90	54	-	-	74	62	25	20	360	233	35	21	-	-	9.0	5.1	37	16	290	220	NE
pH	11.2	9.3	8.3	7.8	7.7	7.6	7.8	7.7	9.8	8.6	8.6	8.5	9.4	8.7	8.5	8.1	8.6	8.0	9.7	8.5	10.4	9.2	8.8	7.9	6.5
Conductivity ($\mu S.cm^{-1}$)	35300	23492	1710	1257	6040	4192	1730	1334	5150	3290	2410	2240	64000	47438	4100	3716	2060	814	1680	1303	2220	1273	2870	1820	NE
Turbidity (NTU)	226	94	45	22	23	17	24	19	70	48	41	33	-	-	106	-	65	32	111	82	-	-	39	20	50*
Temperature (^oC)	35.5	27.7	33.1	27.0	27.1	23.0	25.0	21.8	29.8	24.0	22.1	19.0	43.1	33.8	23	17	31.2	24.5	22.1	18.2	45.0	29.9	30.5	25.9	45
Disolved Oxygen ($mg.L^{-1}$)	-	-	3.6	2.8	4.1	3.4	3.1	2.7	3.5	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NE
Suspended solids- 10´ ($ml.L^{-1}$)	2.0	0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	2	< 0.5	< 0.1	< 0.1	0*
Suspended solids- 2h ($ml.L^{-1}$)	7.5	1.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	1	< 0.3	< 0.1	< 0.1	< 0.1	< 0.1	1.0	< 1.0	2	< 0.6	0.1	< 0.1	1
Total solids ($mg.L^{-1}$)	20370	10304	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1393	748	-	-	NE
Fixed solids ($mg.L^{-1}$)	19988	10025	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	985	418	-	-	NE
Volatile solids ($mg.L^{-1}$)	770	363	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	428	330	-	-	NE
BOD$_{5\ days}$($mg.L^{-1}$)	39	24	-	-	-	-	-	-	-	-	-	-	37.6	-	-	-	-	-	-	-	45	36	-	-	50*
COD ($mg.L^{-1}$)	225	119	89	63	142	91	149	76	243	129	98	83	295	171	180	120	98	46	370	116	300	189	165	76	250*
Total Nitrogen ($mg.L^{-1}$)	22	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41	15	15	10	35*
Ammoniacal Nitrogen ($mg.L^{-1}$)	14	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	7	25
Iron ($mg.L^{-1}$)	1.03	0.26	1.88	0.54	1.10	0.35	0.30	0.19	0.61	0.34	13.00	3.35	0.44	0.28	0.47	< 0.21	0.28	0.16	1.68	0.91	-	-	0.67	0.21	2
Zinc ($mg.L^{-1}$)	0.07	0.04	0.06	< 0.05	0.04	< 0.04	0.07	< 0.05	0.05	< 0.05	0.04	< 0.04	0.08	< 0.05	0.51	< 0.20	1.09	< 0.05	0.04	< 0.04	-	-	0.75	< 0.30	2
Chromium ($mg.L^{-1}$)	0.03	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	< 0.02	0.01	< 0.01	-	-	-	-	-	-	0.05	< 0.02	0.2
Sulfides ($mg.L^{-1}$)	0.097	0.04	0.014	0.014	0.054	0.025	0.024	< 0.016	0.027	< 0.020	0.027	0.019	0.065	<0.040	0.127	< 0.060	-	-	-	-	-	-	-	-	1
Total Hydrocarbons ($mg.L^{-1}$)	8.9	2.1	-	-	-	-	-	-	-	-	-	-	-	-	11.7	3.9	-	-	-	-	-	-	-	-	30
Phenols($mg.L^{-1}$)	0.119	0.050	-	-	-	-	-	-	-	-	-	-	-	-	0.078	0.048	-	-	-	-	-	-	-	-	0.5
Mercury ($mg.L^{-1}$)	0.003	0.001	-	-	-	-	-	-	-	-	-	-	0.002	< 0.002	-	-	-	-	-	-	-	-	-	-	0.005
Cadmium ($mg.L^{-1}$)	0.010	0.007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Lead ($mg.L^{-1}$)	0.10	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Nickel ($mg.L^{-1}$)	0.01	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Dichloro ethane ($mg.L^{-1}$)	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NE

(*)Exceptions: turbidity maximum levels in relation to Municipal Regulation 8862, suspended solids and COD maximum levels variables depending to the company activity

The CTE's report also points out the monitoring results achieved in the pluvial channels existing in the industrial site. Two samples by site were collected for pH, conductivity, turbidity, temperature and mercury analysis, whereas for the rest of the parameters only one sample per site was taken. Maximum, minimum and average values of the analyzed parameters are shown in Table 4. It should be registered that detection limits used are rather high, leading to the absence of detection of heavy metals in the water.

Table 4 - Parameters analyzed at pluvial channels in the industrial site

Parameter	MIN	MAX	AVE
Temperature (^{o}C)	9.5	20.0	12.8
pH	8.3	10.0	9.0
Conductivity (μS.cm^{-1})	510	43,000	14,630
Turbidity (NTU)	3	350	75
Total Hydrocarbons (mg.L^{-1})	< 0.1	0.7	< 0.2
Mercury (mg.L^{-1})	< 0.001	< 0.001	< 0.001
Lead (mg.L^{-1})	< 0.01	< 0.01	< 0.01
Cadmium (mg.L^{-1})	< 0.01	< 0.01	< 0.01
Chromium (mg.L^{-1})	< 0.01	< 0.01	< 0.01
Nickel (mg.L^{-1})	< 0.01	< 0.01	< 0.01

Table 5 - Parameters analyzed in shallow and deep wells in the periphery of the industrial area

Parameter	SHALLOW WELLS			DEEP WELLS		
	MIN	MAX	AVE	MIN	MAX	AVE
Temperature (^{o}C)	18.0	23.5	20.8	18.0	19.3	18.7
pH	7.1	7.8	7.5	7.7	8.6	8.3
Conductivity (μS.cm^{-1})	18,100	100,000	55,450	3,680	46,800	24,996
Turbidity (NTU)	-	-	-	0.0	6.0	1.4
Total Alkalinity (mg.L^{-1})	325	738	< 466	-	-	-
Sulfates (mg.L^{-1})	1,000	6,750	3,688	223	2,211	1,313
Chloride (mg.L^{-1})	6,000	27,500	15,625	720	18,495	10,228
Bicarbonates (mg.L^{-1})	< 5	< 5	< 5	147	501	338
Nitrates (mg.L^{-1})	2.5	8.0	5.4	< 1.0	26.4	< 7.5
Nitrites (mg.L^{-1})	< 0.05	< 0.05	< 0.05	< 0.1	0.4	< 0.2
Total Nitrogen (mg.L^{-1})	12	17	14	-	-	-
Ammonium (mg.L^{-1})	1.2	3.6	2.2	-	-	-
Sodium (mg.L^{-1})	4,000	29,000	14,567	-	-	-
Potassium (mg.L^{-1})	200	1,600	743	-	-	-
Calcium (mg.L^{-1})	80	1,160	593	-	-	-
Magnesium (mg.L^{-1})	180	2,630	1,149	-	-	-
Iron (mg.L^{-1})	0.15	86.00	20.68	-	-	-
Mercury (mg.L^{-1})	< 0.001	< 0.002	< 0.0011	< 0.001	< 0.001	< 0.001
Lead (mg.L^{-1})	< 0.01	0.02	< 0.011	-	-	-
Cadmium (mg.L^{-1})	0.003	0.01	< 0.01	-	-	-
Copper (mg.L^{-1})	< 0.01	< 0.01	< 0.01	-	-	-
Chromium (mg.L^{-1})	< 0.01	0.03	< 0.02	-	-	-
Zinc (mg.L^{-1})	0.15	0.34	0.24	-	-	-
Nickel (mg.L^{-1})	< 0.01	0.12	< 0.03	-	-	-
Dichloro ethane (mg.L^{-1})	< 0.1	< 0.1	< 0.1	-	-	-

Aiming the assessment of the contaminants occurrence in groundwater, CTE carried out a monitoring campaign on some shallow and deep wells placed in the periphery of the industrial zone. Average and limit values of the parameters analyzed are shown in Table 5. The values presented for shallow wells refer to one single sample taken in six different wells, except for heavy metals that had two sampling data for each well. With respect to the deep wells, the results are taken from five wells with a single sampling.

Furthermore, CTE carried out a monitoring programme on several wells placed inside the Solvay-Indupa and Profértil sites. Table 6 shows the levels registered for the main polluting agents. In the case of Solvay-Indupa, the minimum, maximum and average values were obtained from eight wells whereas in Profértil they were calculated from samplings in nine wells.

Table 6 - Parameters analyzed in wells located in Profértil and Solvay-Indupa sites

Parameter	MIN	MAX	AVE
		PROFERTIL	
Total Nitrogen (mg.L^{-1})	-	52,5	-
Ammonium (mg.L^{-1})	45	9300	2858
Iron (mg.L^{-1})	0,03	0,19	0,07
Chromium (mg.L^{-1})	0,01	0,10	0,04
Zinc (mg.L^{-1})	< 0,04	< 0,04	< 0,04
		SOLVAY-INDUPA	
Mercury (mg.L^{-1})	< 0,001	0,011	< 0,004
Dichloro ethane (mg.L^{-1})	< 0,1	500	< 80

Moreover, the Comité Técnico Ejecutivo of the Bahía Blanca Municipality, in the course of its Integral Monitoring Programme, has implemented the gaseous pollution continuous monitoring of the Bahía Blanca Estuary (in E.M.C.A.B.B. pointed out in Fig. 3) and also has performed the monitoring of a few organic compounds in the periphery of Petrobras and Solvay-Indupa production plants.

3.3 Livestock-agriculture

Besides the urban and industrial sectors above referred, there is a main socioeconomic primary activity in the region: a mixed livestock-agriculture production system. In a large part of the study area, cattle rising are the pillar of the productive system. The production is mainly bovine in rotation with cultures climatically adapted and resistant to the soil limitations. Wheat is the main culture, followed by oats and brewing barley in minor extent. The summer cultures are less significant with sunflower and forager sorghum prevailing. One of the zones with greater activity is located at the upper part of Napostá Grande watershed.

Regarding to the Sauce Chico watershed, the upper part is nowadays occupied by large livestock development, while in the middle basin there are horticultural management with great extent (more than 100 ha each). At the lower basin, near General Cerri town, there are small farms (of about 12 ha) and others less significant at Villarino Viejo town (of about 4 or 5 ha each) (Fig. 4). There are in total nearly 75 horticultural exploitations with 45 producers managing those (Albaladejo et al, 2000).

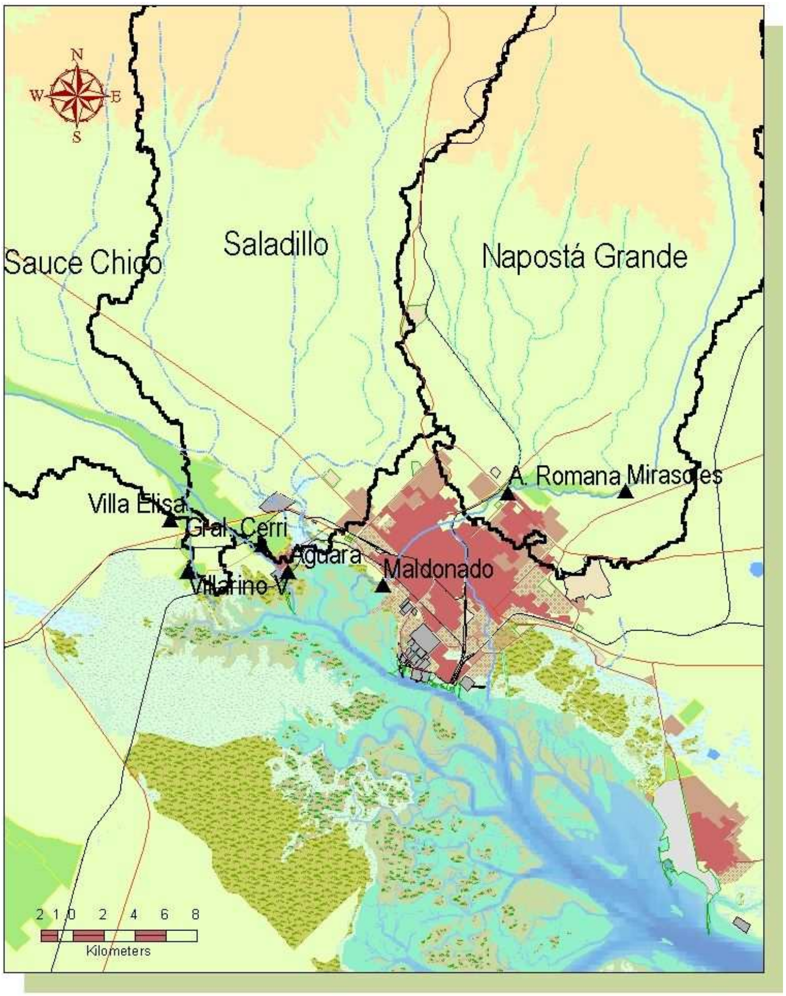


Fig. 4 - Land use at the study site

At the lower part of Napostá Grande basin there are two horticultural producers, one in Los Mirasoles and the other at a sector located at the periphery of Bahía Blanca in the zone known as Aldea Romana (Fig. 5).

Fig. 5 - Horticultural management at Aldea Romana

The existing information about the use and type of agrochemical applied in cultivated soils is scarce and, in general, producers are reticent to offer information on the issue. Nevertheless, it is recognized a tendency to have limited concern in their use, either for pesticides or for fertilizers. Some data obtained through personal communication with producers is shown in Table 7.

Table 7 - Fertilizers and pesticides application in livestock-agricultural areas, accordingly to producer's informal reference

Ranch	Lat [S]	Long [W]	Area [ha]	Livestock [heads]	Culture Types	Fertilizers		Pesticides
Cerro Napostá Grande (Hogar Funke)	38.14747	62.06535	12,899	4,800 (cattle)		PDA [Kg/culture]	UAM [L/culture]	not declarated
					wheat barley	40-50	100	
					oats sunflower		-	
					corn		50	
La Tigra	38.18955	62.10693	1,150	700 (cattle)		UREA-PDA [Kg.year^{-1}]		circumstantial for *Lepidoptera*
					forages wheat corn	100		
Belardinelli	38.17253	62.15842	300	1,000 (sheep)		UREA [Kg.year^{-1}]	P[Kg.year^{-1}]	fumigation
					wheat sunflower forages	40	40	
Anzueta	38.23758	62.18168	300	150 (cattle)	wheat oats	not utilized		not utilized

There is an ample set of different chemical compounds presently applied by the horticultural producers, aiming to protect the cultures against plagues or to control plant development.

At the moment, a monitoring programme to assess the agrochemicals used in horticulture is being carried out, through the "Programa de Promoción y Desarrollo del Cinturón Hortícola de

Bahía Blanca", implemented by the Bahía Blanca Municipality in collaboration with the Department of Agronomy of the Universidad Nacional del Sur.

The partial data collected within the framework of this program have been yielded by courtesy of Ing. Agr. Jorge Lusto, and are presented in Table 8 for Sauce Chico watershed.

Table 8 - Pesticides used at the lower part of Sauce Chico watershed

PRODUCT	CHEMICAL CLASSIFICATION	HERBICIDES	INSECTICIDES	FUNGUICIDES
			[Kg.year^{-1}]	
Chorpyriphos	organophosphorated		84	
Delthametrine	pyrethroid		66	
Methamidophos	organophosphorated		38	
Dimetoate	organophosphorated		30	
Endosulphan	organophosphorated		25	
Pirimicarb	carbamate		23	
Linuron	substitued urea	22		
Clethodim	cyclohexadione	9		
Zineb	dithiocarbamate			50
Mancozeb + methalaxil	ditiocarbamato/phenylamide			22
Captan	dicarboximide			22
Carbendazim	benzimidazole			19
Carbofuran	carbamate		s/d	
Methil bromate	halogenated alkyl		s/d	s/d

The pesticides more applied correspond to the insecticides, as can be seen in Fig. 6.

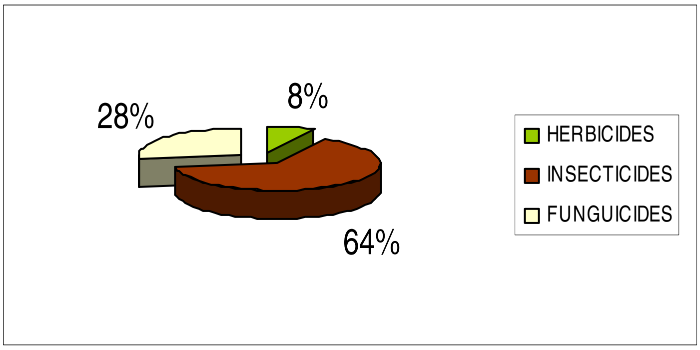
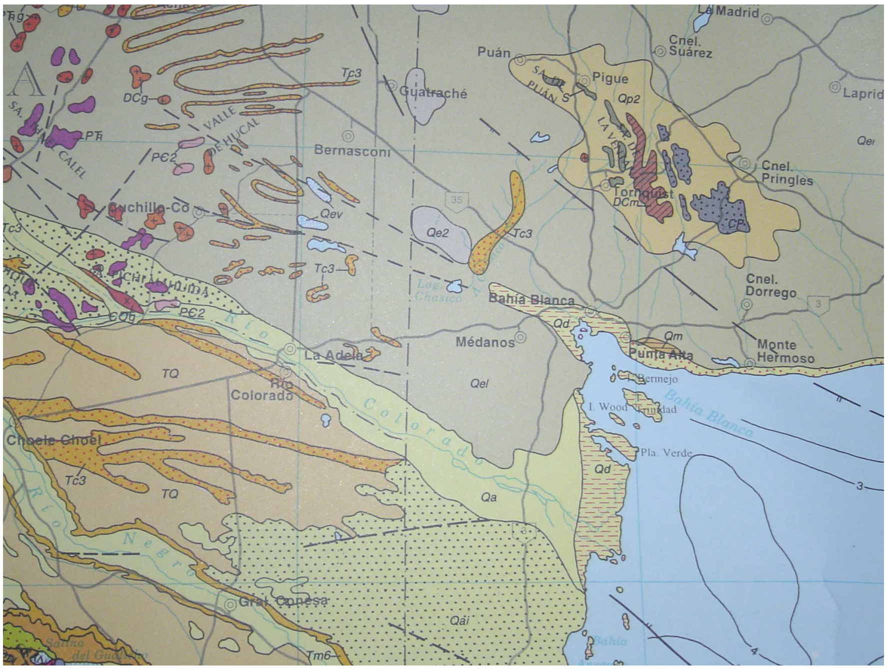


Fig. 6 - Proportion in the use of different pesticides

According to Ing. Agr. Jorge Lusto, horticultural producers of Aldea Romana and Los Mirasoles make use of no more than 4 kg.year^{-1} of pesticides.

4 GEOLOGY

The geological and geophysical characterization of the study area has been subject to various previous global studies that concern the main morphostructural regions of Sierras Australes de la Provincia de Buenos Aires and of Colorado basin (Bonorino, 1988; Albouy 1994, Carrica, 1998). Fig. 7 shows the geology of the area (SEGEMAR, 1997).



Legend:

S: Silurico, Gr. Ventana

DCm: Devónico-Carbónico marino, parte del Grupo Ventana

CP: Carbónico Permico, Grupo Pillahuincó

Tc3: Mioceno, Fm. Chasicó

Qp2: Pleistoceno

Qel: Loess reciente

Qm: Cuaternario marino Querandinense (6.000 años)

Qd: Cuaternario deltaico

Fig. 7 - Photo of the geological map of the study area (SEGEMAR, 1997)

In a very simplified way, the study area is included in the Colorado basin that is characterized by faulted bedrock partially covered by a Palaeozoic substratum. Since tertiary age, no significant faults occurred and the overlying sediments were smoothly deposited towards the centre of the basin in a synclinal like structure. Besides the quartzite outcrops from Palaeozoic, the sediments from the upper tertiary and quaternary ages are the ones outcropping mostly in the study area (with Tc3 and Qd symbols in Fig. 7 map).

In synthesis, from the base to the top, the stratigraphy of the region is composed by:

- An igneous-metamorphic complex of Precambrian-Palaeozoic inferior age (not outcropping, since depths are between 1,430 and 1,920 m, *cf.* Bonorino, 1988);
- Quartzite rocks from Palaeozoic age that form the mountain nucleus of the region;
- A complex set of layers of sedimentary origin, from Ceno-Mesozoic age, with different lithology and thickness, better described in the Section 9.2 Hydrogeological characterization (for further detail see Fidalgo *et al.*, 1975, Bonorino, 1988; De Francesco, 1992a, Albouy 1994, Carrica, 1998);
- The remaining quaternary formations of the regional stratigraphy have a small geographic expression and, therefore, have a low hydrogeologic interest.

5 SOILS

The various morphologic processes have formed soils with differentiated characteristics. Zubiate and Pinedo (1980) have classified them taxonomically according to the North American systematic "Soil Taxonomy", finding the presence of Mollisols, Entisols and Aridisols.

5.1 Mollisols soil sector

The morphology that dominates the Buenos Aires province sector is the edge of the steppe, prairie or pampean pasture grounds (Bruniard, 1997). It corresponds to the rainiest section of western Pampas, located to the east of the isohyets of 500 mm and dominated by Mollisoles soils, which are subdivided in the calcareous plain, hills and valleys and the sandy plain. These soils are the most developed in the region, with: good content of organic matter; sandy loam texture; structure in blocks and appropriate fertility. Many of them present, as a basic characteristic, a level of calcrete ("tosca") at different depths. In some cases, this one is beneficial because it avoids the loss of soil humidity by percolation. Others soils are more sandy, without calcrete in their profile and with a larger permeability (Zubiate and Piñedo, 1980).

5.2 Calcareous plain, hills and valleys

This area is included between isohyets of 500 mm in the west and 700 mm in the east. Some soils have been developed from sandy silty sediments and on a limestone substrate (Zubiate and Piñedo, 1980). The majority of them show a moderate erosion degree. The humidity of the region is demarcated to the east by the isohyets of 700 mm, those that associated to brown and chernozem soils, determine prairie vegetation.

The irruption in the landscape of the Ventana ridge, in the southwest of Buenos Aires province, determines its influence towards the coastal area through the undulations of the land displacing the ending of the plain to this sector of the province. This part contains the only perennial water courses that flow to the coast, as described in section 2. The axis formed by the La Vidriera sabkha and the sandy formation originating from the absolute depressions area, gives rise to the plains formed by the old contributions of the Colorado river.

Towards the west, the progressive humidity deficiency and the domain of the sandy soils originate the phytogeography formations that surround the pampean pasture ground and determine the transition or ecotones towards semi-desert areas (Araoz, 1975), giving rise to the Espinal Province (Cabrera, 1958).

6 GEOMORPHOLOGY AND TECTONICS

Geomorphology and tectonics play an important role in water circulation and pathways as they define the natural physical characteristics of the surface. In the study area, there are two main geomorphologic units: the mountains to the NE and the plain in the medium and low watershed areas.

The structure of the sedimentary basin started to be shaped in Palaeozoic age with the quartzite formations that, in the Permic Superior, were folded forming the present Sierras Australes de la provincia de Buenos Aires. Only in the hilly area, the Palaeozoic formations outcrop, forming a positive core that is the main source of continental sediments of the region.

Latter, during Upper Jurassic and Medium Cretaceous times, this hydrogeologic basement was fractured and fragmented in blocs. The process was probably connected with the Atlantic Ocean opening and it resulted in an extensive fault system N-S and E-W that gave rise to gradients of 100-300 m between blocks that can even reach 1000 m, accordingly to seismic information (Bonorino, 1988).

The thick sedimentary cover started during Mesozoic times. By then, the basin was subsiding with no special orogenic period, but having some bedrock faults responsible for the slope of the sediments deposited. The main subsiding period happened during Miocene period when a sea transgression occurred. The basin filling occurred in the upper Miocene age, represented by the continental deposits, and after in the Pleistocene there were a set of sea transgressions and regressions sediments that covered the wide valleys.

During the Holocene there was a lift in the continental area due to a marine regression that allowed the outcrop of the Pleisto-Holocene marine sediments and the deepening of the rivers due to the decrease of its base level. From a geomorphologic point of view, the coastal zone is a platform of marine abrasion built over the plio-pleistocenic sediments carried in the last transgression in the Holocene period (Sala *et al.*, 1985).

The upper tertiary and quaternary formations form the phreatic aquifer of post-Pliocene age.

7 MONITORING INFRASTRUCTURES AND DATA

In the next sections, both a hydrologic and a hydrogeologic characterization of the reference situation is made, including surface and groundwater of Napostá Grande and Sauce Chico watersheds. The results presented hereinafter derive from several previous studies carried out in the region by Bonorino 1988, 1989, 1991, 1994, 1999; Carrica *et al.*, 1992; Albouy 1994; Rossi 1996; Bonorino *et al.*, 1996; Bonorino *et al.* 1996, 1997, 1999, 2000, 2001; Carrica 1998; Carrica e Lexow 2002, 2004, 2005; Albouy *et al.*, 2005, among others (*cf.* Bibliography). Some of the original data of those studies, and other unpublished data from Autoridad del Agua, Universidad Nacional del Sur, and CONICET, where kindly made available to this project by their authors. Table 9 presents a synthesis of the existing information and the corresponding dates of sampling and Table 10 shows the amount of information available for the ECOMANAGE project.

Table 9 - Existing data for surface and groundwater of Napostá Grande and Sauce Chico watersheds

	NAPOSTÁ		**SAUCE CHICO**	
	Superficial	**Groundwater**	**Superficial**	**Groundwater**
Source	C. López, O. Bisiuk (ADA) Fabiana Limbozzi (UNS) Hugo Freije (UNS) ECOMANAGE	Jorge C. Carrica (UNS) Fabiana Limbozzi (UNS-CONICET) ECOMANAGE	Autoridad del Agua (ADA) Hugo Freije (UNS) ECOMANAGE	René Albouy (UNS) ECOMANAGE
Corresponding dates	1999-2000 1992-1994 1997-2006 2005-2006	1986-1989 2000-2002 2005-2006	1993-1994 and 1999-2000 1997-2006 2005-2006	1988-1990 2005-2006

The data from previous studies was complemented with new one gathered during ECOMANAGE project (cf. Fig. 9) - including data from new piezometers installed for the project - allowing to update the available information in terms of time, space and new elements. The four piezometers installed during March 2006 are close to Sauce Chico river and Maldonado mouths (Fig. 8).

Fig. 8 - Piezometer installed for ECOMANAGE project

With the aim of obtaining a diagnosis of the present situation in reference to the groundwater and surface water nutrients levels, three sampling campaigns were carried out during the months of April, June and July of the year 2006. Alkalinity, hardness and levels of calcium and chlorides of water samples were determined, among other parameters.

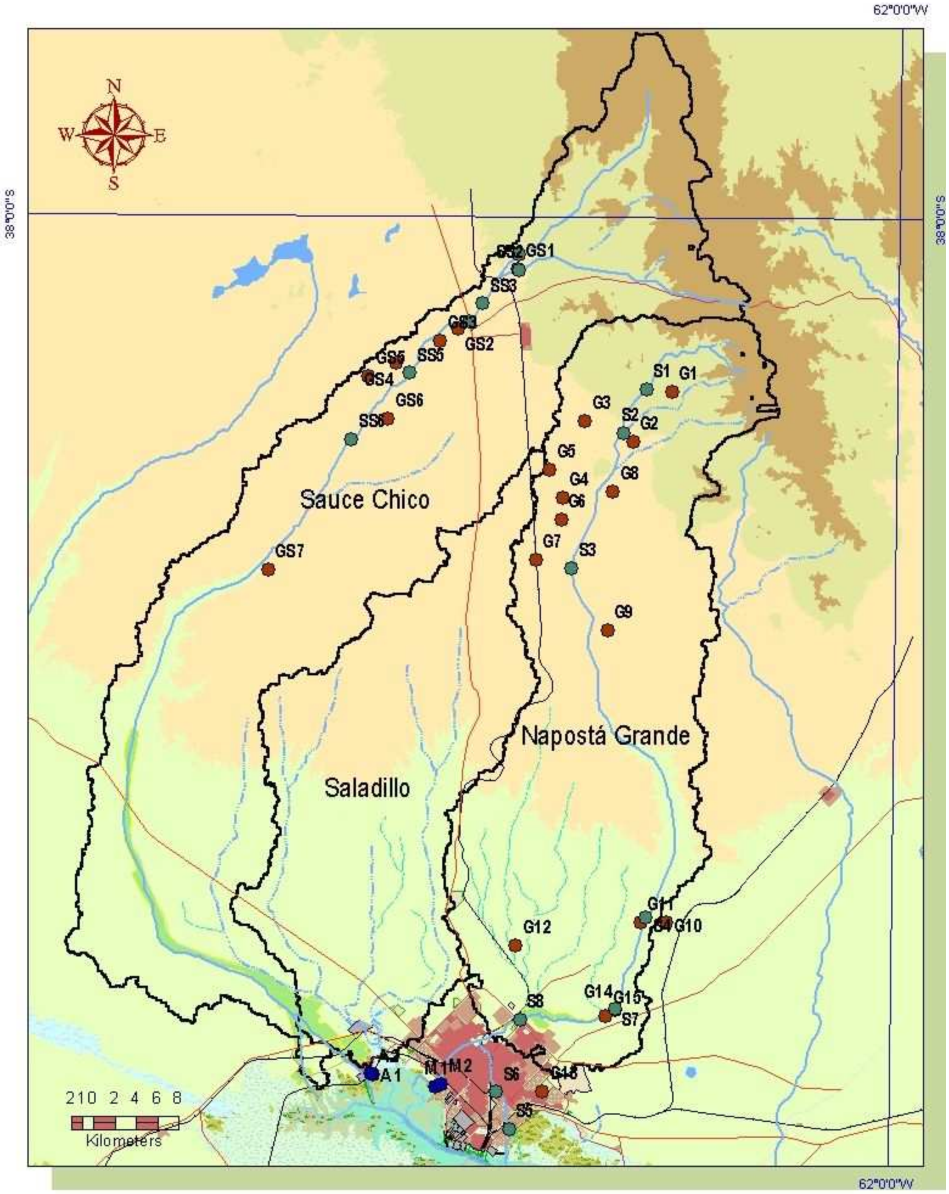


Fig. 9 - Sampling points of ECOMANAGE project, for groundwater and surface water, in the two main watersheds of Bahía Blanca region

The two first campaigns were accomplished throughout whole Napostá Grande watershed (Fig. 9). For the samples obtained in April, a complete physico-chemical analysis was done, including the determination of nitrates, nitrites, ammonium, and phosphates levels. In June, the in situ parameters were analysed and samples were collected for nutrients determination.

The last campaign was carried out in the upper part of Sauce Chico watershed (Fig. 9). Conductivity, pH, temperature, turbidity, dissolved oxygen, nitrites, nitrates, ammonium, phosphates and organic matter were determined. In the wells, besides groundwater sampling, the depth to the water able was also measured.

Altogether, the data that was possible to gather for this project, from previous studies and with the new ECOMANAGE data, corresponds to 136 location, 82 in Napostá Grande watershed (22 in superficial water and 60 in groundwater) and 54 in Sauce Chico watershed (13 in superficial water and 41 in groundwater). This data has been collected by several authors, as indicated in Table 9, and corresponds to a total of 620 analysis carried out since 1988 to the present date.

Table 10 - Synthesis of the information available for the ECOMANAGE project concerning surface and groundwater of Napostá Grande and Sauce Chico watersheds

Quantification	**NAPOSTÁ**		**SAUCE CHICO**		**Total**
	Superficial	Groundwater	Superficial	Groundwater	
n. of points	22	60	13	41	136
n. of analysis	277	75	236	42	620
Dates	1992-2006	1986-2006	1993-2006	1988-2006	1988-2006

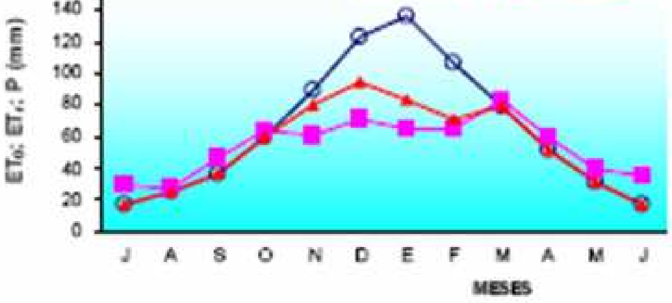
In the section 10, a more detailed analysis of these data is carried out.

8 HYDROLOGY

This area is characterized by a hydrologic year that starts in the end of summer, in February, where the maximum precipitation values occur (Fig. 10). Before this period the water reserves have reached a minimum and the drainage network in the upper watershed in partially inactive with the evapotranspiration processes being responsible for important losses of water. The small fraction of water not subject to evapotranspiration constitutes the soil water with diminutive drainage.

Winter is the month with less rainfall. Nevertheless, the humidity in the watershed is high due to the low evapotranspiration rate and to the effect of aquifers recharge that also feeds the rivers producing rather high flowrate.

Spring is the second rainiest season. The watershed has good water storage allowing a rapid surface runoff. The end of spring is signed by rare precipitation events that are summed up to a high evapotranspiration rate which are responsible for the decrease in water reserves, clearly seen in the river flow rate. This phenomenon has its higher expression in summer.



Source: BHC

Fig. 10 - Meteorological variations along the year in the Bahía Blanca

The hydrodynamic conceptual model of the regional phreatic aquifer was defined by Bonorino, 1988; Albouy, 1994, Carrica, 1998 and Bonorino *et al.* 1996, and synthesized in Bonorino *et al.* 2001. The recharge is done with the precipitation surplus in the entire watershed, being the most important sector the hill area and decreasing towards the coastal area. It is likely that some lateral and vertical circulation to the deeper aquifers also occurs. Therefore, the regional circulation scheme considers one preferential area of recharge close to the hills (about 16.5 % of the rain, according to Bonorino, 1991), one circulation area in the plains and a discharge area in the coastal area.

An analysis of the main water flow contribution to the estuary was recently done in a work carried out by Heffner (2003). The area considered comprises the north margin of the Bahía Blanca estuary, from the Sauce Chico river until the city of Punta Alta (see Fig. 7), being the same area of interest for inland water under ECOMANAGE project. Contributions studied comprise surface and groundwater, as well as industrial and urban effluent discharges.

Concerning surface drainage, the area comprises the following main set of courses: Sauce Chico, Napostá Grande, Maldonado channel (from a natural drainage), Saladillo de García and Dulce, where the last two constitute the Maldonado river.

According to the study above referred and to other studies (*e.g.* Carrica, 1998), the surface water contribution to the estuary is mainly coming from Napostá Grande and Sauce Chico rivers with 95% of the total flowing water (*cf.* Fig. 11).

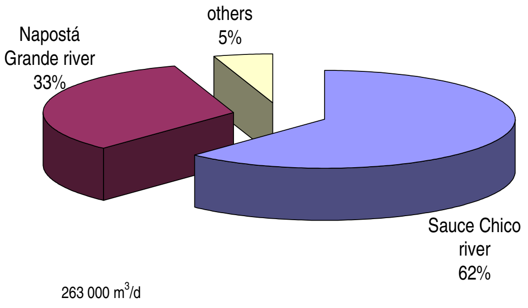


Fig. 11 - Surface water contribution to the estuary (Heffner, 2003)

The main characteristics of these two watersheds are:

- Napostá Grande – with a drainage area of 1.237 km^2; flowrate: 0.5 to 200 m^3/s; average flowrate: 0.9 to 1 m^3/s (aprox. 86 400 m^3/d).
- Sauce Chico – with a drainage area of 1600 km^2; length: 110 km; flowrate: 0.8 to 1.9 m^3/s; average: 1.5 to 1.9 m^3/s (aprox. 164 000 m^3/d).

In total, the surface water contribution to the estuary is approximately 263 000 m^3/d (*cf.* Fig. 11). Based on this fact, these will be the only two watersheds further analysed in this report.

9 HYDROGEOLOGY

9.1 Previous studies

Several works and research studies have been done previously about the hydrogeology of the study area of Bahía Blanca. Considering the interest of having an idea about their content, a very short list and abstract of their main features is hereinafter presented.

The first work was done by Wichmann (1918), which has performed the geologic and hydrogeologic assessment of the area. The author describes some hydrologic and hydrogeologic characteristics as well as the physical and chemical properties of the main strata containing water, based on the perforation wells existing at the time.

In 1964, García and de García have published an overall study about the water resources of Bahía Blanca region. The work contains an exhaustive analysis of the existing documentation about the climatology, geology, hydrology and hydrogeology, especially based on the deep wells drilled by ex-Dirección Nacional de Geología y Minería of the Bahía Blanca area. The same author, García (1969), presents a synthesis of the state-of-the-art concerning both surface and groundwater explaining the advantages of their simultaneous use, the technical problems that could arise from the exploitation, and the needs for further development.

In the beginning of the seventies, the Comité de Investigaciones de Aguas Subterráneas (C.I.A.S.) made a hydrogeologic inventory of the Buenos Aires province, based on a census of the wells at a 1:50 000 scale, with measurements of piezometric levels and chemical characteristics of the phreatic aquifer. This information was published by the Dirección y Manejo de Aguas Subterráneas, DYMAS (1974) with the title "Contribución al Mapa Geohidrológico de la Provincia de Buenos Aires, escala 1:500.000. Zona de Bahía Blanca y Nordpatagónica" and complemented with an analysis of the hydrogeologic environment.

Exception made to the works of Sala (1975) and Sala *et al.* (1983, 1985), which covered general issues about the hydrogeology, the hydrodynamics and the hydrochemistry of the province, there were no publications about the hydrology of the area until 1988. Carrica and others have made then a water balance of the upper part of Napostá Grande watershed with the purpose of characterizing the real evapotranspiration of the area.

In the same year, a PhD by Bonorino (1988) about the hydrogeology of the hydrothermal deep aquifer of Bahía Blanca is published, based on new geophysics, geologic and hydrogeologic information that allowed to up to date the deep stratigraphy and tectonics of the region.

Bonorino (1989) characterized the precipitation in the region and explained the main factors responsible for its mineralization along the pathway and, based on that, in 1991 estimates the water recharge in the hilly sector and its evolution along the infiltration pathway. In 1992, Carrica *et al.* (1992) updated this theory based on more information collected about water chemistry, presenting then the hydrochemical evolution of the phreatic aquifer from the hilly side of Sierras Australes through the vadose zone and the phreatic aquifer.

Albouy (1994) formulated the regional water balance and built up the hydrogeologic model of the phreatic aquifer of the upper Sauce Chico watershed.

Lexow, Carrica and Bonorino, (1994) estimated the vulnerability to pollution of the phreatic aquifer of the upper Napostá Grande watershed, using DRASTIC and GOD methods. Albouy and Bonorino (1998) did the same approach to the upper Sauce Chico watershed using DRASTIC methodology.

In 1997, Bonorino, Albouy and Carrica have analysed the hydrogeology of Sauce Chico, Napostá Chico and Grande, and Chasicó to determine and evaluate complementary sources of groundwater to supply Bahía Blanca needs.

Bonorino, Panarello, Carrica and Albouy (1996) have analysed the isotopic characteristics of the groundwater in relation with the phreatic aquifer dynamics as well as some watershed close to the accidental part of Sierras Australes.

Albouy (1994) and Carrica (1998) have developed their PhD about the hydrogeology of Sauce Chico and Napostá Grande watershed areas, respectively, and have considered the thematic globally.

In 1999, Bonorino, Albouy, Lexow and Carrica (Bonorino *et al.*, 1999), have studied the issue of nitrate content in the aquifer close to the hilly area of Sierras Australes.

Bonorino, Albouy, Carrica and Lexow (2000) have made an evaluation of the likelihood of exploiting groundwater in the upper and medium part of Napostá Chico watershed area.

In 2001, Bonorino, Albouy and Carrica (2001) have made a hydrochemic analysis of the phreatic aquifer in the SW hilly area of Sierras Australes, describing the main hydrochemical processes responsible for the existing changes in groundwater composition.

Carrica and Lexow (2002) have made an estimation of the aquifer natural recharge in the upper part of Napostá Grande watershed using computer and chemical water balance methods. The same authors have advanced in this work in 2004 and 2005 using experimental plots. Carrica and Robledo (2002) have tried to estimate recharge using recession curves from river hydrographs. Finally, Albouy, Carrica and Bonorino (2005) have identified an analysis of drainage processes in the aquifer under Napostá Chico and Sauce Grande watershed.

Carrica, Albouy and Bonorino (2003) have analysed the hydrodynamic changes of the coastal aquifer in the Ing. White area with reference to previous state. In 2005, the same authors have made a preliminary flow model of the phreatic aquifer in the coastal area of Bahía Blanca applying the Modflow model.

Carrica, Albouy and Bonorino (2003) have established a conceptual model about the hydrogeology of the site including recharge, discharge to the estuary, connection between surface and groundwater, as well as the influence of the industrial and petrochemical site (from the beginning of the XX century) in the quality of local surface and groundwater.

9.2 Hydrogeological characterization

The conceptual hydrogeological model hereinafter synthesized is based on the lithoestratigraphic scheme proposed by DYMAS (1974), modified by Bonorino (1988). The presentation is a simplified version of this complex system, aiming to understand the basic structure in which the groundwater study carried out in this project occurs.

9.2.1 Crystalline bedrock

The hydrogeological basement in the area is composed by the crystalline bedrock and the by the Palaeozoic sediments that form the nucleus of the Sierras Australes de la Provincia de Buenos Aires. The outcrops of these formations appear only in the high and median basin and are represented only by the Palaeozoic quartzite and quartzitic sandstones. Their deepness and thickness strongly varies from place to place.

This formation is generally classified as an aquifuge. It is considered that this rocks have no primary porosity and therefore no storage or transmissivity of water. Nevertheless, in some areas the folds and fracturation systems can produce a significant secondary porosity that plays and important role in water circulation creating springs, locally denominated "ojos de agua", and feeding the rivers up gradient all year long.

9.2.2 Hipoparanian Sector

This section includes the geologic formation from upper Cretaceous to Oligocene. Its presence can be registered in the lower and medium meridional parts the watersheds. It comprises different sets of formations, of marine and continental origin, that can act as confined aquifer, aquitard and aquifuge.

The deep hydrothermal system of Bahía Blanca corresponds to the upper part of this hydrogeological sector, inserted in the formations known as Colorado and Ombucta. This important aquifer, due to its complexity and magnitude, has been studied by several authors, among which are the works of Wichmann (1918), García y García (1964) and Bonorino (1988).

The recharge area of this system was identified to be located in the SW hill side of Sierras Australes. Nevertheless, a hydraulic connection between the phreatic aquifer and the deep regional flux is also supposed to exist, being responsible for the entrance of the surplus of water generated in the upper part of the basin to supply the regional deeper flow.

9.2.3 Paranian Sector

It is represented by a sedimentary miocenic formation of marine origin that results from a transgression period, known as Barranca formation. It overlaps the previous section in disconformity. This sector is classified as an aquiclude with some intercalations of aquifer formations with high content of salt. Close to Bahía Blanca this formation appears between 250 and 350 m below the surface. No outcrops are known. Some wells have natural thermal springs with 30 m^3/h (water between 25 and 34°C).

9.2.4 Epiparanian Sector – phreatic aquifer

At the present state of knowledge this sector is, from a hydrogeologic point of view, the most interesting system in terms of continuity in water transmission, constituting the phreatic aquifer of this region (Carrica *et al.*, 2003). It is composed of one or two main formations that outcrop in the area, depending on the region, and is composed by a set of sediments that extend from the Mio-Pliocene to the present days.

The main hydrogeological formation is "La Norma", which belongs to the Miocenic superior-Pleistocene inferior (De Francesco, 1992). It forms the lower limit of the system in the study area and outcrops in several parts of the basin. Its lithology is mainly fine sand to clay with a calcium carbonate cement as well as calcareous levels, known as "sedimentos pampeanos" (Fidalgo *et al.*, 1975). The mineralogical composition of these sediments is quartz and alkaline feldspaths and volcanic sediment, being the smaller fraction composed by calcite, illite, and montmorillonite (Bonorino *et al.*, 2001). This is a multi-layer system with aquifer-aquitard levels that is regionally considered with a homogeneous transmissivity.

In some parts of the coastal area, from 5 m above the sea level until the bottom of the Bahía Blanca estuary, the pampean sediments are covered by sand, limes and clay (bottom to top) formations of marine environment, denominated "Maldonado formation" (Fidalgo, 1983), a Pleistocene Superior formation also known as post-pampean. Its thickness can reach 15-20 m close to the main channels and decreases towards the continent until it disappears some 4 to 5 km from the coast. This formation has very low hydraulic gradient and a hydrodynamic where vertical movements dominate.

Accordingly to the information available, the maximum thickness of the overall aquifer formation is less than 200 m, decreasing towards the hill side of Sierras Australes (Bonorino *et al.*, 2001). Regionally the base of this aquifer is difficult to define as well as the continuity of different sedimentary layers that might occur. This aquifer is considered in close hydraulic connection with the surface water of the valley above due to the rapid changes in the piezometric levels after rain events as well as to the low salinity of its waters.

The isopiestic maps existing in the Sauce Chico watershed correspond to data obtained in 80-90 by Albouy (1994). Close to the hills the predominant flow direction is NE-SO, casi parallel to Sierra de la Ventana, an important area of groundwater recharge. Here the surface water acts as influent towards the phreatic aquifer. In the medium part of the watersheds the groundwater flow is mainly N-S. In the plain area, the situation is reversed and the groundwater feeds the rivers in most parts of its extension. The groundwater flow in the low part of the watershed is divided in 3 sectors (Bonorino, 1988) with different directions due to fault systems and several other vicissitudes, like the various subterraneous works at Bahía Blanca city. The morphology of the phreatic surface is radial and divergent with the concavity towards the upper part of the terrain. The hydraulic gradients are very different from the upper and lower watershed: the higher values are closer to the hills around 13 per thousand, lowering to the medium area of the watershed to values of the order of 2 to 6 per thousand, and in the south values in some parts to less than 1 per thousand.

The lithologic and geometric changes of the aquifer and the insufficient and disperse information does not allow to confer representative values of the hydraulic characteristics. Here are presented some of the existing values for the cases where information was collected. The permeability of this system is attributed to a secondary porosity from macropores and microfissures.

Torrente *et al.* (1989) have determined permeability values of 0.08 y 2 m/d and an effective porosity of 12.5%, based on laboratory results of granulometric and volumetric analysis in samples with loess with lime (60 - 70%) of the hilly area. Bonorino *et al.* (2000) based on 6 pumping tests have determined transmissivity values between 50 and 200 m^2/d, K between 0.5 and 2 m/d, and specific yield 0.1 (Albouy *et al.*, 2005). It is possible that the permeability in the lower zones is bigger due to the higher content of sandy in the existing soils (Rossi, 1996). In the coastal zone pumping tests have given transmissivities between 51 and 62 m^2/d (Bonorino and Sala, 1983). Carrica, 1998 has determined for a specific sector of Napostá Grande values of transmissivity of 93 m^2/d and hydraulic conductivity of about 1.2 m/d, considering a local aquifer thickness of 75 m.

The base of this sector, in the low and medium watershed, is composed by sand and clay that became more sandy southwards. This level is an aquifer resurgent or semi-resurgent with water of stable quality (2 a 5 g/l of total dissolved solids) also with recharge in SW hill side of Sierras Australes. Transmissivity values area about 50 m^2/d, with permeability of about 2.5 m/d.

The values estimated for the aquifer using groundwater flow models in stationary conditions show good fitting for permeability values between 1-3 m/d and transmissivity values between 100 and 180 m^2/d.

9.3 Groundwater contributions to the estuary

In what concerns the groundwater contribution to the estuary, Heffner (2003) concludes that this value is about 0.6% of the total water flowing to the estuary (*cf.* Fig. 12).

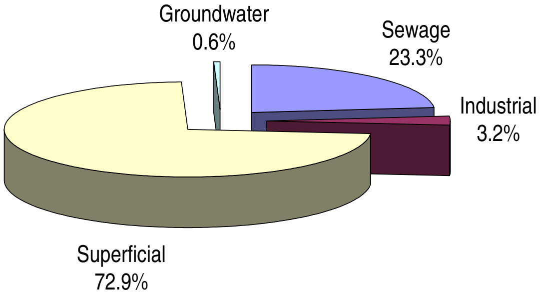


Fig. 12 - Origin of main water contribution to the estuary (Heffner, 2003)

These values were calculated using Darcy law, where the flowrate is calculated as the product of soil permeability (Kc) times the flow area (A) and the hydraulic gradient ($\partial h/\partial L$). The author has assumed an average Kc from bibliography, the hydraulic gradient from the phreatic level mapping and has calculated the flow for four different areas, being the area the product between the thickness of the aquifer and the coastal line distance. The calculated value was 2 000 m^3/d. This value concerning groundwater contribution will be further studied and validated using other methodologies, under this project.

Contributions from industrial and urban effluent (sewage) are presented in Fig. 12. Further details about its calculation can be consulted in Heffner (2003). This issue will be further developed in Deliverable 2.8 for Bahía Blanca.

10 HYDROCHEMISTRY

10.1 Introduction

As above referred in Section 7, the origin of the data gathered for this project comes from several previous studies in the region as well as from new monitoring campaigns carried out specifically for this project. The data refers to both surface and groundwater of the main regional watersheds contributing to the estuary: Napostá Grande and Sauce Chico (*cf.* Section 2).

The water composition in the area is a result of a set of factors that influence its quality, *e.g.* the climate, topography, geology, type of soils and vegetation. The precipitation over the existing outcrops in the study area can turn to be direct surface runoff. In the case of high intensity rain events, this water can have a composition close to that of the rain, or can result in infiltration through the fractures with some interconnection and appear again at the surface in springs enabling infiltration into the phreatic aquifer. The water composition depends on the paths of circulation, as well as on the time of permanence in the aquifer or the river.

As a result of what was said above, the water quality varies in time and space and its characterization validates mainly a specific sampling period and local.

In the next sections a more detailed analysis and interpretation of the data is made, divided in the two main contributing watersheds, and considering its surface and groundwater.

10.2 Surface water of Napostá Grande

The data used for the characterization of the surface water at Napostá refers to 22 sampling points, with 277 analyses collected since 1992.

Fig. 13 presents the origin of these data, as well as the information collected by each institution, and the sampling period to which it refers to. The 22 sampling points include the 8 data points with new information collected by the local ECOMANAGE team in 2006 for this project (*cf.* Fig. 9, Fig. 14 and Fig. 16).

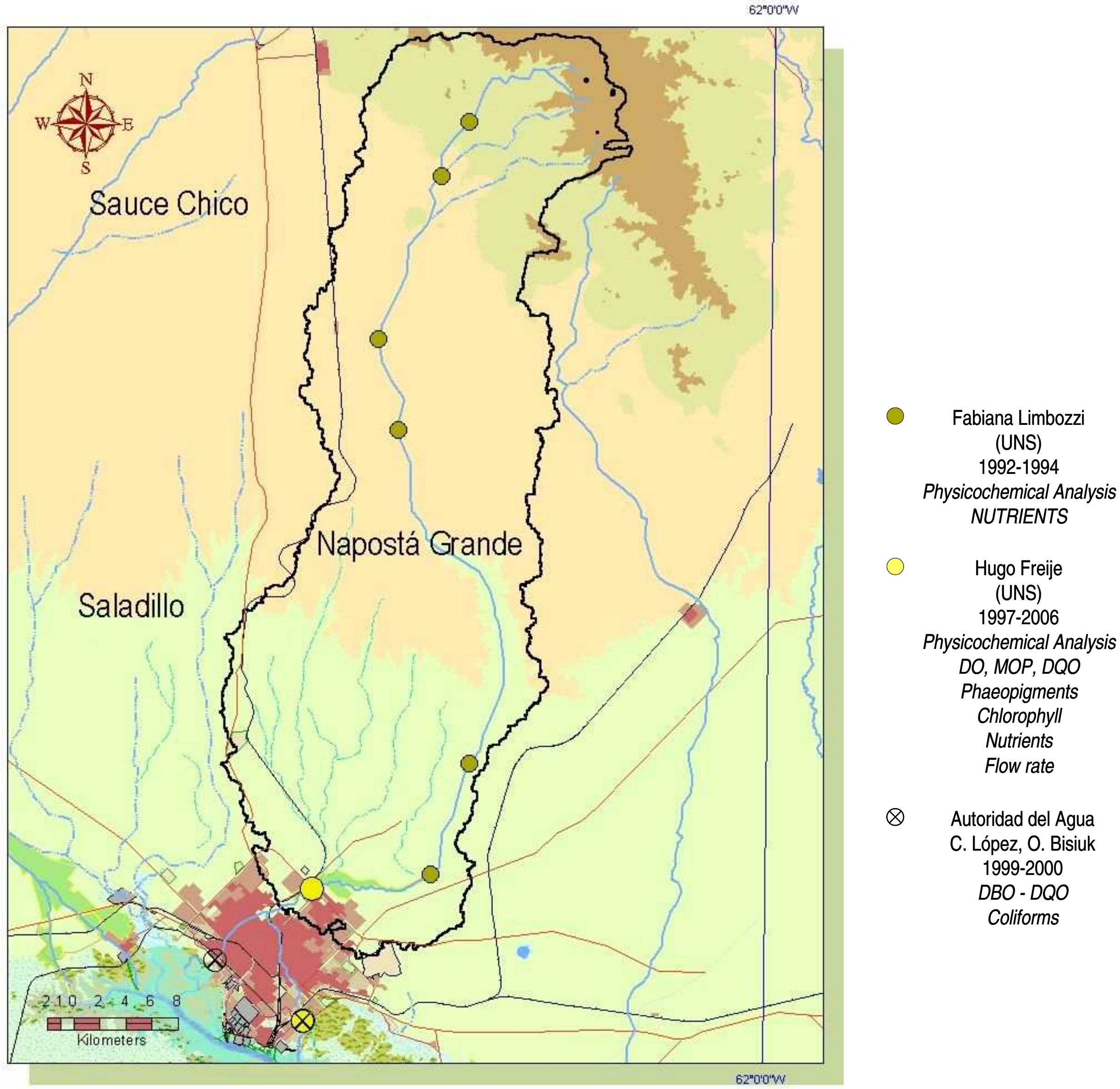


Fig. 13 - Surface water monitoring points at Napostá Grande watershed

Fig. 14 - Sampling area at Napostá Grande river (Puente Canesa)

Table 11 and Table 12 present the results obtained under ECOMANAGE campaigns for surface and groundwater in the Napostá Grande watershed.

Table 11 - Physico-chemical results of the water collected at Napostá Grande watershed on April 2006 for ECOMANAGE project

SITE	Lat [S]	Long [W]	Color	Odor	Turbidity	Sediment	TDS	Alkalinity	Hardness	Cl^-	SO_4^{2+}	Ca^{2+}	Mg^{2+}	Fe	As	F^-
			U.C		N.T.U.						[mg.L^{-1}]					
S1	38.14530	62.09288	5	*sg*	0.3	Null	194	83	78	19	9	25	4	0.013	0.005	0.1
S2	38.18291	62.11711	5	*sg*	0.3	Null	300	173	134	34	11	37	10	0.016	0.008	0.5
S3	38.29657	62.17097	5	*sg*	0.2	Null	468	207	146	48	48	38	12	0.012	0.031	1.0
S4	38.59079	62.08802	15	*sg*	2.7	Null	839	278	153	44	164	38	14	0.028	0.095	2.6
S5	38.77030	62.23328	8	*sg*	3.7	Null	1,129	224	186	204	239	35	24	0.019	0.100	2.4
S6	38.73941	62.24746	8	*sg*	2.6	Null	1,170	312	178	212	236	41	18	0.021	0.110	2.9
S7	38.66841	62.12065	5	*sg*	1.7	Null	1,032	308	180	195	215	35	23	0.020	0.090	3.0
S8	38.67787	62.22260	15	*sg*	7.2	Null	1,136	312	168	220	212	18	30	0.013	0.080	2.8
G1	38.14757	62.06529	5	*sg*	0.2	Null	249	124	148	15	5	40	12	0.013	0.003	0.5
G2	38.18955	62.10693	5	*sg*	0.4	Null	328	173	149	23	15	40	12	0.044	0.014	0.6
G3	38.17239	62.15832	5	*sg*	0.2	Null	870	300	123	115	73	33	10	0.037	0.032	1.3
G4	38.23758	62.18168	5	*sg*	0.2	Null	442	226	159	28	24	48	10	0.022	0.025	0.6
G8	38.23175	62.12747	8	*sg*	1.6	Null	603	274	178	55	61	44	17	0.060	0.010	0.8
G11	38.59530	62.09411	5	*sg*	0.6	Null	1,383	395	57	240	258	13	6	0.029	0.200	7.3
G12	38.61581	62.22768	5	*sg*	0.2	Null	1,410	226	172	299	311	32	23	0.024	0.064	4.3
G13	38.73849	62.19822	10	*sg*	6.5	Null	2,673	330	176	780	386	59	7	0.079	0.080	2.1
G14	38.66906	62.12023	500	*sg*	49.4	Present	1,955	203	132	610	445	14	24	0.127	0.080	2.7
G15	38.67413	62.13044	100	*sg*	134.0	Present	1,875	117	80	386	367	17	9	0.040	0.170	5.8

Note: S1 to S8 designate surface water sampling sites and G1 to G15 indicate groundwater sampling sites. sg means Sui Generis

Table 12 - Physico-chemical results of the water collected at Napostá Grande watershed on April and June 2006 for ECOMANAGE project

SITE	Lat [S]	Long [W]	Cond [μS.cm^{-1}]		pH		T [ºC]		Turb [NTU]		DO [mg.L^{-1}]		NO_2^- [mmoles.L^{-1}]		NO_3^- [mmoles.L^{-1}]		PO_4 [mmoles.L^{-1}]		NH_4 [mmoles.L^{-1}]		Water depth wm[m]
			April-06	Jun-06	April-06	Jun-06	April-06	Jun-06	April-06	Jun-06	April-06	Jun-06	April-06	Jun-06	April-06	Jun-06	April-06	Jun-06	April-06	Jun-06	
S1	38.14530	62.09288	266	420	7.7	8.0	12.0	9.8	1	21	5.7	5.6	0.2	0.1	5	35	0.4	0.4	14.2	10.7	-
S2	38.18291	62.11711	440	521	8.2	8.1	21.0	9.4	4	14	7.5	4.9	0.1	0.5	144	23	0.6	0.3	14.2	4.3	-
S3	38.29657	62.17097	687	727	9.0	9.0	13.3	11.1	2	6	12.5	11.4	0.3	0.2	112	70	0.3	0.8	10.6	6.4	-
S4	38.59079	62.08802	1,220	1,340	9.6	9.3	13.9	11.0	4	16	11.3	9.1	0.6	0.4	161	42	0.4	0.8	5.5	8.6	-
S5	38.77030	62.23328	1,730	nd	9.0	nd	14.3	nd	10	nd	7.9	nd	2.6	nd	106	nd	2.2	nd	8.7	nd	-
S6	38.73941	62.24746	1,770	nd	8.7	nd	14.6	nd	9	nd	8.5	nd	1.3	nd	90	nd	1.6	nd	10.2	nd	-
S7	38.66841	62.12065	1,480	nd	9.1	nd	12.9	nd	3	nd	9.3	nd	0.7	nd	46	nd	0.5	nd	7.1	nd	-
S8	38.67787	62.22260	1,760	nd	9.4	nd	13.2	nd	64	nd	9.5	nd	0.7	nd	35	nd	0.8	nd	3.9	nd	-
G1	38.14757	62.06529	371	412	7.3	7.8	15.7	8.7	2	37	5.8	5.2	0.0	0.1	203	132	0.5	0.3	10.2	7.5	6.7
G2	38.18955	62.10693	485	494	8.1	7.9	15.4	10.4	3	1	6.5	6.5	0.1	0.1	309	326	0.7	0.9	13.4	7.5	6.0
G3	38.17239	62.15832	1,320	1,340	7.9	7.8	15.7	15.1	1	1	5.6	4.9	0.0	0.1	916	1,438	0.4	0.4	7.9	6.4	6.3
G4	38.23758	62.18168	683	nd	8.1	nd	15.8	nd	1	nd	7.9	nd	0.0	nd	574	nd	0.5	nd	10.2	nd	nd
G5	38.21440	62.19551	nd	842	nd	8.6	nd	9.1	nd	4	nd	8.9	nd	1.9	nd	744	nd	1.3	nd	5.4	4.3
G6	38.25615	62.18278	nd	835	nd	7.9	nd	15.6	nd	0	nd	3.9	nd	0.1	nd	770	nd	0.8	nd	3.2	10.9
G7	38.28970	62.20971	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	21.4
G8	38.23175	62.12747	903	nd	8.4	nd	14.5	nd	18	nd	7.5	nd	0.3	nd	315	nd	0.2	nd	14.2	nd	13.4
G9	38.34921	62.13190	nd	1,020	nd	8.4	nd	12.5	nd	2	nd	6.3	nd	0.1	nd	289	nd	1.1	nd	0.0	16.0*
G10	38.59459	62.06570	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	24.2
G11	38.59530	62.09411	2,130	2,190	8.2	8.5	18.3	18.4	2	3	7.5	3.7	1.6	0.3	234	250	3.3	2.2	7.1	2.1	28.4
G12	38.61581	62.22768	2,220	2,230	8.2	8.6	16.2	13.1	74	6	8.3	6.9	0.0	0.1	283	521	0.4	0.7	7.9	4.3	nd
G13	38.73849	62.19822	4,250	nd	8.0	nd	19.4	nd	34	nd	7.4	nd	7.0	nd	149	nd	0.4	nd	14.2	nd	36.0*
G14	38.66906	62.12023	3,180	nd	8.4	nd	17.3	nd	72	nd	8.2	nd	2.5	nd	71	nd	3.1	nd	21.3	nd	6.0*
G15	38.67413	62.13044	2,080	nd	8.3	nd	15.1	nd	67	nd	8.1	nd	0.0	nd	135	nd	1.9	nd	7.1	nd	6.0*

Note: S1 to S8 designate surface water sampling sites and G1 to G15 indicate groundwater sampling sites.
(*) indicates “informed” and (nd) means “not determined”

The set of information available is very different. Some places have been monitored monthly since the end of the nineties, having therefore more than 70 analyses, and some other places have results of samples taken only once. On the other hand, the available information about each parameter also differs, being possible to find parameters that were analysed for 260 different samples (case of electrical conductivity) and others for 8 samples (case for hardness), as can be seen in the top part of Fig. 15.

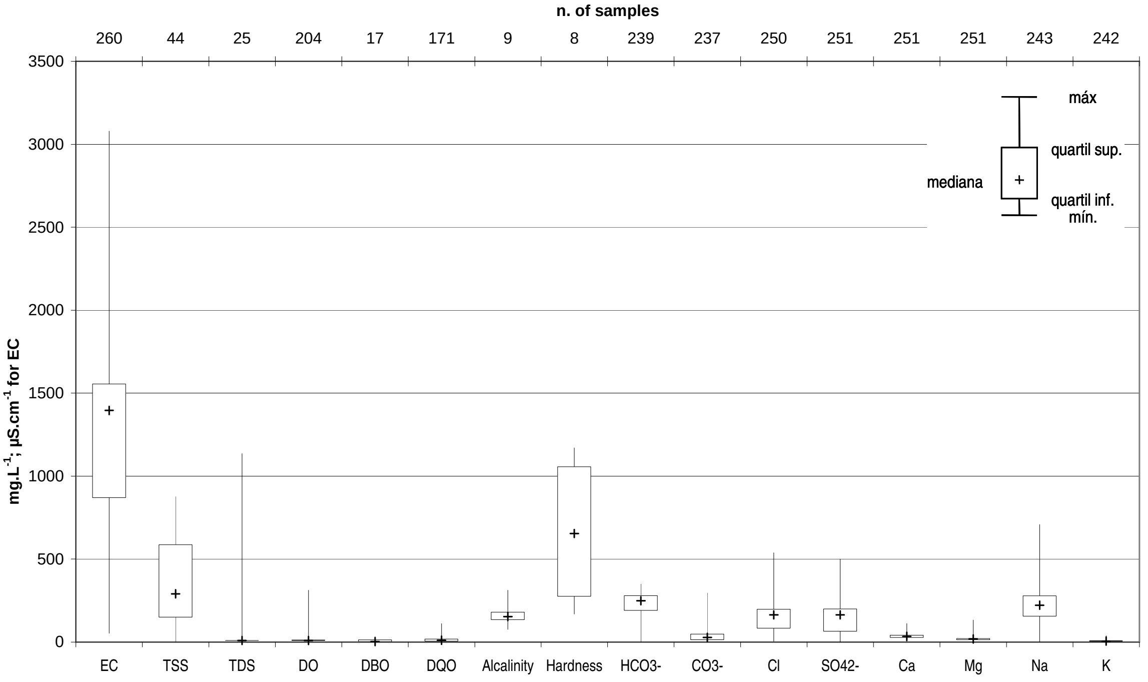


Fig. 15 - Concentration of major ions and other water properties in surface water of Napostá Grande watershed

Concerning the main water quality features, it is possible to observe that the water electrical conductivity mainly ranges between 800 and 1600 µS.cm^{-1}, with a median value of about 1400 µS.cm^{-1} (*cf.* Fig. 15). Fig. 16 shows the present spatial distribution of these values along the basin. It is possible to detect a general trend for an increase of the water electrical conductivity downgradient. No significant changes are observed comparing the current situation to the results in the 90 decade (*cf.* Fig. 25), although the sampling points are not the exactly the same.

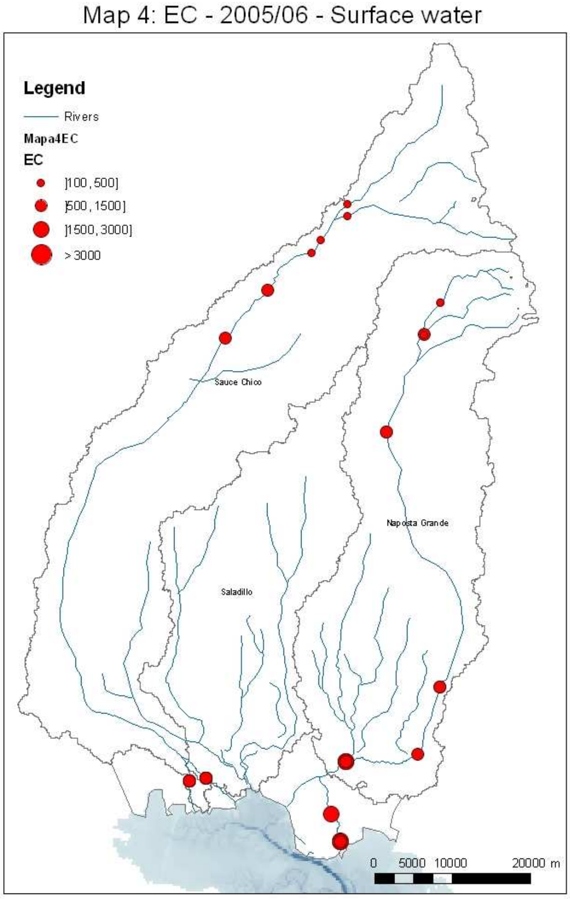


Fig. 16 - Electrical conductivity values (µS.cm^{-1}) of surface water in 2005/06, in Napostá Grande and Sauce Chico watersheds, including the data collected by ECOMANAGE team

The major ions content in the water shows considerable changes along the watershed and therefore it is possible to find different facies (cf. Fig. 17). The water shows a high content of suspended solids in most analyses and also hardness. Considering pH (*cf.* Fig. 18), most waters are alkaline, possibly due to the calcareous origin of some of the soil composition, which is also responsible for the water hardness.

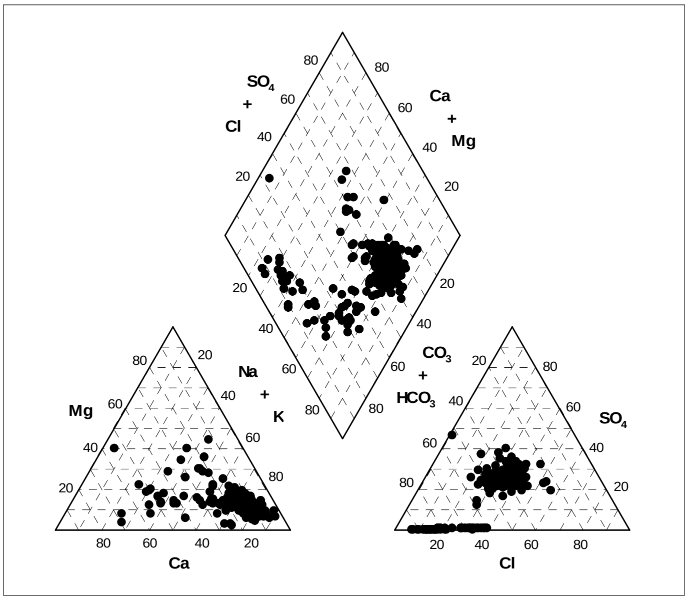


Fig. 17 - Piper diagram for the surface water in Napostá Grande watershed

As can be seen in Fig. 18, the concentration of nitrogen in water, in all its main forms, is low. By the opposite, arsenic (As) and fluoride (F) content are quite high for the less than ten samples analysed. The As median is 0.09 mg.L^{-1} and the F median is 2.38 mg.L^{-1}, being the guideline values proposed by the World Health Organization (WHO, 2006 in Annex I) 0.01 and 1.5 mg.L^{-1}, respectively. The presence of these two elements is random in space and it can be attributed to the contact with some components of the loessic sediments ("loess") which cover this region (Bonorino *et al.*, 2001).

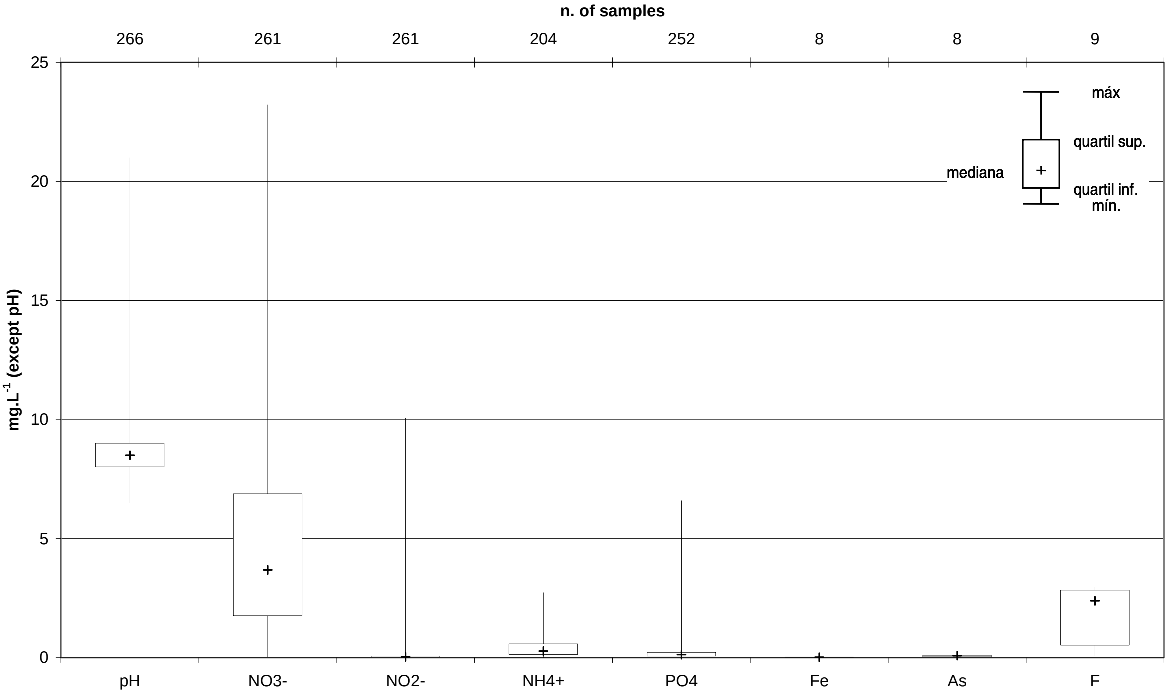


Fig. 18 - Concentration of some ions and pH in surface water of Napostá Grande watershed

The influence of the pressures identified in section 3 can be seen in the water quality of Napostá, namely in the samples taken monthly in the river since 1997, upstream and downstream the city of Bahía Blanca, as can be seen in Fig. 19. In most cases, it is possible to observe a slight increase in the electrical conductivity of the water in the samples taken after the city. However, it is in the nitrate content that this contrast is clearer, with several analyses doubling the nitrate content in the samples taken after the city.

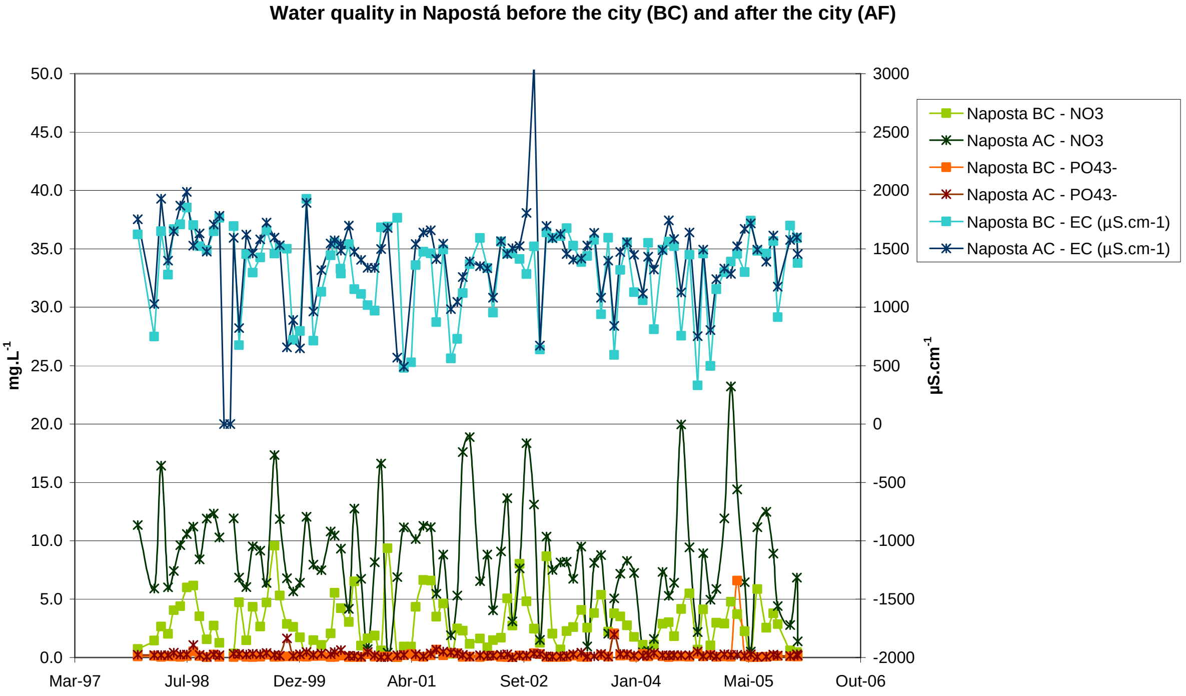


Fig. 19 - Surface water quality in Napostá Grande river, before and after the city of Bahía Blanca

Although the influence of the city in terms of water quality is clear for nitrates, their values are still above the guideline of 50 mg.L^{-1} defined by WHO (2006) for drinking water (see Annex I). In Fig. 20 and Fig. 21 it is possible to observe a spatial distribution of the values in the 90 decade and the values registered after 2000. Once more, the influence of anthropogenic nitrate sources is possible to observe closer to the city.

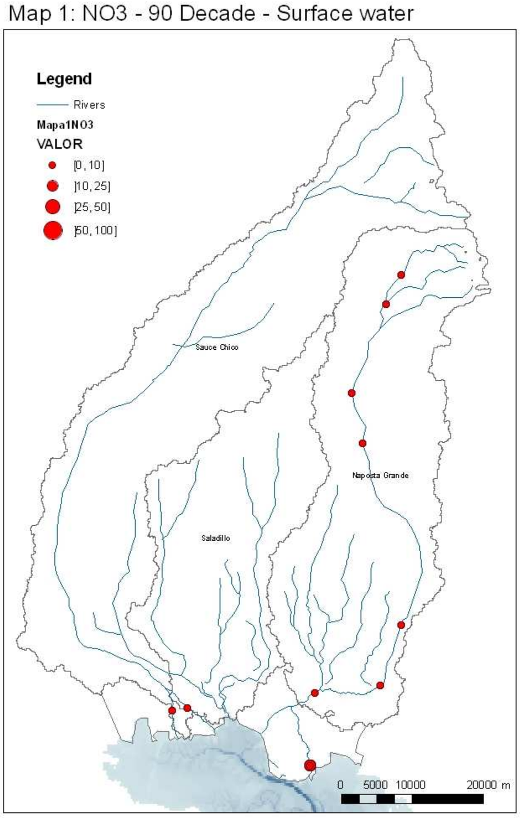


Fig. 20 - Nitrate values (mg.L^{-1}) of surface water in the 90's, for Napostá Grande and Sauce Chico watersheds

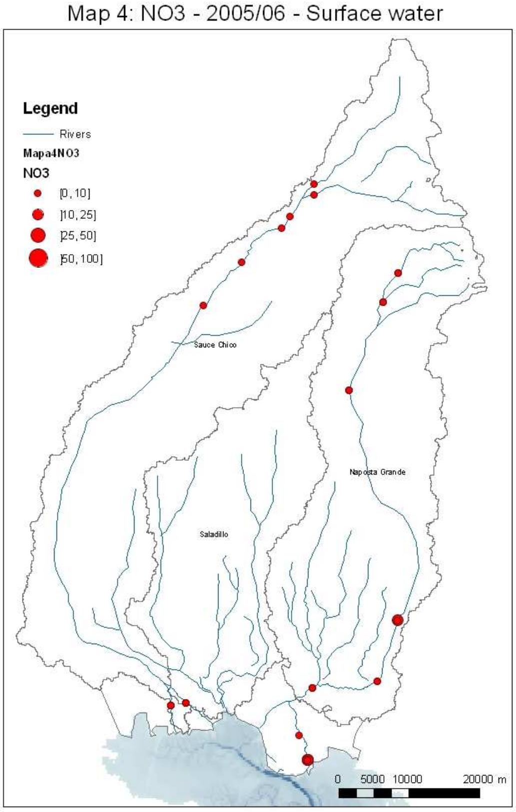


Fig. 21 - Nitrate values (mg.L^{-1}) of surface water in 2005/06, for Napostá Grande and Sauce Chico watersheds, collected by ECOMANAGE team

The situation concerning nitrate content is already different for groundwater, where the influence of diffuse pollution can be observed in the upper and medium part of the watershed, as will be further analysed in the next section.

10.3 Groundwater of Napostá Grande

Groundwater was monitored and sampled in several parts of the watershed and during different periods of the year, as shown in Fig. 22, totalizing 60 sampling points and 75 analyses, done since 1986. These 60 points include the new piezometers installed during ECOMANAGE project and other samples taken for this project, represented in Fig. 9, Fig. 26, Fig. 23, Table 11 and Table 14.

In most sampling points the water was collected only once, with some few exceptions for 2 or 3 samples taken in the same well. Therefore, the existing data does not allow an assessment of water chemical composition evolution in one area, as was possible for some cases for the watershed surface water.

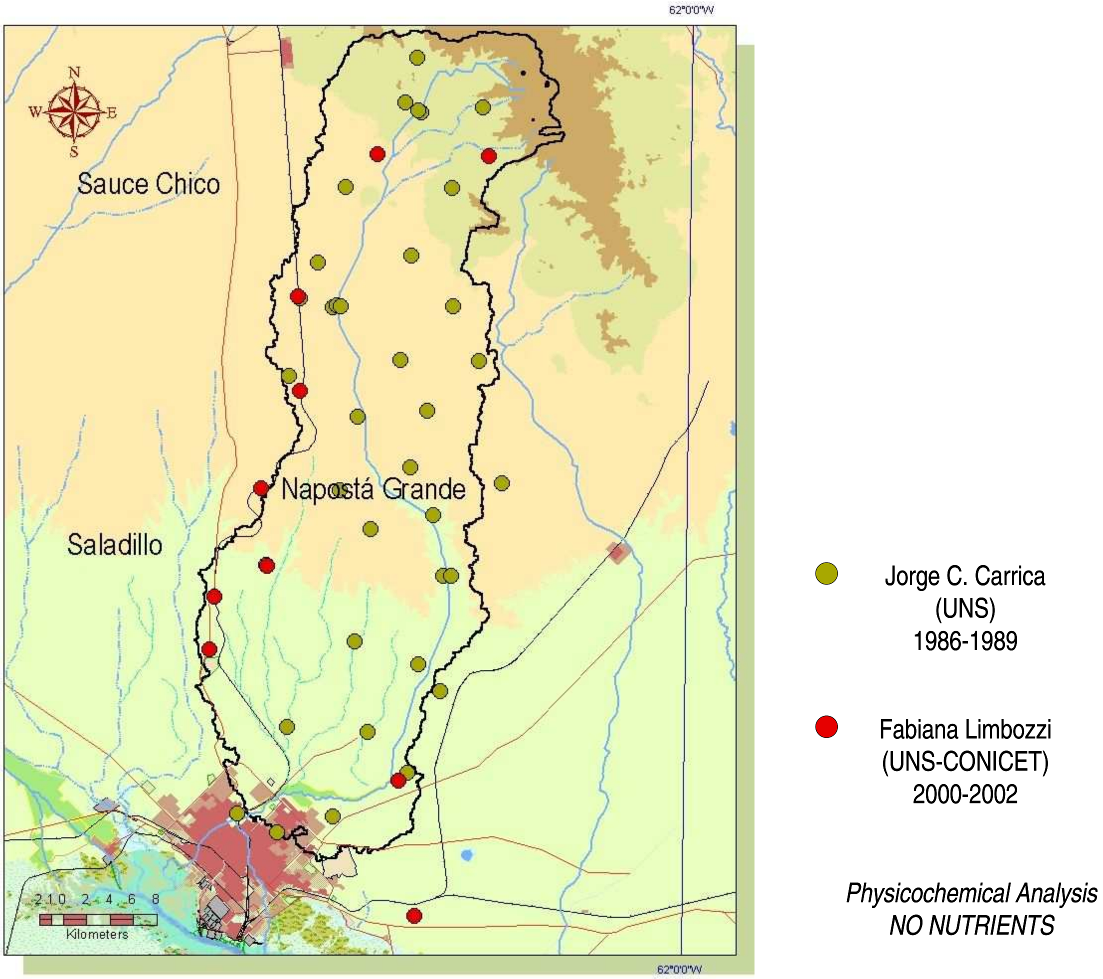


Fig. 22 - Groundwater monitoring points at Napostá Grande watershed

Fig. 23 - Groundwater monitoring in La Viticola

The existing data for the major ions is represented in the Piper diagram of Fig. 24. These data correspond to 39 samples that were taken by Carrica (1998) in a sampling period between 1986 and 1989.

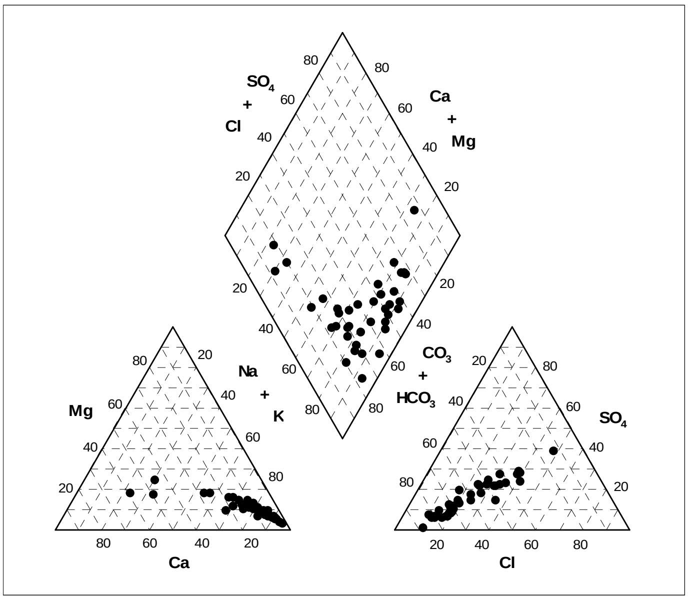


Fig. 24 - Piper diagram for the groundwater in Napostá Grande

The results presented in the Piper diagram confirm that almost all water samples are bicarbonated-sodic or, less frequently, calcic. Some authors (Bonorino *et al.* 2001) refer an evolution of this facies towards the aquifer discharge area in estuary to a sodium-chlorinated facies.

Concerning the main groundwater characteristics, the electrical conductivity of the water ranges from 160 and 6420 µS.cm^{-1}, with a median value of 1268 µS.cm^{-1}. In Fig. 25 it is possible to observe a tendency to and increase in the electrical conductivity values towards the estuary in the samples collected during the nineties. In fact, there is an increase of salinity downgradient due to an enrichment of salts from evaporation and the water circulation in the aquifer along the watershed reaching a maximum in the coastal discharge area.

In Fig. 26 a present situation concerning groundwater values for electrical conductivity is presented for the whole study area. No big changes are observed concerning the values or the trend of bigger values close to the estuary, although the sampling points are not exactly the same.

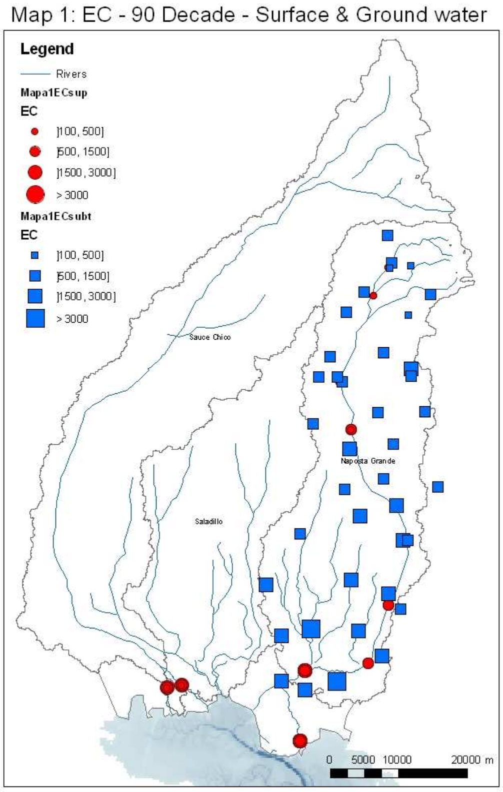


Fig. 25 - Electrical conductivity values (μS.cm^{-1}) in the 90's, both for surface (dots) and groundwater (squares)

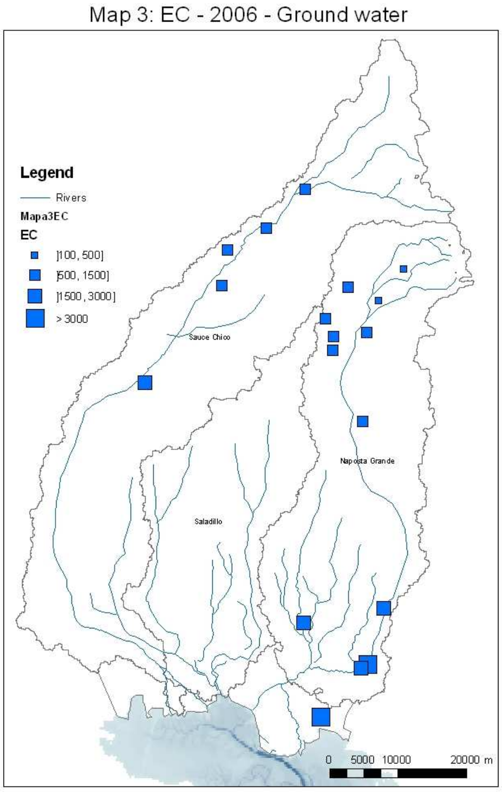


Fig. 26 - Distribution of the electrical conductivity values (μS.cm^{-1}) in the groundwater in the year 2006

The values of the major ions in water are presented in Fig. 27. It is possible to confirm that bicarbonate and sodium ions median values (+) are dominant, conferring the bicarbonated-sodic classification above referred. Nevertheless, chloride and sulphate maximum values can be very high in some few samples close to the estuary.

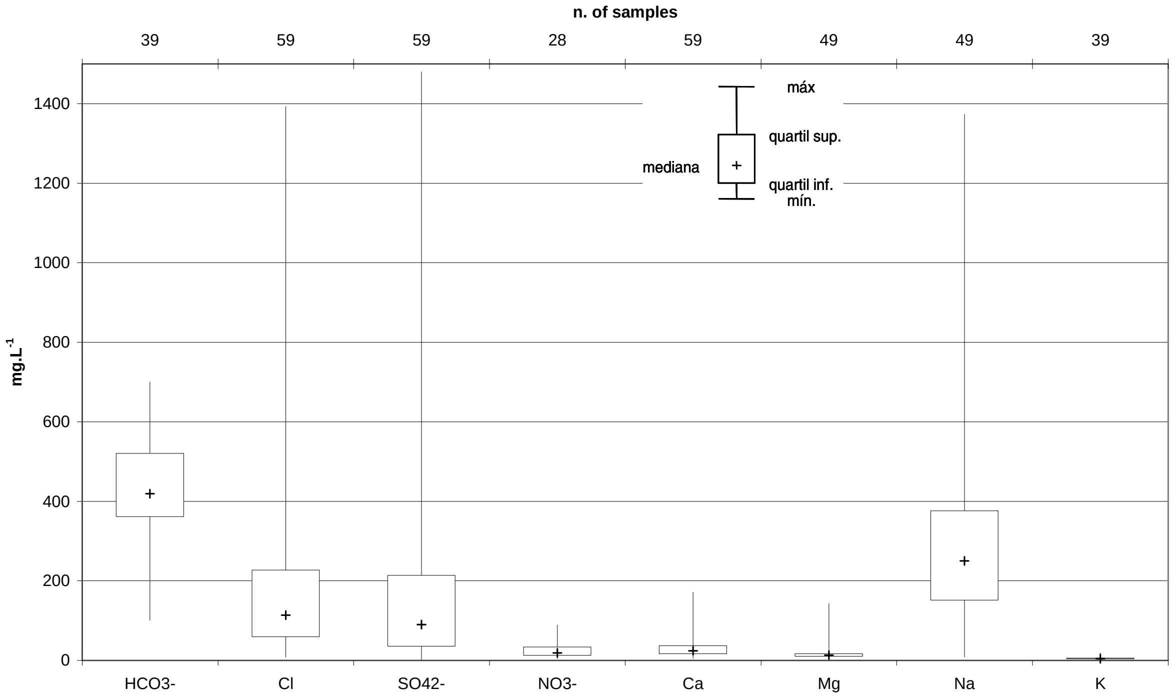


Fig. 27 - Concentration of major ions in the groundwater of Napostá Grande watershed

The groundwater characteristics in terms of electrical conductivity and the cation content confer to most waters a high to very high risk of salinization and a large range of risk to alcalinization for agriculture purposes, as can be seen in the Riverside diagram presented in Fig. 28.

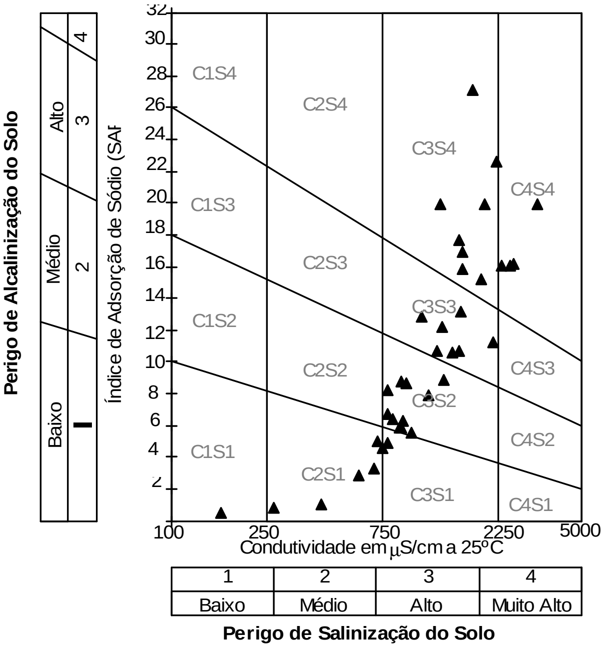


Fig. 28 - Risk of salinization and alcalinization of the groundwater in Napostá Grande watershed

Concerning the nitrate content in the groundwater, values range from 4.4 to 89.2 mg.L^{-1}, with a median value of 18.6 mg.L^{-1}. The higher contents of nitrate are observed in the upper part of Napostá Grande watershed. Possibly this is connected to agriculture deficient practices.

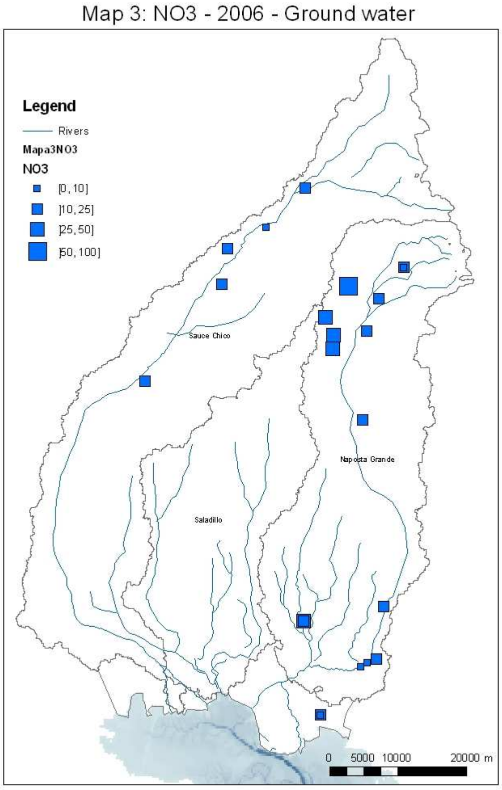

Map 3: NO3 - 2006 - Ground water

Fig. 29 - Nitrate concentration distribution (mg.L^{-1}) in the groundwater in the year 2006

Concerning the remaining elements analysed in groundwater, most are lower than 1 mg.L^{-1}, except for fluorite that can reach 10 mg.L^{-1}, although its median value is 2.7 mg.L^{-1} (*cf.* Fig. 30). For some elements this value exceeds the guideline values proposed by the World Health Organization (WHO, 2006 in Annex I), which produces international norms on water quality and human health in the form of guidelines that are used as the basis for regulation and standard setting, in developing and developed countries world-wide (http://www.who.int/water_sanitation_health/dwq/guidelines/en/index.html). This is the case for arsenic (As) that has a median value of 0.053 mg.L^{-1} (WHO guideline = 0.01 mg.L^{-1}) and fluorine (F) that has a median value of 2.65 mg.L^{-1} (WHO guideline = 1.5 mg.L^{-1}). The presence of these two elements is random in space and it can be attributed to the contact with some components of the loessic sediments ("loess") which cover this region (Bonorino *et al.*, 2001). The concentrations of iron (Fe) are also high but no health significant problem can derive from that.

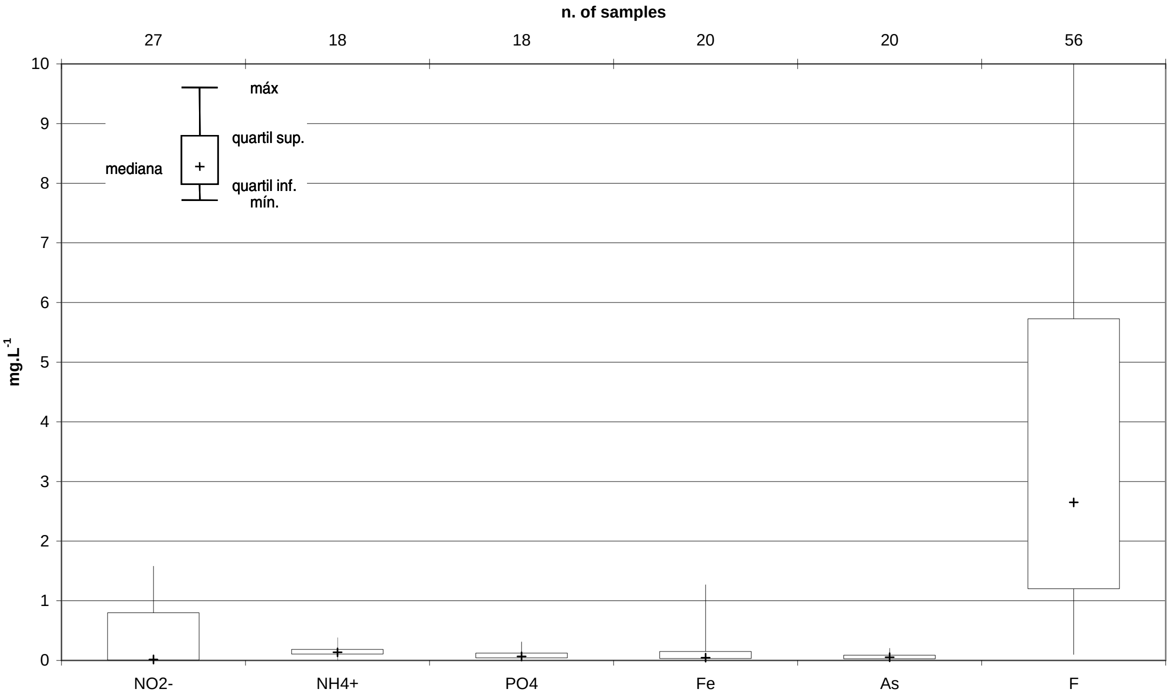


Fig. 30 - Concentration of minor ions in the groundwater of Napostá Grande watershed

There is another area of importance concerning the groundwater quality, *i.e.* the coastal area of Ing. White, where several studies have been carried out (Bonorino and Sala, 1983; Sala *et al.*, 1985; Carrica *et al.*, 2003; Lafont *et al.*, 2005). These studies intended to establish a conceptual model about the hydrogeology of the site including recharge, discharge to the estuary, connection between surface, as well as the influence of the industrial and petrochemical site (from the beginning of the XX century) in the quality of local surface and groundwater. The study area is only 7.7 km^2 large and comprises the sediments of post-pampean age with a hydraulic gradient of 2-3 per thousand, 4 m above sea level. These sediments only outcrop in the area close to the estuary and do not exist in a large area of the studied site.

In a hydrogeochemical point of view the post-pampean sediments of Ing. White area are very different from the chemical data above described. The local groundwater is brine with an electrical conductivity between 47,600 and 108,100 μS.cm^{-1} and highly sodium chloride content, typical from discharge waters will low circulation and high residence time. These values tend to increase in depth, largely surpassing the salt sea water content. The relations between Mg/Ca and Cl/HCO_3 show circulation of water through marine sediments.

Lafont *et al.* (2005) have made an inventory of groundwater quality analysing the presence of minor elements (Ag, Cd, Cr, Hg, Mn, NI, Pb, Sb, Se, U and Zn) and total petroleum hydrocarbons in the water and their spatial distribution, based on 22 sampling points installed, which complement the previous studies in the area from Bonorino and Sala (1983) and Sala *et al.* (1985). The results of this study indicate heavy metals contamination in several wells at Ing. White connected to industrial activity with the following relation: Se >> Mn > Cr > and with a more isolated spatial pattern and concentration Zn > Ag > Pb > Ni. Cd and Hg concentrations were lower than the detection limits; Sb and U were lower than guide value of Argentinean law. Total hydrocarbons are diffused all over the area with the higher values close to the fuel deposits. This pollution affects not only the upper level of post-pampean sediments, but also in a minor extension, the pampean sediments.

In synthesis, the chemical composition of the groundwater is controlled by the mineralogy and chemistry of the aquifers sediments as well as the hydrodynamics of each sector, both from Napostá Grande and Sauce Chico watersheds.

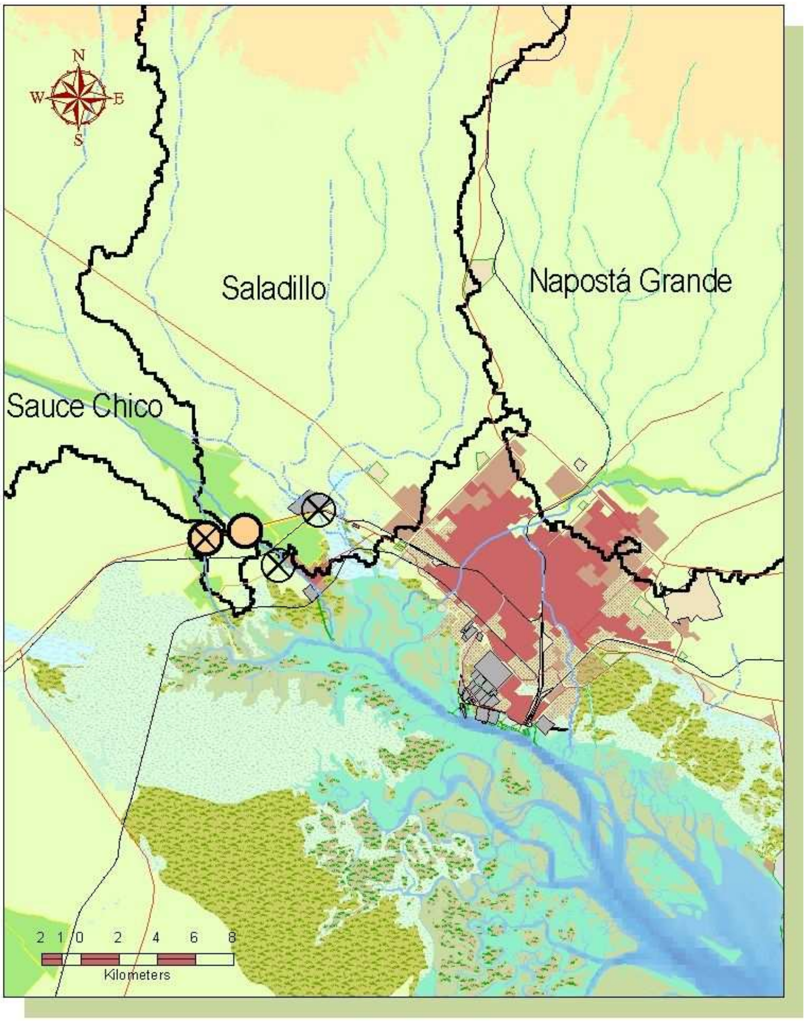
The chemical evolution of the groundwater from rain water, through all the processes in the vadose zone and aquifer, has been extensively explained by Bonorino (1991), Carrica *et al.* (1992) and more recently by Rossi (1996).

Carrica *et al.* (1992) have identified the main processes, based on the analysis and interpretation of hydrogeochemical data: concentration of salts due to evaporation or evapotranspiration in the soil; hydrolysis of feldspaths, carbonates and volcanic sediment from the vadose zone soils and aquifer matrix; cationic interchange of calcium and magnesium for sodium and potassium. As a result, the groundwater in the recharge areas conserve a typical rain water pattern (bicarbonated calcic/magnessic) with a slight increase of bicarbonates, silica, calcium and sodium and loss of potassium as result of the combination of hydrolysis of feldspaths and carbonates processes and the adsorption of potassium by the soil clays. These processes occur not only in the soil level but also in the aquifer itself. The higher salt content downgradient also results from the slow infiltration and the multiples processes of evaporation. As a consequence of these processes and the slow water circulation, the water quality increases in chloride and sodium towards the discharge areas.

Other phenomenon like leaching of loessic sediment is responsible for the presence of silica, sodium and other trace elements in water, as is the case for fluorine and arsenic.

10.4 Surface water of Sauce Chico

The existing information corresponds to data collected by two entities referred to in Fig. 31 plus the new data collected for ECOMANAGE project (*cf.* Fig. 9, Fig. 32, and Table 13). Altogether, the data refers to 13 different points for which there are 236 analyses. Most of the information (about 200 analyses) was collected by Freije only in the 2 spots pointed out in Fig. 31.



● Hugo Freije
(UNS)
1997-2006
Physicochemical Analysis
DO, MOP, DQO
Phaeopigments
Chlorophyll
Nutrients
Flow rate

⊗ Autoridad del Agua
C. López, O. Bisiuk
1999-2000
DBO - DQO
Coliforms

Fig. 31 - Surface water monitoring points at Sauce Chico and Saladillo watershed

Fig. 32 - ECOMANAGE sampling area at Sauce Chico river

The results from the data collected for ECOMANAGE project can be found in Table 13 .

Table 13 - Physico-chemical results of the water collected at Sauce Chico watershed on July 2006 for ECOMANAGE project

SITE	Lat [S]	Long [W]	Cond [μS.cm^{-2}]	pH	T [ºC]	Turb [NTU]	DO [mg.L^{-1}]	NO$_2^-$ [μmoles.L^{-1}]	NO$_3^-$ [μmoles.L^{-1}]	PO$_4$ [μmoles.L^{-1}]	NH$_4$ [μmoles.L^{-1}]	POM [mg C.m^{-3}]	Water depth [m]
SS1	38.03210	62.22990	400	7.6	12.4	0	6.7	0.4	131	0.9	28.9	809	-
SS2	38.04558	62.23011	463	8.2	9.5	16	6.9	0.5	119	0.5	10.7	nd	-
SS3	38.07434	62.26850	457	8.3	11.1	1	7.7	2.8	129	2.4	16.1	445	-
SS4	38.08953	62.28248	481	8.4	11.2	1	8.5	2.6	152	3.0	3.2	3,494	-
SS5	38.13338	62.34659	576	8.6	11.8	16	8.8	1.4	136	1.6	3.2	259	-
SS6	38.18927	62.40778	616	8.9	12.2	14	9.2	0.7	112	1.8	5.4	88	-
GS1	38.04443	62.23138	620	7.3	14.2	0	5.8	0.2	309	2.3	18.2	55	8.4
GS2	38.09596	62.29521	1,040	7.5	15.1	1	6.4	0.2	119	0.6	10.7	nd	10.7
GS3	38.10625	62.31365	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	16.3
GS4	38.12461	62.36090	623	7.5	16.5	2	2.6	0.4	351	0.7	9.6	1,222	24.2
GS5	38.13590	62.39004	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	23.1
GS6	38.17170	62.36901	729	8.4	17.8	2	5.4	0.1	196	0.8	5.4	125	24.4
GS7	38.29968	62.49610	1,620	7.7	16.3	2	5.4	0.1	212	1.1	8.6	54	3.4

Note: S1 to S6 designate surface water sampling sites and G1 to G7 indicate groundwater sampling sites.

The water samples collected in the two points above referred are bicarbonated and chlorinated – sodic. The other points have not enough information about major ions, making a similar analysis not viable.

The water collected in the two points with more information shows no significant change of its pattern since 1997 in what concerns electrical conductivity, nitrate and phosphorous, as can be seen in Fig. 33. The values of electrical conductivity even show a slow tendency to a decrease in its values along the past decade.

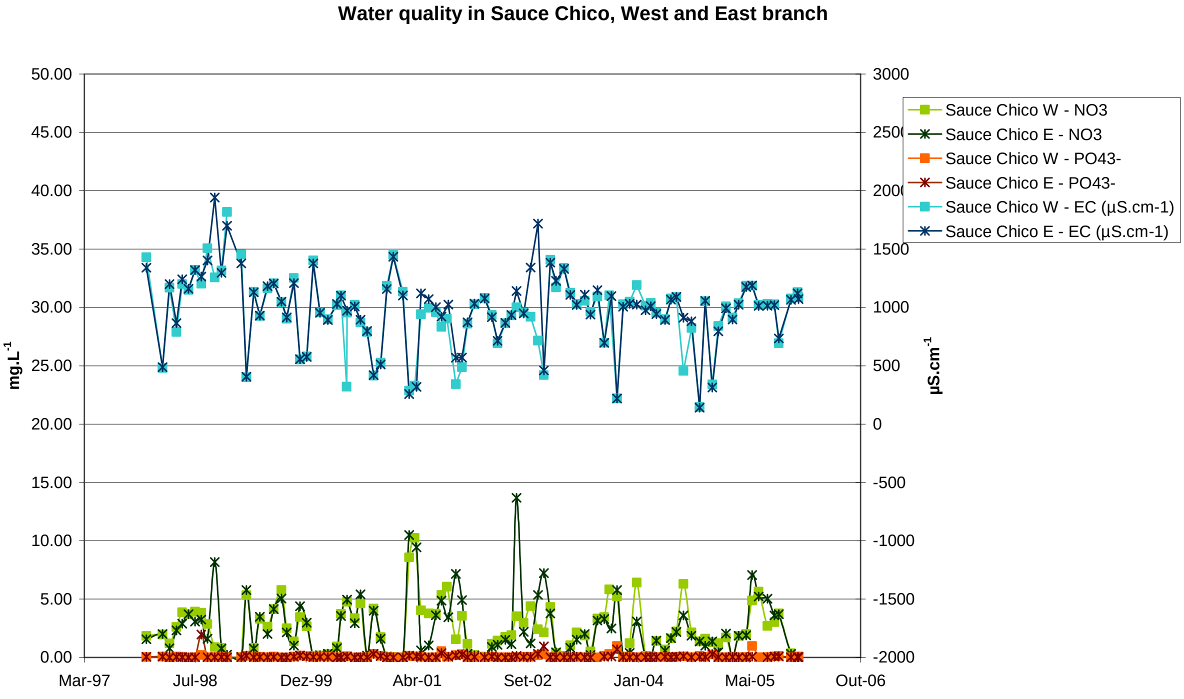


Fig. 33 - Surface water quality in Sauce Chico, in the west and east river branch

Fig. 34 presents a statistical projection of the available data concerning major ions, electrical conductivity and oxygen content in water.

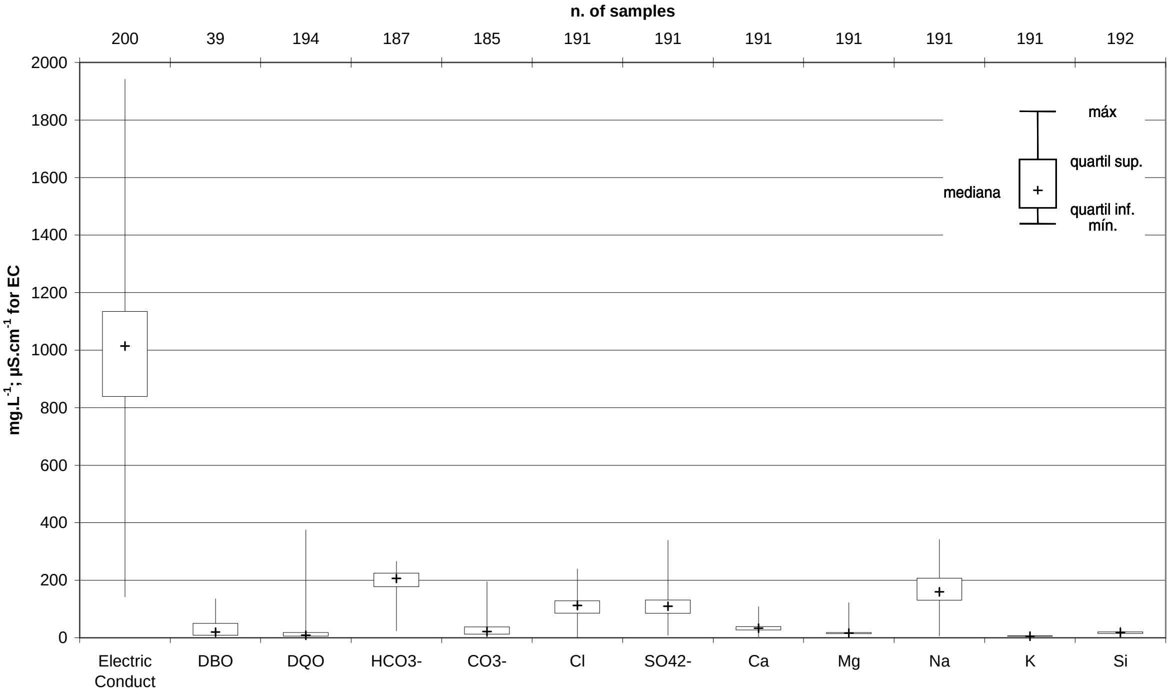


Fig. 34 - Concentration of some elements in the surface water of Sauce Chico river

Albouy (1994) characterizes the surface water in the upper part of Sauce Chico watershed, for data taken in several points of the drainage area, after 30 days without rain. The electrical conductivity increases from the spring to downgradient from 130 µS.cm^{-1} to 375 µS.cm^{-1}. The superficial water has bicarbonated-calcic facies with the following pattern:

$$HCO_3 > Cl > SO_4 \quad \text{and} \quad Ca > Na > Mg > K$$

The same author refers that in the middle of the watershed the water chemical composition changes to bicarbonated-sodic reflecting the effluent nature of it, since it presents the same evolution observed in the phreatic aquifer.

Concerning the nitrogen content in water in Sauce Chico, Fig. 35 shows the existing results with all data available for ECOMANAGE, where it is possible to observe that nitrates as well as nitrites and ammonium have low values. Also dissolved oxygen exists in normal concentrations for surface water.

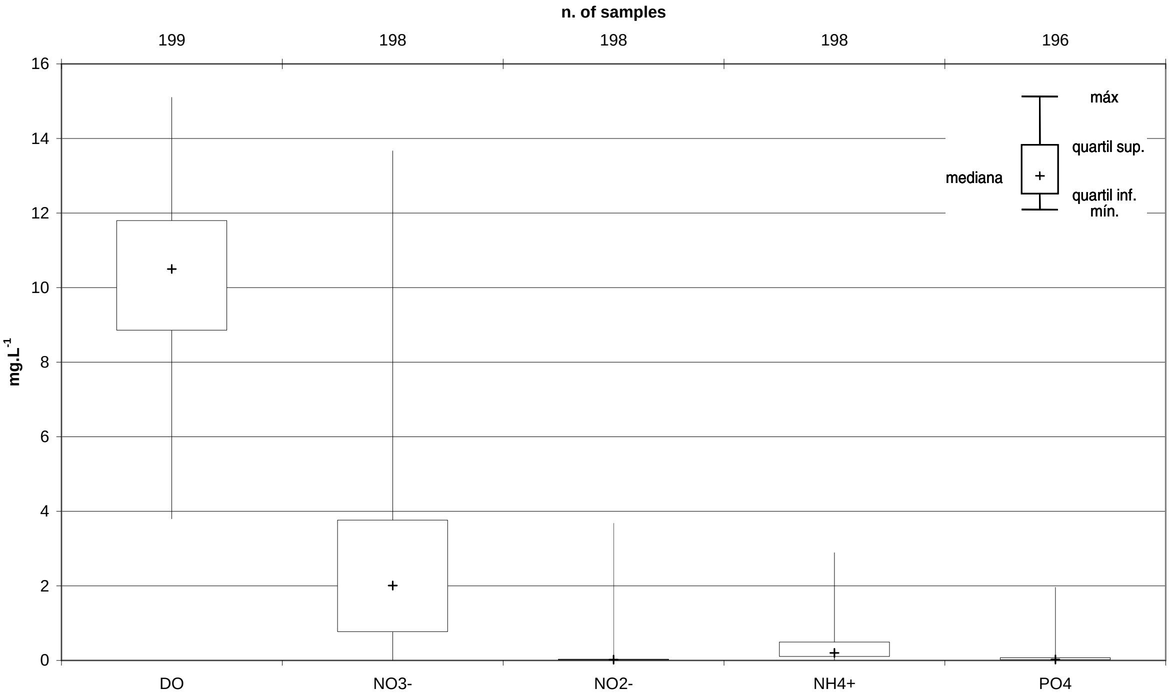


Fig. 35 - Concentration of nitrogen and phosphates in the surface water of Sauce Chico river

10.5 Groundwater of Sauce Chico

The groundwater characteristics within Sauce Chico watershed are presented hereinafter based on the previous analysis (*cf.* Fig. 36) for the period of 1988-1990 (*cf.* Albouy, 1994), now complemented with new data collected for this study, as referred in Fig. 9, Table 9 and Table 13. The data totalize 41 sampling points and 42 analyses.

The aquifer system within Sauce Chico watershed is the same phreatic aquifer of Napostá. The reason why they are presented separately in this report is to help analyzing the amount of information and to better understand the hydraulic connections and influences from the surface water in the groundwater quality. Most studies in the regions also consider them separately.

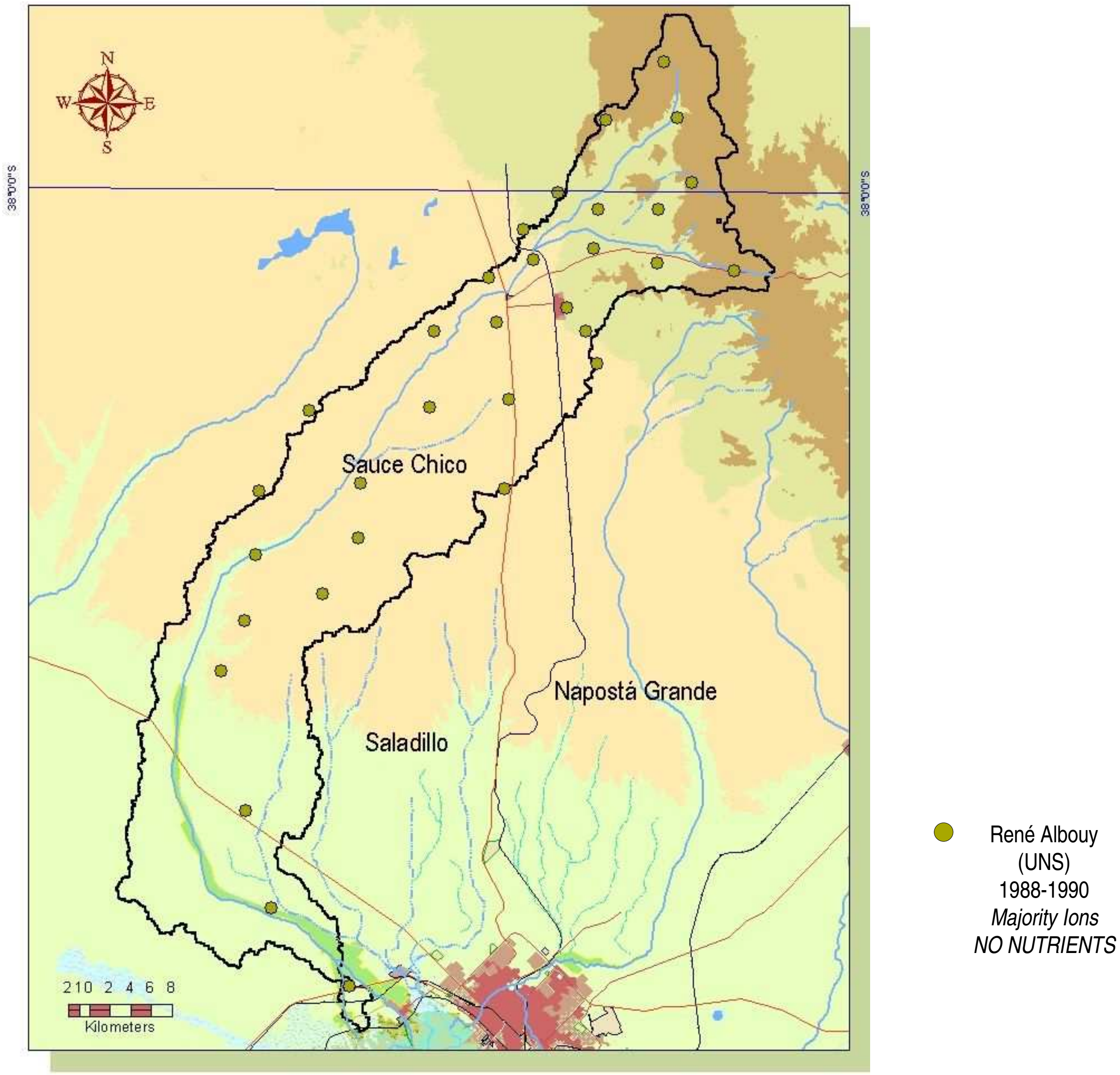


Fig. 36 - Groundwater monitoring points at Sauce Chico watershed

The water facies is bicarbonated calcic, magnessic and sodic (*cf.* Fig. 37). Albouy (1994) refers that the recharge water with low circulation tends to be bicarbonated-calcic converting to bicarbonated-sodic downgradient.

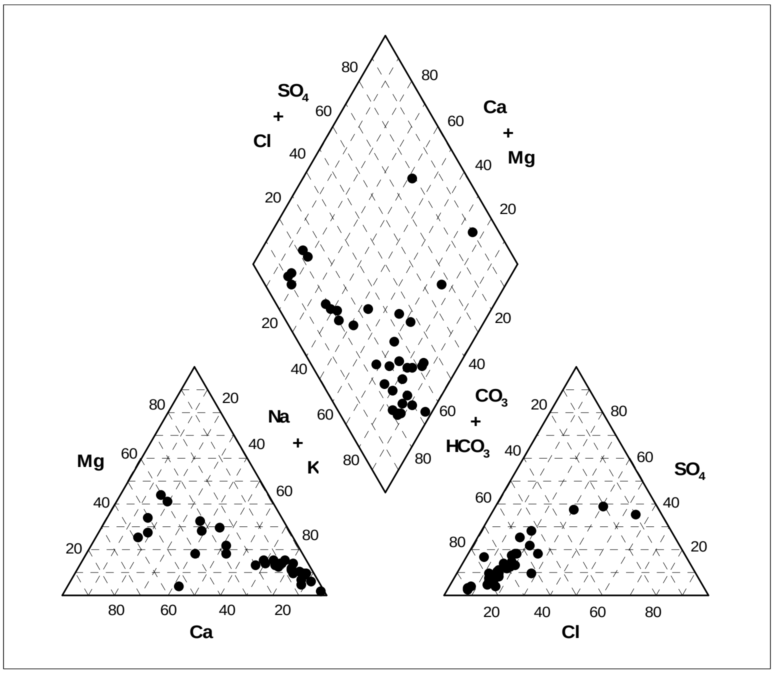


Fig. 37 - Piper diagram for the groundwater of Sauce Chico area

Similar to Napostá Grande watershed, also in this area the ionic concentrations tend to increase towards the estuary due to the ionic enrichment along the aquifer, from the recharge to the discharge area (*cf.* Fig. 39). Concerning the electrical conductivity of waters, values range from 126 and 1620 µS.cm^{-1}, with a median value of 662 µS.cm^{-1}. The lower values are found in the north hilly sector, close to the recharge area, and the more saline sectors are found closer to Bahía Blanca. The higher salinity and electrical conductivity in the discharge area are also related to: the high piezometric levels found; the very low hydraulic gradients; as well as the lower sediment permeability, which favours the evapotranspiration and vertical infiltration in comparison to groundwater horizontal flow (Sala *et al.*, 1985).

Fig. 38 presents a synthesis of the major ions concentrations in the groundwater in the Sauce Chico area.

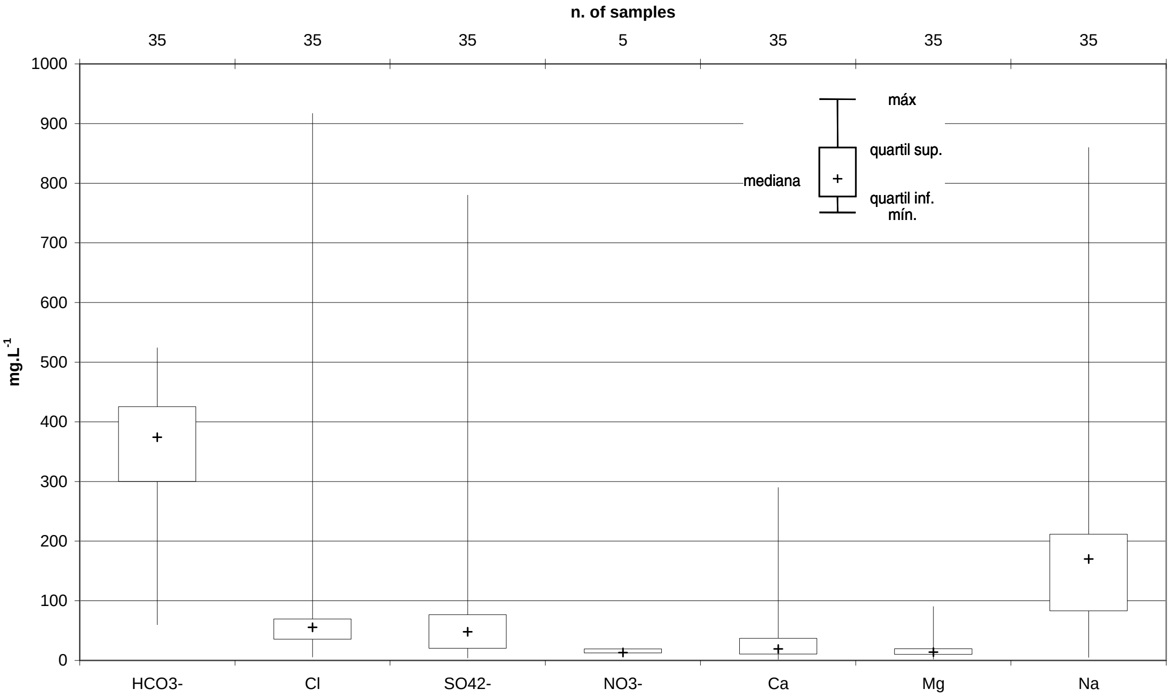


Fig. 38 - Concentration of major ions in the groundwater of Sauce Chico area

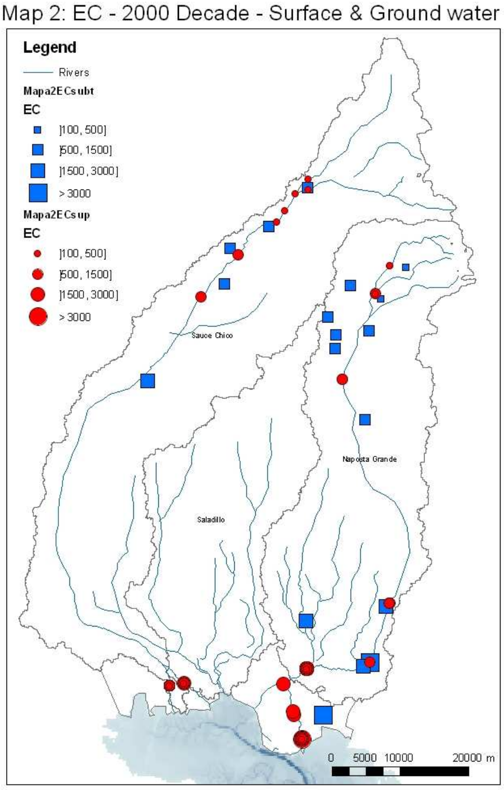


Fig. 39 - Distribution of the electrical conductivity values (µS.cm^{-1}) in the 2000 decade, both for surface (dots) and groundwater (squares)

It is possible to observe that some changes in the groundwater quality are due to chemical differences in the surface water and the local interconnection between the two.

11 SUGGESTION OF A FUTURE MONITORING PLAN

In the framework of ECOMANAGE project, a monitoring plan was settled and carried out by Instituto Argentino de Oceanografía team in Bahía Blanca. In previous sections the results of this work were presented for surface and groundwater of both watersheds: Napostá Grande and Sauce Chico.

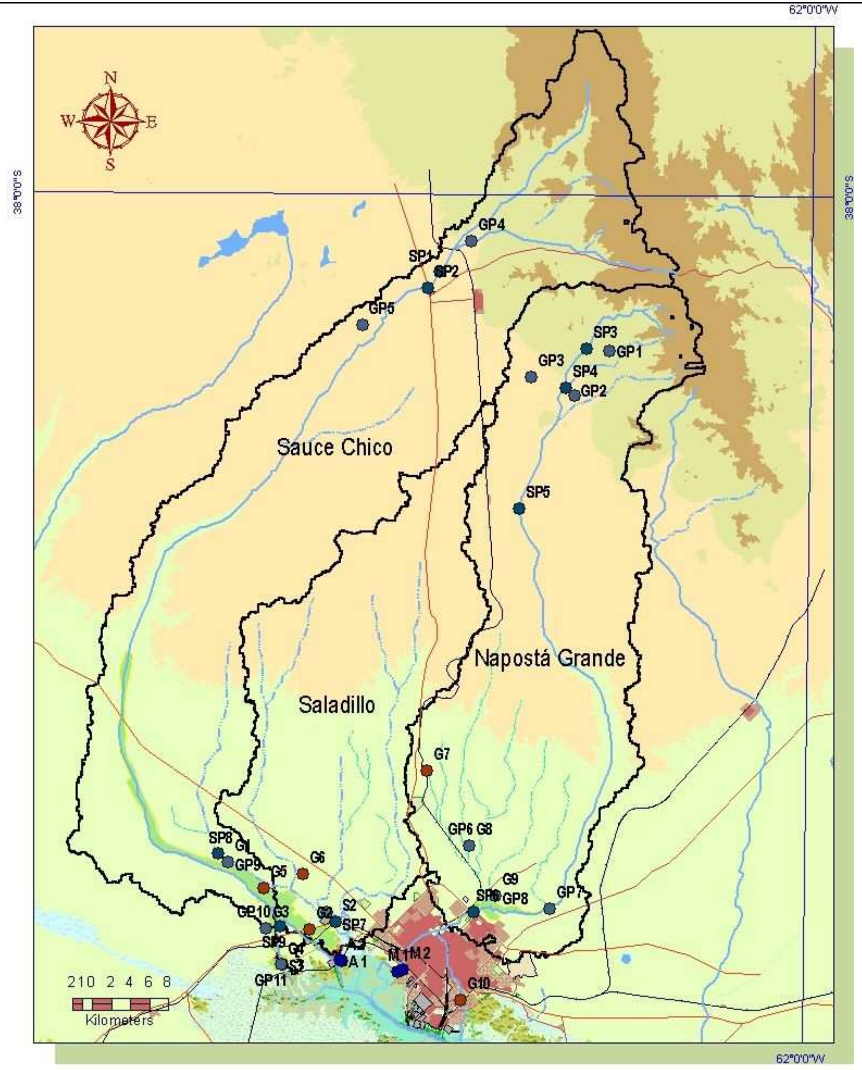
The purpose of that work and the monitoring task under development are mainly two:

1. Update the existing available information and assessing other missing parameters;
2. Fill-up the gaps of information in space.

Following that work and based on the results of the monitoring programme above presented, other sites for future sampling have been selected in sectors near the river mouths, in order to establish the direct incidence that the watersheds might have in the estuary. The sampling sites location and a brief description of their characteristics are shown in Fig. 40 and in Table 14. It is planned to monitor surface water and groundwater for a wide range of constituents, including nutrients and pesticides in those parts of the basins in which high concentrations of nitrate and agricultural chemicals were found or are expected.

Concerning to the surface water, considering that a team of the Universidad Nacional del Sur (National University of South) makes periodically water analysis of Sauce Chico river and Napostá Grande river and that the results are available to the ECOMANAGE team, by courtesy of Dr. Hugo Freije and Lic. Raul Asteasuain, only a single optional sampling site in the Sauce Chico river was included, in the sector where a flow gauge station was installed. However, considering the scarce information available about the water quality of Saladillo river, two points strategically located upstream and downstream to the zone in which the gascompany TGS and a slaughterhouse unload their effluents have also been selected (Fig. 41).

In the new and already existing monitoring points, both for surface and groundwater, it is proposed to continue monitoring the following chemical components: nutrients (nitrogen various forms and phosphorous), organic matter, E-coli, dissolved oxygen, chloride, and, if possible, some pesticides.



- **S** - superficial water points: where the same parameters will be monitored
- **SP** - superficial water points: where new parameters will be also included
- **G** - groundwater points: where the same parameters will be monitored
- **GP** - groundwater points: where new parameters will be also included

Fig. 40 - Location of the new ECOMANAGE monitoring points

Fig. 41 - Siracusa slaughterhouse's water treatment plant

Table 14 - Characteristics of the new ECOMANAGE monitoring points

SITE	Lat [S]	Long [W]	Note
S1	38.67974	62.39948	Before slaughterhouse and TGS gas company
S2	38.68845	62.38844	After slaughterhouse and TGS gas company
S3	38.72836	62.45216	Flow gauge station
G1	38.63229	62.51815	Before horticultural zone
G2	38.69569	62.41912	After slaughterhouse and TGS gas company
G3	38.69508	62.47218	After horticultural zone
G4	38.72935	62.45286	Flow gauge station
G5	38.65710	62.47455	After horticultural zone
G6	38.64357	62.42787	Before slaughterhouse and TGS gas company
G7	38.54505	62.27984	Before landfill (IPES)
G8	38.61596	62.22769	After landfill (IPES)
G9	38.66256	62.19570	After private cemetery
G10	38.76106	62.23688	After city
A 1	38.72490	62.38020	Piezometer
A 2	38.72480	62.38260	Piezometer
M 1	38.73540	62.31270	Piezometer
M 2	38.73330	62.30695	Piezometer
SP1	38.07434	62.26850	Before paper mill
SP2	38.08953	62.28248	At paper mill
SP3	38.14530	62.09288	Livestock-agricultural management
SP4	38.18291	62.11711	
SP5	38.29657	62.17097	
SP6	38.67787	62.22260	Aldea Romana horticultural zone
SP7	38.68845	62.38844	After slaughterhouse
SP8	38.62498	62.53001	Before horticultural zone
SP9	38.69339	62.45561	After horticultural zone
GP1	38.14757	62.06529	Livestock-agricultural management
GP2	38.18955	62.10693	
GP3	38.17239	62.15832	
GP4	38.04443	62.23138	
GP5	38.12461	62.36090	
GP6	38.61581	62.22768	
GP7	38.67413	62.13044	Los Mirasoles horticultural zone
GP8	38.66256	62.19570	After Cemetery
GP9	38.63229	62.51815	Before horticultural zone
GP10	38.69508	62.47218	Horticultural management
GP11	38.72935	62.45286	

In Napostá watershed, a measuring point near the river mouth was included, in a section downgradient of almost all the Bahía Blanca city. Also some points of interest located upstream and downstream of a private cemetery and of a landfill (IPES- Fig. 42) have been selected.

Fig. 42 - IPES Industrial waste treatment plant

Monitoring of the Sauce Chico river upstream and downstream from a paper mill is an ongoing activity. At the lower part of study area the sampling sites have been selected in sectors in which the horticultural activity is intense. Also one groundwater sampling point close to a landfill in the Napostá Grande watershed has been included and one sampling site of Saladillo surface water downstream from the slaughterhouse and TGS unloading points for monitoring of water-quality changes.

In reference to groundwater in the Sauce Chico watershed, some points located upstream and downstream to the sector with greater horticultural development have been selected, as well as in Saladillo river upgradient and downgradient to above mentioned companies discharges.

Finally, we hope to be able to collect periodically groundwater samples in the piezometers installed in the zone denominated Estación Aguará and near of the Maldonado mouth (A1, A2, M1, M2).

Fig. 43 shows a horticultural sector located among the points Ig and IIIg (Table 14).

Fig. 43 - Google Earth image of horticultural area at Sauce Chico watershed

12 CONCLUSIONS

As a result of the analysis and interpretation of the water quality, in connection with the sources of pollution (Pressures) in the region, the following conclusions can be drawn:

The influence of the pressures identified can be seen in the water quality of **Napostá Grande river**, namely in the samples taken monthly in the river since 1997, before and after the city of Bahía Blanca. In most cases, it is possible to observe a slight increase in the electrical conductivity of the water in the samples taken downstream the city location. However, it is in the nitrate contents that this contrast is clearer, with several analyses doubling the nitrate content in the samples taken after the city. Yet, their values are above the guideline of 50 mg.L^{-1} defined by WHO (2006) for drinking water.

For the **groundwater in Napostá Grande watershed**, there is an increase of salinity downgradient, due to an enrichment of salts from evaporation and the water circulation in the aquifer along the watershed reaching a maximum in the coastal discharge area. The present situation concerning electrical conductivity shows no big changes from the 90 to the present situation. However, values are high in terms of electrical conductivity and the cation content, conferring to most waters a high to very high risk of salinization and a large range of risk to alcalinization regarding potential agriculture activities. Also the nitrate content is high in the area, with the highest values in the upper part of the watershed, possibly as a result of pressures caused by deficient agriculture practices. The presence of arsenic and fluorine higher than WHO guidelines in some of the samples has been attributed to the contact with some components of the loessic sediments which cover this region (Bonorino *et al.*, 2001). The concentrations of iron are also high but no health significant problem can derive from that.

There is another area of importance concerning the groundwater quality, *i.e.* the coastal area of Ing. White. The local groundwater is brackish with an electrical conductivity between 47,600 and 108,100 µS.cm^{-1} and a highly sodium chloride content, typical from discharge waters with low circulation and high residence time. The results of these studies indicate heavy metals contamination in several wells at Ing. White, connected to industrial activity as well as total hydrocarbons that are diffused all over the area with the higher values close to the fuel deposits.

The water samples collected in **Sauce Chico river** refer mainly to two monitoring points. They show bicarbonated and chlorinated – sodic facies. No significant changes are observed in the water pattern since 1997 in what concerns electrical conductivity, nitrate and phosphorous. All of them have normal concentrations for surface water.

Groundwater in the Sauce Chico watershed show ionic concentrations that tend to increase towards the estuary due to the ionic enrichment along the aquifer, from the recharge to the discharge area in Bahía Blanca estuary. The higher salinity and electrical conductivity in the discharge area are also related to: the high piezometric levels found; the very low hydraulic gradients; as well as the lower sediment permeability, which favours the evapotranspiration and vertical infiltration in comparison to groundwater horizontal flow (Sala *et al.*, 1985).

The effects of the pressures identified in section 3 can, to some extent, be detected in the state of quality of both surface and groundwater in the area. Therefore, it is advisable to carry out environmental management measures regarding inland waters protection from those identified sources and to develop monitoring in the area in order to assess the beneficial effects of those measures.

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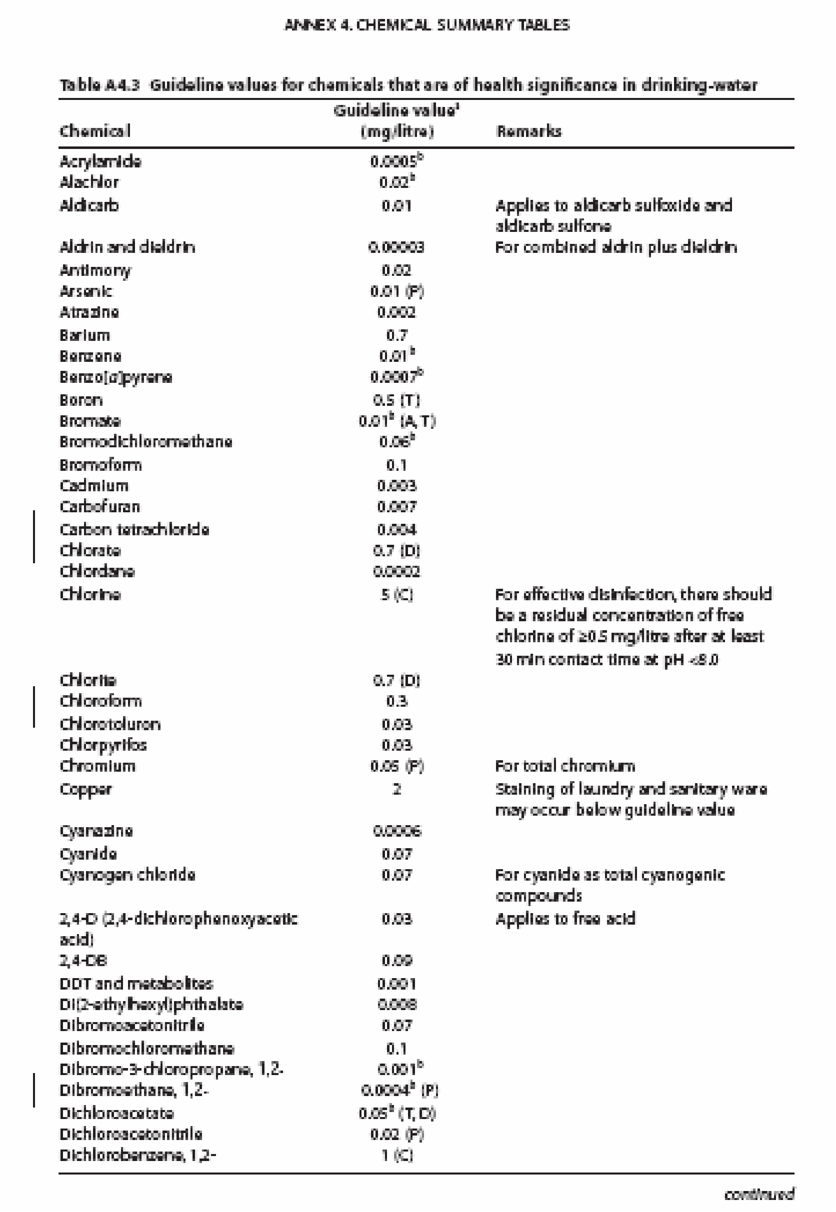
Annex I

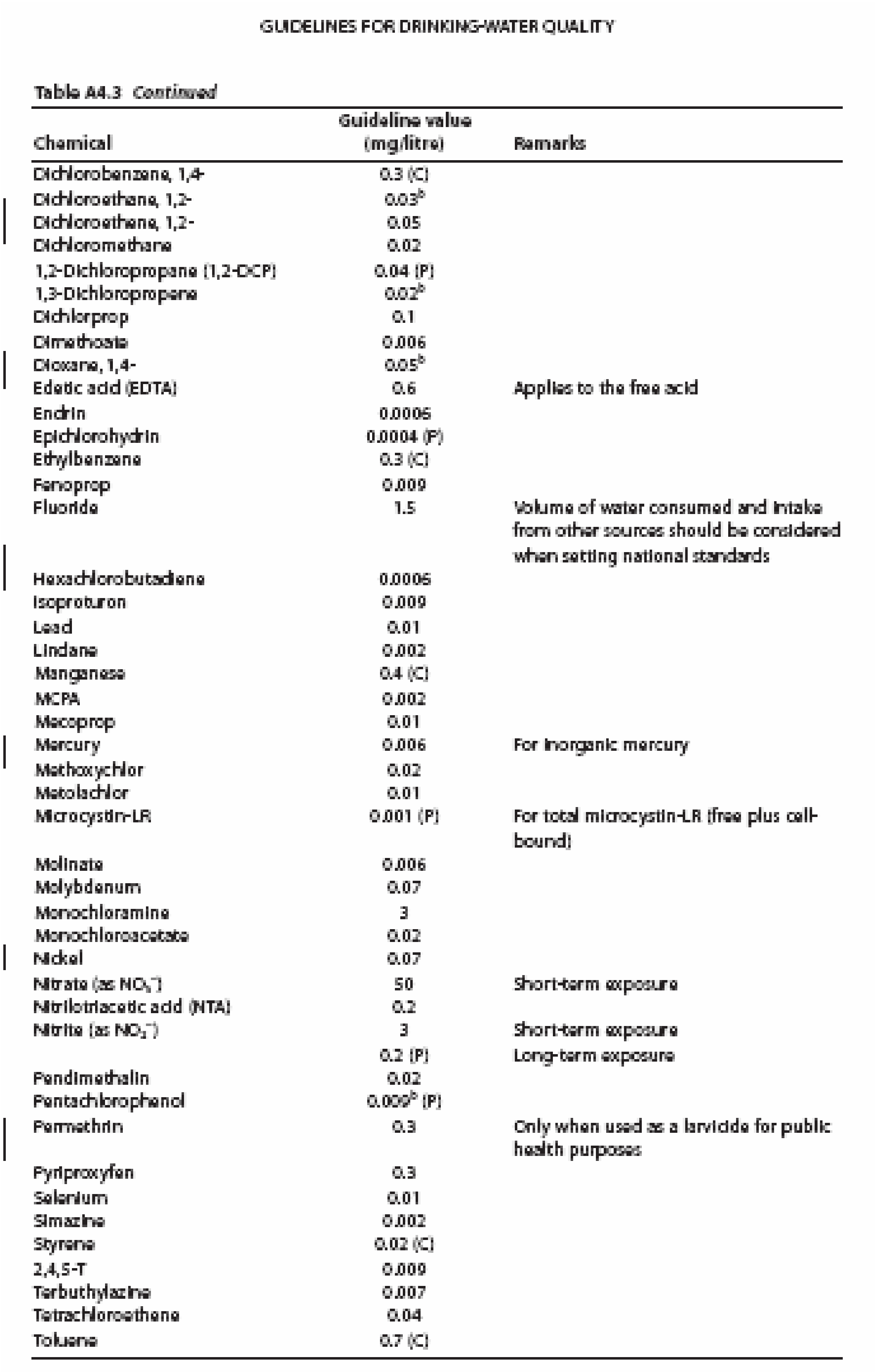


ANNEX 4. CHEMICAL SUMMARY TABLES

Table A4.3 Guideline values for chemicals that are of health significance in drinking-water

Chemical	Guideline value^{a} (mg/litre)	Remarks
Acrylamide	0.0005^{b}	
Alachlor	0.02^{b}	
Aldicarb	0.01	Applies to aldicarb sulfoxide and aldicarb sulfone
Aldrin and dieldrin	0.00003	For combined aldrin plus dieldrin
Antimony	0.02	
Arsenic	0.01 (P)	
Atrazine	0.002	
Barium	0.7	
Benzene	0.01^{b}	
Benzo[*a*]pyrene	0.0007^{b}	
Boron	0.5 (T)	
Bromate	0.01^{b} (A, T)	
Bromodichloromethane	0.06^{b}	
Bromoform	0.1	
Cadmium	0.003	
Carbofuran	0.007	
Carbon tetrachloride	0.004	
Chlorate	0.7 (D)	
Chlordane	0.0002	
Chlorine	5 (C)	For effective disinfection, there should be a residual concentration of free chlorine of ≥0.5 mg/litre after at least 30 min contact time at pH <8.0
Chlorite	0.7 (D)	
Chloroform	0.3	
Chlorotoluron	0.03	
Chlorpyrifos	0.03	
Chromium	0.05 (P)	For total chromium
Copper	2	Staining of laundry and sanitary ware may occur below guideline value
Cyanazine	0.0006	
Cyanide	0.07	
Cyanogen chloride	0.07	For cyanide as total cyanogenic compounds
2,4-D (2,4-dichlorophenoxyacetic acid)	0.03	Applies to free acid
2,4-DB	0.09	
DDT and metabolites	0.001	
Di(2-ethylhexyl)phthalate	0.008	
Dibromoacetonitrile	0.07	
Dibromochloromethane	0.1	
Dibromo-3-chloropropane, 1,2-	0.001^{b}	
Dibromoethane, 1,2-	0.0004^{b} (P)	
Dichloroacetate	0.05^{b} (T, D)	
Dichloroacetonitrile	0.02 (P)	
Dichlorobenzene, 1,2-	1 (C)	

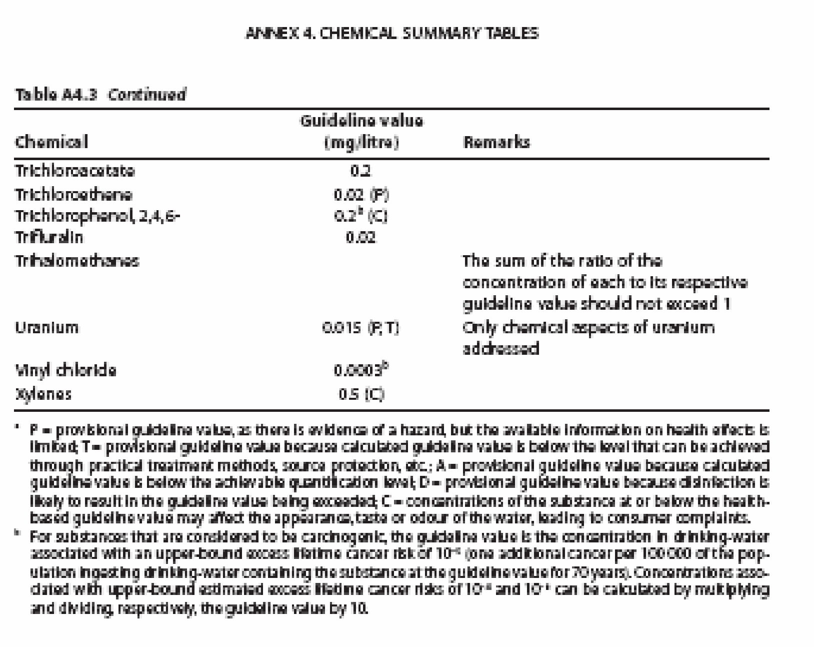
continued



GUIDELINES FOR DRINKING-WATER QUALITY

Table A4.3 *Continued*

Chemical	Guideline value (mg/litre)	Remarks
Dichlorobenzene, 1,4-	0.3 (C)	
Dichloroethane, 1,2-	0.03^b	
Dichloroethene, 1,2-	0.05	
Dichloromethane	0.02	
1,2-Dichloropropane (1,2-DCP)	0.04 (P)	
1,3-Dichloropropene	0.02^b	
Dichlorprop	0.1	
Dimethoate	0.006	
Dioxane, 1,4-	0.05^b	
Edetic acid (EDTA)	0.6	Applies to the free acid
Endrin	0.0006	
Epichlorohydrin	0.0004 (P)	
Ethylbenzene	0.3 (C)	
Fenoprop	0.009	
Fluoride	1.5	Volume of water consumed and intake from other sources should be considered when setting national standards
Hexachlorobutadiene	0.0006	
Isoproturon	0.009	
Lead	0.01	
Lindane	0.002	
Manganese	0.4 (C)	
MCPA	0.002	
Mecoprop	0.01	
Mercury	0.006	For inorganic mercury
Methoxychlor	0.02	
Metolachlor	0.01	
Microcystin-LR	0.001 (P)	For total microcystin-LR (free plus cell-bound)
Molinate	0.006	
Molybdenum	0.07	
Monochloramine	3	
Monochloroacetate	0.02	
Nickel	0.07	
Nitrate (as NO_3^-)	50	Short-term exposure
Nitrilotriacetic acid (NTA)	0.2	
Nitrite (as NO_2^-)	3	Short-term exposure
	0.2 (P)	Long-term exposure
Pendimethalin	0.02	
Pentachlorophenol	0.009^b (P)	
Permethrin	0.3	Only when used as a larvicide for public health purposes
Pyriproxyfen	0.3	
Selenium	0.01	
Simazine	0.002	
Styrene	0.02 (C)	
2,4,5-T	0.009	
Terbuthylazine	0.007	
Tetrachloroethene	0.04	
Toluene	0.7 (C)	



ANNEX 4. CHEMICAL SUMMARY TABLES

Table A4.3 *Continued*

Chemical	Guideline value (mg/litre)	Remarks
Trichloroacetate	0.2	
Trichloroethene	0.02 (P)	
Trichlorophenol, 2,4,6-	0.2[b] (C)	
Trifluralin	0.02	
Trihalomethanes		The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1
Uranium	0.015 (P, T)	Only chemical aspects of uranium addressed
Vinyl chloride	0.0003[b]	
Xylenes	0.5 (C)	

[a] P = provisional guideline value, as there is evidence of a hazard, but the available information on health effects is limited; T = provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc.; A = provisional guideline value because calculated guideline value is below the achievable quantification level; D = provisional guideline value because disinfection is likely to result in the guideline value being exceeded; C = concentrations of the substance at or below the health-based guideline value may affect the appearance, taste or odour of the water, leading to consumer complaints.

[b] For substances that are considered to be carcinogenic, the guideline value is the concentration in drinking-water associated with an upper-bound excess lifetime cancer risk of 10^{-5} (one additional cancer per 100 000 of the population ingesting drinking-water containing the substance at the guideline value for 70 years). Concentrations associated with upper-bound estimated excess lifetime cancer risks of 10^{-4} and 10^{-6} can be calculated by multiplying and dividing, respectively, the guideline value by 10.

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