The Framework Program for the Sustainable Management of La Plata Basin's
Water Resources, with respect to the effects of climate variability and change

Transboundary Diagnostic Analysis for the La Plata Basin TDA

CIC Cuenca del Plata

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December 2016

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Comité Intergubernamental Coordinador de los Países de la Cuenca del Plata
Transboundary Diagnostic Analysis for the La Plata River Basin - TDA. - 1a edición especial - Ciudad Autónoma de Buenos Aires : Comité Intergubernamental Coordinador de los Países de la Cuenca del Plata - CIC ; Estados Unidos : Organización de los Estados Americanos - OEA, 2017.
Libro digital, PDF

Archivo Digital: descarga y online
ISBN 978-987-4187-01-7

1. Gestión de los Recursos Hídricos. 2. Recursos Hídricos.
CDD 333.91

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Preface

The La Plata Basin is one of the most important in the world, due to its surface area and socioeconomic characteristics. It encompasses over three million square kilometres, is currently inhabited by over 110 million people and produces over 70% of the GDP of the five Basin countries.

The Basin is a hydrological system with a remarkable biological diversity and productivity; it is home to the largest wetland corridor in South America and it is recognised as one of the most important basins in the world as a result of the amount, variety and endemism of its ichthyofauna. In spite of its richness, it is one of the most socially and economically affected basins by cyclic flooding and persistent drought periods. The relationship between hydrology, changes in land use and the uncertainties with respect to the future climate poses a number of challenges to reduce the vulnerability to natural disasters and address environmental management and the needs of the economically marginalised people. In this scenario, the required social and economic development, within the regional integration framework that contains it, suggests the need for a great effort in the valuation, awareness and education in relation to nature.

In 2001, the governments of the five countries that make up the Coordinating Intergovernmental Committee of the La Plata Basin Countries (CIC) decided to incorporate into the organisation the technical capacities to address these challenges and agree upon an Action Plan to guide management, where water resources, including the relationship between surface and ground waters and their links with land use and climate, play a key role. In this effort, which, for the first time, developed an integrated approach, the participating institutions agreed on the need to strengthen a common Basin vision, with the goal of identifying and prioritising common problems and their main causes so as to address them on a joint and coordinated basis.

Based on this background, and with the support of the GS/OAS and UNEP, funding was requested and obtained from the Global Environment Facility (GEF) to conduct the *Framework Programme for the sustainable management of the water resourses of the La Plata Basin,* with respect to the effects of variability and climate change (Framework Programme). The Programme was created as a long-term management process, to be executed by the five countries in a coordinated way, within the framework of the CIC. During the initial phase of the project formulation (2003-2005), and based on a participatory process, the main challenges at basin level were identified and the preliminary management proposals aimed at solving or mitigating the identified problems were drafted.

In phase 1 of the Framework Programme - executed between 2010 and 2016 - the conducted diagnosis was expanded, and the Basin problems were characterised more precisely and thoroughly, thus obtaining a comprehensive vision of the status of the hydrological systems. Using this better knowledge, the Transboundary Diagnosis Analysis (TDA) was consolidated and the Strategic Action Programme (SAP) was formulated as a document of priority policies and actions agreed upon by the five countries to solve the main identified problems, particularly those of transboundary character.

The tasks were carried out with the active participation of each country's national institutions, through specialists appointed to constitute the Thematic Groups, which acted as the platform of planning and technical consensus in the implementation of the different sub-components in which the execution of the Framework Programme was organised. The products obtained from this effort are sumarised in a series of publications - to which the present document belongs.

The Coordinating Intergovernmental Committee of the La Plata Basin Countries would like to thank every person and institution that supported and participated in the execution of the Framework Programme for their commitment and effort. It also recognises the valuable cooperation and contribution made by the Organisation of American States (OAS), through its Department of Sustainable Development, which collaborated and supported the CIC in the Programme execution, and the United Nations Environmental Programme (UNEP), which acted as the implementing agency of the Global Environment Facility (GEF).

The work developed during this first phase of the Framework Programme was a pioneer experience, where over 150 institutions and 1,500 experts of the region were able to articulate each country's interests and wills in search of a common interest, aimed at the integrated water resources management within the context of variability and climate change. It its expected that the management experience and the developed technical tools will nurture and strengthen the will for regional cooperation and integration so as to make progress towards the goal of achieving sustainable development and the well-being of the inhabitants of the La Plata Basin countries.

Presentation

During the IV Inter American Dialogue on Water Management (Foz de Iguazu, Brazil, 2001), the countries of the La Plata Basin (LPB) —through representatives from their foreign ministries, authorities, and technicians from entities related to water resource management—agreed to carry out a regional program to advance the integrated management of water resources in relation to climate in the Basin.

Based on this interest and within the framework of the Intergovernmental Coordinating Committee of the Countries of the La Plata Basin (CIC), they secured funding from the GEF for the preparation and implementation of the *Framework Program for the Sustainable Management of La Plata Basin's Water Resources, with respect to the effects of climate variability and change* (hereinafter referred to as the Framework Program). The activities were supported by technical and administrative assistance from the Department of Sustainable Development of the General Secretariat of the Organization of American States (DSD-GS/OAS), within the framework of a collaborative agreement signed with the CIC and United Nations Environment Programme (UNEP), as the GEF implementing agency.

The overall objective of the project is to strengthen cross-border cooperation between the governments of Argentina, Bolivia, Brazil, Paraguay, and Uruguay to ensure the integrated and sustainable management of the shared water resources of the Basin in the context of climate variability and change, capitalizing on development opportunities.

During the formulation phase of the Framework Program (2003-2005), a preliminary analysis of the main environmental problems in the LPB and the barriers to overcome was elaborated. Through a broad participatory process, the state and behavior of water systems were characterized, synthesizing the main current and emerging critical transboundary issues (CTIs), their associated causal chains, preliminary proposals for solutions, and information gaps. As presented in the Macro- Transboundary Diagnostic Analysis (MAC-TDA), the main CTIs of the Basin are: i) Extreme hydrological events linked to climate variability and change; ii) Water quality degradation; iii) Sedimentation of waterways and bodies of water in the Basin; iv) Disruption and loss of biodiversity; v) Unsustainable use of fishery resources; vi) Unsustainable use of aquifers in critical areas; vii) Water use conflicts and the environmental impact of irrigated crops; viii) Lack of disaster contingency plans; and ix) Poor water health and the deterioration of environmental sanitation.

In Phase 1 of the project, it was decided to incorporate navigational limitations and the development of hydroelectric potential as CTIs—topics that were already covered by other components of the Framework Program—as two fundamental socioeconomic sectors for regional integration.

Phase 1 made it possible to deepen knowledge to characterize the CTIs in a more precise and detailed way, obtaining an integral vision of the state of the transboundary hydrological system, which facilitates the development of strategies for the integrated management of water resources.

The activities were carried out with the active involvement of specialists and authorities from the various governmental and academic institutions linked to the management of water resources, the environment, and the climate of each country. At the national level, the designated specialists formed National Project Units (NPUs) led by a National Coordinator responsible for the monitoring and coordination of project activities in each country. At the regional level, specialists from institutions in each country were grouped according to the different topics (hydrological balance, land degradation, ecosystems, water quality, etc.), forming Working Groups (WGs) responsible for the formulation, implementation, and monitoring of project activities in the different components, within the framework of the project document guidelines and resolutions of the Steering Committee.

After an initial period of data collection and analysis, technical studies were developed to cover information gaps and to consolidate the work and results of the WGs. Consolidation efforts were initially undertaken for each component of the project and then integrated into thematic pillars, grouping the themes of water resources, environment and climatology, and the Transboundary Diagnostic Analysis (TDA) foundations presented here.

The Framework Program also included the development of Demonstrative Pilot Projects and priority projects focusing on critical problem solving in select areas and sub-basins, carried out by local actors, including the main governmental and non-governmental organizations. The objective was to lay the foundation for the sustainable use of the Basin's land, water, and biological resources as input for the formulation of the Strategic Action Program (SAP), including a plan for adaptation measures.

On the other hand, there was a Fund for Promoting Public Participation (FPPP) aimed at promoting greater involvement of civil society organizations whose profile were related to specific project activities. Twelve initiatives related to Demonstrative Pilot Projects were implemented in this way, consolidating the participation of civil society organizations and academic institutions at the local level, providing a local view of the CTIs.

The TDA, as a result of this process, served not only to update and provide depth to the CTI analysis that affects the development of the Basin, but it also provided the technical-scientific and legal-institutional basis for the formulation of the Strategic Action Program. As a management experience, the TDA managed to articulate more than 500 specialists and 150 institutions in the Basin, contributing concretely to the construction of policies aimed at strengthening transboundary cooperation, recognizing that it is only possible to solve common and shared problems through the coordinated action and joint work of the Basin countries.

Executive Summary

Description of the La Plata Basin

The La Plata Basin (LPB) is one of the largest basins in the world, with an area of approximately 3.1 million km^2. It is formed by three main water systems: the Paraguay, Paraná, and Uruguay river systems, draining approximately one fifth of the territory of the South American continent. The LPB can be subdivided into 7 sub-basins: Upper Paraguay, Lower Paraguay, Upper Paraná, Lower Paraná, Upper Uruguay, Lower Uruguay, and the sub-basin of the La Plata River.

The current population of the Basin is more than 110 million people, and it includes the capitals of all five countries that compose it: Argentina, Bolivia, Brazil, Paraguay, and Uruguay. The richness of mineral resources, the value of its forests, and the fertility of its soils have made the LPB a region of strong population attraction that today favors its economic development, which translates into a concentration of 70 percent of the GDP of these countries.

The countries of the Basin present a disparate Human Development Index, which shows the diversity of its social and economic conditions.

In some urban and rural settlements in the Basin there are health situations caused by biological contamination due to the lack of adequate sanitation facilities and treatment services. Epidemics of waterborne diseases such as diarrhea, cholera, malaria, and dengue are common in certain regions.

From the hydro climatic point of view, the LPB has an important diversity of climates, ranging from the dry and very hot ones of the western Chaco—with less than 600 mm/year of precipitation—to the humid regions of southern Brazil and southeast Paraguay—with more than 2,000 mm/year of precipitation. These climates have an inter-seasonal or inter-annual variability that often results in extreme events of droughts or flood. In particular, its precipitation is conditioned by the La Niña and El Niño phenomena, as it is one of the regions most affected in the world by the latter.

Over the last 30 years, rainfall in the Basin has increased on average between 10 and 15 percent, resulting in larger increases in river water levels, which reached 30 percent, a change that may have been influenced by the considerable transformation in land use that took place in the last two decades. Around

40 percent of the original coverage has been replaced by areas of human use. Agriculture and livestock cause the greatest changes, followed by deforestation and urbanization.

In the LPB there are two large geological basins of tectonic origin, the Paraná Basin and the South American Gran Chaco Basin, which house the most important aquifer systems in the region.

As a result of the geological and climatic evolution, a great diversity of soils has been developed in the Basin. As with the vast majority of soils in Latin America, those in this region are poor in nutrients, acidic, affected by erosion and surface washing, and high in concentrations of iron and aluminum oxides in the subsurface. The Basin is responsible for a wide variety of production in various agricultural and forestry products, including soybeans, maize, wheat, coffee, beef, and other food by-products. The current problems related to soil resources are due to inadequate enabling systems and changes in land use, which have led to deforestation and overexploitation of natural resources.

The LPB hosts the largest river wetland system on the planet of almost 3,500 km², connected by the axis of the great Paraguay, Paraná, and La Plata Rivers, which determines a hydrological and biological continuum from the great Pantanal in the Upper Paraguay to the Paraná Delta and the La Plata River estuary.

The Basin is recognized as one of the most important in the world for the quantity, variety, and endemism of fish species. Its rich ichthyofauna reaches 908 species, 40 percent of which have socio-economic relevance. Some of the species (sábalo, surubí, dorado) are undergoing intense exploitation in some stretches.

Deforestation due to agriculture has reduced the soil's ability to capture and store carbon and water and to anchor soils, leading to increases in erosion rates in some areas and sedimentation in others.

In the Basin, 601 protected areas have been created covering 22.8 million hectares, representing a protection of 7.2 percent of its total area. Considering the Aichi Targets from the Convention on Biological Diversity (CBD)—which aim to reach 17 percent protected areas for the period 2011-2020—the current percentage of protected areas is low, practically one-third of the target. There are also 29 Ramsar sites covering almost 85,000 km² and 18 Biosphere Reserves (MAB-Unesco) covering almost 361,000 km².

Regarding sediment production, the majority comes from the upper basins of the Bermejo and Pilcomayo rivers. They are the main cause of the need to clarify the water for consumption by the riparian cities, as the sediment is deposited into the navigable channels and causes the progressive advance of the Parana River Delta over the La Plata River. Another determining process in sediment production and transport is related to anthropogenic land use activities.

The Selva Misionera Paranaense (SMP) is part of the Atlantic Forest ecoregion complex, originally covering an area of 47,000,000 ha. Since the mid-twentieth century there has been a gradual loss of forest mass with the aim of replacing it with pastures, agricultural crops, and forest plantations, leading to extraordinary soil degradation, alterations to the hydrological cycles, and causing local climatic fluctuations. This ecoregion continues to be one of the most diverse biological ecosystems on the planet, internationally considered a high priority for conservation because of the ecological importance of its remnants.

Water Resources

With regard to the hydrometeorological balance in the Basin, the Upper Paraguay presents alternating of mean values of excesses in summer and autumn and deficits in winter-spring. In the Lower Paraguay, the right-margin contribution areas present deficit balances towards the west, while the left-margin contribution zones present excess balances. In the Upper Paraná region there is a deficit in winter and part of spring, but there is balance annually. Also in the Lower Paraná the areas of right-margin contribution, which to the west have deficient balances, and left-margin contribution, where they are positive, can be differentiated. In the whole basin of the Uruguay River, balances are generally positive, although there are months with deficits.

The results of the studies carried out on climate change projections and their possible impact on the water level of the rivers of the LPB—for the periods 2011-2040, 2041-2070, and 2071-2100—indicate an increase in average and minimum water levels in the Uruguay and Iguazú rivers and an initial reduction in average water level followed by a subsequent increase in the northern region of the Paraná basin—mostly in the basin of the Paranaíba River—and in the Upper Paraguay region. On the other hand, a reduction in minimum water levels is foreseen.

The projections also indicate an increase in the average and minimum water levels in the Chaco region, represented by the Bermejo and Pilcomayo rivers, and an initial reduction of the average water level, followed by an increase with respect to the reference period in the Paraná River, in Itaipu. The same is true for minimum water levels. In the middle and lower reaches of the Paraná River, it is expected that both average and lower water levels initially decrease, and then increase in the future.

The LPB is also rich in groundwater resources. It coincides in large part with the Guaraní Aquifer System (GAS), one of the largest groundwater reservoirs in the world. To the west of the Basin is the Yrendá-Toba-Tarijeño Aquifer System (YTTAS), which coincides mainly with the semi-arid zone of the Gran Chaco Americano.

The natural development of urban and rural populations associated with the sharp increase in agricultural and industrial activities has significantly increased the use of water resources, particularly those of underground origin.

The main activities related to water use in the Basin are urban services and those of the agricultural, industrial, mining, energy (hydroelectric generation), transport (navigation), ecosystem protection, and tourism sectors.

The demand for potable water is satisfied by the large rivers of the Basin, by small surface-level sources close to cities, or by groundwater. With the growth of cities, water supplies are often overexploited or polluted, with a consequent risk to the health of the population.

Agriculture is the main economic activity carried out in the La Plata Basin and is the one that generates the greatest changes in land use. The main crops correspond to annual cycles: soybeans, wheat, maize, and rice. Rice is produced with flood irrigation and is one of the major consumers of water.

Industrial activity is diversified and is particularly related to the main urban centers in Argentina and Brazil, such as the metropolitan areas of São Paulo and Buenos Aires. In these regions, the most important industrial production is related to automotive development and petroleum derivatives.

The production of the mining industry occupies an important place among the economic activities of the countries of the LPB, although it is not a high-production mineral area.

The LPB has a very important hydropower generation capacity. Its use is a significant portion of the energy generation in the countries involved.

Navigation is carried out on the Paraguay-Paraná waterway, the main route that connects the Basin countries; the Uruguay River; the section downstream of the Salto Grande dam; and Tietê-Paraná, where navigation takes place within Brazil due to the lack of sluices in the Itaipú dam.

The Basin comprises a region with remarkable ecosystems, from the Iguazu Falls to the huge wetland corridor that connects the Pantanal with the Paraná Delta, at its mouth in the La Plata River, constituting an important freshwater reserve with a rich biological and cultural diversity, extremely appropriate for the implementation of sustainable development strategies which include ecotourism programs and projects.

Regarding demands, quantitative estimates identified areas of the Basin with existing or potential conflicts, such as the Pilcomayo and Bermejo rivers, due to the diffuse water contamination from crops and mining; the Tiete River—the São Paulo Metropolitan Region—due to the high demand for water, polluted springs, low water levels and, therefore, low assimilation capacity of urban pollution in the headwaters of the basin; and high demand for irrigation water in Brazil, Uruguay, and Argentina, with potential conflicts with urban uses, among others.

Hydro-meteorological Monitoring Systems

Hydro-meteorological observation and forecasting is one of the main activities of the meteorological services of the five Basin countries. The private sector and non-governmental organizations also participate in hydro-meteorological observations.

In Bolivia, meteorological services also include hydrological observations, but in the other four countries these are carried out by other national institutions as well as regional or provincial and national entities that require information for specific purposes, such as the energy sector. Since hydro-meteorological information is generated by networks operated by different actors, there exists a challenge for integrating information.

The hydrological parameters and water quality monitoring network in the LPB shows a marked asymmetry both in terms of quality and quantity. The number of stations, their characteristics, distribution, and density of the network present important differences, especially at the sub-basin level.

The LPB process of radar installation is underway. In Argentina in 2011, the National Meteorological Radar System (SINARAME) was launched, with the objective of developing and constructing meteorological radar and designing and implementing an Operations Center with capacity to receive, process, and analyze the respective data. In Brazil, one of the strategic objectives of the National Plan for Managing Risks and Responses to Natural Disasters is to expand the network that observes weather and climate conditions in the national territory; the radar is part of a system of prevention and warning of extreme climatic conditions, a network that is being amplified by the acquisition of new radar with the latest technology. In Paraguay, a meteorological radar is operating in Asunción and plans are underway to extend the radar network in the middle of the eastern region of the country in order to obtain better regional coverage. The possibility of meteorological radar operating in Uruguay, and regionally integrated, would help to close the gaps in meteorological radar observation in the Basin.

In the LPB there are several sources of information that update meteorological satellite data and images every 30 minutes. Meteorological services in the region process information from the GOES-13, which is available in real time. Various types of images are available in an operative form throughout the day (infrared image, visible image, cloud top, and water vapor), useful information for defining the state of the situation and climatic prognosis. Products from other satellites, generally polar orbit, are available with additional complementary information, such as precipitable water and instability indexes.

The WMO Integrated Global Observing System (WIGOS) is an integrated proposal to improve and develop the World Meteorological Organization (WMO) observation system. WIGOS-SA/CP is the implementation of WIGOS in southern South America/La Plata Basin, whose main objective is "to create a homogeneous hydro-meteorological network in southern South America, with the participation of the five countries of the Basin and their respective meteorological and hydrological services and organisms dealing with water issues, the CIC and WMO." The implementation of WIGOS will allow its members, in coordination and collaboration with other national agencies, to better respond to natural disasters, improve monitoring and prediction services, and adapt to climate change.

In September 2015, the Third Workshop on Hydro-meteorological Networks of the La Plata Basin was held in Brasilia, with the aim of establishing proposals for the SAP and to follow up on the WIGOS program. Amongst the important conclusions of the Workshop, among other things, is defining basic strategic hydro-meteorological networks for the LPB with a regional vision and creating Regional (virtual) Applied Hydro-meteorological Centers as integration entities.

For its part, the Regional Climate Center for Southern South America (CRC-SAS)—a virtual organization, constituted in the form of a network according to the principles defined by the WMO—is in its initial phase of implementation and offers climate services in support of national meteorological and hydrological services and to other users in the countries of Southern region of the continent.

The Global Framework for Climate Services (GFCS) is an initiative of the United Nations led by the WMO to guide the development and application of scientific information and climate services to support decision-making in climate-sensitive sectors. The priority areas for GFCS are, among others, agriculture and food security, energy, disaster risk reduction, health, and water. In the LPB, the CRC-SAS could help strengthen regional and sub-regional collaborative capacities, identify user needs, identify research units, and generate products that support the projects in execution.

In the Basin, the National Institute of Meteorology (INMET) and the Center for the Prediction of Weather and Climate Studies (CPTEC) in Brazil, and the National Meteorological Service (SMN) in Argentina have operational models for making numerical climatic predictions for hydrological purposes.

Institutional Characteristics

The La Plata Basin System is the set of bodies created to meet the objectives of the La Plata Basin Treaty, which formally includes the meeting of Foreign Ministers, the Intergovernmental Coordinating Committee of the Countries of the La Plata Basin, the Intergovernmental Committee of the Paraguay-Parana Waterway (CIH), and the La Plata Basin Financial Development Fund (FONPLATA).

The La Plata Basin Treaty (TCP), which came into force in 1970, highlights the search for a better and more rational utilization of water resources and for their sustainable development.

The CIC, created in February 1967, became the permanent organ of the Basin, in accordance with the TCP. Since its inception, the CIC has concentrated on areas of common interest in the five countries, facilitating studies, programs, and infrastructure works on hydrology, natural resources, transport and navigation, land, and energy. The need for technical management capacity in the LPB was recognized in December 2001 in the agreements from the meeting of Foreign Ministers of the Basin held in Montevideo, which approved a new Statute for the CIC that incorporates two representatives per country—one political, with plenipotentiary authority, and a second technical representative. The technical representatives of the countries constitute the Project Unit of the La Plata Basin System.

In addition to the CIC, a number of complementary agreements have been integrated and signed within the framework of the TCP, leading to the creation of different institutions and agencies with specific competencies in the Basin, such as FONPLATA, its financial instrument, and CIH, in charge of the Paraguay-Parana Waterway. The Treaty also recognizes the possibility of other independent binational or tri-national agreements to address issues of specific interest to the parties, giving rise to numerous agencies.

In 1995, the institutional framework for regional integration was strengthened by the Treaty of Asuncion, which created Mercosur, designed to encourage intraregional and international trade among member countries.

Climate Variability and Change in the La Plata Basin

The tropical and subtropical part of South America is characterized by the South American Monsoon System, a seasonal atmospheric circulation system conditioned by seasonal solar radiation, with a marked influence on the hydroclimatic regime of the LPB. One of its main characteristics is the well-defined annual cycle of precipitation in most of the Basin, with maximums in summer and minimums in winter.

This seasonality is more accentuated in the sub-basins of the Paraguay and Paraná rivers, attenuating a little in those of the Uruguay and in the La Plata River. The total annual precipitation is very variable in the Basin, increasing from west to east, with greater precipitation in the sub-basins of the Upper Paraná and Upper Uruguay, with nuclei that exceed 2500 mm, while the dry zone is in the region of the Gran Chaco Americano, with nuclei less than 600 mm.

During spring and the austral summer, dominant systems are observed that connect the Amazon to Southeastern South America, the South Atlantic Convergence Zone (SACZ) —a convective cloud band that stretches from the southern Amazon to southeastern Brazil and the South American Low-Level Jet (SALLJ). These systems act producing rains.

Systematic increases in precipitation and runoff since the mid-1970s are consistent with the increase in the frequency of SALLJ events, which is corroborated by observations indicating extreme events of more frequent rainfall in the last 30 years.

The development of El Niño and La Niña events, phenomena related to the surface temperature of the Tropical Pacific Ocean, has marked effects on the climate of the better part of the LPB, especially on the scale of interannual time, affecting the variability of rainfall. In El Niño years, intense precipitation and runoff have been observed, as in 1982-1983 and 1997-1998. In La Niña years, a tendency toward rainfall deficit or drought has been observed. The relationship of rainfall to these events is a predictor of rainfall for future months, as they can be detected early.

On the other hand, deforestation and changes in land use as a result of human activity increased rapidly in the last 60 years, and there is evidence that these anthropogenic actions modify the thermodynamic characteristics of the lower atmosphere due to complex interactions between climate, hydrology, vegetation, and the management of water and land resources. Among the changes detected are increases in rainfall and river water level, as well as changes in atmospheric surface circulation and extreme temperatures, which could be linked to climate change.

On the one hand, the LPB has experienced extreme precipitation events with increasing frequency and intensity and, on the other hand, there has been a tendency in the central and northern part of the Basin to delay the beginning of the austral spring or an increase in the extension of the dry season.

Between autumn and spring, the incursion of extratropical cyclones is frequent in the LPB, responsible for much of the precipitation occurring in the winter in the eastern part of the Basin and in the sub-basins of the Lower Paraná, the Uruguay, and in the La Plata River itself, coinciding with a reduction in the precipitation in the sub-basins of the Paraguay.

The year 2015 was the warmest since the mid-nineteenth century, when temperature measurements became available. According to WMO data, the global mean surface temperature beat all previous records by a surprisingly high margin, 0.76 ± 0.1°C above the 1961-1990 average. In the LPB, a higher than average temperature was observed, between 0.5°C and 1.5°C. The commonly used tools for assessing the current situation and climate projections are climate models: Global Atmospheric or Global Coupled Ocean-Atmosphere. However, the horizontal atmospheric resolution used by these models is rather gross, and the regional climate in many parts of the world may be affected by circulations occurring on a smaller scale. That is why the regionalization technique is useful for improving the information of the global models. Downscaling using regional climate models has a reputation for being a very useful tool for generating climate change scenarios in high resolution for studies of climate impacts and adaptation to climate change.

Extreme weather projections from climate models still have a large component of uncertainty. Even so, the knowledge of the variability observed in the climate, at the most extensive time scales possible, serves as a foundation for analyzing the future climate, trying to separate observed natural variability from that which is a consequence of anthropogenic action.

Forecasting with Climate Change Models

As part of the project activities, during Stage 1 simulations with the ETA regional climate model were carried out, for the RCP 4.5 (moderate) scenario comprising the period 1960-2100, which reproduced a current climate with seasonal precipitation and air temperature fields that could be considered acceptable in comparison with the data observed for the same period.

ETA climate modeling has enabled regional results to be derived from scenarios established by the Intergovernmental Panel on Climate Change (IPCC) and translated into other indicators such as risk, water levels, soil moisture, and erodability. Although the conclusions are important and indicative of the possible impacts, it is considered that the approach has limitations, since in the light of the current uncertainties of the global climate models the most advisable thing for managing future scenarios is to use a set of models (instead of a single model, as in this case) to then consider the "assembly" of results.

Seasonal precipitation was generally reproduced acceptably, with a tendency to underestimate summer precipitation in the SACZ, whereas in winter and spring the tendency is to overestimate precipitation in the eastern part of the Basin (Upper Paraná and Upper Uruguay). With respect to the temperature of the current climate, a good reproduction can be observed, although it underestimates the temperature in the summer and autumn in the southeast (Upper Uruguay) and in the winter in the central-west of the Basin (Lower Paraguay and Lower Paraná), while somewhat overestimating the temperature in the aforementioned SACZ model.

Regarding future climates, seasonal precipitation and air temperature fields were analyzed for the periods 2011-2040, 2041-2070, and 2071-2100, which are compared with the present climate.

Future precipitation, according to the model, presents differences or anomalies for different periods in relation to the reference period, 1961-1990. In 2011-2040 it is possible to observe a trend of negative anomaly of precipitation in much of the LPB, mainly during the summer and, to a lesser extent, in autumn and spring. This negative anomaly extends over the entire SACZ, from the Atlantic coast of the Southeastern region to the Midwest region, where the analyzed domain ends. It is worth noting the strong negative anomalies of the summer in the Upper Paraná sub-basin. The decrease in precipitation is also observed in the winter season (June, July, and August/JJA) over the southeastern part of Brazil, albeit to a lesser extent. Meanwhile, there is a trend of increasing precipitation in the Upper Uruguay sub-basin during spring and autumn, extending to the La Plata River.

On the other hand, the future climate temperature for the analyzed periods shows a persistent warming trend with respect to the reference period in the whole Basin. In 2011-2040, the biggest anomalies are observed in the Upper Paraguay (Pantanal) sub-basin, especially in the summer, when the anomalies reach 3.5°C. In the same region, maximums are also observed in autumn and spring, with winter being the season with softer anomalies, although with significant values of 2°C or higher. In 2041-2070, climate warming continues to rise, with anomalies between 2.5°C to 4.0°C in spring and summer, with milder increases in autumn and winter, from 2.5°C to 3.0°C for the whole Basin, the warmest area being the Pantanal region in the Upper Paraguay.

In spite of the negative precipitation trend and positive temperature anomalies being more pronounced than in other models, it is possible to say that the ETA model can be considered a valid guide for the analysis of future climatic scenarios.

When considering immediate climatic scenarios, the period 2011-2041 presents situations such as a decrease in precipitation in much of the Basin and a considerable increase in temperature. This scenario could affect water resources in the LPB. In a scenario with lower precipitation and higher temperature, the regional hydrologic balance could lead to decreasing average water levels, facilitating the occurrence of extreme events such as the greater possibility of droughts and forest fires.

With a scenario in which soil moisture is declining or in permanent deficit, it could cause a strong impact on agriculture and livestock production and, consequently, socio-economic damage. At the same time, the reduction of surface and groundwater resources would compromise the supply of potable water for human consumption, while the decrease in the average water levels could also affect the quality of the water in the transboundary rivers. The advance of the agricultural frontier could increase the concentration of pollutants in watercourses, as well as sediment transport and deposit.

Even without regard to climate change, disaster risk will continue to increase in many countries, provided that more vulnerable people and goods are exposed to climatic extremes. Given the results of the ETA model, consecutive dry days would decline during the 21st century, while consecutive wet days would increase in the same period, keeping consistent with the annual precipitation trend. The occurrence of extreme events also tends to be manifested in rainfall intensity, since the days with heavy rains would be increasing in the present century, especially in the southeastern region of the Basin, as well as days of heavy rain.

Forecast of Socio-economic Impacts

In the next 30 years, which are the most important considering the useful life of the projects, rainfall and water level rates should decrease in the upper sub-basins of the Paraná, Paraguay, and Uruguay rivers in Brazil in the rainy months (December, January, and February/DEF). Rainfall and water level in the lower basin of these rivers would tend to increase.

The main impact on urban development is observed in reduced water security, especially in those cities that are in the headwaters of the rivers and with very large populations; in addition, the reduction in water level rates aggravates the ability to dilute untreated effluents.

With regard to rural development, the countries of the region are important players in the global community of agricultural *commodities*. In the scenario of reduced precipitation and water level in the upper basins, grain production is affected, mainly in the central-western region of Brazil, which is currently the region with the highest agricultural production. On the other hand, it improves the water availability for agricultural production in the lower basins of Argentina and Uruguay.

Also, the reduction of precipitation and water level in the upper basins directly affects hydroelectric generation, considering that 60 percent of its generation is concentrated in southeastern Brazil and, in turn, that a large part of the water levels that feed hydroelectric projects in the international stretches originate in the upper basins.

For navigation, which depends on water levels in the upper basins, considering the climate change scenarios presented, the impact may represent a significant increase in costs, mainly in the middle and upper reaches of the Paraguay River, in order to permit for navigation with adequate draft over time.

The most critical conditions for extreme events are increases in droughts in the upper watersheds due to reduced rainfall, while for the environment the main impacts will be due to the lower water quality of the headwaters due to lower water levels and the reduction of effluent dilution; and reduced water water levels, which will impact wildlife and the elevation of the water table in the Pampa, due to increased rainfall.

Legal-institutional Framework

There is sufficient legal framework in the five LPB member countries for the management and protection of natural resources and, in particular, of water resources, which is integrated with constitutional, legal, and regulatory provisions at the national, provincial, state, or municipal level, including climate change in some cases. However, there is a gap between the legal framework and its practical application. Except for specific cases, the normative advances have not been accompanied by effective regulation and implementation of management instruments that require the corresponding allocation of financial, human, and logistical resources.

The five countries of the Basin have ratified the Ramsar Convention on Wetlands, the United Nations Framework Convention on Climate Change, and the Convention on Biological Diversity, among other global agreements. Among the regional ones, mention may be made, among others, of the Convention on the Use of the Uruguay River Rapids in Salto Grande (Argentina-Uruguay), the Treaty of Itaipú (Brazil-Paraguay), and the Mercosur Environmental Framework Agreement (Argentina-Brazil-Paraguay-Uruguay).

All countries have national standards in this field, such as the General Environmental Law (Argentina); The Mother Earth Law, which incorporates a framework on climate change (Bolivia); The Water Law (Brazil); The Law on Water Resources (Paraguay); and the Law on National Water Policy (Uruguay).

There are multilateral organizations that operate within the LPB, such as the Intergovernmental Coordinating Committee of the Countries of the La Plata Basin (1967), the Administrative Commission for Rio de la Plata (1973), the Tri-national Commission for the Development of the Pilcomayo River Basin (1995), and the Binational Commission for the Development of the Upper Bermejo and Río Grande de Tarija Basin (1995), among others. This includes both national and inter-jurisdictional institutions, as well as national or basin-wide plans in all countries.

The legal-institutional framework on specific issues, such as extreme hydrological events, is made up of agreements, such as those referencing Combating Desertification in Countries Affected by Severe Drought (1994); national standards such as Brazil's National Law on Protection and Civil Defense, and national plans such as the Federal National Flood Control Plan of Argentina.

Regarding the water quality degradation, the countries have ratified the Stockholm Convention on Persistent Organic Pollutants (1989) and have their own regulations, such as the Law on the granting of effluent discharges (Brazil). In terms of sedimentation of watercourses and bodies, one example is Paraguay's law on restoration of forests protecting the watercourses of the Eastern Region and their conservation.

To the broad normative panorama—of which only the main examples have been cited—agreements and specific norms on other topics such as navigation, hydroelectricity, contingency plans for disasters, alteration and loss of biodiversity, sustainable use of fishery resources, and the sustainable use of aquifers in critical areas, among other topics should be added.

Critical Transboundary Issues

The Transboundary Diagnostic Macro-Analysis (Macro-TDA), developed during the period 2003-2005, identified, on a scientific and social basis, the current and emerging critical transboundary issues (CTIs) in the LPB and their causal chains.

The critical issues identified were: extreme hydrological events linked to climate variability and change; water quality degradation; sedimentation of waterways and bodies of water in the Basin; disruption and loss of biodiversity; unsustainable use of fishery resources; unsustainable use of aquifers in critical areas; water use conflicts and the environmental impact of irrigated crops; lack of disaster contingency plans; and poor water health and the deterioration of environmental sanitation, later adding navigational limitations and the development of hydroelectric potential.

As part of the initial activities of the subsequent process, the project document was updated and the causal channels of each CTI were reviewed, making corresponding adjustments.

The execution of the project from 2011 to 2016 made it possible to develop activities aimed at deepening knowledge on the issues to consolidate and update the diagnostic.

The process was developed with the involvement of different Working Groups (WG), with representation from governmental and academic institutions of the five countries of the Basin with competence in each subject. Demonstrative pilot projects and priority projects for the resolution of critical problems in the Basin were also developed to provide local management experiences and information for the preparation of this TDA and the SAP, catalyzing existing initiatives in the countries involved.

Causes and recommendations

The main causes of extreme hydrological events include: lack of urban and territorial planning, poor coordination of information on extreme events, and lack of regional disaster prevention policies and education and awareness processes. In light of this, it is recommended to consolidate, expand, and improve coordination between the various systems of monitoring, information, climate prediction, and early warning; to improve urban and territorial planning to increase resilience and reduce vulnerability to extreme events; to promote the development of regional policies and to strengthen the legal framework for the prevention and management of such events and exchange experiences with research, awareness, and environmental education programs, among other issues.

In terms of water quality degradation, the following are the main causes: inadequate treatment of wastewater, lack of training of environmental managers, lack of development policies that encourage the use of clean technology and waste minimization, and the lack of compliance with existing regulations. For mitigation, it is recommended, principally, to seek funding sources for the construction and operation of domestic and industrial wastewater treatment plants, to promote the implementation of sustainable agricultural practices and the rational use of agrochemicals, and to develop programs to train environmental managers.

As for the sedimentation of waterways and bodies of water, the main causes of this problem have been: the inadequate use and management of land (expanding agricultural activity, use of marginal soils, elimination of natural pastures, overgrazing); the lack of incentives, extension policies, and training to apply sustainable agricultural techniques to technical-economic weakness by state agencies. To this end, it is recommended: to promote the development and harmonization of standards for the protection and use of natural resources; to develop land use planning and agro-ecological zoning; to strengthen institutional capacities for land-use management; to implement land reclamation and erosion control programs in priority areas; and to develop training and extension programs in soil management and conservation techniques.

The main causes detected for the alteration and loss of biodiversity were: the replacing of natural ecosystems with productive activities; the lack of incentives for the care and conservation of natural systems; the lack of protocol for the control of invasive species; and the lack of social awareness about the value of water resources and biodiversity. In light of this, it is recommended to establish cooperation mechanisms among countries in the field of biodiversity conservation; to develop river and coastal ecological corridors and other forms of participatory conservation; to encourage the development of transboundary protected areas; and to promote the adoption of regional minimum budgets for biodiversity conservation.

Regarding the unsustainable use of fishery resources, the main causes are: the overexploitation of species of objective commercial interest; the lack of technical and political coherence in the design and implementation of fishery policies; the lack of harmonious and integrated policies for the protection of aquatic life throughout the Basin; and the use of unsustainable techniques and difficulty in accepting new technologies. Recommendations include the promotion of integrated policies, standards, and compatible criteria for the protection and sustainable use of fishery resources throughout the Basin; the strengthening of management and control tools and mechanisms; the execution of vulnerability studies of priority riverine habitats, and the implementation of awareness-building and training programs on sustainable production techniques.

Regarding the unsustainable use of aquifers in critical areas, the main causes are: the existence of contaminant outbreaks from agriculture and household and industrial drainage; the lack of groundwater use management; the lack of transboundary institutional coordination for shared control and management; and low social participation. The main recommendations in this area are: to develop integrated and participatory management tools; to carry out vulnerability studies to identify areas of risk at the regional and local levels; and to develop regional inventories and databases and encourage greater social participation.

As for water use conflicts and the environmental impact of irrigated crops, the main causes are: the scarce or poor information available on shared water resources (inventory of uses and availability); the lack of joint management bodies for shared water resources; asymmetries in legal-institutional structures for the integrated management of shared resources; and lack of social awareness about the value of resources and their limited availability. With regard to the recommendations, the main ones are: to promote agreements and the development of common legal frameworks for water use management; to strengthen the management capacity and institutional coordination of relevant agencies in the five countries; to generate information and facilitate public access to data of interest for managing supply and demand; and to establish strategies for communication, diffusion of information, and public awareness about management.

Regarding the lack of disaster contingency plans, the main causes have been: the risk of breaks due to errors in dam operation; the lack of review of the dams' safety criteria, taking into account the impacts of climate change; the absence of national and transnational regulations governing dam safety; and the lack of awareness surrounding the risk to the populations located downstream of these types of works and to the operating companies themselves. For this reason, the main recommendations: are to establish common safety standards and criteria, considering the incidence of climate variability and change; to develop and adopt national and transnational safety and operational standards for emergencies; to develop or update contingency plans and programs in the event of dam rupture; and to develop awareness-raising measures amongst citizens on prevention and risk reduction.

The main causes of poor water health and the deterioration of environmental sanitation include: the lack of information on waterborne diseases; the inefficiency of control over industrial changes and agrochemicals; the asymmetry of legal and technical criteria for the management of water resources and public health; and resistance to changing habits. Recommendations include: strengthening research and the generation and dissemination of data on waterborne diseases; promoting policies and programs for the treatment of solid waste, industrial waste, and the management of agrochemicals; strengthening the capacity of local managers and the articulation and institutional coordination of organisms and institutions in the water and sanitation sectors of the countries; and to promote education and public awareness programs on environmental hygiene and health.

For navigational limitations, the main causes are: the lack or insufficiency of infrastructure to overcome natural critical points; inadequate joint institutional management; asymmetries and weaknesses in country regulations; and the preference for land transport. In response, it is fundamentally important to harmonize regional policies for river transport; to adapt the legal and institutional framework for river navigation; to develop transboundary plans for the maintenance and dredging of inland waterways; and to promote an integrated transport system.

Regarding the development of the hydroelectric potential, the respective analysis of its causes was not carried out. However, the recommendations that stand out are: to make agreements for energy integration between the countries of the Basin; to integrate hydro-meteorological monitoring networks from hydraulic use to other information systems; and to take actions to take advantage of the regional interconnected communications system in order to improve the transmission of information for early warning hydrological systems.

TDA Conclusions as a Contribution to the SAP

The development of each of the Critical Transboundary Issues makes it possible to understand the hydro-environmental behavior of the La Plata Basin, both from a historical point of view and from one projected for the future. In order to understand natural phenomena, better knowledge of the anthropic activities that have affected this hydro-environmental behavior must be cultivated, particularly surrounding the change in land use, especially driven by the development of the agriculture and livestock industries and the increase in urbanization. Such hydro-environmental behavior, modified by the actions of humans, is the direct or relatively more indirect basis for the analyzing each one of the CTIs.

Based on the analysis of the main causes identified for the CTIs and the recommendations arising from the execution of this phase of the project, the following are the general recommendations to be considered for the Strategic Action Program (SAP), grouped into technical, economic-managerial, political-institutional, and socio-cultural points:

Technical recommendations:

- Promote joint monitoring of the quantity and quality of shared water resources.
- Encourage coordination between observation and warning systems in the face of extreme events (floods and droughts) in the Basin countries.
- Improve urban and territorial planning to increase resilience and reduce vulnerability to extreme events.
- Exchange experiences on risk management among national, bilateral, and multilateral agencies.
- Develop or update contingency plans and programs in the event of broken dams and other accidents.
- Promote structural, maintenance, and operations improvements in ports.
- Promote actions to reduce the vulnerability of river transport.
- Develop cross-border plans for maintenance and dredging of inland waterways.

Economic and managerial recommendations:

- Develop river and coastal ecological corridors and other forms of participatory conservation.
- Establish mechanisms for cooperation among countries in the field of biodiversity conservation.
- Establish common safety standards and criteria, considering the incidence of climate variability and change.
- Promote the exchange of information

and experiences related to dam operation and safety.

Institutional-political recommendations:

- Promote institutional cooperation and coordination throughout the Basin, including the consolidation of the CIC as a coordinating body.
- Harmonize legal frameworks for the management of transboundary water resources.
- Promote the adoption of regional minimum budgets for biodiversity conservation.
- Develop and apply protocols for the control and management of invasive species.
- Make regional policies compatible and adjust the legal and institutional framework for river navigation.
- Make regional policies for hydroelectric development compatible.

Socio-cultural recommendations:

- Promote greater participation of society in actions aimed at solving common problems in the Basin.
- Develop and exchange experiences on research, education, and citizen awareness programs on water resources and other environmental considerations.
- Promote education and citizen awareness programs about specific environmental problems in the Basin.

Chapter 1: Characterization of La Plata Basin

1.1 Location

The La Plata Basin (LPB), geographically located between 14 and 37 degrees south latitude and 43 and 67 degrees west longitude, is one of the most extensive basins in the world, with an area of approximately 3.1 million km². It is the second largest in South America and fifth largest on the planet. It covers almost all the south-central Brazil, southeastern Bolivia, a large part of Uruguay, the entire territory of Paraguay, and a large area of central and northern Argentina. The La Plata Ba-

The falls on the Iguazú River, on the border between Argentina and Brazil, in the middle of the Selva Misionera Paranáense, is one of the most emblematic landscapes of the Basin.

sin corresponds to 25 percent of the total area of the five countries.

The Basin is formed by three main water systems, those of the Paraguay, Paraná, and Uruguay rivers, draining approximately one fifth of the territory of the South American continent. The last two form the La Plata River, which water levels into the South Atlantic Ocean (**Figure 1.1.1**). **Table 1.1.1** shows the LPB's land distribution by country and by water system.

Figure 1.1.1

General map of the La Plata Basin

Table 1.1.1

Distribution of the area of La Plata Basin by country and by water system

Country	Area of water systems (km²)				Total area by country (km²)
	Paraná	Paraguay	Uruguay	The La Plata River itself (*)	
Argentina	583,885 38.7%	186,051 16.6%	63,584 18.0%	150,535 79.2%	**984,056** **30.9%**
Bolivia	–	221,994 19.8%	–	–	**221,994** **7.0%**
Brazil	877,385 58.1%	362,434 32.4%	174,199 49.3%	–	**1,414,018** **45.6%**
Paraguay	53,000 3.5%	353,752 31.5%	–	–	**406,752** **12.8%**
Uruguay	–	–	115,668 32.7%	39,577 20.8%	**155,245** **4.9%**
Total area by water system	**1,510,513**	**1,120,154**	**353,451**	**190,113**	**3,182,064**
% of the La Plata Basin	**47.6%**	**35.3%**	**11.1%**	**6.0%**	**100.0%**
Extension of the principal rivers (km)	**4,800**	**2,600**	**1,800**	**700**	

(*) The total area includes the surface of the La Plata River, 30,325 km², shared by Argentina and Uruguay.

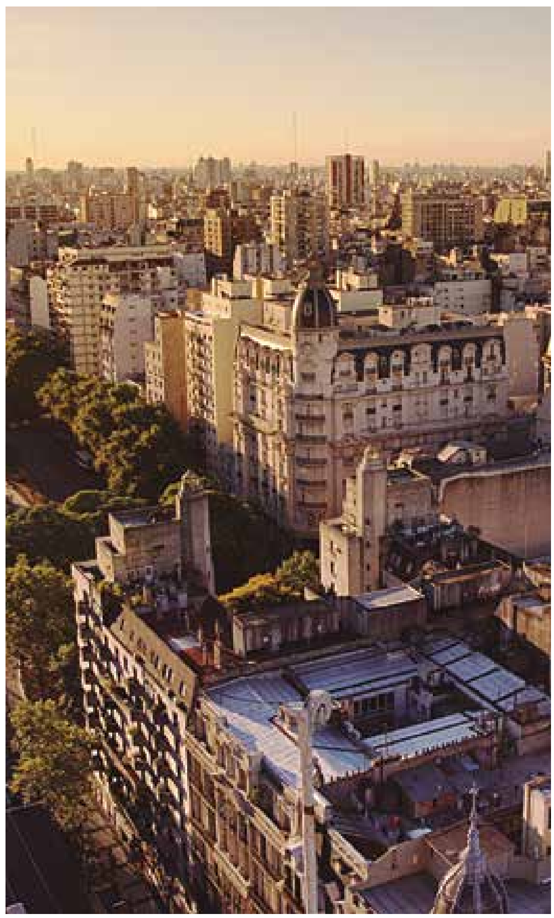
1.2 Socioeconomic Characteristics

1.2.1 Demography

In the LPB, where the current population exceeds 110 million people, there are at least 20 cities with more than 500,000 inhabitants, including the capitals of four of the countries that make up the Basin: Buenos Aires, Brasilia, Asunción, and Montevideo. Sucre, the constitutional capital of Bolivia, is also located in the Basin; and one of the largest megalopolis and industrial concentrations in the world, the city of São Paolo (Brazil), which houses more than 20 million people, is located on one of the tributaries of the Paraná River.

Table 1.2.1.1 shows the population and density indicators for the Basin countries as a whole. The average density is 20.2 hab/km². The urban population is 86.3 percent, with Argentina, Uruguay, and Brazil being the countries with the highest percentage of urban population.

Regarding the data at the level of the whole Basin, a population estimate was carried out with census data between 2010 and 2012, depending on the country in question. The results indicate a total population of 111,400,482 inhabitants, corresponding to 26.1 percent in Argentina, 1.8 percent in Bolivia, 63.3 percent in Brazil, 6.0 percent in Paraguay, and 2.8 percent in Uruguay. The corresponding details are shown in **Table A.1** of the *Appendix*.



São Paulo and Buenos Aires, the bigest cities in the Basin

Table 1.2.1.1

Area, population, and urban population by country

Country (*)	Area (in millions of km²)	Population (in millions of inhabitants)	Density (Inhabitants/km²)	% Urban population
Argentina	2,780	41,775	15,0	94,0
Bolivia	1,099	10,598	9,6	68,3
Brazil	8,616	201,497	23,4	86,3
Paraguay	0,407	6,888	16,9	64,1
Uruguay	0,176	3,418	19,4	92,8
Total	**13,078**	**264,176**	**20,2**	**86,3**

(*) The data in the table refers to the Basin countries as a whole, not only to the portion corresponding to the La Plata Basin.

Source: Statistical Yearbook for Latin America and the Caribbean. ECLAC, 2014.

1.2.2 Socioeconomic Indicators

The richness of mineral resources, the value of its forests, and the fertility of its soils have made the LPB a region of strong population attraction that today favors its economic development, which translates into a concentration of 70 percent of the GDP of these countries.

Table 1.2.2.1 shows the Gross Domestic Product of each country and the corresponding *per capita* value. It should be noted, however, that *per capita* income in Brazil has great variation, as it is lower in the northern and northeastern states than in the south, southeastern, and midwestern states, where the Basin is located.

The economies of Argentina, Brazil, and Uruguay, with a strong agricultural and livestock component, also show significant industrial production and services, while Bolivia's economy is based on its mineral resources and Paraguay's maintains its development based on agro and hydroelectric power.

Table 1.2.2.2 shows the distribution of the employed population by economic sector in 2011. Following a worldwide trend, the greatest employment is concentrated in services, although Bolivia and Paraguay have an important part of their population turning to agricultural activity.

As for the share of each sector of the economy within the GDP, agriculture has a relatively small impact on the economies of the countries, with the exception of Paraguay. The water and energy sectors account for between one and 10 percent of the economies, while the combination of water-related sectors (agriculture, transport, and energy) varies between 16 percent and 35 percent. **Table A.2** of the *Ap-*

Table 1.2.2.1

Gross Domestic Product by country

Country (*)	GDP (in millions of dollars)	% of total GDP of the 5 countries	GDP *per capita* (**) (in dollars)
Argentina	477,028.3	16.9	11,614.4
Bolivia	27,035.1	1.0	2,625.1
Brazil	2,249,090.9	79.5	11,3348
Paraguay	24,595.3	0.9	3,684.7
Uruguay	49,918.7	1.8	14,703.3
Total	**2,827,668.3**	**100**	

(*)The data in the table refers to the Basin countries as a whole, not only to the portion corresponding to the La Plata Basin.

(**) According to market prices in 2012.

Source: Statistical Yearbook for Latin America and the Caribbean. ECLAC, 2013.

Table 1.2.2.2

Total employed population, by sector

Country (*)	Agriculture/ Livestock	Industrial	Services
Argentina	1.2	23.8	74.4
Bolivia	31.6	18.9	44.1
Brazil	15.3	21.9	62.7
Paraguay	25.5	17.8	56.6
Uruguay	10.1	21.5	68.4

In percentages, data from 2011.

(*)The data in the table refers to the Basin countries as a whole, not only to the portion corresponding to the La Plata Basin.

Source: Statistical Yearbook for Latin America and the Caribbean. ECLAC, 2013.

Cattle-ranching, an activity of great importance in the La Plata Basin.

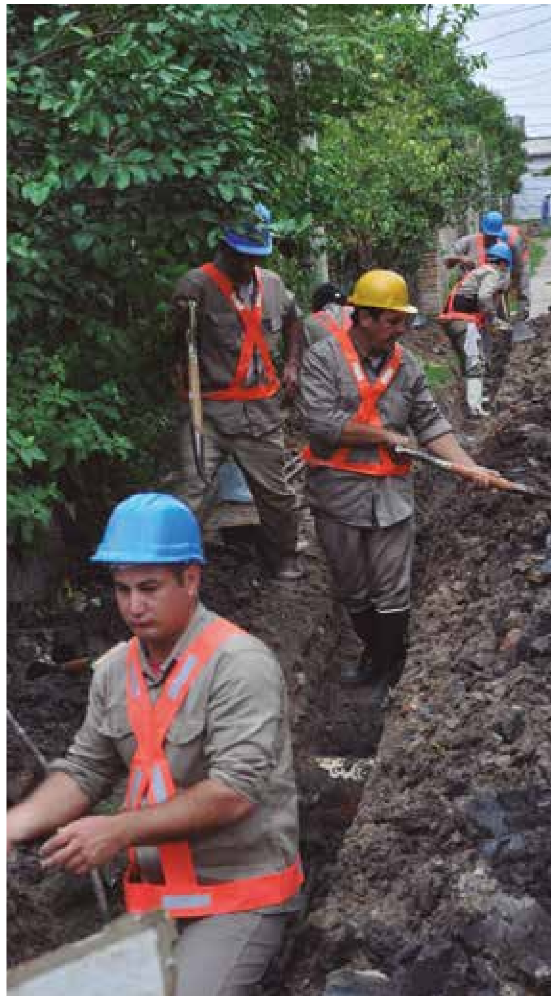
pendix shows a breakdown of each sector as a percentage of GDP.

The Human Development Index (HDI) in the states, provinces, or departments of the LPB countries varies between 0.806 and 0.899 for Argentina, between 0.514 and 0.689 for Bolivia, between 0.725 and 0.824 for Brazil, is 0.659 for all of Paraguay, and between 0.706 and 0.841 for Uruguay.

The illiteracy rates for the same jurisdictions vary between 3.6 and 11.0 percent for Argentina, between 6.2 and 11.9 percent for Bolivia, between 4.1 and 8.5 for Brazil, 4.7 for all of Paraguay, and between 0.9 and 3.5 for Uruguay. **Table A.3** and **A.4** of the *Appendix* show the corresponding details of the last two indices mentioned.

1.2.3 Health

The health-related situation in the countries of the LPB can be analyzed in general terms by indicators such as life expectancy at birth and infant mortality rates. Such indicators not only provide information on health, but also, indirectly, on the population's living conditions and their access to and quality of health services.



Laying water systems.

Life expectancy at birth in the respective departments, states, or provinces varies between 70.9 and 77.2 years for Argentina, between 62.0 and 69.5 years for Bolivia, between 74.2 and 76.2 for Brazil, 72.5 years for all of Paraguay, and between 75.1 and 77.2 years for Uruguay.

On the other hand, infant mortality rates vary between 8.9 and 14.9 percent for Argentina, between 37.2 and 65.5 percent for Bolivia, between 9.8 and 17.7 percent for Brazil, 15.2 percent for all of Paraguay, and between 5.4 and 11.4 percent for Uruguay. **Tables A.5** and **A.6** of the *Appendix* show the corresponding details for these last two indices.

The serious situation in the urban and rural settlements of the Basin caused by biological contamination related to the lack of sanitation facilities and wastewater treatment services should be noted. Episodes of waterborne diseases such as diarrhea, cholera, malaria, and dengue are common in certain regions. **Table 1.2.3.1** shows the percentages of the population with access to potable water and sanitation in the Basin countries. Although the figures appear to indicate a good situation at the country level, it should be remembered that the concept of "access to improved sources" involves systems of very diverse quality in terms of availability of services.

With regard to potential health risks in drinking water sources, a number of blue-green algae blooms or toxigenic cyanobacteria have been recorded in different river systems in recent years. If they grow disproportionately, these organisms produce cyanotoxins that may affect the health of the population—since potable water treatment systems are not adapted for their removal—as well as the health of domestic and wild animals (fish mortality) and of livestock, by contaminating troughs. It is, therefore, a public health problem that requires action to minimize its negative effect on at-risk populations.

It is also worth considering schistosomiasis (especially in Brazil), a parasitic waterborne disease transmitted by freshwater snails, which, according to the World Health Organization (WHO), is the second most important parasitic disease after malaria because of the damage it causes to the health and the economies of the countries that are plagued by it.

As for more specific problems, it is important to note that in several areas of Argentina the population must consistently use water with a high arsenic content –a natural element found in the earth's crust– above acceptable limits for drinking water standards. Although significant efforts have been made to minimize or eliminate this contaminant in drinking water through physio-chemical treatments, the problem has arisen in many localities, especially in populations without potable water service networks.

Table 1.2.3.1

Access to improved sources of potable water and sanitation

	Drinking water			Sanitation		
Country (*)	**Country total**	**Urban**	**Rural**	**Country total**	**Urban**	**Rural**
Argentina	99	99	98	97	97	99
Bolivia	88	96	72	46	57	24
Brazil	98	100	76	81	87	49
Paraguay	94	100	83	80	96	53
Uruguay	99	100	95	96	96	96

In percentages. Data from 2012.

(*)The data in the table refers to the Basin countries as a whole, not only to the portion corresponding to the La Plata Basin.

Source: Statistical Yearbook for Latin America and the Caribbean. ECLAC, 2014.

1.3 General Description

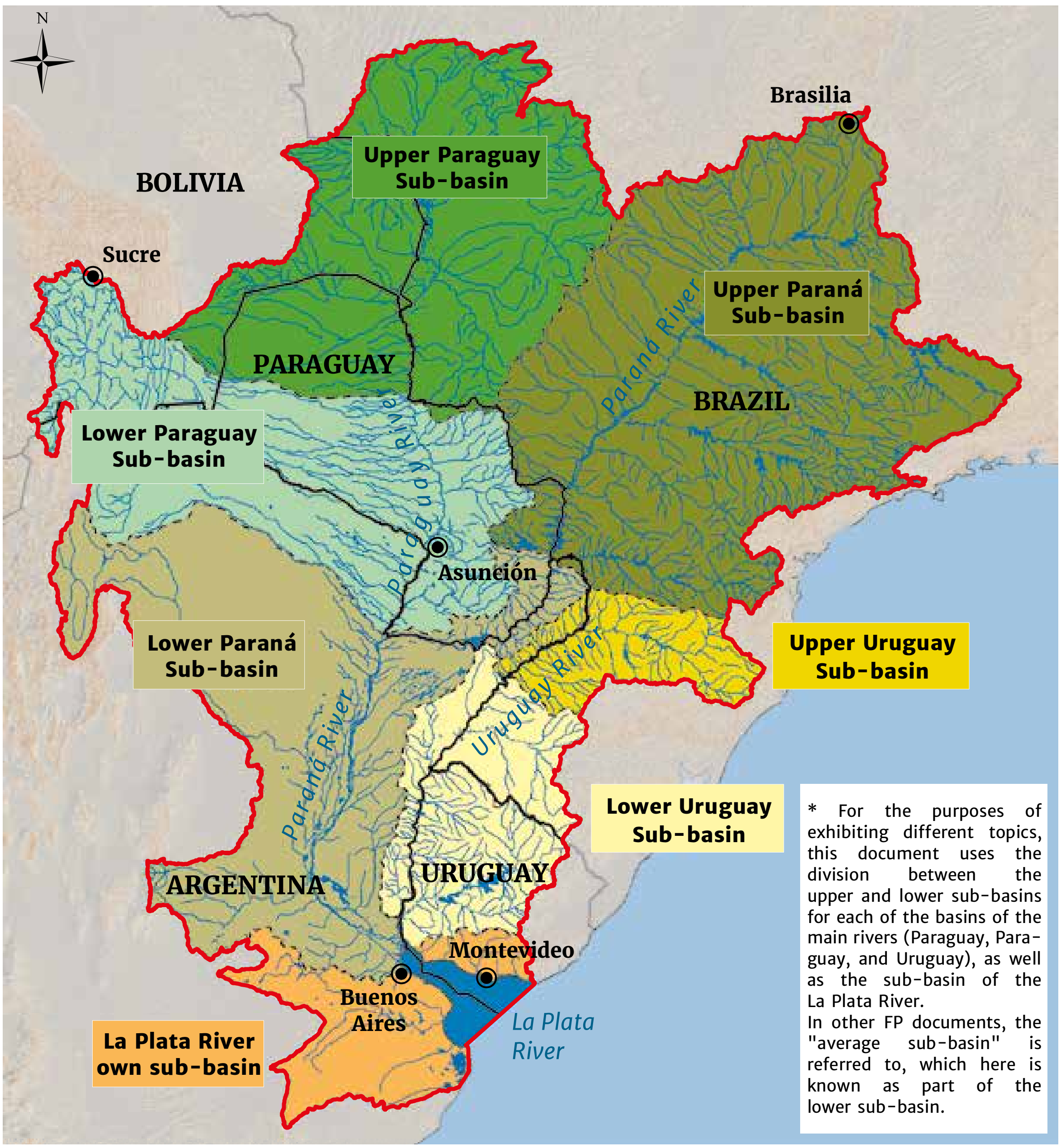
1.3.1 Characterization of the Sub-basins

The La Plata Basin can be subdivided into seven sub-basins, which are identified and whose main geographical features are detailed, respectively, in **Figures 1.3.1.1** and **1.3.1.2**. Their most outstanding features are:

The Upper Paraguay (until its confluence with the Apa River): Includes two large environments: the Planalto and the great Pantanal wetland. The formation of the

Figure 1.3.1.1

Map of sub-basins (*)



* For the purposes of exhibiting different topics, this document uses the division between the upper and lower sub-basins for each of the basins of the main rivers (Paraguay, Paraguay, and Uruguay), as well as the sub-basin of the La Plata River.
In other FP documents, the "average sub-basin" is referred to, which here is known as part of the lower sub-basin.

Figure 1.3.1.2

Geographic characteristics of the sub-basins

Pantanal acts as a large water reservoir at the head of the La Plata system, which also retains increasing amounts of sediment, caused by the agriculture in the Planalto region. The sedimentation constitutes a strong threat to the ecosystem because of the great variety of species whose natural habitat is in this wetland. Maintaining the slow drainage of the Pantanal is key to avoiding a higher incidence of flooding downstream of the Paraguay River and in the already heavily affected Paraná River.

The Lower Paraguay (from the confluence with the Apa River to the confluence with the Paraná): the Paraguay River, in spite of the contributions it receives in its upper basin, has a negative water balance in part of this section, if only considering its right margin tributaries –as indicated later in **Table 1.4.1.1.1**– since their overwater level does not return to the main channel, recharging lateral depressions in which the water is retained until it evaporates. Nevertheless, its left margin tributaries—Aquidaban, Jejui, Aguaray, and Tebicuary—generate important contributions. Along the main course of Paraguay is the city of Asunción, the capital of Paraguay, affected by frequent floods. This section is an important part of the Paraguay-Paraná Waterway and receives, from its right margin, two tributaries: the Pilcomayo and Bermejo rivers.

The Pilcomayo River basin is particularly critical because of centuries-long mining pollution in the upper basin, with significant environmental liabilities. It is note-

The Pantanal, in the Upper Paraguay River Basin.

worthy that the heavy sediment load has caused, in its middle section, the extinction of its channel by tunneling, which is why its waters overwater level to its right or left margins, forming baths. Downstream, the so-called Lower Pilcomayo, which appears hydrologically disconnected from the upper river, is one of the numerous streams that drain the Chaco and water level into the Paraguay River, with a much lower water level than in its upper section, upstream of the tunneling.

As for suspended sediment production levels, the Bermejo River basin has a similar behavior. The Bermejo River is currently the source of more than 70 percent of the sediments transported by the Paraná River in Corrientes (Argentina), which affect the channels of the waterway and the ports of Buenos Aires and Montevideo. To the west of the Basin is the Gran Chaco Americano region, which is an important area of semi-arid lands, where the presence of good quality fresh water aquifers with saltwater aquifer interferences has been observed. Altogether, the system is called the Yrendá-Toba-Tarijeño Aquifer System (YTTAS).

The upper Paraná (up to the confluence with the Iguazú River): Both urban and rural anthropogenic impacts are detected throughout its extension. It is the basin most influenced by the construction of dams, deforestation, and the presence of large cities. As noted below (see section 1.4.2.6), this section of the Paraná River is navigable upstream from the Itaipu dam, together with its tributary, the Tietê River.

The lower Paraná (from the Iguazu River to its mouth in the La Plata River): The characteristics of this region are the great flood plains and the wetland corridors, some quite large such as the Ñambucú, the Iberá, and the Paraná Delta. There are wetland areas under protection such as the Iberá Estuary in Argentina, but there is no common and integrated management policy between countries, as they are strongly dependent on the surface water system and, eventually, the groundwater. The Yacyretá dam constitutes partial interference for fish migrations that move upstream for reproduction, as it has a fish elevator that allows them to be transported to their reservoir. The lower part constitutes the backbone for navigation through the Paraguay-Paraná waterway. Along its banks are important cities, periodically affected by the floodwaters of the Paraná, which has led to the implementation of alert systems, particularly in Argentina.

The upper Uruguay (up to the section set for the Garabí dam): The basin passes from a basaltic spill cover, represented by the Rio Grande do Sul and Santa Catarina Plateau, to the Campos Sulinos, where the lows are predominant with changes in land use. Maize, soybean, and wheat farms predominate in the upper part, while in the lower section, rice cultivation by flooding predominates. In this part of the basin there is an important production of pigs and birds that generate major pollution problems.

The lower Uruguay (from Garabí to the mouth of the La Plata River): In this part of the basin some conflicts arise due to the alternative use of water between rice irrigation, supplying the cities, and the conservation of ecological water levels in the rivers. In this sense, due to the transboundary nature of the waters, the Cuareim-Quaraí river basin, which borders Brazil and Uruguay, deserves attention. Hydroelectric projects in the Negro River and the Uruguay River (the binational Salto Grande) cause some alterations in the water system and in aquatic biodiversity, although Salto Grande has fish pass systems. The lower Uruguay has a series of islands and coastal wetlands that require attention for their management. Due to their natural and cultural riches, they have relevant potential for ecotourism and nautical tourism, which enhances the value of their conservation.

La Plata River (its own sub-basin): La Plata River is the last stretch of the Basin, in which the Paraná and Uruguay rivers converge and then water level into the South Atlantic. It is characterized by the intrusion of salty ocean waters and the high level of nutrients and fish species, some of high commercial value. The city of Buenos Aires—which represents the largest industrial settlement in Argentina with a port characterized by the strong accumulation of sediment that runs into the Paraná river—is on its coast, as well as the city-port of Montevideo and the coastal settlements of Uruguay.

1.3.2 Climate

From the hydro-climatic point of view, the LPB has an important diversity of climates, ranging from the dry and very hot ones to the west of Chaqueño, with less than 600 mm/year of precipitation, to the humid regions of the south of Brazil and Southeast of Paraguay, with more than 2,000 mm/year of precipitation. These climates present an inter-seasonal or inter-annual variability that often results in extreme events of droughts or floods of great magnitude. There are also important and interesting meteorological systems that generate severe weather in the LPB, as it is one of the regions of the world with the highest frequency of thunderstorms. In addition, a large part of the basin is part of the South American tornado zone.

The climate of the LPB presents important gradients that determine its hydrological behavior. The northern part of the basin is under the influence of a monsoon rainfall regime, with a pronounced peak in the summer. The great Pantanal wetland plays a key role in storing the runoff from the rains in the Upper Paraguay, delaying its major contributions to Paraná almost six months. In the central and eastern zones of the La Plata Basin the seasonal variation is small, as it is the region with the highest precipitation and contribution to the large rivers. To the west of the Paraguay-Paraná (Gran Chaco Americano) axis, precipitation progressively diminishes to the west, which, together with the high temperatures that determine high levels of evaporation, defines a semi-arid and, in some areas, arid climate. Consequently, the runoff is very small and the contributions of the tributaries of that region to the La Plata system are minimal. The southern part of the LPB presents a temperate climate, although with warm summers and with rains that decrease towards the west.

The LPB presents a high year-on-year climatic variability. In particular, its precipitation is conditioned by the El Niño-Southern Oscillation (ENSO) phenomenon in its cold (La Niña) and warm (El Niño) phases, being one of the regions most affected in the world by this phenomenon. For example, during El Niño, high precipitation is recorded in the eastern and central regions of the LPB, which causes huge floods in the Paraguay, Paraná, and Uruguay rivers, with consequent economic and social damages. On the other hand, certain social behaviors, such as unplanned urban expansion and land use in river flood valleys, have led to an amplification of the impacts of these floods.

Over the last 30 years, rainfall in the Basin has increased on average between 10 and 15 percent, resulting in higher river water levels, which reached 30 percent, with great benefits for hydroelectricity. This large change in water level rates may have been influenced by the huge change in land use that took place in current years.

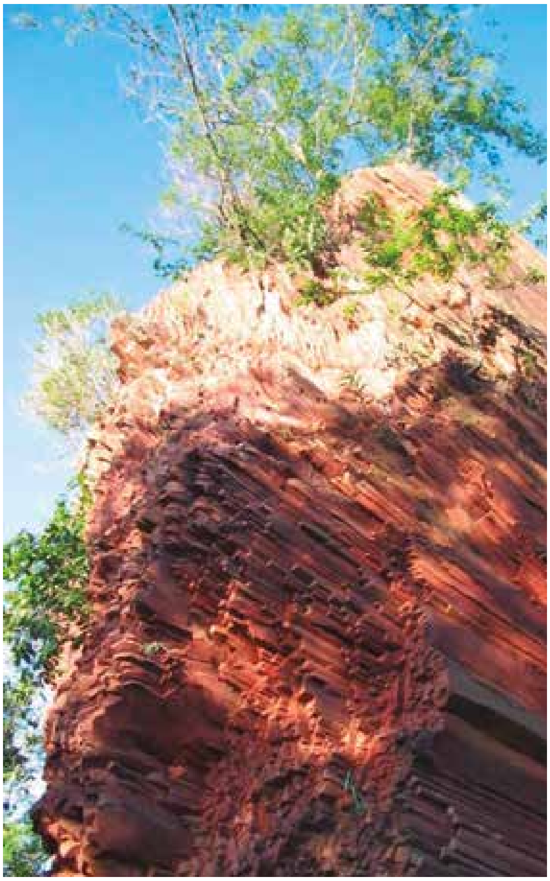
1.3.3 Geology

The geology of the extensive La Plata Basin is made up of raised structures and sedimentary basins, the result of tectono-magmatic and sedimentary events that form a variety of magmatic, metamorphic, and sedimentary rocks from the Precambrian to the Quaternary period.

The tectonic behavior has strongly influenced the geology of the area, including the current drainage, such as that of the major water tributaries: Paraná, Paraguay, and Uruguay.

In the LPB there are two large geological basins of tectonic origin: the Paraná and the South American Gran Chaco, which until the Mesozoic Era were of a single basin—the Chaco-Paranáense—following its evolution from that period. These two basins are home to the most important aquifer systems in the region, the Yrendá-Toba-Tarijeño Aquifer System (YTTAS) and the Guaraní Aquifer System (GAS).

The Serra Geral Formation is one of the largest continental volcanic formations on the planet. The rocks produced can be found in the form of lava water levels, whose volume is estimated at 780,000 km³, covering a large part of south and southeastern of Brazil. The post-basalt sediments of sandstone and conglomerates of the Baurú and Caiuá groups were deposited in a semi-arid or desert continental environment: the so-called Caiuá desert.



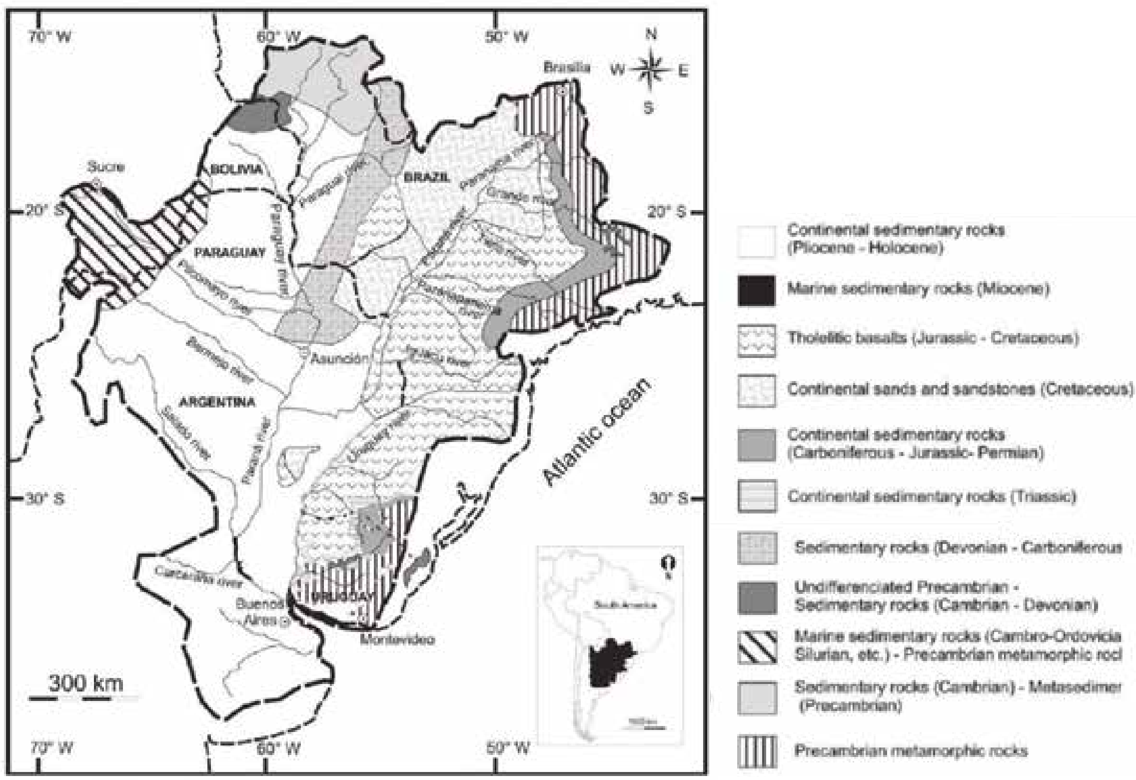
Sandstone columnar of the Patiño Formation, Tertiary. Cerro Koi, Aregua, Paraguay.

Figure 1.3.3.1 shows a geomorphological diagram of the LPB where a predominance of the basaltic formations of the Jurassic-Cretaceous period can be observed in the upper Paraná River and the eastern banks of the Uruguay River. To the east of the Paraná, the sedimentary rocks of Pliocene-Holocene origin predominate.

In the southeastern (east of the Uruguay River) and northeastern regions of the Basin (in Brazil), there are metamorphic rock formations from the Precambrian period. In the region west of the Paraná and Uruguay rivers there is a more recent forma-

Figure 1.3.3.1

Geomorphologic structure of La Plata Basin (*)



(*) This figure is being reviewed by the respective Working Group.

tion, mainly of sedimentary rocks of the Cenozoic era, due to the South Atlantic incursion in the Paleogene period.

In the sub-basin of the upper Paraguay the sedimentary rocks of the Cambrian and the meta-sedimentary rocks of the Precambrian predominate.

1.3.4 Soils

The LPB boasts a great diversity of soils as a result of the geological and climatic evolution. As with the vast majority of soils in Latin America, those in this region are poor in nutrients (characteristic of tropical areas), acidic (product of intensive land use in agricultural areas), and affected by erosion processes, surface washing, and high concentrations of iron and aluminum oxide in the subsurface.

Large areas with soils influenced by salts are also identified, mainly in endorheic basins where water has no direct outwater level to the sea (the Gran Chaco Americano of Paraguay, Bolivia, and Argentina). The origin of these salts is the product of the weathering of rocks with high levels of salt caused by water erosion, old marine sediments, and deposits of saline groundwater evaporation. The arid regions are concentrated near the pre-Andean mountain range characterized by shallow soils and rugged relief.

The soils of this region are characterized for the entire LPB according to the FAO classification presented in **Figure 1.3.4.1.**

In general, the LPB is responsible for the production of a wide variety of diverse agricultural and forestry items, including soybeans, maize, wheat, coffee, beef, and other food by-products, preferably grown on lateritic soils -a product of basalt- and sandy soils.

The current problems related to soil resources are due to inadequate systems of habilitation and change in land use, which have allowed deforestation and overexploitation of natural resources.

The LPB has one of the highest rates of suspended solids transport in the world. The largest solid inputs come from the Bermejo River basin, an affluent part of the Paraguay River. Also in the upper Paraguay-Pantanal, there are significant wetland conservation problems related to the increase of sediment. Another critical area is the Gran Chaco, where soil degradation is the main axis of analysis for the integrated management of natural resources.

Land degradation is also associated with the periodic occurrence of climate change effects on socio-economic activities, generating in many cases population migration and increases in poverty. However, it is noteworthy that in recent decades there has been an increase in awareness around the adoption of good agricultural practices and the proper management, conservation, and restoration of this resource.

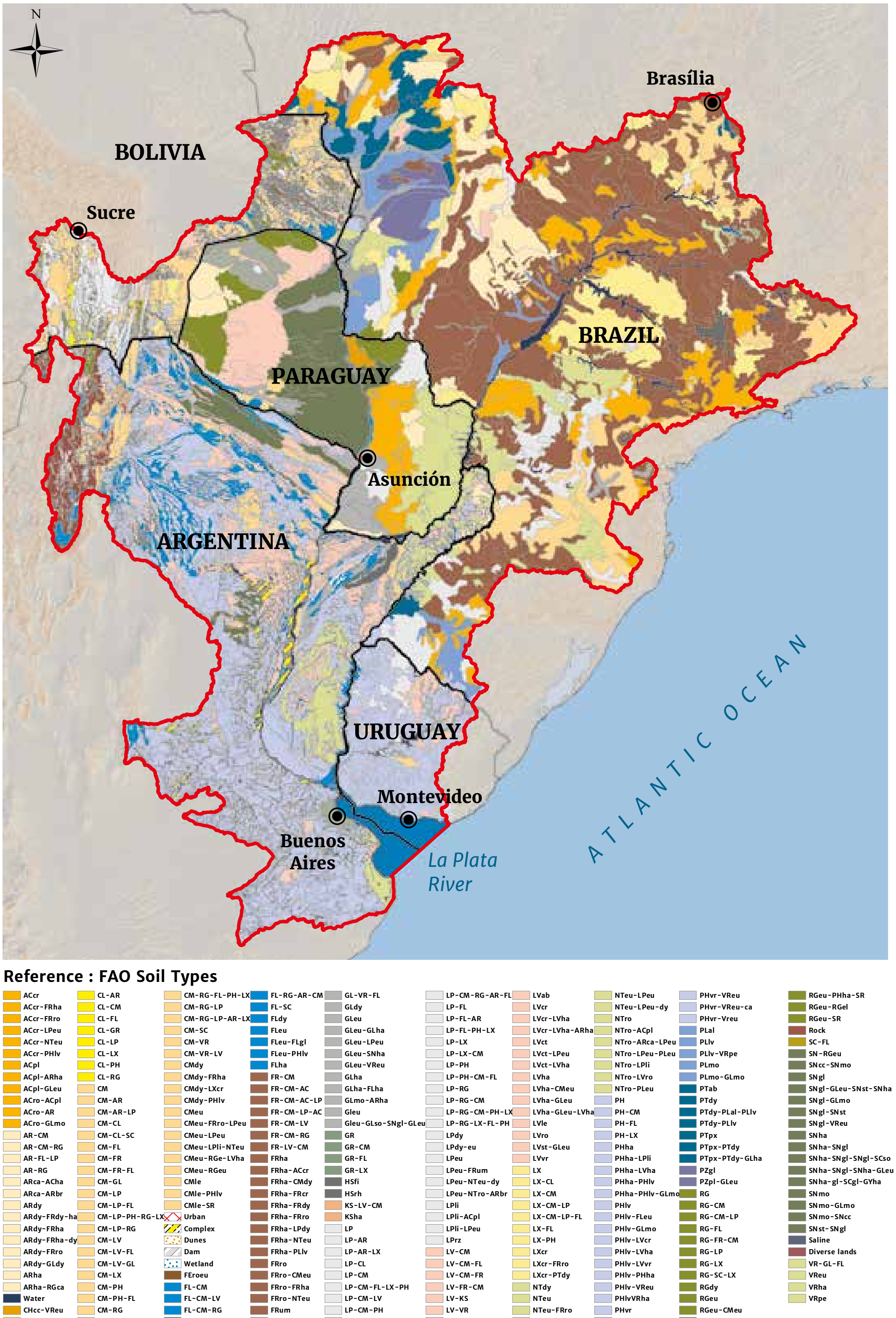
1.3.5 Principal Wetlands

The LPB hosts the largest river wetland system on the planet of almost 3,500 km^2, formed by a corridor of wetlands connected by the axis of the great rivers Paraguay, Paraná, and La Plata (**Figure 1.3.5.1**).

The Iberá Estuary in Corrientes, Argentina.

Figure 1.3.4.1

Soils of the La Plata Basin



The floodplain of the Paraguay River and its continuation to the Paraná River determines a hydrological continuum of wetlands and a biological corridor that extends from north to south from the great Pantanal in the upper Paraguay, passing through the wetlands of the lower Chaco, the wetlands of San Pedro, Ypacaraí, Ypoá, and Ñeembucú in the eastern Paraguay, the broad floodplain of the Paraná River, the Iberá Estuary (Argentina), to the Paraná Delta and the La Plata River Estuary (Samborombón in Argentina, and Santa Lucía in Uruguay).

Figure 1.3.5.1

Principal wetlands of the La Plata Basin

The main axis of the wetland corridor is a transverse secondary system, with emphasis on the Chaco wetlands associated with the Pilcomayo and Bermejo rivers in lower Paraguay, those of the upper Paraná, and the ones transverse to the Uruguay River, like the Negro and those of the humid pampa region.

1.3.6 Aquatic Biodiversity: The Ichthyofauna

The LPB is recognized as one of the most important basins in the world for the quantity, variety, and endemism of fish species. Its ichthyofauna numbers 908 species. Siluriformes (42 percent) and Characiformes (34 percent) are the most important orders, followed by Perciformes (9 percent) and Cyprinidoniformes (8 percent).

The sub-basins of the Paraná (upper and lower) and Paraguay (upper and lower) have the highest species richness, with a decreasing tendency towards the sub-basins of the southeast (lower Uruguay and La Plata River).

Of existing fish species (480), 53 percent are endemic, exclusively inhabiting any of the seven sub-basins. The level of endemism is highest in the upper Paraná, it is intermediate in the western sub-basins of the Basin, while the lowest levels are found in the lower part (lower Uruguay and La Plata River).

The threat of extinction is only 2.4 percent if all the 908 species are considered, although that number is likely to be underestimated. In the Paraná (upper and lower) and lower Paraguay are the highest number of threatened species, while in the upper Uruguay there is only one threatened species. In the other sub-basins intermediate values are found.

The presence of 13 species of exotic fish in the Basin have been documented, several of them identified as invasive. The main ones are herbivorous carp (*Ctenopharyngodon idella*), Asian carp (*Cyprinus carpio*), head carp (*Hypophthalmichthys nobilis*), tilapia (*Tilapia rendalli*), Nile tilapia (*Oreochromis niloticus*), rainbow trout (*Oncorhynchus mykiss*) and the African catfish (*Clarias gariepinus*).

In addition to fish, amphibians, reptiles, and several exotic invertebrates, mainly mollusks and crustaceans, have been identified. There are 392 records of exotic species distributed throughout 146 localities, located mostly in the Paraná (upper and lower) and La Plata River.

1.3.7 Fisheries in the La Plata Basin

The rich ichthyofauna represents a key resource for the region. Forty percent of the fish species (367) have socio-economic relevance as a resource for commercial, artisanal, subsistence, recreational/sport, and aquarism fishing, which sustains tourism activities in the Basin. The use and valuation of fish fauna is more important in the sub-basins of the Paraguay (upper and lower) and the lower Paraná.

Some of the species (tarpon, surubí, dorado) are undergoing intense exploitation in some stretches. In addition, anthropic action—through contamination by different types of effluents, the construction of infrastructure works, and the drying up of wetlands for conversion into agricultural and livestock areas—have a negative impact on fish stocks.

Aquaculture is carried out in ponds and *raceways*, followed by cultures in floating cages. In the first category, the cultivation of tarpon and sturgeon (*Acipenser baerii*)

Fish farming in the Itaipú reservoir.

stands out, while in the second category sturgeon is widely prevalent. Exotic species such as tilapia (*Oreochromis niloticus*), herbivorous carp (*Cenonopharyngodon idella*), and madrecita (*Cesterodon holopteros*) are also grown. In installations of the National Directorate of Aquatic Resources of Uruguay (DINARA) they produce seeds, juvenile and adult black catfish (*Rhamdia quelen*), pejerrey, tilapia, sturgeon, herbivorous carp, and common carp (*Cyprinus carpio*).

There are at least 1,338 instances of fisheries or confinement of exotic species in the LPB, which is a strong threat due to the probability of specimen escaping that could eventually become invasive. The highest concentration of fisheries is in the lower and upper Paraná (941 and 358, respectively). In the rest of the Basin, the number is low or very low: 11 and 14 in the sub-basins of Paraguay, six and seven in Uruguay, and only one in the La Plata River (**Figure 1.3.7.1**).

1.3.8 Ecosystems and Anthropogenic Pressure

The LPB has undergone a considerable transformation in land use, as about 40 percent of the original coverage has been replaced by areas of human use. Livestock and agriculture cause the greatest changes, followed by deforestation and urbanization. Impacts from fishing, mining, multi-purpose hydraulic works, and an increase in extreme weather phenomena should be added to these other activities. All of these can affect the river and terrestrial ecosystems of the Basin.

As a result of agriculture and large-scale agro-industry development, about half of the natural vegetation of the LPB has been changed by pastures. Deforestation due to agriculture has reduced the land's capacity to capture and store carbon and water and to anchor soils, leading to increases in

Figure 1.3.7.1

Number of fisheries in the sub-basins

Nº of cultivation centers per sub-basin

Upper Paraná: 358
Lower Paraná: 941
Upper Paraguay: 14
Lower Paraguay: 11
Upper Uruguay: 6
Lower Uruguay: 7
La Plata River itself: 1
TOTAL: 1,338

Sub-basin pressure descriptors

Nº of cultivation centers of exotic fish species

- 1 - 7
- 8 - 357
- 358 - 941

erosion rates in some areas and sedimentation in others, causing changes in the availability of water.

Large-scale farming practices, due to the intensification of soybean production since the early 1990s and the development of one of the world's largest livestock breeding industries, have also resulted in soil compaction, a reduction in water infiltration, an increase in surface runoff, and sedimentation problems.

In the Basin, the largest number of inhabitants and the settlement of large cities occurs in upper Paraná (61.8 million people and six large cities), followed by the La Plata River sub-basin (24.9 million and five major cities). The lower Paraná and the Uruguay have intermediate values, while the lowest values occur in the remaining sub-basins. Increased urban development, industry, agriculture, and transport have led to degradation of water quality and a decline in fish quantities.

The development of dams and their respective reservoirs has transformed some stretches of river into lakes, expanded other bodies of water, and flooded some terrestrial ecosystems. The results include variations in the speed of erosion in several rivers in the Basin, changes in fish communities, loss of biodiversity and wildlife habitats, and degradation of other environmental functions in several areas. The highest concentration of reservoirs occurs in the upper Paraná, while there are none registered in upper Paraguay or in the sub-basin of the La Plata River; in the remaining sub-basins there is a smaller number. There are plans to construct new dams and to increase the level of some current uses, indicating that the alteration of river ecosystems will increase in the future.

1.3.9 Protected Areas

In the La Plata Basin, 601 protected areas have been created covering 22.8 million hectares, representing a level of protection of 7.2 percent over the total area of the Basin. Considering that the 2010 goal from the Convention on Biological Diversity (CBD) was set at 10 percent conservation areas in relation to territorial coverage, and that the current 2011 to 2020[1] Aichi Targets set the goal at 17 percent, the current percentage of protected areas is low, less than half of the target by 2020.

The vast majority of protected areas are under public administration (347 areas, corresponding to 51 percent of the total protected area), although there is a considerable fraction of privately managed areas (194 areas, representing 8 percent of the total protected area) or mixed (34 areas, with 12 percent of the total protected area) (**Figure 1.3.9.1**). Private protected areas are well developed in the national systems of Argentina, Brazil, and Paraguay, smaller in Bolivia, and non-existent in Uruguay.

In addition, there are 29 Ramsar Sites covering almost 85,000 km² and 18 Biosphere Reserves (MAB-UNESCO), covering almost

1 The Aichi Targets (the name of the Japanese city where they were established) are part of the Strategic Plan for Biodiversity 2011 to 2020 from the Convention on Biological Diversity. Target 11 states: "By 2020, at least 17 percent of terrestrial and inland water areas and 10 percent of marine and coastal areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and are integrated into the wider landscape and seascapes."

Figure 1.3.9.1

Protected areas of the La Plata Basin

Nº of protected areas by sub-basin
(2012 inventory)

Upper Paraná: 313
Lower Paraná: 82
Upper Paraguay: 61
Lower Paraguay: 66
Upper Uruguay: 29
Lower Uruguay: 39
La Plata River itself: 11
TOTAL: 601

Nº of protected areas by sub-basin
(2012 inventory)

- 11 - 39
- 40 - 81
- 82 - 313
- 1,8% protected surface area of total area of the sub-basin (in %)

361,000 km². The sub-basins of the Paraguay (upper and lower) present the highest number of Ramsar sites and Biosphere Reserves, while the upper Uruguay and upper Paraná have the smallest quantity of sites and protected surface area.

They have also identified 264 important areas for bird conservation (IBA), which highlights the relevance of the conservation of this biological group. The highest concentrations of these areas occur in the lower Paraguay and lower Paraná, while the upper Uruguay and the sub-basin of the La Plata River have the smallest amounts.

1.3.10 Sediment Production and Transport

The study and understanding of the sediment component within the context of the hydrological cycle of a basin is a relevant data for the management of the sustainable use of natural resources; this implies studying their production, transport, and deposit. Sediments play a significant role in the morphological dynamics of river beds, which impact the provision of drinking water and water for irrigation, navigation, and maintenance of waterways, bridges, and in the useful life of reservoirs. The scale of these processes is continental or subcontinental, so the sediment component is a cross-border issue, particularly where the borders are in areas in full morphological development (**Figure 1.3.10.1**).

The largest specific production of sediment in the LPB comes from the Andean sector, which includes eastern Bolivia, the Puna of Argentina, and the sub-Andean Sierras, corresponding to the high basins of the Bermejo and Pilcomayo rivers. This region contributes fine sediments, mainly quartz and illite silts, which are transported to the Chaco plateau by the Bermejo, Pilcomayo, and other rivers of lower water level.

The Bermejo River basin is the source of the sediments that provide the characteristic color or turbidity to the waters of the Paraná River and the La Plata River, and they are the main cause of the need to clarify the water for consumption in the riparian cities. The contribution of suspended solids from the Bermejo River constitutes approximately 70 percent of the solid load of the Paraná River in Corrientes, and it is considered that the annual magnitude of this contribution to the Paraguay-Paraná-La Plata River system is around 123,000,000 tons/year (considering the data records from 1969 to 1989). This solid load is responsible for the sediments deposited in the navigable channels and one of the main causes of the progressive advance of the Patagonian delta into the La Plata River.

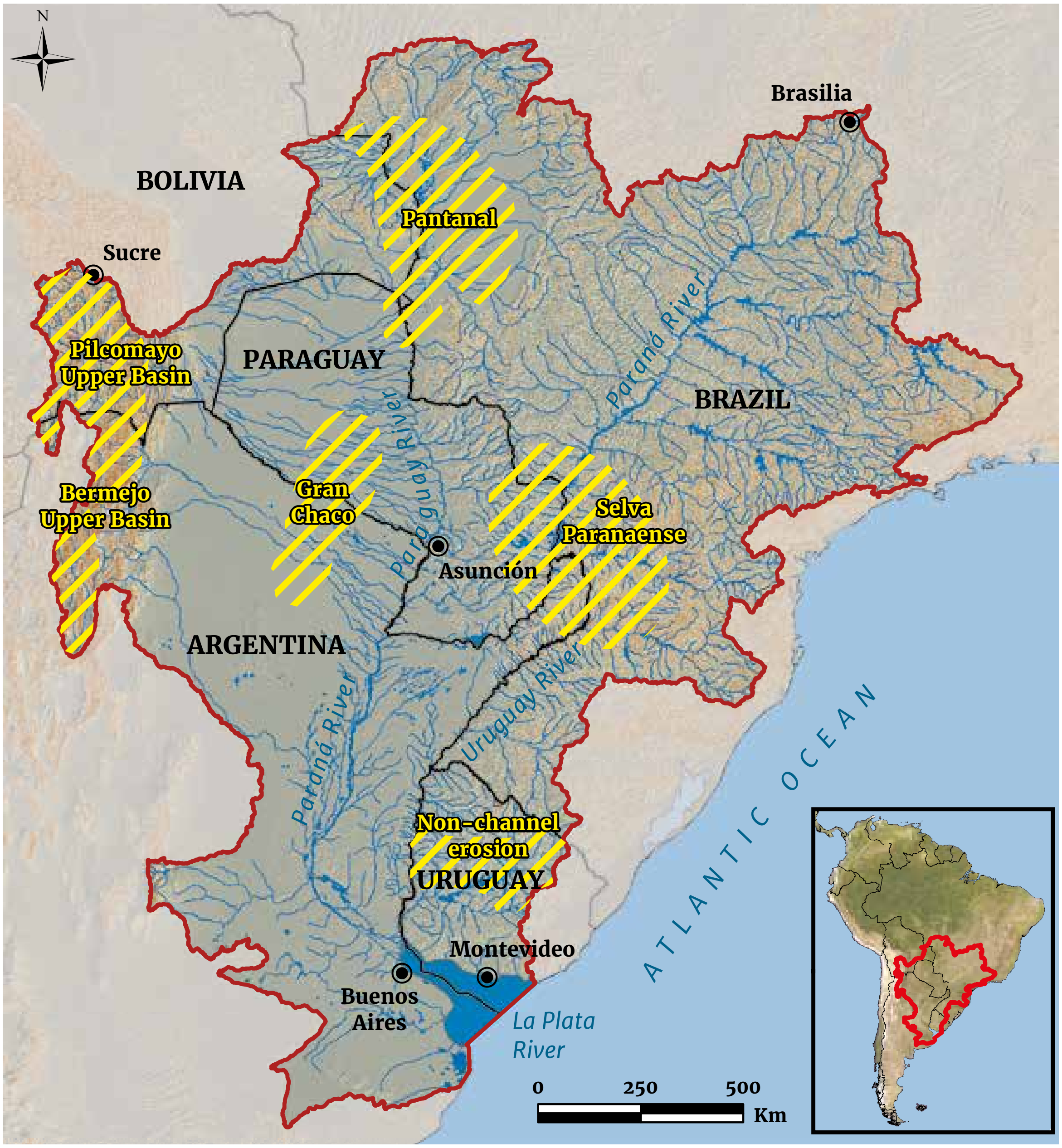
The sediment production in the upper basin of the Pilcomayo River is somewhat larger than that of the Bermejo River. With an average annual water level of 210 m³/s and an annual sediment contribution of the same magnitude as the Bermejo, it does not have sufficient energy to transport its solid cargo to the Paraguay River, thus depositing the sediments in the wetlands of the Chaco plain, near the border between Argentina and Paraguay. This solid contribution of 110 million tons annually causes morphological changes in the channels, water bodies, and altimetry of the floodplain.

Another detrimental process in sediment production and transport in the LPB is related to anthropic land use. Agricultural, livestock, and forestry activities need large spaces, so humans resort to deforestation of the native forest.

The traditional agricultural practices of clearing land formerly occupied by forests, regardless of the slope of the terrain, facilitate the loss of soil due to rain and wind. This is compounded by the increase in frequency or intensity of these forces, establishing a relationship between climate variability and change and loss of natural cover. A tentative map of isoerodents is presented in **Figure 1.3.10.2** as a representation of rain erosivity the LPB.

Figure 1.3.10.1

Areas with higher criticality associated with land degradation



1.3.11 Critical Biomes

The Selva Misionera Paranáense (SMP) forms part of the complex of ecoregions of the Atlantic Forest, which originally covered an area of 47,000,000 ha. (**Figure 1.3.11.1**). Since the mid-twentieth century there has been a gradual loss of the forest mass, being replaced with pastures, agricultural crops, and forest plantations, leading to extraordinary soil degradation, alterations in the hydrological cycles, and causing local climatic fluctuations. In Brazil and Paraguay only isolated fragments remain, representing 7 percent of the original surface. In Argentina, there are still 1,000,000 ha (30 percent of the original surface), of which 450,000 ha correspond to protected natural areas.

This ecoregion remains one of the most diverse biological ecosystems on the planet. The ecological importance of the SMP reserves has been internationally recognized as a high priority for conservation.

In recent decades, governments have undertaken a series of actions aimed at regulating activities and use of the territory occupied by the SMP. In this way, the territorial planning of native forest policies emerged, which are a fundamental tool to control deforestation and regulate the activities that can be conducted. While the initiatives undertaken by each country in relation to the conservation of the SMP are very valuable and form the basis for all conservation actions within the ecoregion, it would be of paramount importance to generate joint work initiatives and strengthen the ongoing initiatives within the framework of shared resources, the only way to ensure their conservation.

Figure 1.3.10.2

Tentative isoerodent map for the La Plata Basin

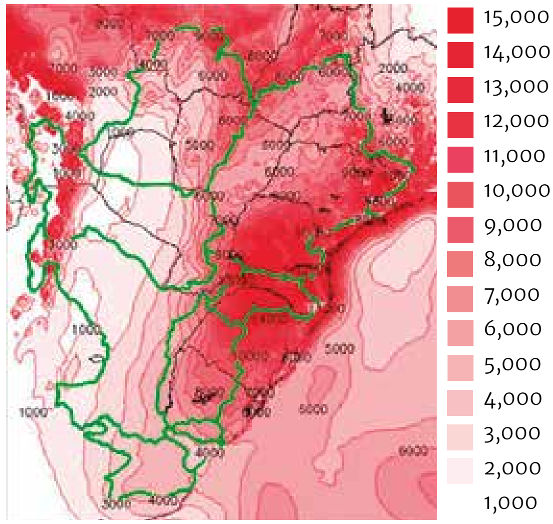
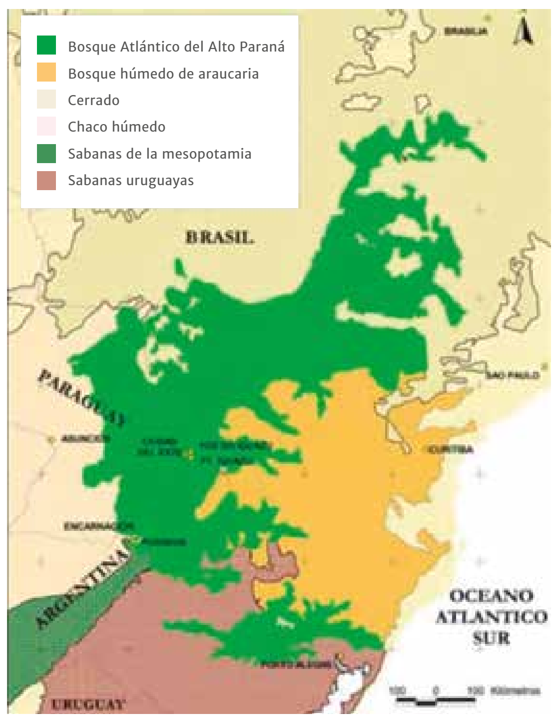


Figure 1.3.11.1

Atlantic forest ecoregion of the Upper Paraná



1.4 Water Resources

1.4.1 Availability of Water Resources

The concept of water availability in a given territory is associated with the productive and service activities of the region and their respective water use, both consumptive and non-consumptive.

Given the physical and climatic expanse and variability of the La Plata Basin, all types of activities and uses are presented, meaning that water availability is made up of meteoric water for agricultural activity in drought conditions, of surface water available to satisfy distinct consumptive uses (human, animal, industrial, and irrigation, among others) and non-consumptive uses (hydropower generation, navigation, recreation), and of groundwater that also satisfies the different types of consumptive uses, particularly irrigation.

Meteorological water availability is represented by the terms of the hydro-meteorological balance between precipitation and evapotranspiration.

Surface water availability is represented by river water levels, distributed by sub-basin. Some of the hydrological variables that can be used for characterization are the mean water level rate (specific water level rate) and reference water level rates, such as Q95[2] for availability in drought, 60 percent of the average water level for annual regulation capacity, among others.

The availability of groundwater is the pumping potential of aquifers limited by their recharge, and, in turn, groundwater recharge is the average amount of water entering the aquifer.

1.4.1.1 Meteoric Waters

The hydro-meteorological balance simply expressed by the difference between the mean monthly precipitation (P) and the mean monthly evapotranspiration potential (ETP) is the first indicator of the regions that present average conditions of water excess or deficit, which is directly related to the possibility of conducting rainfed agriculture. **Table 1.4.1.1.1** presents these balance terms at the level of selected basins for each of the defined sub-basins.

The upper Paraguay presents alternation of average values of excesses in summer and autumn and of deficits in winter-spring. In the lower Paraguay, the right margin contribution areas present deficient balances towards the west, while the left margin contributions have excess balances.

In the upper Paraná region there is a deficit in the winter and part of the spring, but it balances out annually. Also in the lower Paraná the areas of right margin contribution, which to the west have deficit balances, and left margin contributions, where they are positive, can be differentiated.

In the whole Uruguay River basin, the balances are generally positive, although there are months with deficits.

1.4.1.2 Surface Water

The water balances developed in Argentina, Bolivia, Paraguay, and Uruguay were elaborated based on the Témez CHAC model, a monthly time step. In Brazil, the MGB-IPH

2 Q95 is the water level rate with a 95 percent probability of exceedance in the daily water level duration curve.

Table 1.4.1.1.1 **Monthly average monthly precipitation (P). monthly average potential evapotranspiration (ETP) and the difference**

			SET	OCT	NOV	DEC
Paraguay	Upper Paraguay	**Paraguay River in Cáceres (24.141 km²)**				
		Basin precipitation (mm)	61.0	147.4	197.3	262.7
		ETP Basin (mm)	173.6	181.7	157.6	152.9
		P-ETP (mm)	-112.6	-34.3	39.7	109.8
	Middle and Lower Paraguay	**Rivers and streams of Salta and Formosa, tributaries of the Paraguay River (28.010 Km²)**				
		Basin precipitation (mm)	13.8	42.3	76.7	128.3
		ETP Basin (mm)	146.2	181.2	190.3	207.1
		P-ETP (mm)	-132.4	-138.9	-113.6	-78.8
		Tebicuary River (27.325 km²)				
		Basin precipitation (mm)	101.9	170.5	175.0	140.5
		ETP Basin (mm)	99.4	131.0	149.3	170.3
		P-ETP (mm)	2.5	39.5	25.8	-29.8
Paraná	Upper Paraná	**Rio Grande in Furnas (52.100 km²)**				
		Basin precipitation (mm)	64.2	109.6	179.0	269.5
		ETP Basin (mm)	132.5	131.9	130.4	126.8
		P-ETP (mm)	-68.3	-22.3	48.6	142.7
		Río Iguaçu in UHE Baixo Iguaçu (61.947 km²)				
		Basin precipitation (mm)	160.1	232.8	171.1	174.1
		ETP Basin (mm)	91.4	123.0	144.0	155.7
		P-ETP (mm)	68.7	109.8	27.1	18.4
	Middle and Low Paraná	**Impenetrable region (35.094 km²)**				
		Basin precipitation (mm)	17.4	49.7	84.9	121.9
		ETP Basin (mm)	122.9	153.9	160.7	170.6
		P-ETP (mm)	-105.5	-104.2	-75.8	-48.7
		Corrientes River (23.583 km²)				
		Basin precipitation (mm)	82.3	149.1	146.6	122.3
		ETP Basin (mm)	90.5	120.1	138.1	157.9
		P-ETP (mm)	-8.2	29.0	8.5	-35.6
Uruguay	Upper and Lower Uruguay	**Río Negro Alto (24.652 km²)**				
		Basin precipitation (mm)	106.3	115.9	106.9	106.3
		ETP Basin (mm)	69.3	100.8	127.3	156.2
		P-ETP (mm)	37.0	15.1	-20.4	-49.9

Source: MP2016f.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	ANNUAL
Paraguay River in Cáceres (24.141 km²)								
280.4	254.3	232.3	127.9	50.8	11.5	7.9	16.1	**1.650.0**
145.3	126.6	136.9	124.2	123.7	131.3	157.3	193.3	**1.804.0**
135.1	127.7	95.4	3.7	-72.9	-119.8	-149.4	-177.2	**-155.0**
Rivers and streams of Salta and Formosa. tributaries of the Paraguay River (28.010 Km²)								
151.8	116.4	108.9	48.9	17.9	7.3	3.7	6.1	**722.0**
208.8	168.6	153.9	105.7	84.5	65.8	83.7	116.7	**1.713.0**
-57.0	-52.2	-45.0	-56.8	-66.6	-58.5	-80.0	-110.6	**-991.0**
Tebicuary River (27.325 km²)								
154.2	140.3	124.6	172.4	143.8	98.7	80.5	66.2	**1.569.0**
160.4	129.9	128.5	94.0	65.8	47.5	65.4	86.3	**1.328.0**
-6.2	10.5	-3.9	78.4	78.0	51.2	15.0	-20.1	**241**
Rio Grande in Furnas (52.100 km²)								
266.6	170.1	158.6	72.0	45.2	21.3	17.4	18.1	**1.391.6**
132.4	124.7	124.3	106.5	92.4	81.0	96.2	124.0	**1.403.0**
134.2	45.4	34.3	-34.5	-47.2	-59.7	-78.8	-105.9	**-11.4**
Río Iguaçu in UHE Baixo Iguaçu (61.947 km²)								
183.6	165.4	132.3	155.3	181.0	159.0	126.3	114.4	**1.955.5**
150.4	122.9	112.4	84.3	62.3	50.2	57.1	74.9	**1.228.5**
33.2	42.5	19.9	71.0	118.7	108.8	69.2	39.5	**727.0**
Impenetrable region (35.094 km²)								
128.0	97.7	104.1	59.0	24.2	10.4	4.2	6.8	**708.0**
173.9	147.0	136.7	95.7	72.4	56.5	71.4	97.7	**1.459.0**
-45.9	-49.3	-32.6	-36.7	-48.2	-46.1	-67.2	-90.9	**-751.0**
Corrientes River (23.583 km²)								
123.5	145.3	139.6	173.4	92.6	84.6	65.1	56.1	**1.380.0**
160.0	131.4	120.0	83.8	62.0	46.8	54.5	72.8	**1.238.0**
-36.5	13.9	19.6	89.6	30.6	37.8	10.6	-16.7	**142.0**
Río Negro Alto (24.652 km²)								
113.5	134.4	110.9	122.1	125.5	105.6	110.7	91.8	**1.258.0**
158.7	118.0	102.5	64.2	40.2	28.5	32.8	49.4	**999.0**
-45.2	16.4	8.4	57.9	85.3	77.1	77.9	42.4	**260.0**

hydrological model was used, with daily passage. The models allow the determination of the relationships between precipitation, evapotranspiration, and water level for each of the basins.

The results obtained on monthly water balance levels by sub-basin were integrated throughout the LPB at characteristic sites, comparing them with observed water level data, which allowed for an estimation of error in the mean annual water level rate for the period 1971 to 2010. **Figure 1.4.1.2.1** shows the sites considered and, in **Table 1.4.1.2.1**, the corresponding values, together with the indication of the relevance of the site in terms of percentage of its average water level rate with respect to the total average water level of the La Plata River.

In turn, the seasonal variability of this surface water availability can be characterized by the chronological sequence of annual water levels at the indicated characteristic sites.

Annual water levels

The chronological curves of average annual water levels observed in the Paraná and Paraguay rivers in the period from 1970/71 to 2011/12 clearly show the importance of the contribution from the year 1982/83 in first place, and from 1997/98 in second place, where annual water levels were two times the module (**Figure 1.4.1.2.2**).

In order to have an idea of the representativeness of the analyzed period in relation to the available historical records, the annual water level curves at the Pilcomayo Port station on the Paraguay River (**Figure 1.4.1.2.3**) and at the Corrientes station after the confluence of the Paraná with the Paraguay River are also presented (**Figure 1.4.1.2.4**). In both cases, the yearly water levelrate calculated for the period from 1970 to 2012 is between 9 and 10 percent greater than the one that arises from calculating this module for the entire period of 1905-2012.

The chronological curves of annual mean water levels observed in the Uruguay River during the period from 1970/71 to 2011/12 confirm the existence of extreme years in the 1982/83 and 1997/98 hydrological years observed in the Paraná and Paraguay rivers (**Figure 1.4.1.2.5**). The sequence of annual water levels in Paso de los Libres for the entire documentation period (1910 to 2012) shows that the yearly water level rate for the period from 1970 to 2012 is 11.5 percent higher than that which would be calculated for the entire period (**Figure 1.4.1.2.6**).

Monthly water levels

The average monthly water level graphs observed in the Paraná and Paraguay rivers, during the period from 1970/71 to 2011/12, show a difference between the two rivers (**Figure 1.4.1.2.7**). In the Paraná River, before its confluence with the Paraguay, the high water situation in summer-autumn and the depletion of the water levels in winter and part of the spring is clearly seen, a distribution that remains after the confluence, but less markedly. In the Paraguay River, the system is more uniform in terms of the distribution of water levels throughout the year, with a relative peak at the beginning of winter, which shows the influence of the Pantanal as a regulator and retarder of floods.

The distribution of water levels in the Uruguay River during the year shows that monthly water levels increase toward middle-to-late winter and during the spring, and decrease in summer and fall (**Figure 1.4.1.2.8**).

Table 1.4.1.2.1

Summary of average annual water levels (1971 to 2010)

La Plata River	Simulated flow (m³/sec)	Observed flow (m³/sec)	% error	% of simulated flow rate in relation to the water level of the La Plata River
Paraná River				
Paraná River until confluence with the Paraguay River				
Paraná River in Porto Primavera	7,913	7,938	-0.3	29.1
Paraná River in Guaira	11,725			43.1
Paraná River in Itaipu	12,886	11,746	9.7	47.3
Paraná River downstream of the Iguazú confluence	14,871			54.6
Paraná River in Itatí	14,404	13,916	3.5	52.9
Paraguay River until confluence with the Paraná River				
Paraguay River in Puerto Pilcomayo (*)	3,805	3,964	-4.0	14.0
Paraguay River in Puerto Bermejo (**)	5,091	4,696	8.4	18.7
Paraná River from Corrientes to La Plata River				
Paraná River in Corrientes	19,077	18,989	0.5	70.1
Paraná River in Santa Fe - Paraná	19,889	19,041	4.5	73.1
Total Paraná River	**19,706**			**72.4**
Uruguay River				
Uruguay River in El Soberbio	2,423	2,384	1.6	8.9
Uruguay River in Paso de los Libres	4,593	4,789	-4.1	16.9
Uruguay River in Concordia (***)	5,624	5,725	-1.8	20.7
Total Uruguay River	**7,058**			**25.9**
Inputs from the right bank of the La Plata River	**203**			**0.7**
Inputs from the left bank of the La Plata River	**259**			**1.0**
Total La Plata River	**27,225**			**100**

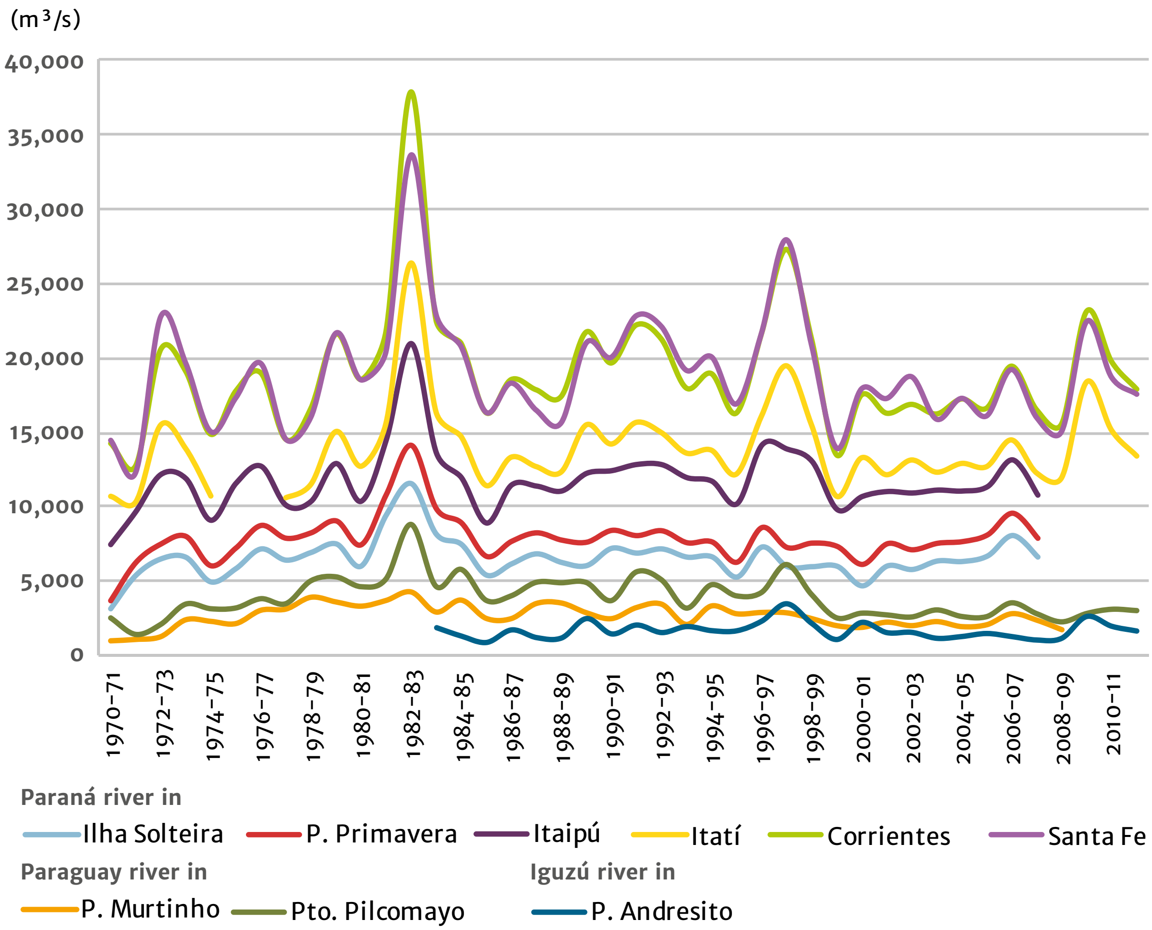
(*) Does not include spillage from the Pilcomayo.
(**) Observed flow 1983/84.
(***) Observed flow until 2003/04.

Figure 1.4.1.2.1

Surface water balance of the La Plata Basin. Characteristic sites

Figure 1.4.1.2.2

Paraná, Paraguay, and Iguazú rivers. Annual water levels



The Uruguay River, at the Argentine-Brazilian border.

Figure 1.4.1.2.3 **Paraguay River in Pilcomayo Port. Annual water levels**

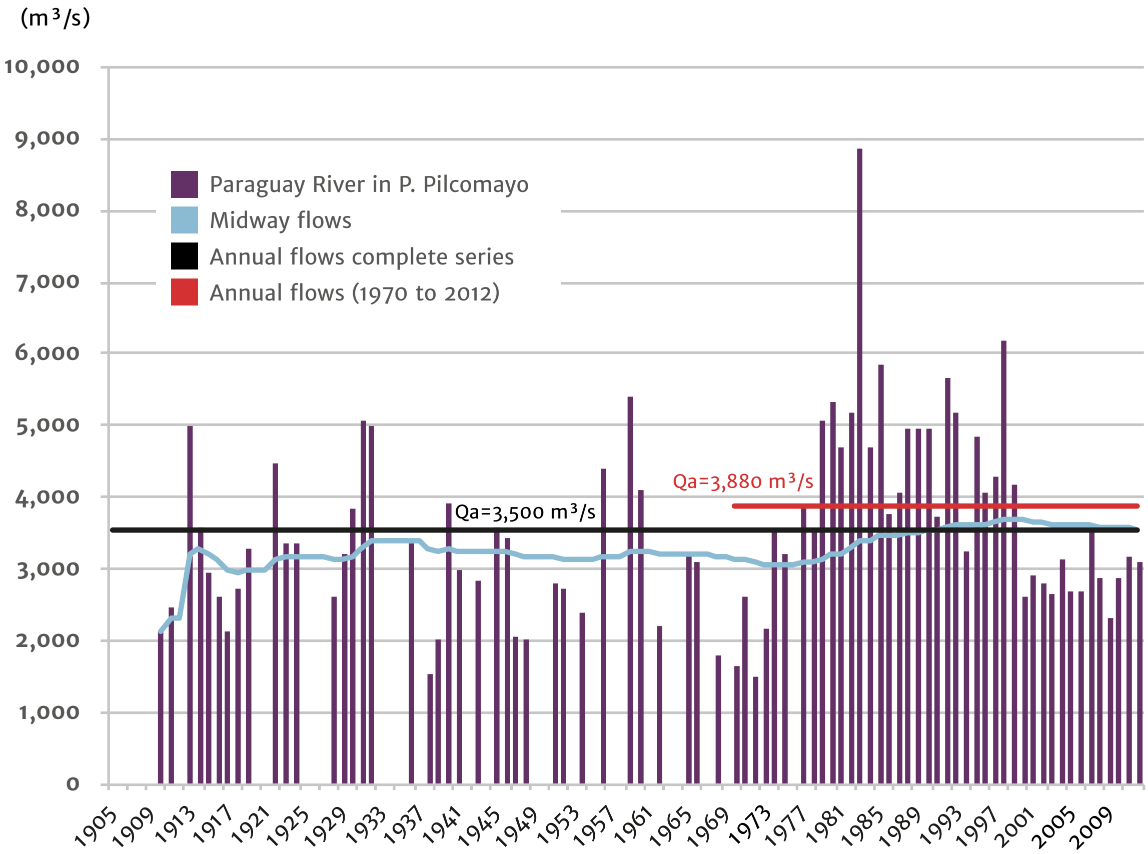


Figure 1.4.1.2.4 **Paraná River in Corrientes. Annual water levels**

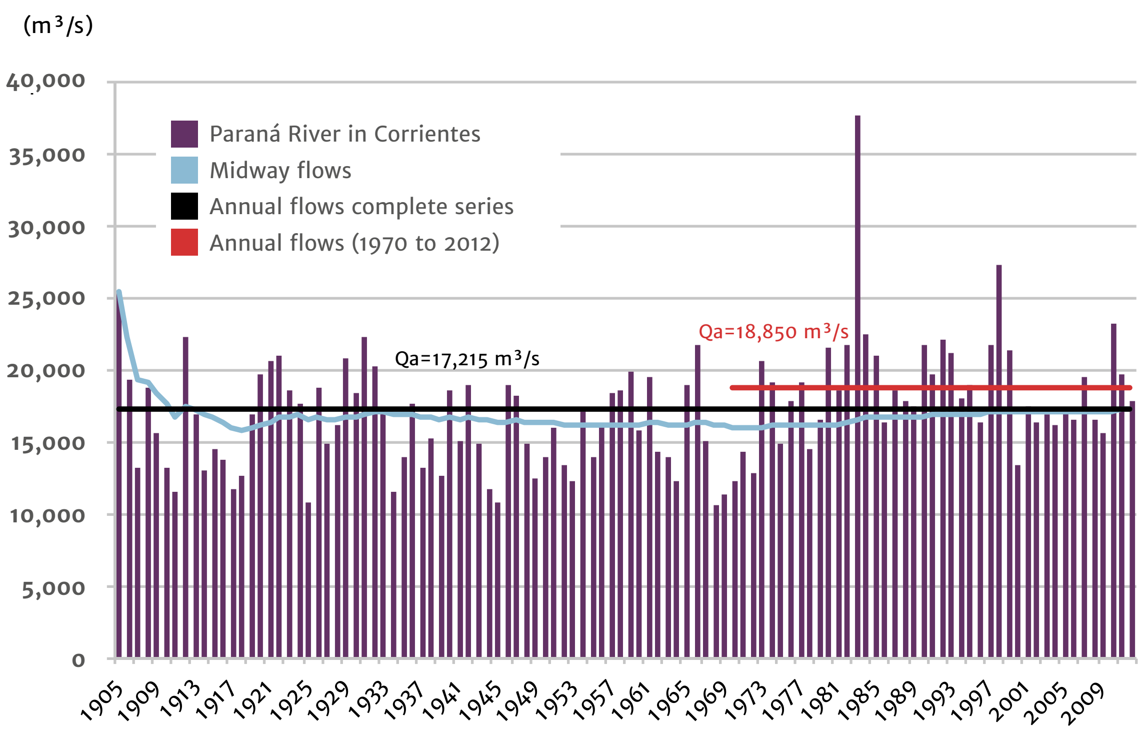


Figure 1.4.1.2.5

Uruguay River. Annual water levels

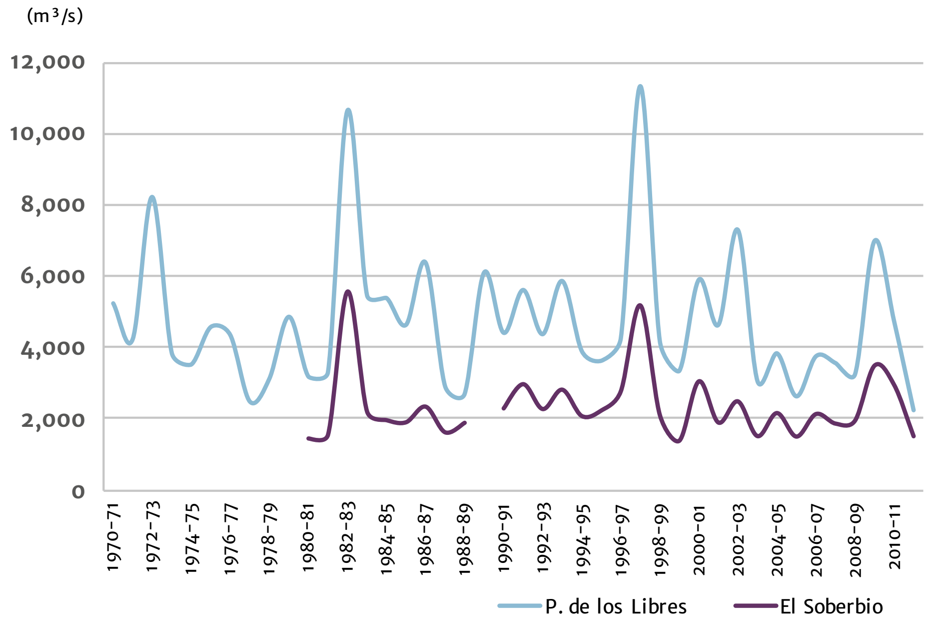


Figure 1.4.1.2.6

Uruguay River at Paso de los Libres. Annual water levels

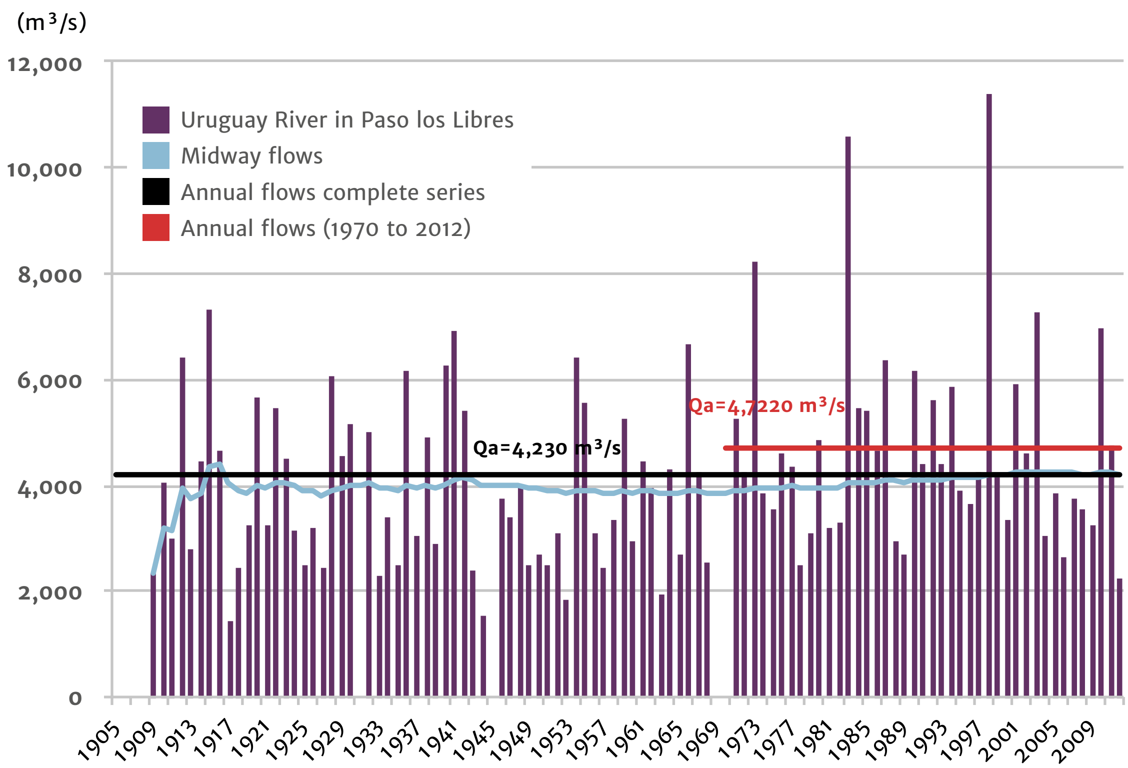


Figure 1.4.1.2.7

Paraná, Paraguay, and Iguazú rivers. Average monthly water levels

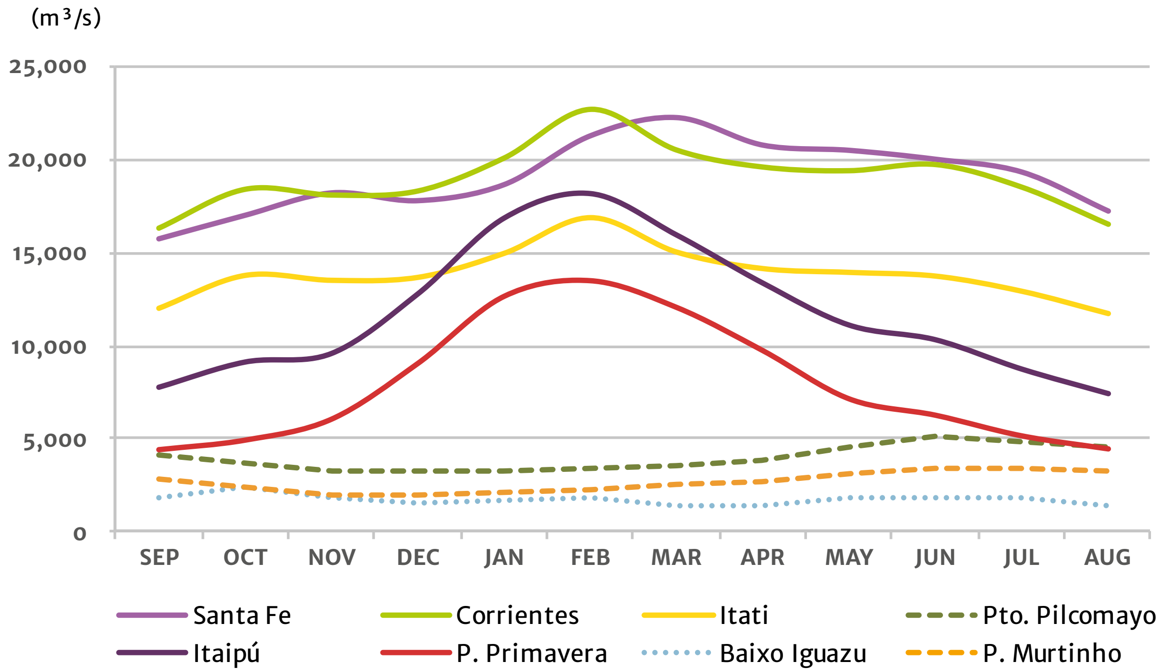
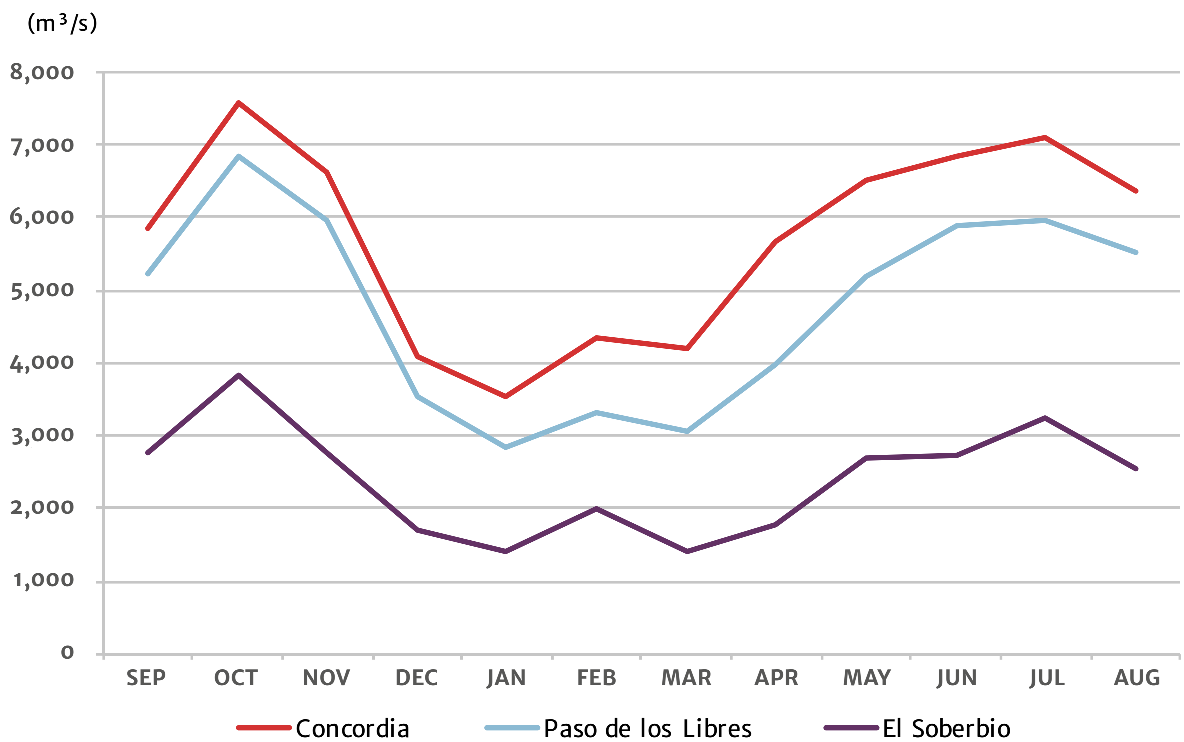


Figure 1.4.1.2.8

Uruguay River. Average monthly water levels



Specific and characteristic water levels

As a synthesis of surface water availability, **Table 1.4.1.2.2** is presented, where it can be observed that the range of values indicated is very broad, indicating the hydrological heterogeneity that is due to the expanse of the sub-basins considered. These ranges are higher in the sub-basins of lower Paraguay and lower Paraná, which directly corresponds to the deficient hydro-meteorological balances that occur in the west of the contributing basins, as previously presented.

Also, these indicators vary when they are calculated on small, medium, and large contributing basins, and they are available for all basins and sub-basins in which the surface water balance was modeled.

It should be noted that this availability can be affected by climate change, as shown by the projections that are presented later.

Water level projections for specific climatic scenarios

As will be seen in *Chapter 2*, the MGB-IPH model was adjusted for the simulation of different rivers in the La Plata Basin. Then this model was used for the round of climate projections, based on data from the ETA model, a high resolution regional model used by the Center for Weather Forecasting and Climate Studies - National Institute for Space Research (CPTEC-IN-PE) in Brazil. The climatic projections with the ETA model at 10 km of horizontal resolution were based on the boundary conditions obtained from the *Hadley Center* Global Environmental Model-HadGEM2-ES, considering an intermediate stage gas emission among the scenarios considered in AR5 (Fifth Report) of the Intergovernmental Panel on Climate Change (IPCC).

Changes in monthly mean water levels and in hydrological seasonality were assessed

Table 1.4.1.2.2

Values of specific water levels (qme) and Q95 in relation to the mean water level (Qme)

Sub-Basin	q_{me}[1] L.s⁻¹.km²	$Q95/Q_{me}$[2]
Upper Paraguay	3 - 21	0.37 - 0.41
Lower Paraguay	2 - 15	0.09 - 0.27
Upper Paraná	13 - 25	0.24 - 0.58
Lower Paraná	1 - 14	0.0 - 0.17
Upper Uruguay	23 - 28	0.20 - 0.28
Lower Uruguay	7 - 23	0.05 - 0.20

Period 1971 to 2010, in summary form for each sub-basin.

q_{me} = specific mean flow rate = Q_{me}/A, A= area of the basin,

Q_{me} = mean flow; Q95 = flow with 95% of the duration curve.

by calculating the monthly mean water levels in the current reference period (1960 to 1990) and three future sub-periods (2011 to 2040, 2041 to 2070, and 2071 to 2099).

The results of the projected impacts of climate change on the water level of the rivers in the LPB indicate that there may be an increase or decrease in median and minimum water levels, depending on the region and the period analyzed.

In the Uruguay River, the projections indicate an increase of average and minimum water levels. In the northern region of the Paraná basin—especially in the Paranáíba river basin—and in the upper Paraguay region, projections indicate that there will be an initial reduction in average water levels for the near future scenarios, followed by a subsequent increase in the more remote scenarios. The projections of minimum water levels, for their part, indicate a reduction.

In the Chaco region, represented by the Bermejo and Pilcomayo rivers, the projections indicate an increase in the average and minimum water levels. In the Paraná River, in Itaipu, the projections indicate an initial reduction—in relation to the referenced situation—of average water levels for the near-future scenarios, followed by an increase for the more distant ones. The same is true for minimum water levels. Already in the middle and lower reaches of the Paraná River, projections indicate that both the mean and minimum water levels initially decrease, and then increase in the future.

Figure 1.4.1.2.9 shows the relationship between average monthly water levels simulated in some representative seasons for the three future scenarios and the current situation (1960 to 1990).

It is worth remembering that the study was based on the climatic scenarios of the IPCC AR5 (the *Hadley Center* Global Model HadGEM2-ES), regionalized –downscaling– using the ETA regional model at 10 km horizontal resolution (ETA-10 km). Therefore, the uncertainty of climate predictions related to the overall model used to make the projection is not being considered. Differences among global models are recognized as one of the main sources of uncertainty in climate change projections.

In *Chapter 2.1.1 Climatic Variability*, some additional observations are made on this topic.

1.4.1.3 Groundwater

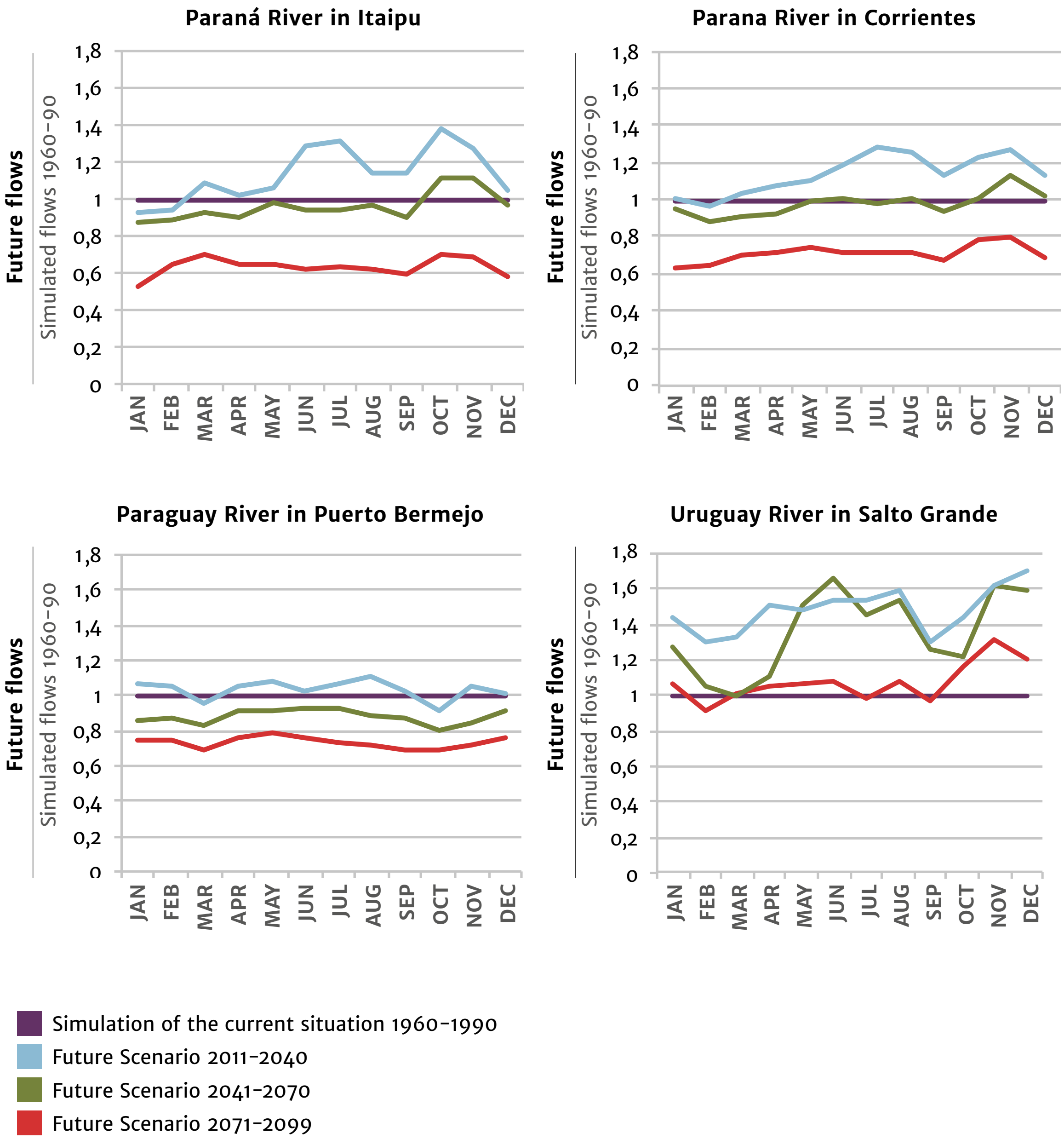
The La Plata Basin is also rich in groundwater resources. It coincides in large part with the Guaraní Aquifer System (GAS), one of the largest groundwater reservoirs in the world, with an area of 1,190,000 km². To the west of the Basin lies the Yrendá-Toba-Tarijeño Aquifer System (YTTAS), which coincides mainly with the semi-arid zone of the Basin, the Gran Chaco Americano biome.

The YTTAS covers an area of approximately 410,000 km² (200,000 km² in Argentina, 30,000 km² in Bolivia, and 180,000 km² in Paraguay) and represents one of the most important transboundary groundwater reserves in South America. It is an aquifer system of great regional importance, as it is in a region with a semi-arid climate, water scarcity, and in which the other aquifers are of brackish or salt water, not suitable for human consumption or agricultural production.

The presence of native peoples throughout the region is noteworthy, with similar social problems. In numerous places their communities spread into the three countries without considering the political-ad-

Figure 1.4.1.2.9

Relationship between the simulated monthly average water levels corresponding to three future scenarios and the present situation



ministrative boundaries. The basic productive activity of the area is agriculture and livestock, with great potential in wetlands. The barrier to economic development in the region, which particularly affects the rural peasant sectors, is access to water of the quantity and quality necessary for subsistence and production.

There are also other transboundary aquifers (shared by two or more countries), often with such a small area in relation to the total area of the Basin, that they are not included in the regional maps because of the scales used. However, because of their geographic location and their hydrogeological characteristics, they become strategic for the internal socioeconomic development of the country or region where they lie.

The main transboundary aquifers are (**Figure 1.4.1.3.1**):

- Guaraní Aquifer System: shared by Argentina, Brazil, Paraguay, and Uruguay. Its water level rates vary from 60 to 200 m³/h in zones near affected areas and from 200 to 400 m³/h in confined areas.

- Yrendá-Toba-Tarijeño Aquifer System: shared by Argentina, Bolivia, and Paraguay. Its maximum water level rates reach 10 m³/h.

- Serra Geral Aquifer System: shared by Argentina, Brazil, Paraguay, and Uruguay, with water levels varying between 10 and 100 m³/h.

- Pantanal Aquifer System: shared by Bolivia, Brazil, and Paraguay.

- Bauru-Caiuá-Acaray Aquifer System: shared by Brazil and Paraguay. The Caiuá section has water levels between 40 and 60 m³/h and the Bauru section has moderate water level rates ranging from 10 to 20 m³/h.

- Agua Dulce Aquifer System: shared by Bolivia and Paraguay, with water level rates of up to 18 m³/h in the carboniferous aquifers and 36 m³/h in the Cretaceous aquifers.

With the joint work of the five countries of the LPB, between 2011 and 2015 progress was made on the development of a hydrogeological summary map of the Basin at a scale of 1: 2,500,000 (**Figure 1.4.1.3.2**).

It should be noted that in the LPB the natural development of urban and rural populations, coupled with the sharp increase in agricultural and industrial activities, has significantly increased the use of water resources, particularly those of underground origin. This growth, as expected, as well as demographic parameters, is due to the intrinsic characteristics of aquifers, such as the occurrence of potentially productive units and the quality of groundwater.

In relation to the use of the underground resource in each country, the following is observed:

- In Argentina, the areas with the highest groundwater use to meet human needs are located close to urban areas and in rural areas with irrigated agriculture.

- In Bolivia, the main groundwater uses are oriented toward public supply and agriculture.

- In Brazil, this resource has fundamental importance for human supply and industrial use throughout the southeastern and southern regions. In this area, there is greater groundwater exploitation than in the rest of the LPB.

Figure 1.4.1.3.1

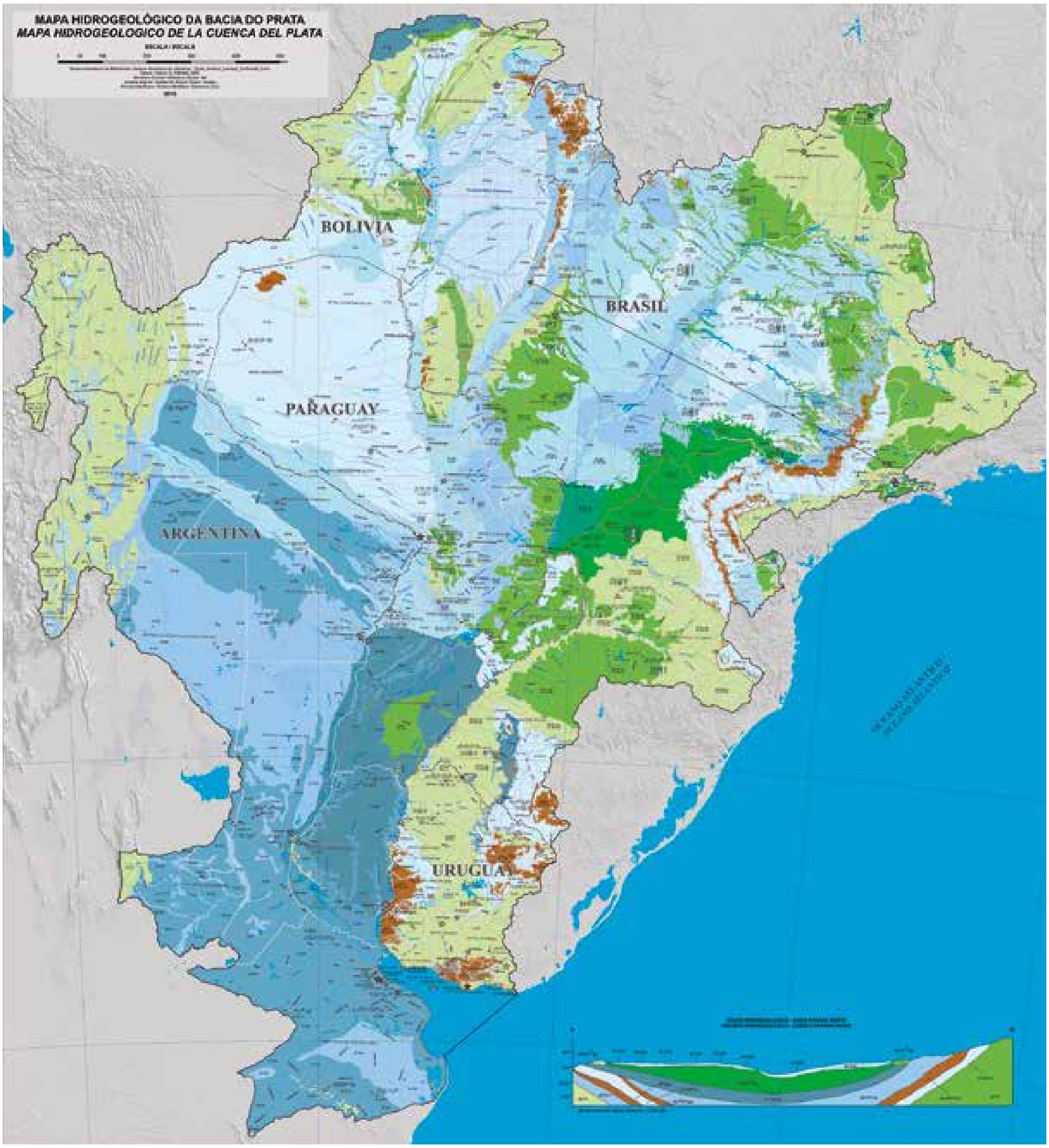
Transboundary aquifers of the La Plata Basin

Transboundary aquifers

- Aquidaban – Aquidauana
- Palermo – Estrada Nova – Bonito River
- Agua Dulce
- Bauru – Caiuá – Acaray
- Botucatu – Tacuarembó – Misiones – Piramboia – Buena Vista
- Permo Carboniferous System
- Serra Geral
- Pantanal
- Yrendá – Toba – Tarijeño Aquifer System (YTTAS)
- Guaraní Aquifer System (GAS)

Figure 1.4.1.3.2

Hydrogeological map of the La Plata Basin



- Also in Paraguay, groundwater is widely used for human and industrial supply, as for example in the periphery of its capital, Asunción. In other regions, it is predominantly used for livestock and for the public supply of dispersed localities.

- In Uruguay, although the volume of groundwater used is relatively low – about 28 percent of total consumption– it is important to emphasize that in many villages in the interior the supply is 100 percent from groundwater, which covers 73 percent of the supply services, while 12 percent is mixed, where groundwater is part of the supply.

Figure 1.4.1.3.3 shows the annual volume of groundwater exploited in the Basin.

Drilling in the Guaraní Aquifer.

1.4.2 Water Resource Users

The main activities related to water use in the Basin are urban services, agricultural and industrial, mining, energy (hydroelectric generation), transport (navigation), and protection of ecosystems.

1.4.2.1 Urban Services

Urban water-related services, commonly referred to as urban waters, involve potable water and sanitation services, urban drainage, and solid waste management, which should address developments and urbanization plans as a fundamental tool for improving the environmental quality of urban areas and the quality of life of their inhabitants.

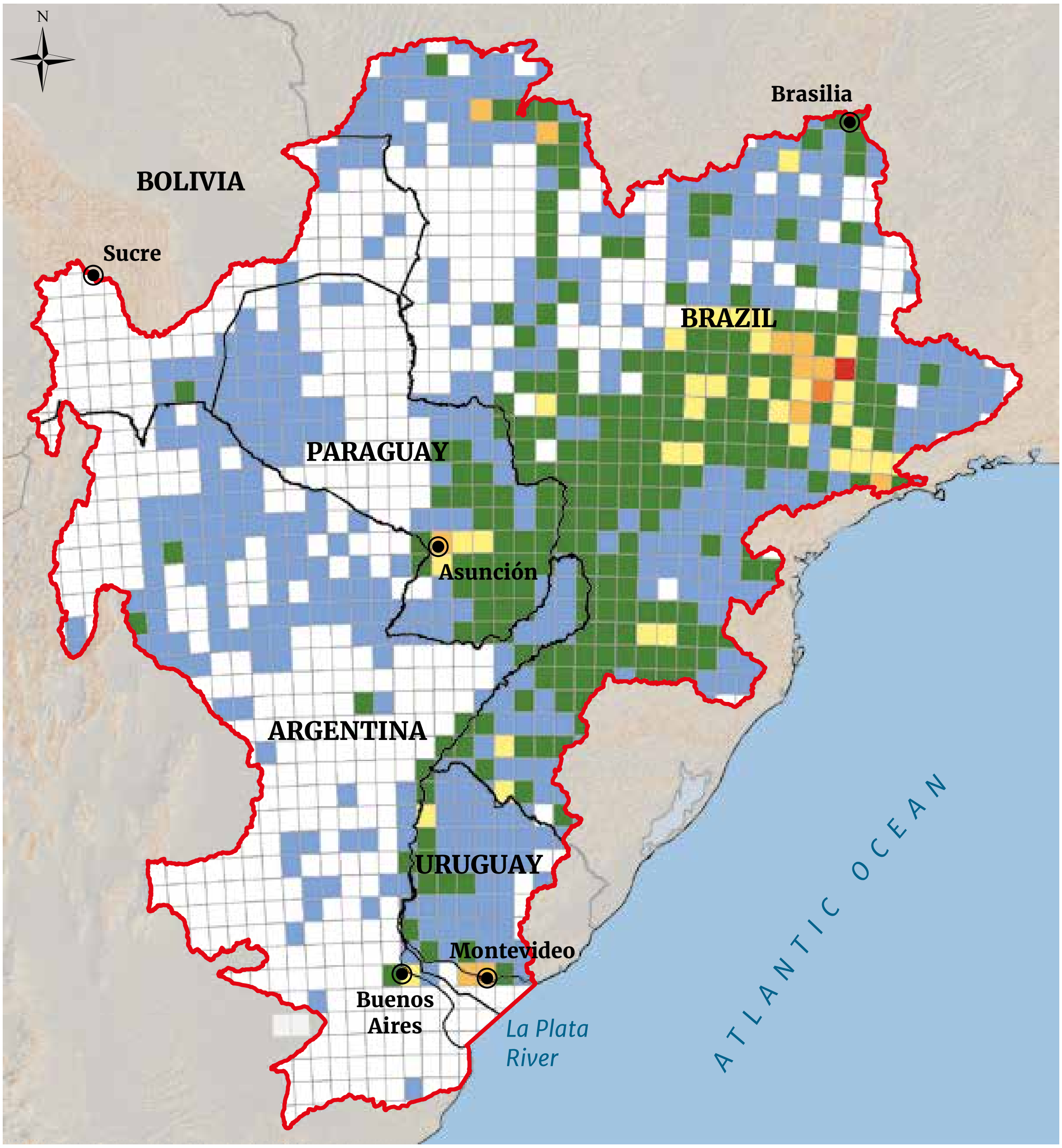
Drinking water and sanitation services

The demand for potable water—depending on the location of the urban area in question—is satisfied by the large rivers of the Basin, by small surface sources close to the cities, or by groundwater. With the growth of cities, water sources—particularly aquifers—are often overexploited or contaminated, with subsequent risk to the health of the population. The cities that present the main problems are those that have a large population and are located in the headwaters of rivers, such as São Paulo, Curitiba, Brasilia, Goiânia, and Campo Grande, among others.

There are other particular situations, such as in the Uruguay River basin where, although water availability is generally sufficient to cover the population's demand, during periods of low water at the headwaters of small streams there may be specific conflicts, mainly considering that the availability of groundwater is low in the region because the Uruguay basin is almost completely located in a basaltic formation (hydrogeological plateau), where the wells have a low capacity (Between 3 and 5 m^3/h).

Figure 1.4.1.3.3

Annual volume of exploited groundwater



Annual exploited volumes (m³/year)

- 0 or No information
- 1 - 1,000,000
- 1,000,000 - 10,000,000
- 10,000,000 - 25,000,000
- 25,000,000 - 50,000,000
- 50,000,000 - 100,000,000
- > 100,000,000

The percentage of the population that uses improved sources of potable water supply and improved sanitation facilities relative to the total urban and rural population varies among the countries that make up the LPB.

The quality of drinking water in urban areas in Argentina, Brazil, and Uruguay is adequate for human consumption, since adequate water treatment is provided in all three countries, which allows for the provision of safe water to the inhabitants connected to the corresponding networks.

The data available for Paraguay is not sufficient to evaluate the physical, chemical, and bacteriological quality of water. However, it is a fact that 100 percent of the users that count on drinking water services receive treated water. In Bolivia, the situation is more heterogeneous, since departmental capitals have superior coverage compared to intermediate cities, although this is not a sufficient guarantee of the quality of service.

Sanitation facilities include the local disposal (black wells) and the public sewage networks. The treatment level of sewage effluents is in many cases is limited to pretreatment or primary treatment.

Urban drainage. Drainage is a service that often does not follow the fast pace of urban development, with corresponding negative impacts on the environment and quality of life of the population.

The rainwater drainage system is a component of the urban infrastructure that is built during the development of the city, generally with a sanitary vision of transferring poor quality water water levels as quickly as possible downstream. With urbanization water water levels increase, mainly due to the increase of impermeable areas, by the importing of water (either by extraction of groundwater or surface water from other basins) and by executing conduits and channels, which generates the transfer of the impacts of upstream urbanization downstream.

Installation of potable water networks.

As expected, storm drainage networks represent a source of contamination from solid urban waste, heavy metals, and other noxious substances that are eventually dumped into urban rivers and streams. In most cases there is no systematic control of the quality and water level of rainwater, so there is no accurate estimate of the impacts that drainage systems have on the water quality of these courses.

To date, very few cities in the Basin have developed regulatory mechanisms to control the urban impact of storm drainage. Among the main ones are Porto Alegre and Brasilia in Brazil, and Resistencia, Santa Fe, and Rosario in Argentina.

Solid urban waste. Urban solid waste collection and treatment services represents an environmental problem that affects the quality and water level of drainage water and urban rivers and streams. The main waste is the product of erosion and sedimentation within cities—produced by increased runoff velocity—and the inadequate management of waste produced by the population, generating degraded urban and semi-urban areas. In relation to drainage, one of the main problems is managing large volumes of waste and sediment that reduce the capacity of urban watercourses, causing floods. Most of the cities in the Basin do not yet have a capacity for sustainable management of urban waste.

1.4.2.2 Agricultural Sector

Agriculture is the economic activity in the La Plata Basin that generates the greatest changes in land use. The main crops correspond to annual cycles: soybean, wheat, maize, and rice. Rice is produced with irrigation from flooding and is one of the major consumers of water in the Basin.

Argentina has a 12.8 percent share of arable land, which represents 35 million hectares of its national territory. This is the highest percentage in the Basin, followed by Brazil, Paraguay, and Uruguay, respectively. The Argentine provinces that make up the Basin produce 90 percent of the country's cereals (soy, maize, and sunwater leveler) and seed oils, and maintain 70 percent of its cattle stock, generating 60 percent of the country's GDP. Cotton, tobacco, beans, sugar cane, citrus fruits, and rice are also grown.

In the Brazilian sub-region of the Uruguay River, subsistence crops and livestock, with practices of domestic livestock, alternate with the production of soybeans, millet, maize, and rice, depending on the characteristics of the soil. In the Paraguay River system in Brazil, land use is rapidly changing, leading to the extension of the livestock/agricultural frontier, due to the cultivation of soy and cattle ranching. These processes occur on the Plateau and in the Pantanal, although in the latter the conservation areas maintain it as a frontier for the future. Finally, 57 percent of the Brazilian portion of the Paraná River is used for grazing livestock and agriculture, with the remaining area corresponding to native forests. The main agricultural activities are cattle breeding and the cultivation of oranges, soy, sugar cane, and coffee. It is important to note that 10 percent of the cattle raised in Brazil are born within the LPB.

In Paraguay, agriculture occupies the eastern part of the country, with a high share of mechanized activities due to the predominance of soybean cultivation. Pasture farming areas have undergone considerable variation in recent years due to changes in land use. Pastures generally occupy deep, well-drained soils in the farms and are intended for cattle fattening, while livestock raising is concentrated in low, unproductive areas. Along the right bank of the Paraguay River, in the Chaco region, the agricultural area has remained stable, although in recent years there was a decrease in the area occupied by this activity due to the great livestock expansion in the central Chaco and the frequent droughts that have occurred in recent years.

Agricultural use in Uruguay is expressed in the coexistence of crops, livestock stock, plantations, and natural fields with a distribution by region that presents differences over time. A number of regions can be identified in the country, depending on the different combinations or arrangements of activities—predominantly agriculture, cattle-raising and milking, livestock in pastures, raising livestock with feedlots, horticulture and fruit growing, and the milk sector. Maize, barley, rice, and oats are the main crops. 80 percent of Uruguayan cattle are raised in the LPB.

The main water demands correspond to regions with flood irrigation for rice cultivation. The main regions are the Tebicuary River basin in Paraguay and southern Brazil, northern Uruguay and eastern Argentina, near the Uruguay, Cuareim-Quaraí and Ibicuí rivers. In these regions there is a large number of small reservoirs to reserve water for irrigation, which implies a potential conflict with the supply for cities in drought years.

In the central-western region of Brazil there is a great expansion of irrigation agriculture, with sowing and harvesting occurring up to four times a year due to the great availability of water, resulting in a great economic profitability. In the same region there are conflicts over water asso-

Rice cultivation in the Argentinean Mesopotamia.

ciated with the expansion of cane for fuel production.

The economies of Argentina, Brazil, and Uruguay also have a strong cattle component. The lower territory of the LPB has traditionally been a region of livestock production. In the Pampa region along the La Plata River, Argentina and Uruguay have high-quality cattle and sheep farms. Products of animal origin are preeminent within the exports of both countries.

In the Upper Paraguay, particularly in the Plateau region, there is one of the largest herds of cattle in the world today. This activity has grown significantly, with impacts on sediment production in the headwaters of the Tacuarí River. In the Pantanal there is a certain balance between environmental preservation of wetlands and breeding livestock.

1.4.2.3 Industry

In the LPB, industrial activity is diversified and is particularly related to the main urban centers in Argentina and Brazil, such as the metropolitan regions of São Paulo and Buenos Aires. In these regions, the most important industrial production is related to automotive development and oil derivatives.

In Argentina, the most important industrial centers are located—in addition to the metropolitan area of Buenos Aires—in the provinces of Santa Fe and Buenos Aires. These include industries related to raw materials from agriculture and ranching such as tanneries and food industries.

In Brazil the industrial sector is diversified, mainly in technology, food, textiles, automotive, aircraft, and oil. The systems

Industrial parks in the province of Buenos Aires, Argentina.

of the Paraná, Uruguay, and Paraguay have the largest part of the country's industrial production.

In Uruguay, the food industry is located in rural areas, while the rest is located in the metropolitan area of Montevideo.

It should be noted that the industrial processing and transformation of agricultural products and organic materials into final products is not homogeneous in all countries.

Industrial waste is as important as domestic waste in the LPB. The large metropolitan areas of São Paulo, Curitiba, and Buenos Aires are the most industrialized areas, where industrial effluents are treated more intensely than domestic effluents. However, the amount of untreated effluents endangers watercourses, as several of these more industrialized areas are located in river sources such as São Paulo in the Upper Tietê, and Curitiba in the Iguazú river basin. In addition, untreated effluents discharged directly into rivers contaminate aquifers.

1.4.2.4 Mining

Production from the mining industry occupies an important place among the economic activities of the countries of the LPB, although it is not a mineral-rich area.

Bolivia, although with little expanse of territory within the Basin, has iron and manganese deposits very close to Puerto Suárez. At the edges of the Andean belt, there are significant reserves of gas and oil. Bolivia and Argentina produce the largest amount of oil in the region.

In the Upper Paraguay sub-basin, opposite the Mutún hill (Bolivia), is the Urucum twin hill where Brazil mines iron ore, which is an export to Argentina, Europe, and China.

One of the important environmental aspects of mining is the byproduct, which is deposited in the sediment of the Basin's rivers and generates historically accumulated effects downstream of the production zones.

To a greater extent, the pollution generated by mining is mainly observed in the Paraguay River system, particularly in two of the main tributary sub-basins, those of the Bermejo and Pilcomayo rivers. In Bolivia, mining is carried out in the upper basins of these two rivers, which causes contamination from the wastewater caused by the extraction and processing activities, as well as by mining erosion. Acid drainage was estimated at approximately four million cubic meters and is related to the discharge of 643,000 tons of total solid waste. The greatest contamination problems appear in the Department of Oruro, where mining has a history of hundreds of years.

In Brazil, mining on the plateau of the Paraguay River causes contamination from mercury deposits in the river's sewers.

1.4.2.5 Hydroelectricity

The La Plata Basin has a very important hydroelectric generating capacity which constitutes a significant portion of the total energy generation for the countries involved. For Paraguay in particular, it accounts for the largest percentage of the GDP.

The sub-basins that have the highest hydroelectric potential are those of the upper Paraná, the upper Uruguay and, to a lesser extent, of the lower Paraná.

The main national hydroelectric power plants in each Basin country (with more than 100 MW of power) are presented in the **Table and Figure 1.4.2.5.1**, with the largest number of plants in operation corresponding to the upper Paraná basin.

Tables 1.4.2.5.2 and **1.4.2.5.3** present, respectively, the existing and projected hydroelectric power plants in the cross-border sections of the indicated rivers. In relation to these sections, the total amount of exploitable power is 29,590 MW, with almost two thirds of it already in operation.

In the electricity matrix of the five countries, hydropower represents more than 75 percent of the installed capacity in Brazil, Paraguay, and Uruguay. In Argentina it represents more than 30 percent. The current trend is the integration of the electricity sector amongst the countries, with the aim of increasing synergies to meet the demand.

The binational Itaipú, still today the largest hydroelectric power plant in the world.

Table 1.4.2.5.1

Main hydroelectric plants in the national stretches of the rivers of The La Plata Basin

Central	River	Power (MW)
Argentina		
Cabra Corral	Juramento	102
Brazil		
Ilha Solteira	Paraná	3,444
Foz do Areia	Iguazú	1,676
Jupiá	Paraná	1,551
Salto Osório	Iguazú	1,078
Emborcação	Paranaíba	1,192
Furnas	Grande	1,216
Itá	Uruguay	1,450
Marimbondo	Grande	1,440
Porto Primavera	Paraná	1,430
Salto Santiago	Iguazú	1,420
Agua Vermelha	Grande	1,396
Segredo	Iguazú	1,260
Salto Caxias	Iguazú	1,240
Estreito	Grande	1,050
Paraguay		
Iguazú	Iguazú	103
Acaray	Acaray	210
Uruguay		
G Terra	Negro	140
Palmar	Negro	330
Baygorria	Negro	100

Figure 1.4.2.5.1

Hydroelectric power plants with more than 100 MW of power

Table 1.4.2.5.2

Hydroelectric plants in the transboundary sections of the La Plata Basin

Central	River	Potencia (MW)
Brazil y Paraguay		
Itaipú	Paraná	14,000
Argentina y Uruguay		
Salto Grande	Uruguay	1,890
Argentina y Paraguay		
Yacyretá (*)	Paraná	3,200
Total existing power		**18,990**

(*) The use of the Aña Cuá branch is projected, which would add power to this binational use.

Table 1.4.2.5.3

Main hydroelectric plants planned in the cross-border sections of the La Plata Basin

Central	River	Power (MW)(*)
Brazil y Argentina		
Garabí	Uruguay	1,152
Panambí	Uruguay	1,048
Argentina y Paraguay		
Corpus Christi	Paraná	2,880

(*) These projects are under study, so the power could vary depending on the final design adopted.

Tailing dam in the Pilcomayo basin, Bolivia.

1.4.2.6 Navegation

Navigation from the La Plata River was the mechanism that facilitated the occupation of the Basin by the Spanish during colonization. Navigation in the LPB presents the following waterways (**Figure 1.4.2.6.1**):

a) Paraguay-Paraná Waterway: the main route connecting the countries of the Basin, an important route for transporting large loads. It represents the largest amount of cargo transported.

b) Uruguay Waterway: in the section downstream of the Salto Grande dam.

c) Tietê-Paraná Waterway: navigation takes place in the stretches within Brazil due to the lack of locks in the Itaipú dam. It is important to internal transportation in that country.

1.4.2.7 Protection of Ecosystems

The La Plata Basin includes several key ecosystems: the Gran Chaco Americano, with an approximate area of 1,000,000 km², the second most important large ecosystem in South America after the Amazon; the Prairies; the Pantanal, with more than 496,000 km²; the system of estuaries, lagoons, and wetlands of Iberá (Argentina) and of Lake Ypoá (Paraguay); the Atlantic Forest, an area designated as a biosphere reserve (UNESCO); the Cerrado and the Paraná Delta, constituting a water system with a remarkable biological diversity and productivity.

Transport of goods on the Paraguay-Paraná waterway.

It should be noted that the existence of a large wetland corridor constitutes an important freshwater reserve with a rich biological and cultural diversity, which is extremely appropriate for the implementation of sustainable development strategies that complement ecotourism programs and projects, which can be a source of income to protect the environment and to improve the lives of riparian communities.

1.4.2.8 Ecotourism

Some of these wetlands have been designated Wetlands of International Importance, or Ramsar Sites, which gives them a greater degree of protection. In this regard, since the year 2007 and within the framework of the Ramsar Convention on Wetlands, the countries moved forward in the construction of the *Regional Strategy for Wetlands of the La Plata Basin* and, in 2012, the Convention formally addressed tourism as one of the many ecosystem services provided by wetlands in the framework of its Eleventh Conference of the Parties (COP11). This event identified the aspects that countries should take into account at the national and local levels to ensure that wetland tourism is sustainable and in accordance with the "rational use" principle established by the Convention.

In the context of COP11, the Secretariat of the Ramsar Convention and the World Tourism Organization (WTO) presented a

Figure 1.4.2.6.1

La Plata Basin waterways

publication highlighting the value of wetland resources for tourism, as well as the economic benefits tourism can contribute to wetland management. In this publication, entitled *Destino Humedales, apoyando el turismo sostenible*, 14 case studies were selected, one of which from the LPB, the Iberá lagoons and estuaries (Corrientes, Argentina), which describes the established management processes.

Likewise, there are 38 national parks in LPB territory (detailed in **Table A.7** of the *Appendix*) and the following 10 World Heritage Sites (UNESCO):

- The Iguazú National Park (Argentina and Brazil)
- The Guaraní Jesuit Missions: San Ignacio Miní, Santa Ana, Our Lady of Loreto, and Santa María la Mayor (Argentina), and the Ruins of San Miguel de las Misiones (Brazil)
- The Humahuaca Gorge (Argentina)
- The Jesuit Missions of Chiquitos (Bolivia)
- The city of Potosí (Bolivia)
- The historic city of Sucre (Bolivia)
- El Barrio Histórico de la ciudad de Colonia de Sacramento (Uruguay)
- The city of Brasilia (Brazil)
- The Pantanal Conservation Area (Brazil)
- Two of the seven former Guaraní Jesuit Missions: Santísima Trinidad de Paraná and Jesús de Tavarangüe (Paraguay)
- The Historic District of the city of Colonia de Sacramento (Uruguay)

- The city of Brasilia (Brazil)
- The Pantanal Conservation Area (Brazil)
- Two of the seven former Guaraní Jesuit Missions: Santísima Trinidad de Paraná and Jesús de Tavarangüe (Paraguay)
- The Historic District of the city of Colonia de Sacramento (Uruguay)

In this sense, ecotourism is increasingly considered a management strategy for protected areas, which, if properly implemented, is a sustainable activity because it is designed to have minimal impact on the ecosystem, to economically contribute to local communities, to be respectful of their cultures, to develop using a participatory process involving all actors, and to be monitored in order to detect positive and negative impacts.

The Jesuit Missions, recognized worldwide, are a tourist attraction in the Basin.

Table 1.4.2.8.1 synthesizes data on entrepreneurship, programs, and projects related to ecotourism in the five countries of the Basin, where a large diversity of typologies cover different market niches.

There are also programs and projects of a cross-border nature (PM, 2016a):

- Pilot project for Biodiversity Conservation in the Paraná River.
- Pilot Project for the Resolution of Water Use Conflicts – Cuareim-Quaraí River Basin.
- Freplata Project – Environmental Protection of the La Plata River and its Maritime Front: pollution prevention and control and habitat restoration.

Project for Environmental Protection and the Sustainable Development of the Guarani Aquifer System.

- Gran Chaco Sustainable Land Management Project in the Gran Chaco Americano Transboundary Ecosystem.
- Strategic Action Program for the Bermejo River Basin. Ecotourism Promotion in the Yungas

1.4.3 Quantitative Estimation of Claims

In order to achieve integrated water balance, indispensable tools for water resource management have developed the quantification of the water demands for different uses in the Basin territory, following a methodology agreed upon in 2012 by the five countries, having carried out estimates for 2010.

The uses considered in the estimation were domestic (rural and urban drinking water), agricultural (crop irrigation), livestock (manufacturing, refrigeration, etc.), and mining (total volume for production, discriminating intermediate processes).

Table 1.4.2.8.1

Ecotourism ventures by country

Country	Typology	Quantity
Argentina	52% ecotourism, 19% community tourism, 17% rural tourism, and 12% Nautical tourism	42
Bolivia	50% community tourism, 31% ecotourism, 19% rural tourism	16
Brazil	80% rural tourism, 20% community tourism	10
Paraguay	46% rural tourism, 42% ecotourism, 8% nautical tourism, 4% community tourism	24
Uruguay	85% rural tourism, 7.5% ecotourism, 7.5% nautical tourism	41
Total		**133**

Source: MP, 2016m.

The integration of the estimates carried out in each country makes it possible to obtain the results presented in **Table 1.4.3.1**, which provides the demand for the different water uses for the whole Basin.

1.4.3.1 Lawsuit Considerations in the La Plata Basin

Irrigation is the principal usage of water, which continually expands with two conflicting characteristics: it mitigates water deficits and sharpens competition with other uses in periods of scarcity. The most relevant case is rice farming which, due to its high water consumption, generates demand conflicts with other sectors –such as urban, livestock and industry– as well as the protection of ecosystems.

Urban use is the second largest demand, and conflicts exist due to a deficiency in the quantity and quality of supply in some sub-basins of the Paraguay, Paraná, and Uruguay rivers. This situation is exacerbated in urban populations, which are constantly increasing due to the strong urbanization that has occurred in recent decades.

Industrial demand occupies third place because of the volume consumed, which has a quantitative value similar to the demand of the livestock industry, and is very important because of the high economic and social value and because of the negative environmental impact resulting from the emission of effluents that contaminate and affect the water supply.

Animal consumption is a priority, as is human consumption, and of great economic significance since the LPB is consolidating as the world's leading producer and exporter of meat. This demand –difficult to assess because it is distributed diffusely throughout the whole territory– is permanently affected, accentuating the problem in periods of drought, since the scarcity of drinking water impacts more than food restriction. There is a need to refine supply systems to ensure supply and minimize diffuse pollution occurring when animals directly access water bodies.

Mining demand is important in part of the region, but there is only partial information available.

Meeting of the project management team, November 2014.

Table 1.4.3.1

Demand for water in the La Plata Basin

a) Integration of data by country

	Demand in hm³/año						
Country	**Population**	**Agricultural**	**Livestock**	**Industrial**	**Mining**	**Total**	**%**
Argentina	4,787	7,304	1,066	2,138	124	**15,419**	**31.5**
Bolivia	125	n/d	n/d	n/d	n/d	**125**	**0.0**
Brazil	6,250	14,128	1,911	6,771	n/d	**29,060**	**59.3**
Paraguay	443	552	484	17	n/d	**1,496**	**3.1**
Uruguay	397	2,011	342	132	47	**2,929**	**6.0**
Total	**12,002**	**23,995**	**3,803**	**9,058**	**171**	**49,029**	
%	**24.5**	**48.9**	**7.8**	**18.4**	**0.0**		**100.0**

b) Integration of data by water systems

	Demand in hm³/año						
Sub-basin	**Population**	**Agricultural**	**Livestock**	**Industrial**	**Mining**	**Total**	**%**
Paraná	8,119	15,067	2,269	7,726	68	**33,250**	**68.0**
Paraguay	625	1,831	527	156	7	**3,146**	**6.4**
Uruguay	588	6,598	594	427	20	**8,227**	**16.8**
La Plata River	2,545	499	413	742	76	**4,275**	**8.7**
Total	**11,877**	**23,995**	**3,803**	**9,051**	**171**	**48,897**	
%	**24.3**	**49.1**	**7.8**	**18.5**	**0.5**		**100.0**

Source: PM, 2016j.

Water treatment plant.

1.4.4 Availability-Demand Ratio

1.4.4.1 General Qualitative Evaluation

The uses of water resources can lead to conflicts when there is no balance between availability and demand for consumptive uses or when non-consumptive uses alter the conditions of the water system with its variability in time and space. **Table 1.4.4.1.1** presents an overview of water resource use in the sub-basins of the LPB, indicating whether there are no dominant problems, whether there are only some problems, or if there are problems.

For its part, **Table 1.4.4.1.2** identifies areas of the Basin with existing or potential conflicts between availability and demand, or with limitations on water use.

Table 1.4.4.1.1

General qualitative assessment of water use

Water Usage	Paraguay		Paraná		Uruguay		La Plata River
	Upper	Lower	Upper	Lower	Upper	Lower	
Human Supply	There are no dominant problems	There are only some problems	There are problems	There are only some problems	There are problems	There are no dominant problems	There are only some problems
Irrigation	There are only some problems	There are only some problems	There are only some problems	There are only some problems	There are only some problems	There are problems	There are only some problems
Hydroelectric power	There are no dominant problems	There are no dominant problems	There are problems	There are no dominant problems	There are problems	There are problems	There are no dominant problems
Navigation	There are problems	There are problems	There are problems	There are problems	There are no dominant problems	There are problems	There are problems
Recreation / Tourism	There are problems	There are only some problems	There are only some problems	There are problems	There are no dominant problems	There are only some problems	There are problems
Aquaculture / Fisheries	There are problems	There are only some problems	There are only some problems	There are problems	There are no dominant problems	There are only some problems	There are problems
Conflict of uses	There are only some problems	There are only some problems	There are problems	There are only some problems	There are problems	There are problems	There are only some problems

Legend (colour key):
- There are no dominant problems
- There are only some problems
- There are problems

Source: Updated by FP (2004)

Table 1.4.4.1.2

Areas of La Plata Basin with existing or potential conflicts between availability and demand, or with limitations on consumptive uses of water

Location	Problem(*)	Type
Upper Paraguay sub-basin		
Cuiabá Metropolitan Region (Cuiabá River)	Reduced availability due to pollution by urban effluents.	Local
Planalto and Pantanal	Sediment deposits in the area of the Pantanal due to the erosive processes in the Planalto.	Regional
Mato Grosso and Mato Grosso do Sul	Low sanitation coverage; only 10% of the water captured is treated. Disorganized disposal of solid waste and discharges directly into the watercourses (Cuiabá, Varzea Grande, and Rondonópolis).	Local
Lower Paraguay sub-basin		
Chaco	Has water restrictions due to lack of supply and diffuse demand.	Regional
Basin of Tebicuary River	Conflict of water uses between urban services, irrigation, artisanal fisheries, and ecosystems.	Regional
Bermejo and Pilcomayo Rivers	Effect of sediment on the water intake. Diffuse contamination of water from crops (Paraguay and Argentina) and bare soil and agricultural activity (Bolivia).	Regional
Upper Paraná sub-basin		
Tietê River, Metropolitan region of São Paulo	High demand for water and contaminated springs. High demand in basin.	Local
São Paulo and Curitiba (Tietê and Iguazú rivers, respectively)	Low water levels and, therefore, low capacity of assimilation of the urban pollution in headwaters of the basin. Low coverage of sanitation and low degree of treatment.	Local
Water systems near Brasilia - Distrito Federal	Strong urban sprawl with areas of irrigated agriculture. High demand, pollution, and conflicts with irrigation use. Head of the basins.	Local
Goiania Metropolitan region	Strong urban expansion and untreated effluents with reduction of quality.	Local
Metropolitan region of Campo Grande	Urban expansion and effluent pollution. Head of the rivers.	Local

Location	Problem(*)	Type
Paranaíba River sub-basin	Strong expansion of irrigation in the basin, conflicts with small hydropower plants and industrial processing of alcohol.	Local
Lower Parana sub-basin		
Paraná River downstream of the confluence with the Bermejo- Paraguay	Flow of solids affecting navigation. Deterioration of water quality.	Regional
Uruguay sub-basins		
Rio do Peixe	Industrial pollution with production and processing of poultry and pigs with loss of water supply for cities.	Local
Tributaries of the Uruguay	Limited availability of water during periods of drought due to lack of regulation.	Local
Ibicuy and Cuaraí	High water demand for rice irrigation in Brazil, Uruguay, and Argentina. Conflict with urban uses.	Transboundary
Uruguay River stretch located in the Brazilian territory	Domestic wastewater with a low level of treatment. Agribusiness, mainly swine and poultry, with inadequate or no treatment of the effluents or wastes generated. Agriculture without soil conservation practices and with the use of agrochemicals. Erosion due to logging and agriculture. Industrial pollution due to mining activity.	Regional Transboundary
Guaraní Aquifer		
South zone of the aquifer, border of Brazil and Uruguay	Investment of the local water level toward the city of Santana do Livramento due to the exploitation of groundwater for 100% coverage of the city.	Local Transboundary
South zone of the aquifer, border of Brazil and Uruguay	Depletion of groundwater levels due to the growth of cities, with the consequent increase in the use of that resource.	Transboundary
Thermal zone, border between Argentina and Uruguay	Possibility of decreasing water levels and temperatures, with large losses of the thermal trade.	Transboundary

(*) The problems are in specific areas and not in the entire sub-basin.

1.5 Monitoring, Alert, and Hydroclimate Prediction Systems

1.5.1 Hydro-meteorological Monitoring Systems

1.5.1.1 Meteorological Observations

Meteorological forecasting and observations in general are some of the main activities of the meteorological services of each country; in the LPB each of the five countries has an institution of this type:

- Argentina: National Weather Service (Servicio Meteorológico Nacional - SMN)
- Bolivia: National Meteorology and Hydrology Service (Servicio Nacional de Meteorología e Hidrología - SENAMHI)
- Brazil: National Institute of Meteorology (Instituto Nacional de Meteorología-INMET)
- Paraguay: Department of Meteorology and Hydrology (Dirección de Meteorología e Hidrología - DMH)
- Uruguay: Uruguayan Institute of Meteorology (Instituto Uruguayo de Meteorología - INUMET)

These institutions are the nexus of each country with the World Meteorological Organization (WMO), which since 1950 is the United Nations agency specializing in meteorology (weather and climate), operational hydrology, and related geophysical sciences.

In some countries, meteorological observations are also made by other agencies, including:

- Argentina: Institute of Agricultural Technology (Instituto de Tecnología Agropecuaria - INTA)
- Brazil: National Spatial Research Institute (Instituto Nacional de Investigaciones Espaciales - INPE); National Center for Natural Disaster Monitoring and Alert (Centro Nacional de Monitoreo y Alertas de Desastres Naturales - CEMADEN), and the Paraná Meteorological System (Sistema Meteorológico de Paraná- SIMEPAR)
- Paraguay: Paraguayan Institute of Agrarian Technology (Instituto Paraguayo de Tecología Agraria - IPTA)
- Uruguay: National Institute of Agricultural Research (Instituto Nacional de Investigación Agropecuaria - INIA)

It should be noted that the private sector and nongovernmental organizations also participate in meteorological observations. Thus, associations of agricultural producers have an active participation in this subject. For example, the Federation of Production Cooperatives (FECOPROD) in Paraguay administers the Network of Agricultural Meteorological Stations, with telemetric transmission also available on the Internet; in Argentina, the Rosario Grain Exchange and Entre Ríos also have similar meteorological observation systems.

1.5.1.2 Hydrological Observations

Meteorological services may also include hydrological observations, such as the case of the SENAMHI of Bolivia, where both types of official observations are carried out by the same institution. But in the rest of the countries of the LPB, hydrological observations are made by other national institutions:

- Argentina: Sub-secretariat of Hydraulic Resources (Subsecretaría de Recursos Hídricos - SSRH), National Water Institute (Instituto Nacional del Agua - INA) and National Directorate of Waterways (Dirección Nacional de Vías Navegables - DNVN)

- Brazil: National Water Agency (Agencia Nacional de Aguas- ANA)

- Paraguay: National Administration of Navigation and Ports (Administración Nacional de Navegación y Puertos- ANNP) and General Directorate for the Protection and Conservation of Water Resources of the Secretariat of the Environment.

- Uruguay: National Water Directorate (Dirección Nacional de Aguas - DINAGUA)

In addition to these institutions, there are regional or provincial entities that carry out hydrological monitoring and national entities that require information for specific purposes, such as the energy sector:

- Paraguay: National Electricity Administration (Administración Nacional de Electricidad- ANDE)

- Uruguay: National Power Plant and Electric Transmission Administration (Administración Nacional de Usinas y Transmisiones Eléctricas- UTE)

The water sector also highlights entities that operate hydroelectric plants in the international and domestic rivers of the Basin, which also operate hydro-meteorological stations:

- Brazil-Paraguay: Binational Itaipú (IB)

- Argentina-Paraguay: Yacyretá Binational Entity (EBY)

- Argentina-Uruguay: Mixed Technical Commission of Salto Grande (Comisión Técnica Mixta de Salto Grande- CTM)

As can be seen above, hydro-meteorological information is generated by networks operated by different actors—public or private, national or binational—which represents a challenge when integrating information.

1.5.1.3 Observation Networks

The LPB has a network for monitoring hydrological parameters and water quality with a marked asymmetry, both in terms of its qualitative and quantitative aspects. The number of stations, their characteristics, distribution, and network density present important differences.

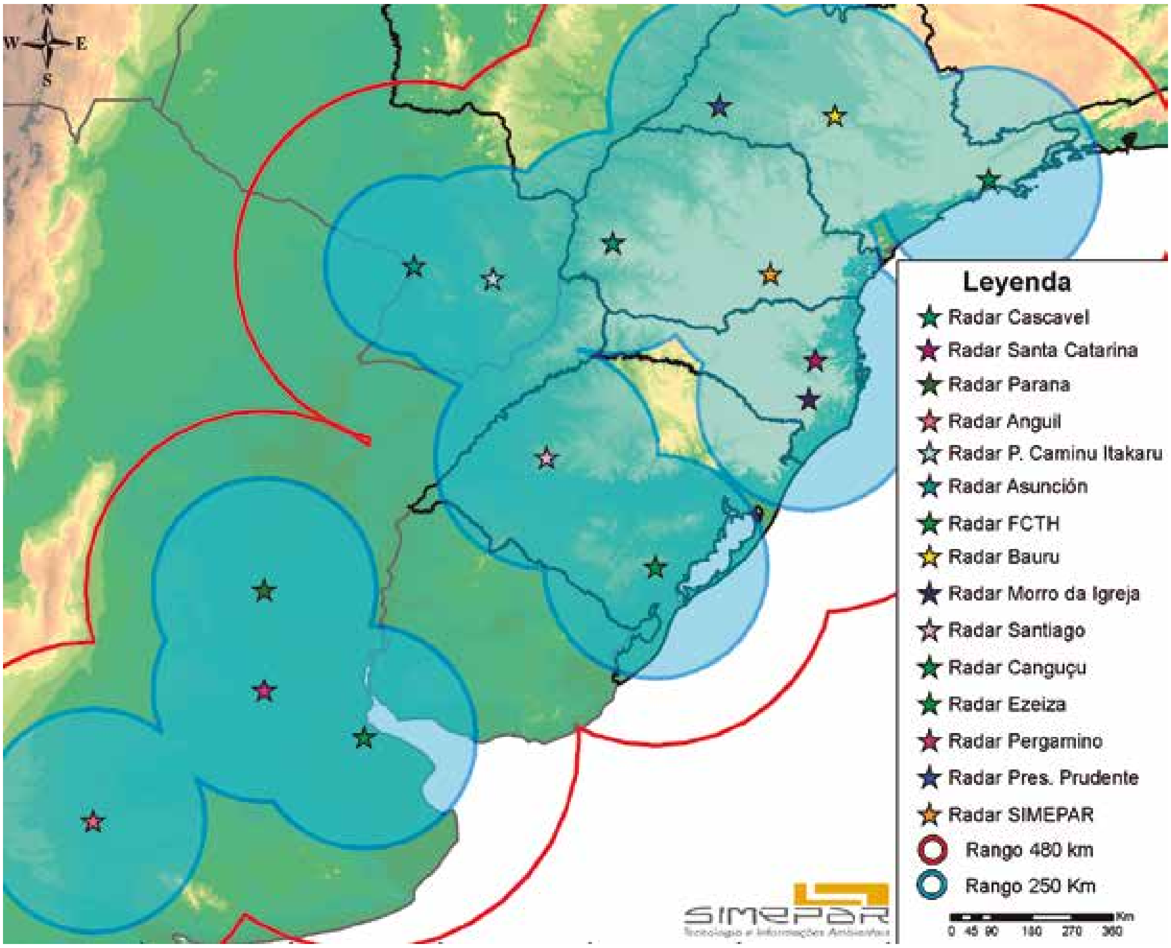
In general, a significant number of stations take mainly pluviometric and hydrometric measurements, with a series of registers of varying length that are used to evaluate the availability of the resource and to plan its multi-purpose use. However, when these networks are considered at the sub-basin level, marked differences are observed, with the sub-basins of Paraná standing out as being the network with the best characteristics, while those of the Uruguay and Paraguay rivers present the greatest deficiencies.

1.5.1.4 Meteorological Radar in the La Plata Basin

The process of installing comprehensive radar coverage in the LPB is underway. For some years now, countries such as Argentina, Brazil, and Paraguay have had hydro-meteorological observation systems that represent a powerful tool for hydro-meteorological prediction and warning with broad applications, such as natural disaster risk management, among others (**Figure 1.5.1.4.1**).

Figure 1.5.1.4.1

Meteorological radar of the La Plata Basin



In Argentina between 2007 and 2010, agreements were initiated between the SSRH and the SMN to create a radar system that covers the entire Argentine territory. For this, they planned to increase the number of sensors integrating the existing radars with new ones manufactured nationally. In 2011, the National System of Meteorological Radar (SINARAME) was launched, jointly developed by the then-Ministry of Federal Planning, Public Investment, and Services and the Ministry of Defense, with the participation of the public company INVAP S.E. The project, coordinated and supervised by the SSRH, holds as its objective: to develop and construct doppler Argentine Meteorological Radar (Radares Meteorológicos Argentinos- RMA) in Band C and double polarization; the design and implementation of an Operations Center with the capacity to receive, process, and analyze the data from the National Meteorological Radar Network and related information; and the integration of the existing radar in the national territory with the new national radar, thus optimizing the available resources and their benefits. This network of meteorological radar will be operated by the National Meteorological Service.

To date, Argentina has the following meteorological radar (MR) involving different areas of the La Plata Basin: SMN 1 MR in Ezeiza (Buenos Aires), INTA 1 MR Doppler in Pergamino (Buenos Aires), INTA 2 Doppler MR in Paraná (Entre Ríos) and Tabacalera Jujuy 1 MR.

The institutions that form the SINARAME are: as founding partners, SMN, INA, INTA, and SSRH. Also currently participating in the project are: the Naval Hydrography Service (Servicio de Hidrografía Naval-SHN), the University of Buenos Aires (UBA), the Center for Marine and Atmospheric Research (Centro de Investigaciones del Mar y de la Atmósfera- CIMA), the National University of Córdoba (Universidad Nacional de Córdoba- UNC), Armada Argentina, the National Civil Aviation Administration (Administración Nacional de Aviación Civil- ANAC), the Department of Agriculture and Climate Contingencies of Mendoza (Dirección de Agricultura y Contingencias Climáticas de Mendoza- DACC), and the company LATSER, which provides agricultural services in Jujuy.

In Brazil, one of the strategic objectives of the National Plan for Managing Risks and Responses to Natural Disasters is to expand the weather and climate observation network within the national territory, which aims to provide the best possible accompaniment for the 821 municipalities considered to be priority areas because they have recorded natural disasters such as mudslides and floods.

Prior to the launch of the Plan in August 2012, the meteorological radar network had 23 stations in operation. This network is being expanded by the National Center for Natural Disaster Monitoring and Alert (CEMADEN) and the Ministry of Science, Technology and Innovation with the acquisition of nine radar units with the latest technology which will be installed in regions that are not currently monitored by other systems. The operation and maintenance of the radar systems will be carried out by CEMADEN, in cooperation with the Department of Air Space Control (DECEA), the Mineiro Institute for Water Management (IGAM), the Federal University of Alagoas (UFAL) and other institutions.

Floods on the Paraguay River.

In the Brazilian part of the La Plata Basin, meteorological radar coverage tends to be complete, and it is operated by several institutions such as CEMADEN, DECEA, DAAE, Paraná Meteorological System (SIMEPAR) and the University of São Paulo.

In Paraguay, the National Directorate of Civil Aeronautics (DINAC) operates, together with the Department of Meteorology and Hydrology, a meteorological radar located in Asunción. There are plans to expand the network with a new radar in the center of the eastern region of the country in order to obtain better regional coverage. This initiative would help improve weather radar coverage in the La Plata Basin, with a vision for regional integration of radar systems from Argentina, Brazil, and Paraguay. DINAC maintains fluid communication with Argentina's SSRH and Brazil's SIMEPAR in the field of hydrological and meteorological observation systems, laying the foundations for a future scenario of expansion and regional integration of the radar network.

At the Basin level, between 2012 and 2015 workshops on Alert Systems, Integration of Monitoring Networks, and Radarization of the La Plata Basin were carried out within the Framework Program, aiming to integrate of the radar systems of Argentina, Brazil, and Paraguay.

The possibility of expanding the radar network and its interconnection in the La Plata Basin is a challenge that entails enormous benefits for the improvement of regional hydro-meteorological warning systems. The possibility of a meteorological radar working in Uruguay and integrated regionally would help to close the empty spaces in the meteorological radar observations in the Basin.

1.5.1.5 Meteorological Satellites

In order to have up-to-date data on meteorological conditions affecting large areas and to monitor and develop meteorological systems of synoptic scale—precipitants or not—that can provide information for forecasts and alerts, workers are traversing the Basin to obtain information from meteorological satellites.

In the LPB there are several sources of information that update data and images every 30 minutes. The meteorological services of the region process information from GOES-13, which is available in real time. Various types of images are available throughout the day (infrared image, visible image, cloud cover, and water vapor), all of which provide useful information to define the weather situation and forecast.

Products from other satellites, generally from polar orbit, are available with complementary information, such as precipitable water and instability indexes.

1.5.1.6 WMO Integrated Global Observing System (WIGOS)

WIGOS (WMO Integrated Global Observing System) is an integrated proposal to improve and develop the WMO observing system. WIGOS will promote the organized evolution of current observational systems (GOS, GAW, WHYCOS) operated by its member countries into an integrated, intelligent, and coordinated observation system. This will cover the growing observation requirements of WMO members in a sustainable manner, improving the coordination of the organization's observing systems with those of associated international organizations.

WIGOS, supported by the WMO Information System (WIS), will be the foundation for providing reliable, real-time observations and products related to weather, climate, water, and the environment for all its members and programs.

The authorities from meteorological and hydrological management bodies of the Basin agreed at the Sixteenth Session of the Regional Association III, WMO (Asunción, September 2014) to implement the WIGOS-SA/CP program in the LPB, whose main objective is "to create a homogeneous hydro-meteorological network in the south of South America, in which the five countries of the Basin and their respective meteorological and hydrological services participate, as well as organisms that deal with hydraulic matters, the CIC, and the WMO."

Among other objectives, WIGOS-SA/CP has the task of adjusting existing networks, optimizing their distribution, expanding the radar network, introducing common quality control processes and exchanging best practices on observations.

In September 2015, the Third Workshop on Hydro-meteorological Networks of the La Plata Basin was held in Brasilia, in which authorities and technicians of the meteorological and hydrological services and of the water resources management agencies of Argentina, Brazil, Paraguay, and Uruguay participated with the aim of establishing proposals for the Strategic Action Program (SAP) and follow-up on the WIGOS Program. Among the conclusions of the Workshop are the following proposals for the SAP: to define basic strategic hydro-meteorological networks for the LPB with a regional vision; to gather the positive experiences from the antecedents to the Guaraní Aquifer System Project and other regional projects; to densify the radar network; to promote the development of geostationary satellites suitable for hydro-meteorological applications; to create Regional (virtual) Hydro-meteorological Centers applied as integration mechanisms; to define unified data exchange protocols; and to promote participative instances of integrated water resource management at the sub-basin level.

1.5.2 Hydroclimatic Warning and Prediction Systems

1.5.2.1 By Country, and Systems at the Basin Level

As described above, there are several sources of hydro-meteorological information available in the LPB. In addition, there are several institutions that perform the data processing in real time in order to generate information from the basic data and thus obtain a hydroclimatic sequence, prediction, or alert.

Since the examples in this field are numerous, for the sake of practicality, only a few examples of products that are generated by organisms from the different countries of the LPB will be listed below.

- **Argentina**

National Weather Service (SMN)

Among the functions of the SMN is "to carry out and disseminate meteorological warnings in the face of meteorological situations that endanger the life or property of the inhabitants." At present, alerts of four types are produced for the national territory: (1) Alert warning, (2) Short-term threats, (3) Alert, and (4) Alerts for persistent phenomena.

The SMN provides a range of products and services which, such as:

- *Satellite precipitation monitoring:* Accumulated precipitation maps are compiled in 10 days for the last month and monthly for the last 12 months, derived from the satellite precipitation estimations provided by Tropical Rainfall Measuring Mission (TRMM), a joint effort between NASA and the Japan Aerospace Exploration Agency (JAXA).

- *Analysis of accumulated precipitation and anomalies in the La Plata Basin:* Monitoring and analysis of hydro-meteorological components is carried out for the LPB as a whole. The products correspond to accumulated precipitation maps and precipitation anomalies in 10 days for the last month as well as monthly for the last 12 months, based on measurements made in surface meteorological stations.

- *Predicted and estimated precipitation analysis at the sub-basin level in the La Plata Basin:* The SMN also produces graphs with the relative frequency of precipitation percentage estimated by satellite information (TRMM) in the different sub-basins of the LPB.

For each sub-basin, graphs are drawn and rainfall values are plotted as intervals and indicate the relative frequency in terms of the number of points within the domain of that sub-basin with respect to the total for the sub-basin, where a value of precipitation over a given interval is recorded. This product allows daily monitoring of the cumulative precipitation behavior in the last 10 days for each sub-basin. In this way, the distribution of precipitation values for the last ten days, focused on the area of interest, is summarized.

To supplement the information provided by the satellite data on the current water situation of each sub-basin (from the point of view of precipitation), histograms of the rainfall amounts predicted by the SMN' ETA Model for the next six days are also prepared (starting on any given day) for each sub-basin. In this case, the histogram represents the relative frequency distribution of the predicted precipitation in the different sub-basins.

National Water Institute (INA)

The NWI is a decentralized agency dependent on the Undersecretariat of Water Resources of the Nation. It is responsible for the development and operation of the Hydrological Information and Alert System of the La Plata Basin (SIyAH).

The objectives of the SIyAH are: (1) To forecast, as far in advance as possible, flood events or pronounced water shortages; (2) To know the state of the basin at all times; and (3) To regularly produce hydrological forecasts at points of interest.

SIyAH relies on the National Hydrometric Network (42 stations) and an International Hydrometric Network (30 stations). In 2013, coinciding with the International Year of Water Cooperation, Argentina undertook a network integration project with the participation of national, provincial, municipal, basin organizations, universities, and companies, which 3,067 hydro-meteorological stations in total.

The products generated are public and available through the internet, and include:

- Daily hydrological information from the La Plata Basin System.

- Possible hydrological scenarios in the LPB for the next quarter.

- Short-term precipitation forecasts.
- Hydrological modeling and forecasting of the height of the Paraná River.
- Products derived from remote devices.

The height forecasts for different points of the Paraná River in the Argentine stretch, which in normal situations are carried out every 5 and 10 days in significant floods or downspouts, are predicting maximums or minimums, respectively, with greater frequency.

ALERT.AR Program

The ALERT.AR program—funded by the Ministry of Defense's Secretary of Science, Technology, and Production—has been implemented since 2014 by the SMN, INTA, and the National Scientific and Technical Research Council (CONICET), with the purpose of generating meteorological forecasts capable of determining environmental conditions for the development of extreme events with a high impact on the population and its goods.

The general objective of the program is to develop and implement multiple operational tools for analyzing information from remote sensors and numerical models in order to allow real-time decisions to be made to improve response time to the meteorological warnings in order to alleviate the human, economic, and social losses generated by storms.

Other Systems

In the framework of the LPB in Argentina, there are other alert systems for specific sub-basins, such as the Salado River Alert System and the Santa Fe City early warning system.

• Bolivia

National Meteorology and Hydrology Service (SENAMHI)

SENAMHI is the body that governs meteorological, hydrological, agrometeorological, and related activities at the national level, with international representation. As a science and technology institution, it provides specialized services to contribute to the sustainable development of the Bolivian State, meeting information requirements at the national and international levels, participating in global atmospheric surveillance and contributing to the Civil Defense disaster prevention.

At present, the SENAMHI database has information on approximately 1,000 meteorological stations distributed throughout the country, including rain gauges. The processing of data was performed manually until 1984; electronic forms were subsequently used until the CICLOM program was implemented in 1994, and—since 2002—SISMET, a locally developed meteorological data processing system, has been used.

With regard to hydrology, information is available on 319 hydrological stations. In 1983, the HYDROM program was introduced for the treatment and storage of hydrometric information and PLUVIOM for rainfall information, both programs provided by ORSTOM. At present, IRD 2002 HYDRACCES is used for the treatment of hydrological data in SENAMHI.

Bolivia's network of hydro-meteorological stations in the LPB currently has 165 stations: 142 meteorological and 23 hydrological.

Bolivia has experience in early warning systems, especially in the rivers of the Amazon

Basin, such as the Beni, Madre de Dios, and in other streams. The Beni Flood Risk Management Program envisages the creation of a system for hydrological forecasting, the strengthening of the hydrometric network, and the strengthening of technical equipment for the support of data management and modeling.

National Integrated Information System for Disaster Risk Management

This risk management system is carried out by the Vice Ministry of Civil Defense (VIDECI), which is supported by the National Disaster Early Warning System (SNATD) which, in turn, has the DEWETRA platform as its technical support.

- Brazil

Center for Weather Forecasting and Climate Studies (CPTEC)

Monthly and seasonal evolution of rainfall in Brazil: The historical knowledge of monthly or seasonal rainfall is one of the most important products to characterize the spatial and temporal distribution of observed rainfall, applied often in emergency, energy, agriculture, or tourism sectors, and are also the basis for the climate forecast. The CPTEC makes boxplot graphics or diagrams available as a product of climate monitoring of monthly and seasonal rainfall for 124 regions in Brazil. These products are generated using a historical series of 30 years of precipitation data on Brazil (1981 to 2010).

On the other hand, using a model of inter-institutional cooperation from several of the country's institutions, a joint analysis was carried out of precipitation occurring in the Rio Grande sub-basin, in the Upper Paraná, during a hydrological year.

National Institute of Meteorology (INMET)

INMET, in its Internet portal, offers information on accumulated precipitation in recent days, presenting cumulative precip-

Floods in Bolivia.

itation maps for the entirety of Brazil for recent specific periods, with daily updates.

Among other climatic products, INMET also provides probabilistic products of quarterly cumulative precipitation, with real-time updating, for any number of meteorological stations, including several located in the LPB.

National Water Agency (ANA)

The ANA is the institution that implements, controls, and examines the management instruments created by the National Water Resources Policy in Brazil. In this way, its regulatory spectrum surpasses just watersheds, as it reaches institutional aspects related to the regulation of water resources at the national level.

The ANA is the National System of Information on Hydraulic Resources (SNIRH) operator, where the Hydrological Monitoring System (telemetry) is available, among other sources of information. Some hydroclimatic products are generated by ANA in collaboration with other agencies; one example is the collaboration with the Climate Prediction Center (CPC) of the National Oceanic and Atmospheric Administration (NOAA) of the United States, in particular an analysis of the precipitation for the 12 hydrological regions of Brazil.

- ### Paraguay

National Directorate of Civil Aeronautics (DINAC)

The Department of Meteorology and Hydrology (DMH), a dependent of DINAC, is responsible for issuing meteorological warnings, particularly those caused by severe storms that generate risky situations due to intense rains, strong winds, and hail. Direct communication with the Secretary of National Emergencies (SEN) allows the activation of a national-level alert system. The DMH has a network of conventional and automatic meteorological stations, a meteorological satellite image capture system, and a meteorological radar; in addition, it has resumed radiosonde observations in Asunción by implementing the Leading Environmental Analysis and Display System (LEAS), which facilitates the display of data and images from automatic observing systems, radar, and satellites.

Challenges and short-term projects include the modernization of the national network for atmospheric monitoring through the implementation of automatic meteorological and hydrological stations with satellite and GPRS transmission, the implementation of a new Meteorological Radar in the eastern region, the implementation of a radiosonde system in Mariscal Estigarribia, the implementation of climate services and the incorporation of qualified human resources.

Another challenge for the DMH is the strengthening of operational hydrology in Paraguay, as it currently has weaknesses such as a hydrometric network of low density and heterogeneously distributed, a dramatic lack of water level measurements, and poor coordination of activities in the field of operational hydrology, which are currently sectoral. As a result, strengthening the sector will lead to advances in the knowledge and prognosis of floods and droughts, the study of the water quality and availability in different basins for different uses, the administration of dredging operations for navigation, and the country's participation in regional and international programs on environmental protection and climate change.

The DMH has the daily behavior of the Paraguay River compared to extreme flood and drought conditions in its portal.

National Administration of Navigation and Ports (ANNP)

In Paraguay, hydrological observations, particularly of daily hydrometric height, are carried out by this organism in coordination with the Hydrography and Navigation Directorate of the Paraguayan Armada, for which it has several measuring points throughout the Paraguayan section of the Paraguay River, and also in the border section. These observations, permanently compared to the average behavior and past observed extremes, are a very useful tool for the emission of hydrological alerts. The ANNP also coordinates activities with DINAC to issue hydroclimatic alerts jointly. A unique case occurs at times of flooding in the Paraguay River, affecting several riverside cities, which require permanent monitoring of the evolution of phenomena, such as El Niño, usually associated with extreme seasonal precipitation. Operationally, DINAC processes the daily data on river levels in the Paraguay River in conjunction with the ANNP and carries out a hydro-climatic analysis of the Paraguay River in situations of defined ENSO phases.

- Uruguay

Uruguayan Institute of Meteorology (INUMET)

Climate services in Uruguay are diverse; by way of example, INUMET produces monthly values of accumulated precipitation and their corresponding anomaly, using all the rain gauges that make up the National Pluviometric Network.

National Institute of Agricultural Research (INIA)

The INIA also performs pluviometric analysis for agricultural purposes, representing seasonal precipitation and its corresponding anomalies, using 75 INUMET meteorological stations and five of its own stations as a database.

The INIA disseminates a Soil Water Balance, calculated based on precipitation, evapotranspiration calculations, and the state of soil moisture, thus obtaining a water health index for 10 days and monthly, with data from 84 meteorological stations.

UdelaR-DINAGUA-SINAE

Uruguay has the National Emergency System (SINAE), which is both specific and permanent in coordinating public institutions for the integral management of disaster risk. The National Directorate of Water (DINAGUA), INUMET, and the University of the Republic (UDELAR) intervene, among other institutions. At the departmental level, Emergency Departmental Committees have been constituted.

The Durazno department has implemented an Early Flood Warning System (SAT). This system is based on a hydrological-hydrodynamic model in an area of 8,750 km², using real-time precipitation data and precipitation and wind forecasts as input, as well as data on topography, soils, geology, and land use. The results of the model give the flood alert level to the city of Durazno on a scale of High, Medium, and Low, with graphs of 20 days (10 past and 10 future) of daily levels of the Yí River in front of the city.

The XII Meeting of the Working Group on Hydrology and Water Resources of the

WMO Region III, held in Uruguay in March 2014, resolved to support the country's proposal to extend this system to the cities of Artigas and Quaraí, located on both sides of the Cuareim/Quaraí binational river, shared with Brazil, and the city of Treinta y Tres, in the Olimar river basin, a sub-basin of the also binational Uruguayan-Brazilian Merín Lagoon.

1.5.2.2 WMO Climate Forums and Services

- ***Regional Climate Center for Southern South America (CRC-SAS)***

The Regional Climate Center for Southern South America (CRC-SAS) is a virtual organization, constituted in the form of a network, according to the principles defined by the WMO. It is in its initial phase of implementation and offers climate services in support of national meteorological and hydrological services and to other users in the countries located in the southern region of the continent.

The CRC-SAS has the following organization: Argentina and Brazil are the responsible countries; Paraguay and Uruguay are member countries; while Bolivia and Chile are associated countries. The collaborating institutions are as follows: for Argentina, the Department of Atmospheric and Ocean Sciences of the University of Buenos Aires, the National Patagonic Center, the CIMA of CONICET and INTA; for Brazil, the Center for Weather Forecasting and Climate Studies and SIMEPAR.

The Executive Committee is composed of the directors of meteorological services and has the following working groups: data, product development, and production management; infrastructure of information technologies, web design, and maintenance; training and capacity building; associated research activities, including mechanisms for interfacing with users.

Regarding the CRC-SAS Network of Meteorological Stations, the countries commit to providing data from a number of defined conventional stations, totaling 313 meteorological stations (**Table 1.5.2.2.1**). Quality control has a superset of controls in literature and used in the region, implemented in R (open and free software) and funds are provided by the Inter-American Development Bank (IDB) to train staff CRC-SAS member country services.

- ***Global Framework for Climate Services (GFCS)***

Participants at the Third World Climate Conference, held in Geneva in 2009, unanimously decided to establish the Global Framework for Climate Services (GFCS), a UN initiative led by the WMO, in order to guide the development and application of climate information and services based on scientific evidence to support decision-making in climate-sensitive sectors. There are four priority areas for the GFCS: agriculture and food security, disaster risk reduction, health, and water.

The GFCS's vision is to enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy, and practice on the global, regional, and local scale. The user interface platform is the pillar of the framework that provides users (government, private sector, etc.), climatologists, and data climate information providers with a structure to interact on all levels.

Table 1.5.2.2.1

Regional Climate Center Southern South America (CRC-SAS)

Weather Station Network CRC-SAS

Country	Weather Stations
Argentina	164 (*)
Bolivia	31
Brazil	83
Paraguay	23
Uruguay	10
Chile	16
Total	**313**

(*) 124 SMN, 40 INTA.

At the regional level it will be possible to establish developmental and capacity-building synergies that may not be within the reach of some individual countries' resources. In the LPB, the CRC-SAS could help strengthen regional and subregional collaboration capacities, identify user needs, identify research and product generation units that collaborate on activities and support the projects being implemented. The provision of climate services is carried out at the national and subnational/local levels, as well as at the supranational level. In this regard, it may be necessary to strengthen the capacity of national meteorological and hydrological services and other agencies that can collaborate on establishing these services, taking full advantage of existing capacities and avoiding duplication.

1.5.2.3 Numeric Weather Predictions for Hydrological Purposes

The precipitation estimate that can occur in the short or medium term is of interest for hydrological purposes. In this sense, the results of Numerical Time Prediction models can be very useful, especially in extreme situations of flooding or drought. In this sense, there are several agencies in the LPB that have operational models, for example:

- INMET of Brazil runs high-resolution models like MBAR 10km, COSMO 2.8km, and COSMO 7km.
- The CPTEC in Brazil runs several meteorological models in an operative way, among them, BRAMS 5km, ETA 15km, ETA 40km.
- The SMN of Argentina runs the ETA 40km model.

1.6. Legal-institutional Framework

1.6.1 La Plata Basin System

The La Plata Basin System is formed by the La Plata Basin Treaty, the Meeting of Ministers of Foreign Affairs of the countries, and by the permanent bodies: the Intergovernmental Coordinating Committee of the Countries of La Plata Basin (CIC), the Intergovernmental Committee of the Paraguay-Paraná Waterway (CIH) and the La Plata Basin Financial Development Fund (FONPLATA).

The La Plata Basin Treaty (TCP), made up of eight articles, came into force in 1970. The objectives are defined in the Preamble, among other things: (i) to permit the harmonious and balanced development and optimal utilization of the principal natural resources of the region and will ensure the conservation of those resources for future generations if they are utilized rationally, (ii) establish firmer institutional arrangements for the La Plata Basin System.

It is worth mentioning Article 1 of the TCP, which highlights the search for a better and more appropriate utilization of water resources and their sustainable development, according to the following:

"The Contracting Parties agree to join forces to promote the harmonious development and physical integration of the La Plata Basin and its zones of direct and measureable influence. To that end, they shall promote, in the region of the Basin, the identification of areas of mutual interest, the carrying out of studies, plans and works, and the formulation of such operating arrangements legal instruments as they may deem necessary to achieve the following objectives:

Technical Meeting with experts from the 5 countries. Sao Jose dos Campos, 2011.

a. Facilitating and assisting navigation;

b. The rational utilization of water resources, in particular by the regulation of watercourses and their multipurpose and equitable development;

c. The conservation and development of animal and plant life;

d. The improvement of road, rail, river, air, electrical, and telecommunications interconnections;

e. Regional complementarity, by promoting and establishing of industries for the development of the Basin;

f. The economic complementarity of areas bordering on the Basin;

g. Cooperation with respect to education, health, and disease control;

h. The promotion of other projects of mutual interest, in particular those relating to the surveying, evaluation, and development of the natural resources of the area;

i. A comprehensive knowledge of the La Plata Basin."

The TCP established the foundation of the management structure in the Basin. The Annual Meeting of Foreign Affairs Ministers (Article 2) established that, as suggested by the CIC, in order to develop common basic guidelines for the revision and evaluation of results, it is necessary to promote consultations on government actions in the integrated development of multinational actions in the Basin and the direct action of the CIC.

Intergovernmental Coordinating Committee of the Countries of the La Plata Basin

The CIC was created in February 1967 during the First Meeting of Foreign Ministers of the LPB, at which time the participating governments agreed to carry out a joint and comprehensive study of the area, with the aim of carrying out multi-national, bilateral, and national policies aimed at the progress and development of the region.

According to the subscribed TCP (Article 3), the CIC became the permanent body of the Basin, "...responsible for promoting, coordinating, and following the progress of multinational efforts to ensure the integrated development of the La Plata Basin and of the technical and financial assistance which it may organize with the support of such international agencies it deems appropriate, and for implementing the decisions adopted by the Ministers of Foreign Affairs."

Since its inception, the CIC has concentrated on areas of common interest in the five countries, facilitating studies, programs, and infrastructure works on hydrology, natural resources, transport and navigation, soils, and energy. In particular, the comprehensive study of natural resources of the LPB conducted by the Organization of American States (OAS) in the 1970s was instrumental in guiding the actions of the countries towards the utilization of energy and transport potential and, because of this, critical environmental zones were registered, such as the sub-basins of the Pilcomayo and Bermejo rivers—characterized by the highest global erosion and sediment transport indices and the Upper Paraguay-Pantanal sub-basin, for the value of its wetland ecosystem and its key role for water regulation in the LPB as a whole.

The need for technical management capacity in the LPB was recognized in December 2001 in the agreements from the meeting of Foreign Ministers of the Basin held in Montevideo, which approved a new Statute for the CIC that incorporates two representatives per country—one political, with plenipotentiary authority, and a second technical representative. The technical representatives of the countries constitute the Project Unit of the La Plata Basin System. This Project Unit was charged with preparing an Action Plan—which was approved by the CIC—and took the initiative to prepare, with the support of FMAM-PNUMA GS/OEA, *the Framework Program for the Sustainable Management of the Water Resources in the La Plata Basin, in relation to the effects of variability and climate change*. In this area, this updated Transboundary Diagnostic Analysis (TDA) and the Strategic Actions Program (SAP) of the La Plata Basin are consolidated in 2016, with an aim at implementation as a future stage.

At the same time, the CIC has signed cooperation agreements with diverse institutions, such as the agreement signed in 2000 with the WMO on Hydrological Alert and Water Quality.

Other organizations and projects in the La Plata Basin

In addition to the CIC, a number of complementary agreements have been integrated and signed within the framework of the TCP, which led to the creation of different institutions and agencies with specific competencies in the Basin, such as FONPLATA, its financial instrument, and the CIH, in charge of the Paraguay-Paraná Waterway. The Treaty also recognizes the possibility of other independent binational or tri-national agreements to address issues of specific interest to its members, leading to the establishment of the agencies detailed in *Chapter 3*.

The institutional framework for regional integration was then strengthened by the Treaty of Asuncion, which created Mercosur in 1995, aimed at encouraging the intraregional and international trade of its member countries.

Chapter 2: Climate Variability and Change in the La Plata Basin

2.1 Key Systems and Processes

With the goal of assessing the effects of climate variability and change on the integrated management of water resources in the La Plata Basin, climate change variability scenarios have been established (the present situation and immediate trends) and the climate change scenarios from the Intergovernmental Panel on Climate Change (IPCC) have also been considered.

2.1.1 Climatic Variability

The tropical and subtropical part of South America is characterized by the South American monsoon, a seasonal atmospheric circulation system which has a pronounced influence on the hydroclimatic system of the La Plata Basin, one of its principal characteristics being its well defined annual precipitation cycle in the largest part of the basin, with maximum precipitation in the summer and minimum precipitation in the winter.

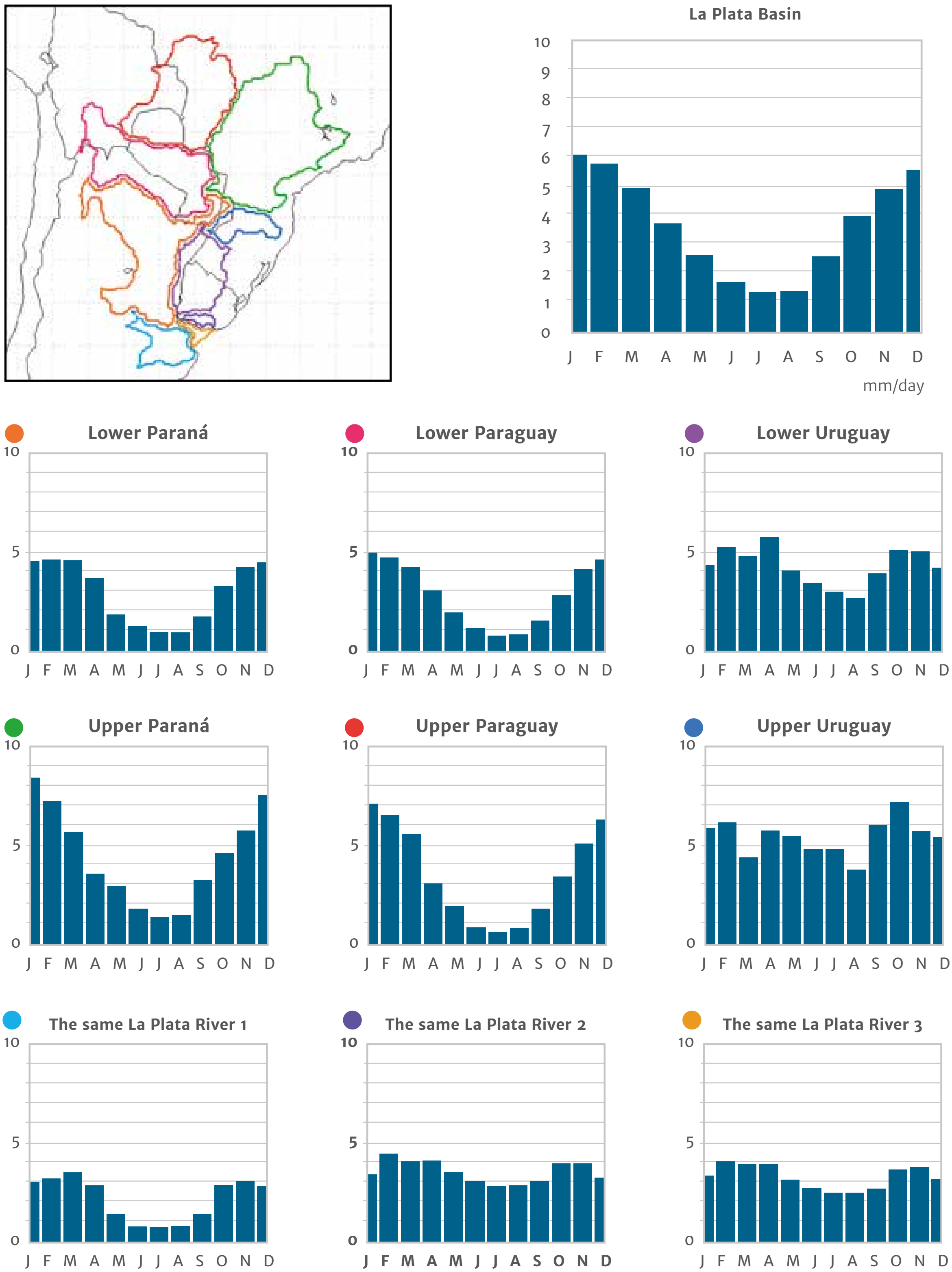
Nevertheless, this seasonal variation is most accentuated in the sub to basins of the Paraguay and the Paraná rivers, and slightly less pronounced in the sub to basins of the Uruguay and the sub to basin of the La Plata River itself (**Figure 2.1.1.1**). The total annual precipitation is highly variable in the Basin, increasing from west to east, with the greatest precipitation in the sub to basin of the Uruguay and upper Paraná, with nuclei that exceed 2500 mm; while the driest zone is the Gran Chaco Americano, with nuclei less than 600 mm.

During the southern spring and summer, the rains of southeastern South America are controlled by both the South Atlantic Convergence Zone (SACZ)—a band of intense convective activity that extends from the south of the Amazon to the southeast of Brazil and the Atlantic Ocean—and the South American Low to Level Jet (SALLJ).

The origin of this jet is associated with the Alisios winds that blow from the Tropical Atlantic Ocean, charged with moisture, that invade the Amazon depositing moisture, which is returned to the atmosphere through evapotranspiration and from there transported towards the south by the SALLJ. This is located in the lowest layers of the atmosphere and extends to an altitude of 3 km, travelling with a velocity that can reach 50 km/hr. With air charged

Figure 2.1.1.1

Climatological precipitation in La Plata Basin (1973 to 2013)



with moisture, upon entering the La Plata Basin, it interacts with other air masses or cold fronts that come from the south of the continent, producing frontogenesis or Mesoscale Convective Systems (MCS) that produce important rainfall for the region (**Figure 2.1.1.2**).

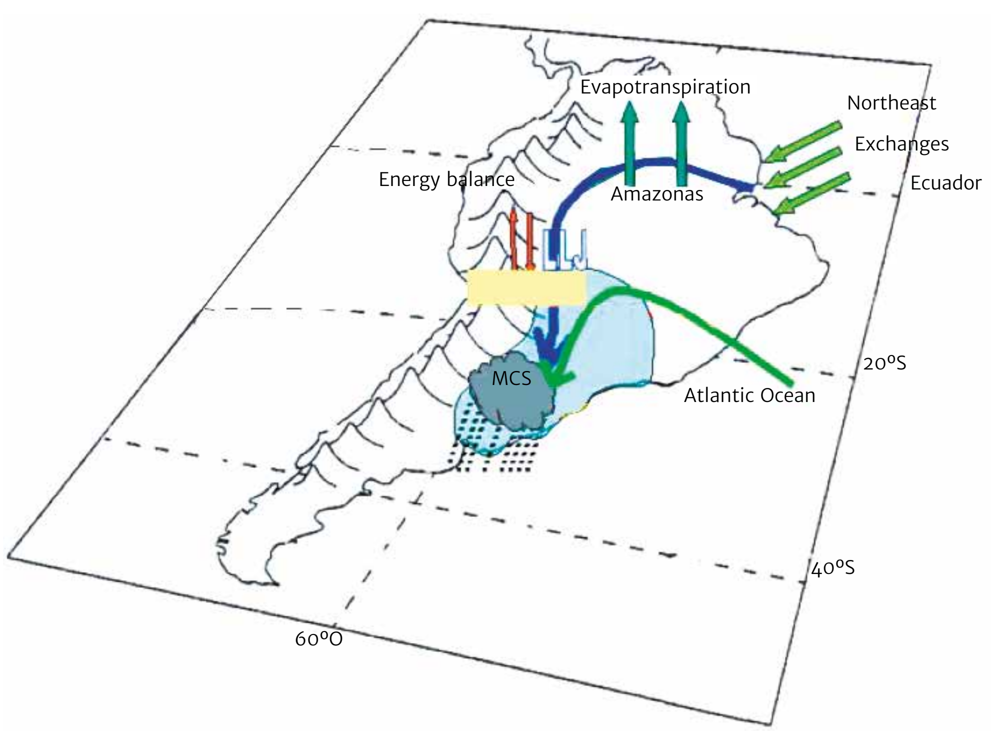
The systematic increase in precipitation and overflow from the middle of the 70s is consistent with the intensity and frequency of SALLJ events, which is apparently corroborated by the observations that indicate more frequent extreme rain events in the La Plata Basin, which have increased in the last 30 years.

El Niño and La Niña events, associated with variations in the surface temperature of the Equatorial Pacific Ocean, has a significant effect on the climate of a large part of the La Plata Basin, especially on the inter to annual weather scale, affecting rainfall variability. Intense precipitation and overflows have been observed during the El Niño years, such as from 1982 to 1983 and from 1997 to 1998. Intense precipitation during neutral El Niño years has also been observed, associated with other forces like blockage situations, intensification of synoptic systems or mesoscale systems. In La Niña years, tendencies of rainfall deficit and drought have been observed.

The relationship between precipitation and El Niño and La Niña events is a predictor of the rain systems for the forthcoming months, given that its evolution can be predicted months in advance.

Figure 2.1.1.2

Conceptual model of lower-level jet east of the Andes



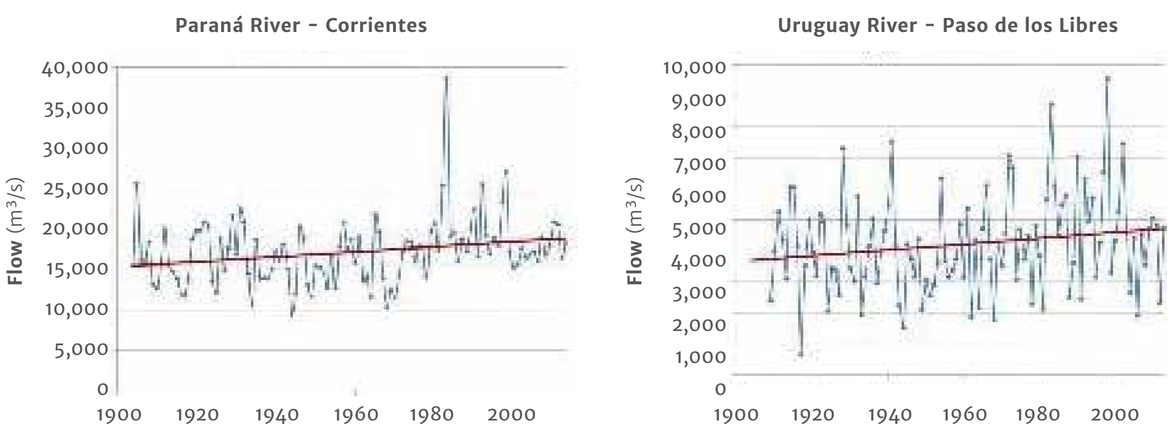
Some of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and FP, 2016c) have demonstrated significant changes and tendencies in precipitation and in water levels in the La Plata Basin. Section 1.4.1.2 *Surface water/ Water level projections for specific climatic scenarios* of this document describes the water level tendencies of the principal rivers of the Basin. In **Figure 2.1.1.2**, positive tendencies can be observed in the average annual water level for the Uruguay and Paraná Rivers since the 1950s. Deforestation and changes in soil use as a result of human activity in the Basin have rapidly increased over the last 60 years and there is evidence that these anthropic actions modify the thermodynamic characteristics of the lower atmosphere. These changes are the result of complex interactions between the atmosphere, hydrology, vegetation, and the management of water and soil resources.

Among the changes detected are the increments of precipitation and river water levels, in addition to modifications in surface level atmospheric circulation and in the extreme temperatures that can be associated with climate change. Existing evidence suggests that changes in soil use could have contributed to increasing the average water level of the Paraná River since 1970. If, on the one hand, the La Plata Basin has experienced precipitation events each time with greater frequency and intensity, on the other, in the central and northern parts of the Basin, it has experienced delays at the start of the southern spring or longer dry seasons. This evidence reveals that throughout the second half of the twentieth century, the dry months have increased to around one to two months, as is reflected by the Hovmüller diagram of the area in the northern part of the basin (**Figure 2.1.1.4**).

Between fall and spring, extra to tropical storms are frequent in the Basin and responsible for much of the precipitation. In particular, during the winter season, they are the cause of the rains in the eastern part of the Basin, in the sub to basins of the Uruguay and the lower Paraná, and in the sub to basin of the La Plata River itself, and the cause of reduced precipitation in the Paraguay River sub to basin.

Figure 2.1.1.3

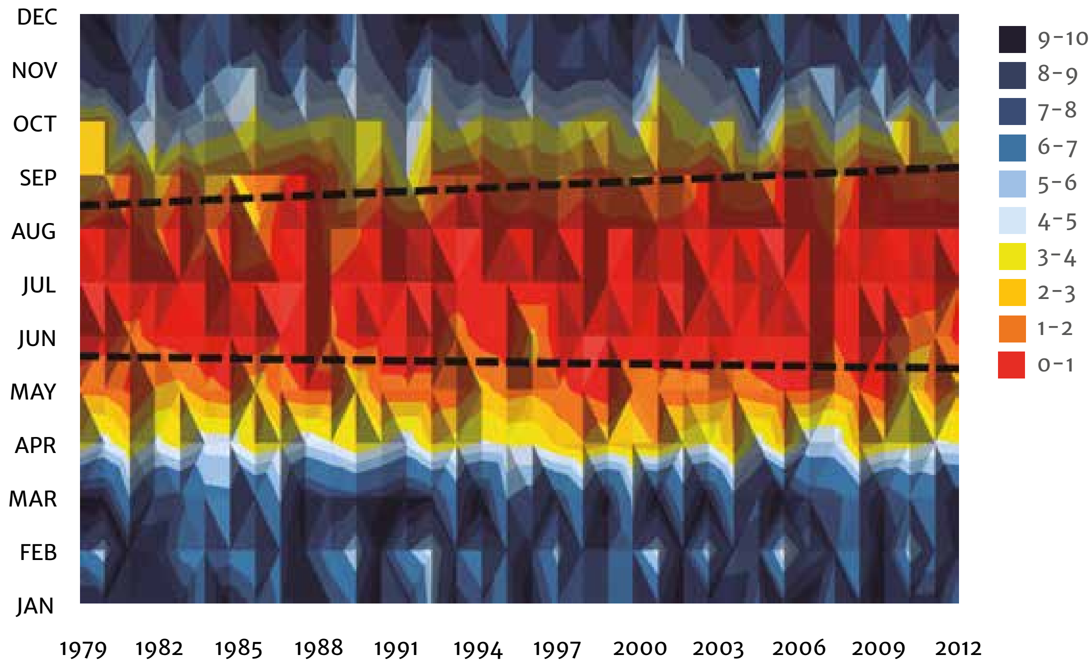
Annual average water levels for the Uruguay and Paraná rivers



Paraná River in Corrientes (1904-2013) and Uruguay River in Paso de los Libres (1909-2013).

Figure 2.1.1.4

Hovmüller diagram for an area in the northern part of the Basin



These mid to latitude meteorological systems transport air masses with cool temperatures and little moisture, producing a significant drop in temperature around the Basin, causing freezes in the central and southern parts between the months of June and July. These climatic winter characteristics can be observed in the annual air temperature cycle. In **Figure 2.1.1.5**, the characteristics of a simple wave with significant annual thermal amplitude can be observed, with the sub to basins of the upper Paraguay and upper Paraná demonstrating higher temperatures than the sub to basin of the La Plata River.

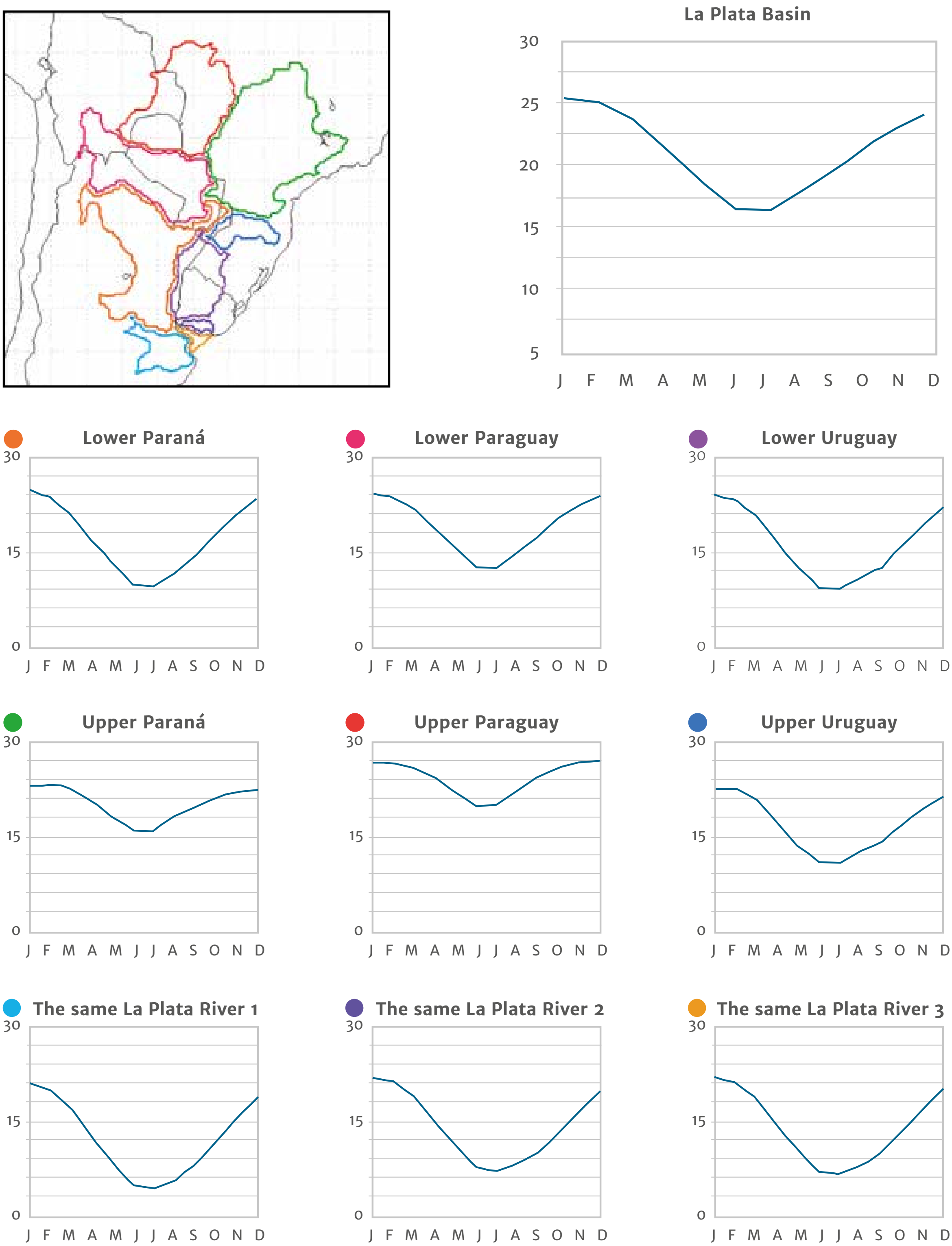
2.1.2 Climate Change

The WMO has confirmed that 2015 was the hottest year since the middle of the nineteenth century, when temperature measurements first became available. Effectively, in 2015, the average global temperature broke all previous records by a surprisingly high margin, 0.76 ± 0.1°C above the average for the period of 1961 to 1990. For the first time, temperatures were reached that surpassed the temperatures of the preindustrial era by approximately 1°C, according to an analysis by the WMO.

According to NOAA scientists, the average global land to surface and ocean to surface temperatures in 2015 were the highest since 1880, when temperature measurements were first registered. The deviation of the global land to surface and ocean to surface temperatures in December 2015 was the highest in the 136 years of the registry. The global temperature in 2015 was strongly influenced by the conditions of a strong El Niño that developed that year and con-

Figure 2.1.1.5

Average climatological temperature of La Plata Basin and its sub-basins (1961-1990)



tinued in 2016. Thus, it is highly probable that 2016 will be the hottest year in history, surpassing even 2015. According to the NOAA, the average temperature for 2015 was 0.90°C higher than the 1880 to 2015 average, greatly exceeding the previous record from 2014.

In the La Plata Basin in 2015 an average temperature greater than the 1961 to 1990 average temperature was observed, between 0.5°C and 1.5°C higher, exceeding the WMO's estimated global average. This anomaly observed in 2015 is not the result of an isolated act, seeing as though the meteorological observations for the La Plata Basin over the last decades demonstrate a constant increase in air temperature in many localities in the region.

The IPCC, in its last report, mentions that the average atmospheric temperature increased by more than 0.85°C throughout the twentieth century and the first years of the twenty to first century. The IPCC's global models reveal that between 1900 and 2100 the global temperature could increase by between 1.8°C and 5.3°C, which indicates a much faster increase in warming, as compared to average temperatures during the twentieth century, a phenomenon without precedent over the last 10,000 years.

The tools commonly utilized to evaluate the current climate and realize climatic projections are the General Circulation Model (GCM) and the Atmosphere to Ocean General Circulation Model (AOGCM). However, the atmospheric horizontal resolution used for those models is not sufficient to describe the climate in regions dominated by phenomena that occur to a lesser extent. For this reason, regionalized technology is useful for improving global information models. Downscaling utilizing Regional Climatic Models (RCM) has the power to be a very useful tool for generating climate change scenarios in high resolution to use in climatic impact and climate change adaptation studies. Dynamic downsizing refers to a RCM model nesting in an AOGCM model. This last one provides the initial and meteorological contour conditions and the RCM generates high resolution simulations.

Nevertheless, sources of uncertainty exist in climate modeling, for example:

1. Uncertainty regarding future greenhouse gas (GHG) emissions and aerosols on solar and volcanic activity that impacts the radiative forcing of the climate system.

2. Uncertainty regarding the direct effects of increased concentrations of GHG emissions on plants, and on the future climate.

3. Uncertainty due to incomplete knowledge of climate functions, which is reflected in the approximations used in the climate models to represent physical processes.

4. Natural climate variability.

Therefore, the response to a model rarely considers the ample range of uncertainty in climate predictions. An inadequate selection of scenarios can compromise how the results of the impact studies are interpreted.

The extreme event projections of the climatic models also have an ample component of uncertainty. Even so, knowledge of observed climate variability, in the most extensive time scales possible, serves as a base from which to analyze the future climate, in order to distinguish between observed natural variability of those consequences and anthropic action.

2.1.2.1 Projections with Climate Change Models

Escenarios de Cambio Climático

The CPTEC has carried out simulations with ETA regional climate change models, with 10 km and 20 km resolutions, for the RCP 4.5 scenario (Representative Concentration Pathways 4.5) (moderated), for the period 1960 to 2100, with the objective of evaluating possible climate change situations (PM, 2016b).

The CPTEC carried out two simulations, the first of the ETA to 20km and the second with 10 km resolution, integrated with the initial conditions and the ETA to 20 km model contour, which utilized the boundary conditions of the global model HadGEM2 to ES.

New RCP scenarios have been used for CO_2 emissions, which are defined by the stabilization levels of radiative forcing (RF) values of greenhouse gases achieved during the twenty to first century. In **Figure 2.1.2.1.1**, four RCP scenarios can be observed.

The methodology utilized consists of the integration of the ETA model for the periods 1960 to 1990, 2006 to 2040, 2040 to 2070, and 2070 to 2099. The periods analyzed were 1961 to 1990, considered "present climate" and 2011 to 2040, 2041 to 2070, and 2071 to 2099, considered "future climates." The temporal scale utilized was seasonal (DEF, MAM, JJA, and SON). The verification of the climatological characteristics of the model for present climate (1961 to 1990) was conducted based on CRU data (Climatic Research Unit), meanwhile the future climate results of the simulation (2011 to 2099) were compared with the present climate results.

It should be pointed out that the studies realized (FP, 2016c) have taken into consideration the results of a single model—the regional ETA model—adapted for climate simulations by the CPTEC to INPE of Brazil. This has allowed for the generation of regional results from the scenarios established by the IPCC, and for the translation of those results into other indicators, such as risk, water levels, soil moisture, and soil erodibility. Nevertheless, this approach possesses limitations, given the uncertainty of the global climatic models. Thus, for the management of future scenarios, it is advisable to employ a combination of models in order to then consider the joint results. This more comprehensive alternative would lead to more representational conclusions, which would take into account current knowledge regarding GCM.

Summary of ETA Results in the La Plata Basin

Analysis of present climate: An important indicator is that the model of the present climate (1961 to 1990) climatologically reproduces the spatial and temporal distribution of the climatological variables and is in accordance with the results of the observations utilized.

The monthly precipitation for the period 1961 to 1990 for distinct areas of the LPB are the result of the CRU model and data. Seasonal precipitation in general was adequately reproduced, with a tendency to underestimate the summer precipitation in the SACZ area (upper Paraguay and upper Paraná), while in winter and spring the tendency is the overestimate the precipitation in the southeastern part of the Basin (upper Paraná and upper Uruguay).

With respect to the temperature of the present climate, a steady reoccurrence can be observed, even though it underestimates the temperature in the summer and fall in the southeast (upper Uruguay) and in the winter in the central to western part of the Basin (lower Paraguay and lower Paraná), while the temperature in the SACZ zone is overestimated a bit (upper Paraguay and upper Paraná).

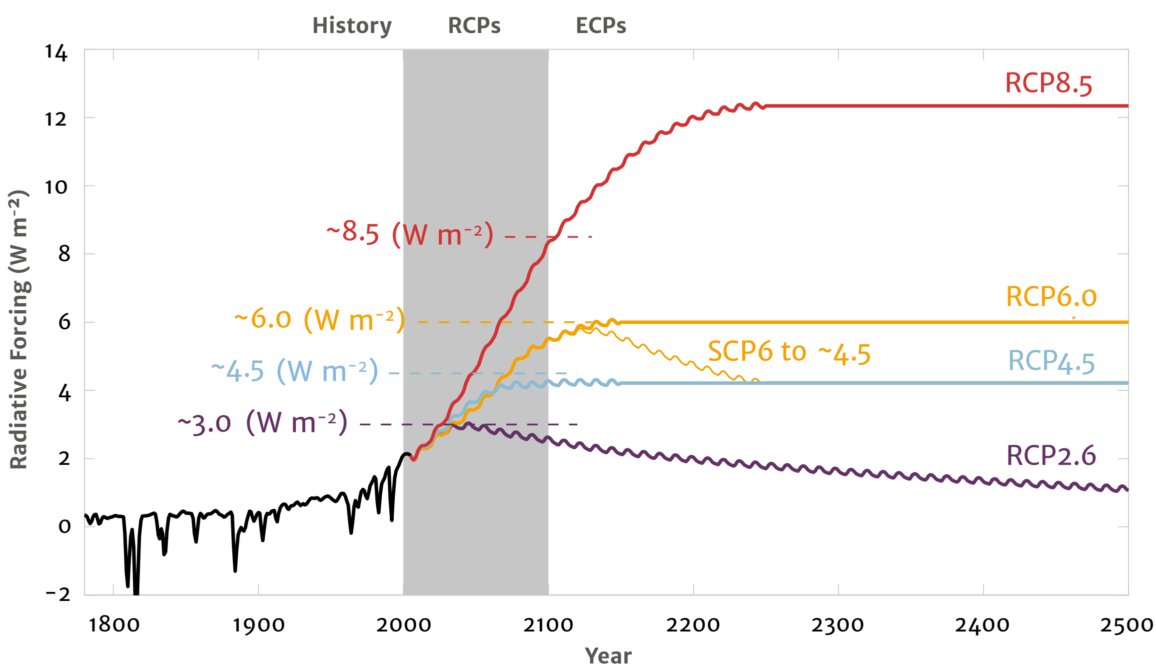
Consequently, the ETA model offers a present climate that reproduces seasonal fields of precipitation and air temperature than can be considered acceptable compared to observed data for the same period.

Analysis of future climates: With respect to future climates, the average result of the seasonal fields of precipitation and air temperature are presented for the periods 2011 to 2040, 2041 to 2070, and 2071 to 2100, which are compared with the present climate. In **Table 2.1.2.1.2** the results of the regional ETA to 10 km model are synthesized for future climatic periods, in relation to the 1961 to 1990 climate.

Precipitation analysis: The precipitation according to Regional Model ETA to 10 km presents future differences or anomalies in seasonal precipitation for the periods 2011 to 2040, 2041 to 2070, and 2071 to 2099 in relation to the climate period of reference, 1961 to 1990 (here the difference is called an anomaly).

Figure 2.1.2.1.1

RCP Scenarios (Representative Concentration Pathways)



Total (natural anthropogenic) RF for RCPs and Extended Concentration Pathways (ECP) for RCP2.6, RCP4.5, RCP6 and RCP8.5, as well as a complementary extension of RCP6 to RCP4.5 with an emission adjustment after 2100 to reach the concentration level of RCP4.5 in 2250.

Source: Adapted from IPCC (2013) (page 89).

Table 2.1.2.1.1

Results of the ETA regional climate model 10 km

Macro Basins	Precipitation			Temperature		
	Periods			Periods		
	2011-2040	2041-2070	2071-2100	2011-2040	2041-2070	2071-2100
Upper Paraguay	Decreases all year	Decreases DEF	Decreases DEF	Increases all year >2°C DEF>3,5°C	Increases all year >3°C	Increases all year >3°C DEF>4°C
Lower Paraguay	Decreases SON-DEF	Increases MAM	Increases MAM-SON	Increases all year >2°C	Increases all year >2,5°C	Increases all year >2,5°C
Upper Paraná	Decreases todo el año	Decreases DEF	Increases MAM-JJA-SON	Increases all year >2°C	Increases all year >2,5°C	Increases all year >2,5°C
Lower Paraná	Increases MAM-DEF	Increases MAM-DEF	Increases MAM-DEF	Increases all year >2°C	Increases all year >2°C	Increases all year >2,5°C
Upper Uruguay	Increases MAM-SON	Increases MAM-JJA-SON	Increases todo el año	Increases all year >2°C	Increases all year >2,5°C	Increases all year >2,5°C
Lower Uruguay	Increases DEF	Increases JJA-DEF	Increases MAM-DEF	Increases all year >1°C	Increases all year >2°C	Increases all year >2,5°C
La Plata River	Increases DEF	Increases DEF	Increases MAM-DEF	Increases all year >1°C	Increases all year >2°C	Increases all year >2,5°C

For future climatic periods in relation to the climate of 1961-1990.

Note: It is important to highlight the presented results that are the product of a single climate model and a single scenario; the regional climate model ETA 10km for the scenario RCP 4.5 (moderate). Consequently, these scenarios of climate change should be considered with the limitations that this situation imposes.

From 2011 to 2040 it is possible to observe a negative anomaly tendency with respect to precipitation in a large part of the La Plata Basin, principally in the summer (DEF) and, to a lesser extent, in the fall (MAM) and in the spring (SON). This negative anomaly extends throughout the area known as the SACZ region, from the Atlantic coast of the southeastern region to the central western region. It is necessary to underscore the strong negative anomalies in summer in the upper Paraná sub-basin. The decrease in precipitation is also observed during the winter season (JJA) in the southeastern part of Brazil, although with lesser magnitude. Meanwhile, an increase in precipitation is observed in the upper Uruguay sub-basin during the spring (SON) and fall (MAM) and in areas towards the La Plata River.

From 2041 to 2070 the negative precipitation anomaly tendency weakens in the SACZ region, continuing lightly during the spring (SON) and winter (DEF). This period highlights a change in the precipitation anomaly in the southeast of South America. Positive anomalies are observed in a large part of the upper Paraná and Uruguay sub-basins from fall to spring, and in the lower Paraná in the summer.

From 2071 to 2100 the negative summer anomalies in the SACZ region, the upper Paraguay, and upper Paraná are more pronounced, meanwhile a significant positive tendency is observed around the upper Paraná and the Uruguay River throughout the year, and in lower Paraná and the La Plata River in summer and fall.

Temperature analysis: According to the model utilized, the future climate temperature for the periods analyzed 2011 to 2040, 2041 to 2070, and 2071 to 2100 demonstrates a persistent warming tendency during the 1961 to 1990 period in all of the LPB.

During 2011 to 2040 the greatest anomalies can be observed in the upper Paraguay (Pantanal) sub-basin, especially in summer, when the anomalies reach up to 3.5°C. In the same region, extremes are also observed in fall and spring, with winter being the season that presents the most subtle anomalies, although with significant values of 2°C or more.

During 2041 to 2070 global warming will continue to rise, demonstrating anomalies of between 2.5°C to 4.0°C in spring and summer, with more subtle increases in fall and winter, from 2.5°C to 3.0°C for all of the Basin, with the warmest zones continuing to be the Pantanal region in the upper Paraguay.

During the period from 2071 to 2100, the warming will persist, and positive anomalies from 2.5°C to 4.0°C will be observed between summer and fall. A similar system will be produced in the winter and spring, with an overall temperature increase throughout the Basin, with the northern zone experiencing the greatest increase in temperature.

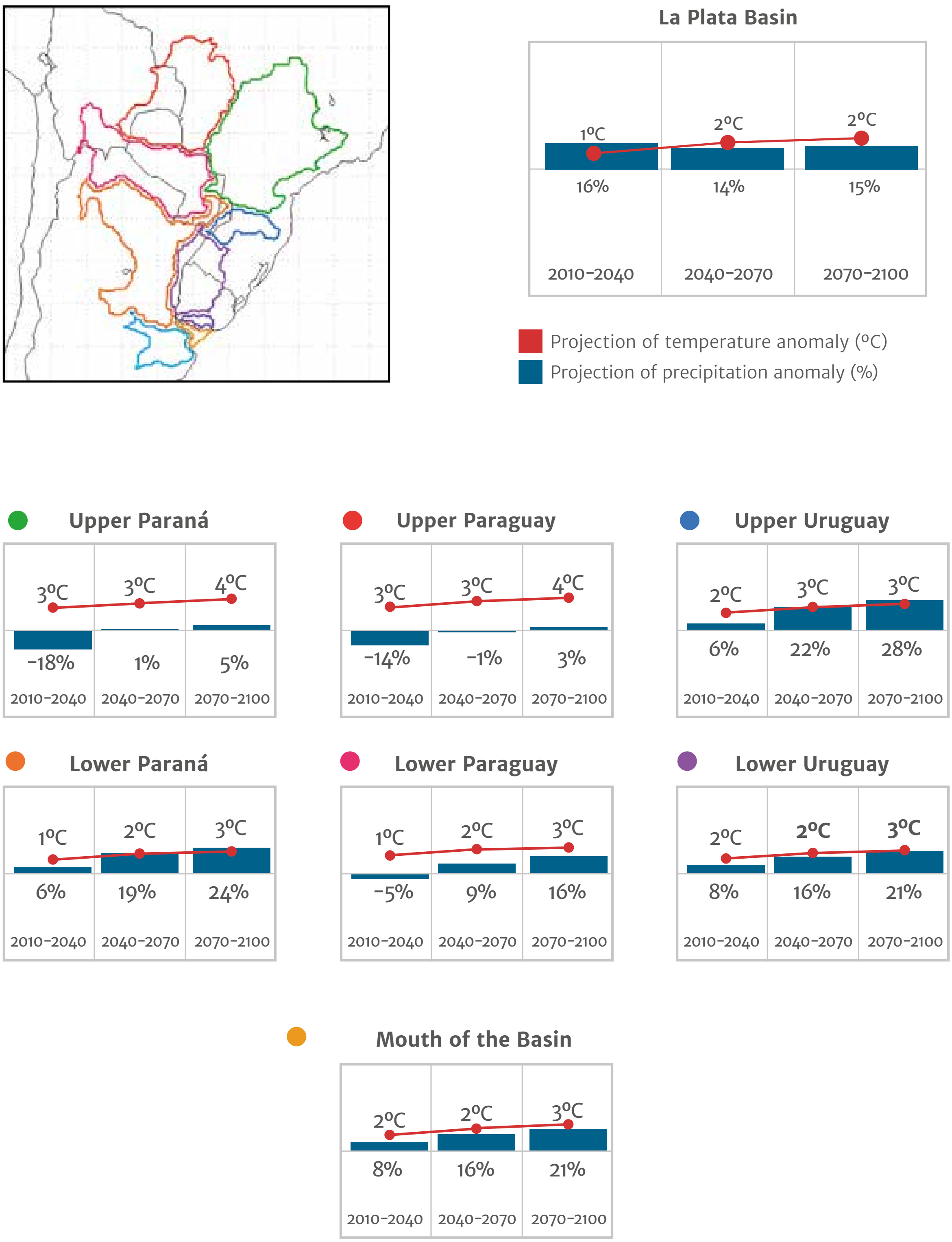
Summary

In annual terms, precipitation and temperature behaviors for all of the Basin, as well as for each sub-basin can be synthesized, as in **Figure 2.1.2.1.2**. The blue bars show the precipitation variation in percentages, meanwhile the red line shows the anomaly of average annual temperatures, which in almost all cases indicates future warming. It is important to emphasize that this integration summary was carried out for each one of the basins (without differentiating between upper, middle, or lower) and in yearly periods.

Understanding the limitations implied by deriving conclusions about future climate by observing a single model and single

Figure 2.1.2.1.2

Projections of the average annual precipitation anomaly (%) and the mean annual temperature anomaly (°C)



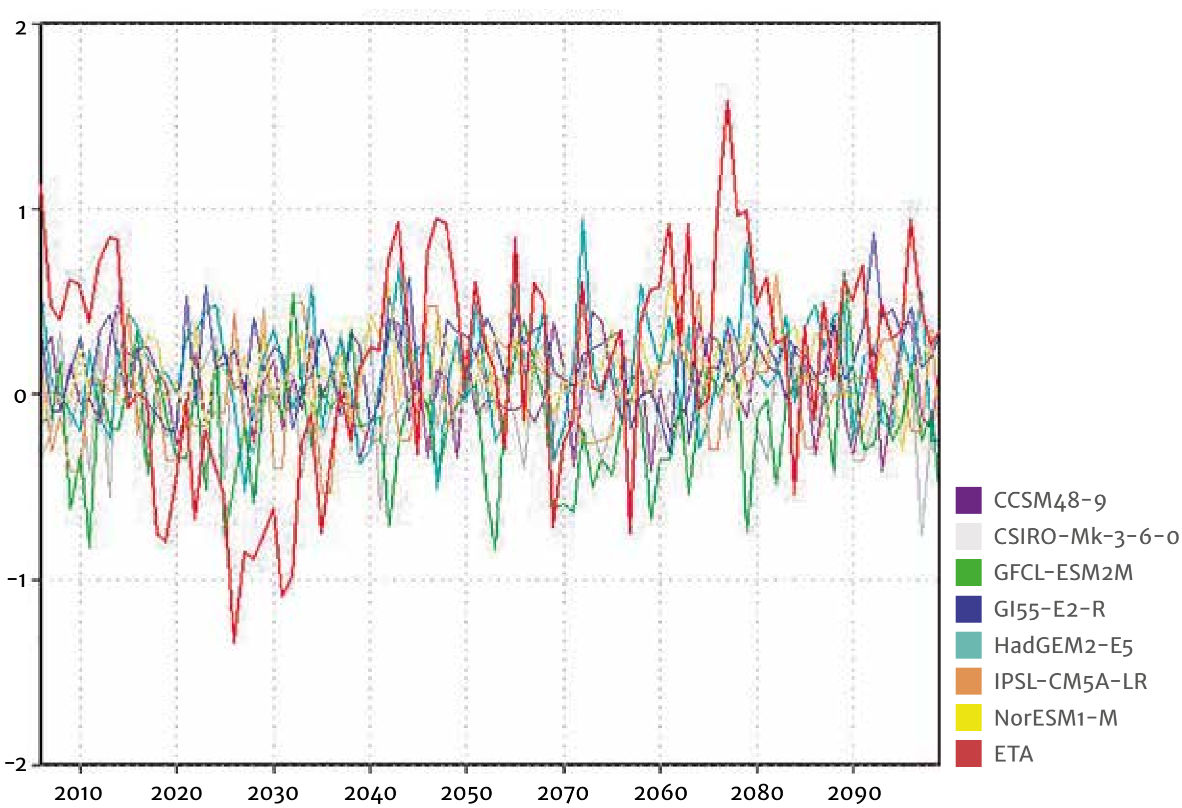
scenario, it was believed best to emphasize the temporal evolution of various other climate models, with the simple objective of comparing them with the projections of the regional ETA model. In particular, the results of seven CMIP-5 (Couple Model Intercomparison Project Phase 5) models were compared: CCSM4, CSIRO-Mk-3-6-0, GFDL-ESM2M, GISS-E2-R, HadGEM2-ES, IPSL-CM5A-LR, NorESM1-M, and the regional ETA model. The historic period (1961 to 1990) was used to calculate the anomaly. In all of the cases, the models correspond to the entire LPB.

Figure 2.1.2.1.3 synthesizes the precipitation anomaly tendency that is integrated and represented for the entire area of the Basin of all the aforementioned models and the ETA, where it can be observed that the regional ETA model shows a much more pronounced negative precipitation tendency than the other models for the period that spans the end of the present decade to the year 2040. After 2040, ETA also mirrors the other models in terms of demonstrating an increase in precipitation towards the end of the century, although it presents greater variability.

With respect to the evolution of air temperature, integrated for all of the basin, the ETA model presents a positive elevated temperature anomaly tendency in relation to the other models throughout the period of integration. Nevertheless, this

Figure 2.1.2.1.3

Evolution of precipitation anomaly (mm/d) for La Plata Basin according to several models



notable tendency is reflected by the other models (**Figure 2.1.2.1.4**).

Given these observations, and considering the limitations that the climate models present for predicting future climate change, compiling the results, we believe that the ETA/CPTEC/INPE model can be considered a guide by which to analyze future climate change scenarios.

Brief discussion of climate in the near future (2011 to 2040)

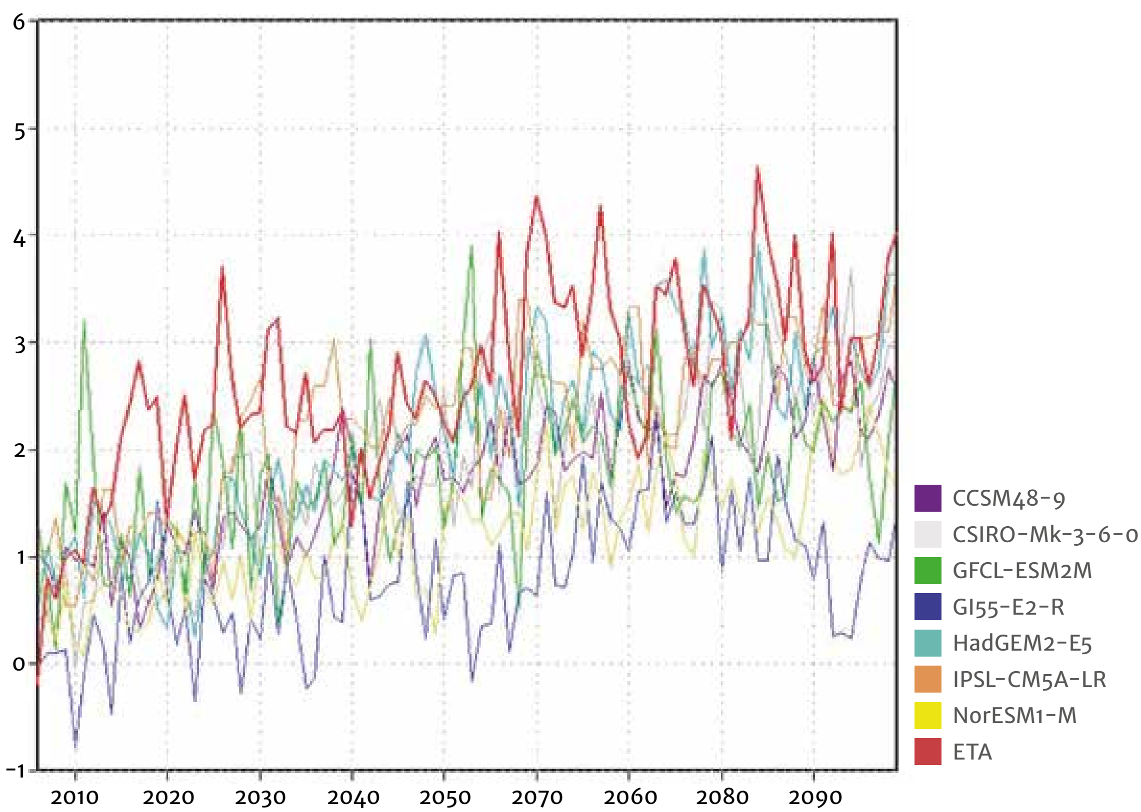
Climate change scenarios are considered useful tools for evaluating hydro-climatic impacts on diverse sectors and for the design of future climate change adaption strategies.

Considering immediate strategies in climate terms, the 2011 to 2041 period presents scenarios such as a decrease in precipitation throughout a large part of the Basin and a considerable increase in temperature. This scenario could affect water resources in the La Plata Basin.

In a scenario with less precipitation and higher temperatures, the regional hydraulic balance could lead to a drop in average water levels, facilitating the occurrence of extreme events, like increased incidence of drought and forest fires. This type of scenario could significantly affect navigation along rivers, like the Paraguay River, resulting in severe economic consequences, given that the regional economy is largely dependent on river transportation.

Figure 2.1.2.1.4

Evolution of the temperature anomaly (ºC) for La Plata Basin according to several models



National SAP Meeting in Argentina in March 2016.

A scenario in which soil moisture is decreasing or in permanent deficit could have strong economic consequences on agricultural and livestock production and, consequently lead to socio- economic losses.

The reduction of surface and groundwater resources would compromise the supply of potable water for human consumption, creating, on the one hand, social conflicts due to water and, on the other hand, health problems due to waterborne diseases.

The reduction in average water levels could also affect the water quality of transboundary rivers. The advance of agricultural boundaries could increase the concentration of contaminants in water resources, as well as the transport and deposit of sediments.

2.1.3 Climatic Extremes

The special report on climatic extremes was elaborated by a special commission of the IPCC in response to a recognized need to provide specific counsel on climate change, extreme meteorological conditions, and extreme climatic events. The main conclusions of the report are:

1. Even without considering climate change, disaster risk will continue to increase in many countries, with greater numbers of people and goods vulnerable to climatic extremes.

2. In the next two or three decades, the expected increase in the frequency of climatic extremes will likely be relatively small compared with normal yearly variations.

3. Nevertheless, in circumstances where the impacts of climate change are more dramatic, their effects within a band of climatic extremes will become more important and will play a more significant role with regard to disaster impact.

4. Any delay in mitigating greenhouse gas emissions will likely bring about more severe and frequent climatic extremes in

the future, and will likely contribute to greater losses due to disasters.

Some of the results of the climatic extremes from the ETA-CPTEC regional model will now be presented. With respect to total yearly precipitation, increases are projected throughout the century. Even if the total annual precipitation for the period 2011 to 2040 is less than what is currently being observed in the north of the Basin, it will later increase. In contrast, precipitation is projected to increase in the central and southern parts of the Basin. The number of days that it will rain will increase throughout the century, allowing for greater activity of precipitation systems (**Figure 2.1.3.1**).

Other ETA results indicate that consecutive dry days will decrease during the twenty-first century, while consecutive wet days will increase during the same period, keeping consistent with the annual precipitation trend. An intensification of dry days in the western part of the Basin is worth paying attention to, as it indicates a more prolonged dry season. In any case, rains during the wet season tend to be potentially more frequent and intense.

Extreme events are also projected to manifest themselves in intense rains, given that the number of days with strong rains will be increasing during the present century, especially in the southeastern part of the Basin.

With respect to temperature, hot days are predicted to increase, especially in the central and northern parts of the Basin, and the cold days are predicted to decrease. This does not imply that sporadic events cannot occur.

It is important to clarify that the results obtained regarding changes in extreme phenomena should be taken with the greatest precaution, given that these results have not been validated through observation.

Consequences of Climatic Extremes

The scientific foundation demonstrates how incremental impacts related to climate, more than extreme events, can have severe consequences in areas where high vulnerability exists.

Flooding—caused by climate change, environmental degradation, or social factors—can lead to a geographic change. Heat stress can cause deaths even in tropical countries where people are accustomed to hot climates.

Sea level rise can exacerbate flooding, erosion, and other coastal risks, threatening infrastructure and populations, compromising socio-economic wellbeing.

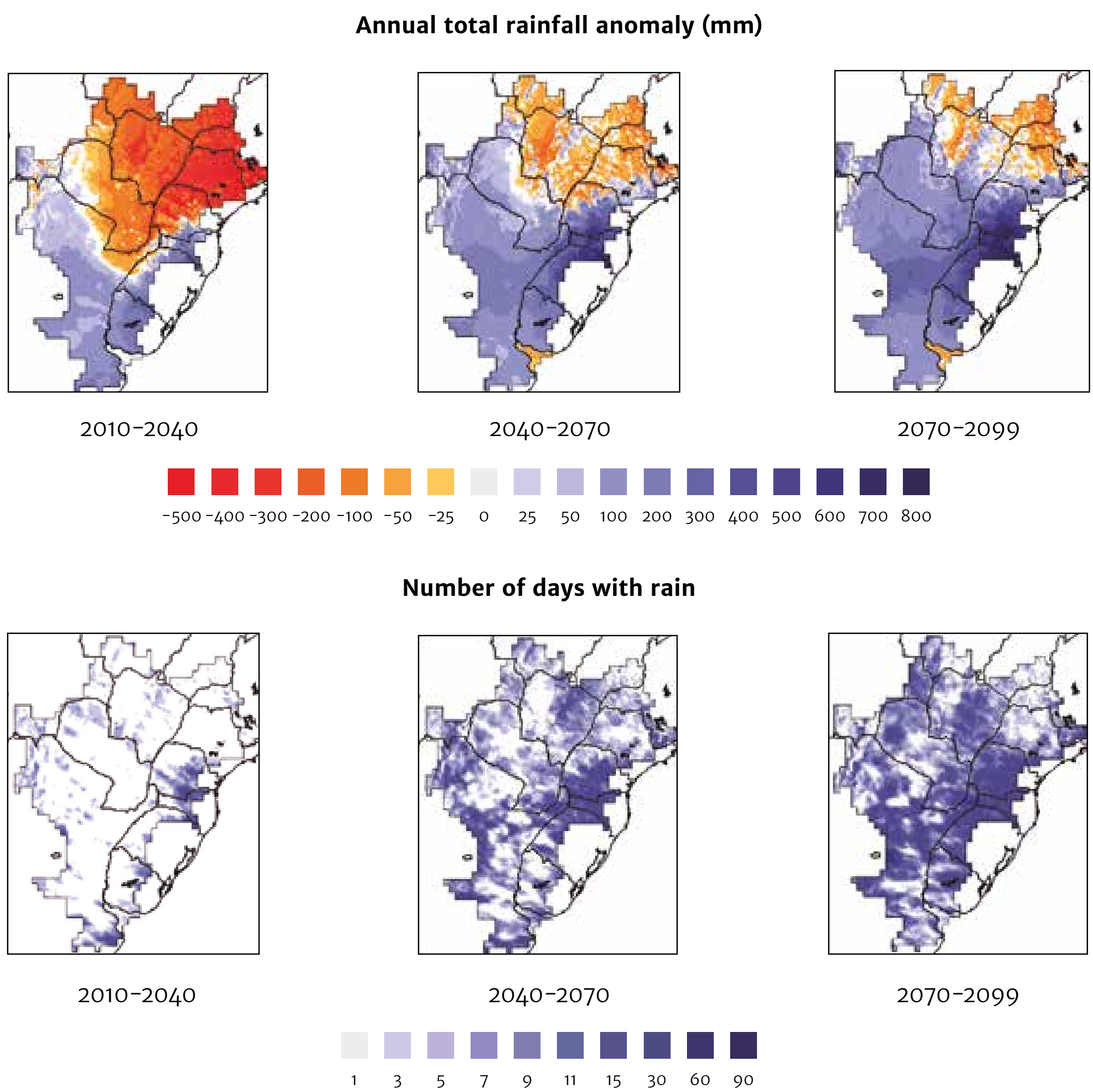
Climatic extremes can impact both human systems and ecosystems in a variety of ways, including economic losses, effects on agriculture, tourism, and urban populations. The gravity of these impacts will depend largely on the level of exposure and vulnerability to climatic extremes. Extreme events have the greatest impact on those sectors that are closely linked to climate, like access to potable water, food security, and public health, among others. There exists large consensus that climate change could affect the management of water resources.

Anticipation of and adaptation to extreme events can help reduce the effects of future disasters. Adaptive capacity includes, long-term, sustainable management mechanisms, for example, improved techniques for capturing rainwater, crop rotation, and construction of homes in more elevated areas.

Transformation may imply the need for behavioral changes, creating a sense of instability and uncertainty. However, transformations are taking place at an unprecedented speed and scale, influenced by globalization, social and technological development, and climate change, and they require that we adapt to these new conditions. Climate change itself implies a large-scale system change, which will have a substantial impact on ecology and society, as well as on climatic extremes. Responses to climate change and changes in disaster risk can be both incremental and transformative. Transformation requires leadership from either political authorities and/or individuals or groups that connect current actions with the construction of a sustainable, resilient, and adaptive future.

Figure 2.1.3.1

Total annual precipitation anomaly



ETA—CPTEC Model.

2.1.4 Conclusions and Recommendations

1. The quantity and quality of available information on water resources in the basin is very important, and reliant upon a critical hydro-meteorological monitoring network. Nevertheless, it could be improved in some sub-basins (see *Chapter 1.5.1.3*) that present insufficient observations, especially with respect to pluviometric and hydrometric observations, which will make a better understanding of water resources possible.

2. The establishment of an Integrated Hydro-meteorological Prediction and Alert System in the La Plata Basin will be most successful if it improves and integrates monitoring networks, especially the surface hydro-meteorological stations and the meteorological radar. With respect to the latter, the possibility of expanding radar coverage in Paraguay and installing a meteorological radar in Uruguay would signify great advancement with respect to regional integration.

3. Water quality measurements constitute a particular case, considering that some areas of the Basin should be improved, especially in the lower Paraguay sub-basin.

4. The rapid advancement of meteorological radar installation and operation in the Basin should be recognized, as well as existing improvement plans with respect to density, especially in Argentina, Brazil, and Paraguay, which allow for opportunities for integration within the Basin system.

5. Advancements regarding the consolidation of CRC-SAS and the implementation of WIGOS-SAS-CP could be very beneficial to the projects that the GFCS will implement in South America, which could be transformed into useful tools for initiatives aimed at improving the Hydro-meteorological and Hydro-climatic Monitoring and Alert Systems of the La Plata Basin.

6. The vision of La Plata Basin should be one of consolidation and creation of a common space. The majority of the hydro-climatic products and services available have a domain that corresponds naturally to a particular country. A vision of the Basin as a unit could be established from the lens of sustainable management of hydraulic resources in the context of climate variability and change.

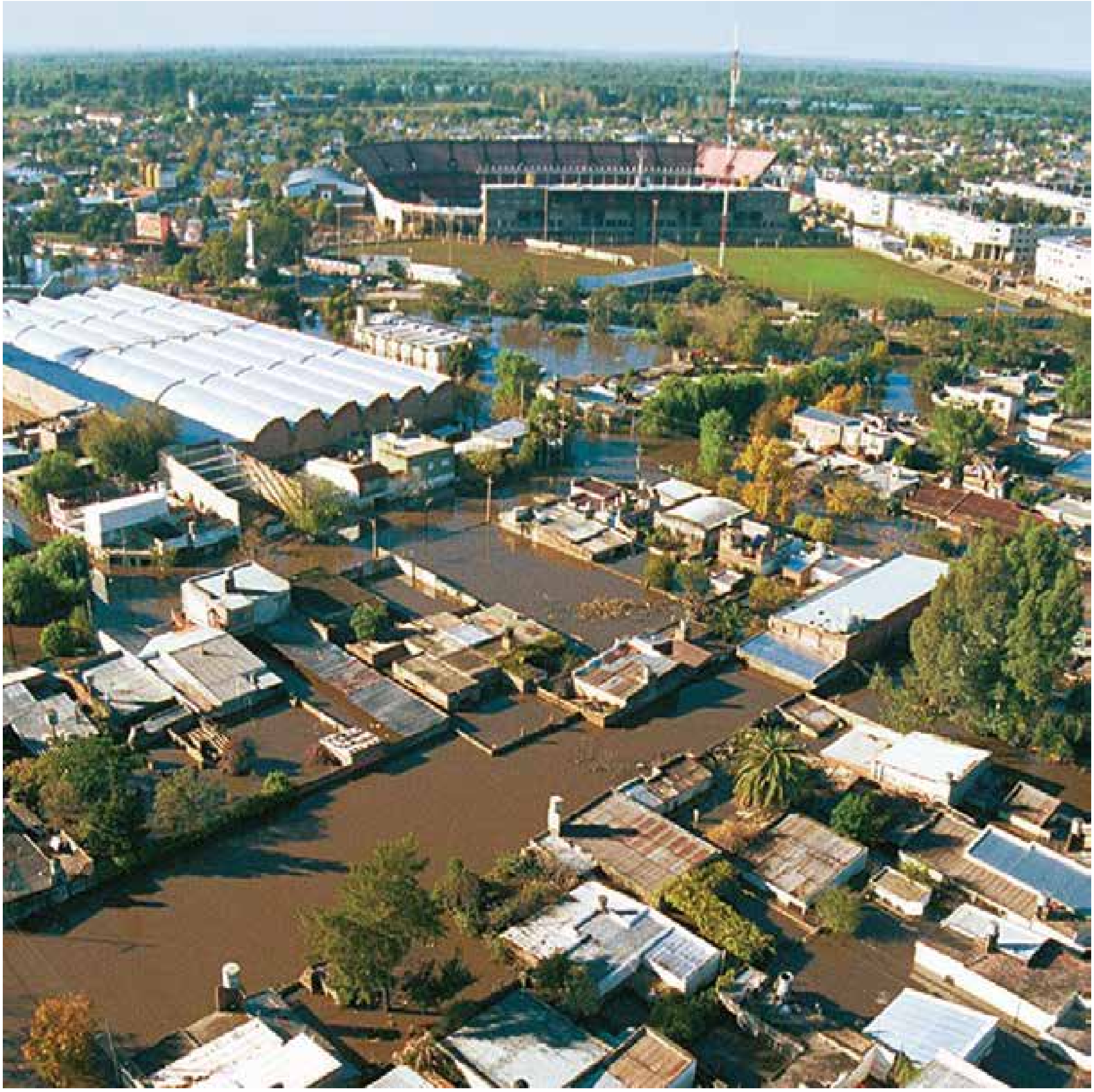
7. A great technical and operational capacity is observed on the part of various national institutions in the region, which could improve current knowledge and, if integrated, could improve knowledge regarding future hydro-climatic scenarios in the La Plata Basin, which could help to establish well-informed adaptation measures.

8. During last few years, the rainfall and extreme events has increased in the Basin. The climatic scenarios present an increase in precipitation towards the end of the century, as compared with the climatology of 1960 to 1990.Temperatures will also increase throughout the twenty-first century. These associated consequences increase the likelihood of damage, which can have particularly devastating effects on agriculture, livestock, water resources, and health, and to urban areas due to flooding and landslides.

9. Nevertheless, these scenarios present a high level of uncertainty. Studies on observed climate variability should be further developed with respect to longer time scales and standardization of methodology to allow for integrated studies and comparative analysis.

10. The results obtained with respect to changes in extreme phenomena should be interpreted with great precaution, given that they have not been validated with observations.

11. The integration of the resources available in the countries that comprise the Basin is an alternative path that can be followed to facilitate decision-making in real time, which will allow for improvements in response time to hydro-climatic alerts, with the objective of reducing human and economic losses caused by



Flooding in the city of Santa Fe, Argentina.

extreme hydro-meteorological events. The areas in which major integration efforts should be made to strengthen existing early warning systems are: monitoring, knowledge and identification of risks, communication and dissemination, and response capacity.

12. The CIC, as an intergovernmental organ, is dedicated to integrating environmental information. Its strategic action strengthens studies, fosters investigation and development, and incentivizes technological innovation in all of the countries that make up the La Plata Basin, through the integration and dissemination of data. As a direct result of this effort, regional knowledge can be strengthened, and, consequently, short-, medium-, and long-term projections can be improved.

2.2 Forecasting Socioeconomic Impacts

Characteristics of rains and flows:

- In the next 30 years, which are the most important considering the useful life of projects, precipitation and flows will decrease in the upper basins of the Paraná, Paraguay, and Uruguay rivers.
- Rains and flows in the lower basins of these rivers will increase

Effects on water systems:

Urban Development: The main impact is observed in the reduction of water security: (a) risk to water availability in cities that are at river headwaters and with large populations, such as São Paulo, Curitiba, and Brasilia; (b) increased risk in the headwaters of the Uruguay River, where quality and quantity limitations already exist; (c) risk of lack of water also due to lack of effluent treatment. In this scenario, the decrease in flow rates aggravates the untreated effluent dilution capacity. The most important impact areas are the upper basins of the Paraná, Paraguay, and Uruguay rivers.

Industrial development is connected with urban development; cities located in headwaters can be affected by the reduction in precipitation and will need to create resilience by reusing water. Conflicts among irrigators, the alcohol industry, and communities may increase in some areas, such as in the Midwest.

Rural Development: The countries of the region are important players within the global community of agricultural commodities. The largest water consumer in the Basin is agriculture, with 70 percent of all consumptive use. In the scenario of reduced precipitation and flow in the upper basins, grain production is affected, mainly in the midwestern part of Brazil, which is currently the region with the highest agricultural production. On the other hand, it improves water availability for agricultural production in the lower basins in Argentina and Uruguay.

Energy: The reduction in precipitation and flow in the upper basins directly affects hydroelectric production, considering that 60 percent of the country's hydroelectric generation is concentrated in southeastern Brazil and, in turn, that a large portion of the flows that feed hydroelectric uses in the international stretches originate in the upper basins. In this scenario, it is necessary to evaluate the sectoral impact of climate variability and change. This sector still is not taking into account the increase in flow due to greater runoff from deforestation into the Basin. A review of hydrological series removing the effect of previously forested areas is necessary to factor this in.

Navigation: The main navigation routes are the Paraná and Paraguay rivers. Navigation depends on flows in the upper basins to allow for navigation with the appropriate draft over time. In the 1960s, there were 13 years of very low flows which, if repeated in the future, would increase the cost of transporting goods through these rivers. It is estimated that the cost increase will be three times that of the 1960s. Considering the climate change scenarios presented in the study, the impact on navigation can represent a significant cost increase, mainly in the middle and upper sections of the Paraguay River.

Extreme events: The most critical conditions are the increase in droughts in the upper basins due to the decrease in precipitation, while in the low basins there is a forecast of increased precipitation. Recent cases of unprecedented intense precipitation have been observed which could lead to an increase in intense rainfall events, but there are no results on extreme events because they constitute scenarios that climate models are not able to predict.

Environment: The main environmental impacts based on climatic changes within a broad area are: (a) increased impacts on water quality in the headwaters due to reduced flow and decreased dilution of effluents; (b) impact on fauna due to the reduction of flows in the upper basins; (c) elevation of the water table in the Pampa due to increased rainfall, with impacts on the population and the environment.

2.3 Conferences of the Parties

2.3.1 United Nations Convention to Combat Desertification

Twelfth Conference of the Parties (COP 12)

COP 12 was held in Ankara, Turkey from October 12 to 23, 2015. While its results are non-binding, they are the fundamental cornerstone for achieving Land Degradation Neutrality (LDN). This concept—which is number 15.3 of the 2030 Sustainable Development Goals—aims to neutralize the degradation of eroded lands throughout the world in order to assure the nourishment of future generations.

The scope of the Convention reaches the five continents and, by consensus, the countries that attended the meeting agreed that the issue of LDN should be on the global agenda for governments. In addition, they agreed that LDN is a fundamental way of combating climate change and that its implementation should be monitored, for which financing provided by the Convention will be available under the umbrella of what has been called the "Ankara Initiative."

It was also decided that the results of COP 12 be brought to the 21st United Nations Climate Change Conference, held in Paris in December 2015, to be included in the agenda.

2.3.2 United Nations Framework Convention on Climate Change

21st Conference of the Parties (COP 21)

The objective of COP 21, held in Paris from November 30 to December 11, 2015, was to create a global agreement on methods to reduce climate change. The resulting Paris Agreement[3], adopted by almost all states, will become legally binding if at least 55 countries representing at least 55 percent of global greenhouse gas emissions, sign it, ratify it, accept it, approve it, or adhere to it.

The Agreement—which will go into effect in 2020—aims to "strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, and for this:

a. To maintain the increase in world average temperature well below 2°C of pre-industrial levels and to continue efforts to limit that temperature rise to 1.5°C above pre-industrial levels, recognizing that this would considerably reduce the risks and effects of climate change;

b. Increase adaptability to the adverse effects of climate change and promote climate resilience and low greenhouse gas emissions in a way that does not compromise food production; and

c. Position financial flows at a level compatible with a path leading to climate-resilient development and low greenhouse gas emissions."

With regard to adaptation, the Agreement establishes that Parties should strengthen their cooperation to enhance this work through the exchange of information, best practices, experiences, and lessons learned in science, planning, policy, and implementation of adaptation measures; the strengthening of institutional arrangements and the strengthening of scientific

3 Paris Agreement. http://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_spanish_.pdf

knowledge on climate, including research and systematic observation of climate and early warning systems in such a way that contributes information to climate services and supports decision-making.

Before the Conference, 146 national climate panels publicly presented the Intended Nationally Determined Contributions (INDC) on climate.

INCDs are commitments that countries submitted to reduce GHGs through mitigation and adaptation actions in accordance with their realities, in some cases to international support (**Figure 2.3.1**).

Among the adaptation actions foreseen by the countries of the Basin, mention may be made of the expansion of early warning systems and disaster response and recovery systems; conservation, restoration, and sustainable management of native forests; the diversification of the energy matrix to reduce the vulnerability and costs of the electricity system in the event of hydraulic generation deficits; the implementation of territorial planning measures to reduce the risk of flooding; the restoration and maintenance of coastal ecosystems that provide protection in the case of extreme events, and ecosystems that protect drinking water sources.

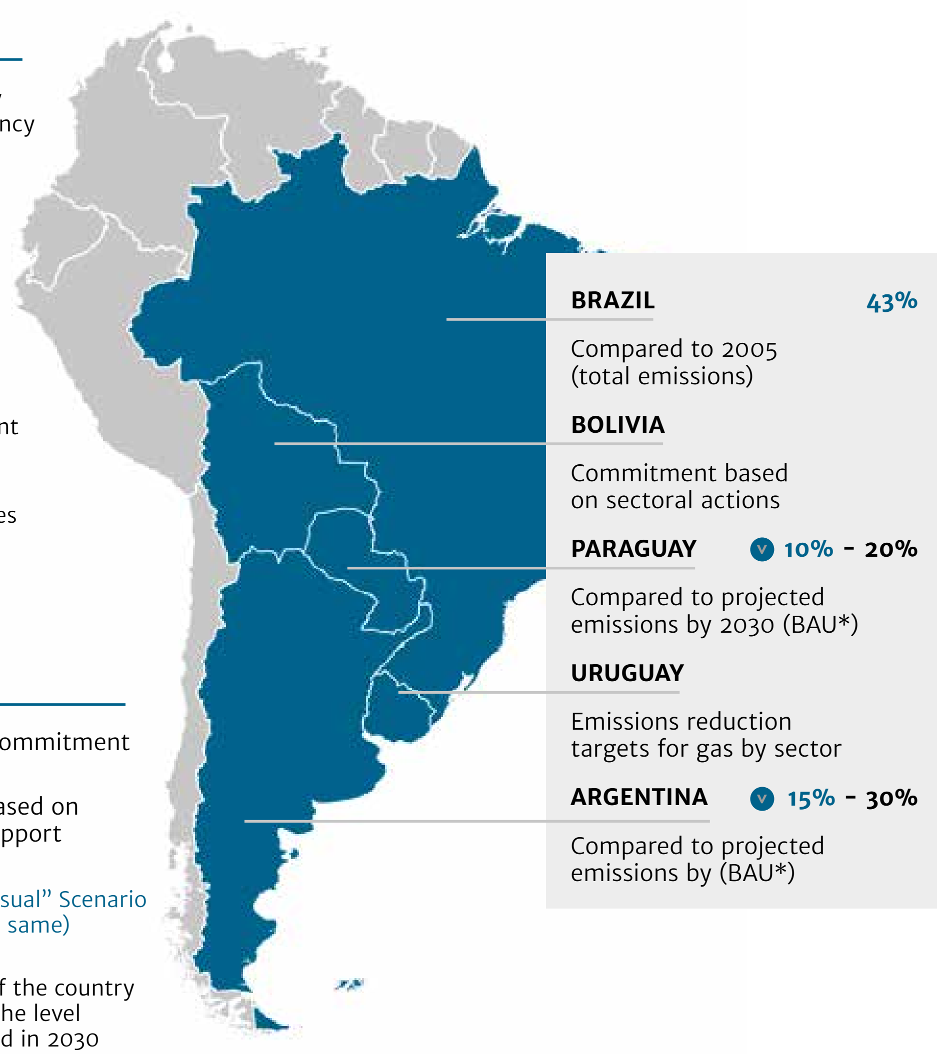
The Paris Climate Summit in December 2015.

Figure 2.3.1

National contributions from the countries of La Plata Basin

Main measures

- Renewable energy and energy efficiency
- Protection of forests
- Good farming practices
- Clean transport
- Waste management
- Improvement of industrial processes



Legend

- Unconditional commitment
- Commitment based on international support

*BAU: "Business as Usual" Scenario (everything stays the same)

The GHG reduction of the country will be compared to the level of emissions projected in 2030 under a growth scenario in which no mitigation actions will be implemented.

IIncludes National Contributions submitted up to October 23, 2015

Chapter 3:
Legal-Institutional Framework

3.1 State of Legal and Institutional Knowledge in the La Plata Basin

There is a legal framework for the five countries that make up the LPB that is sufficient for the management and protection of the natural resources, specifically water resources, which is made up of constitutional, legal, and regulatory provisions at the national, provincial, state, or municipal level. Nevertheless, in various cases it has been detected that implementation tools, as well as institutional capacity in order to put them into practice and monitor their compliance, are missing.

Each of the countries has particular conditions from the legal and institutional point of view, which make up the platform on which the coordination they see necessary may be carried out. Each country will revise and adjust the domestic legal framework based on their specific needs to achieve harmonization within the region.

Although certain principles and tools exist that comparative law analysis indicates are desirable in a legal and institutional framework for environment protection, this legislation does not need to be perfect, but rather *implementable*.

There is a gap between the legal framework and its practical application. In general, the countries have developed an important set of regulations and, in line with regional and international tendencies, have incorporated principles and tools according to the need for management and protection of natural resources, while taking climate change into consideration. Except for very specific cases, these normative advances have not been accompanied by an equally effective implementation of the management instruments that require the corresponding allocation of financial, human, and logistical resources.

At first, institutional excuses come up, such as: scarcity of human and financial resources, lack of training, centralized organizations removed from the local problems, but also—among other causes—the lack of regulation based on better scientific understanding, user unfamiliarity with the regulations, water use habits, and lack of awareness and participation are also important.

From the legal-institutional point of view, the purpose of the TDA is to provide a general overview of a process that, once legitimized through the participation of the countries, can “appropriate” the results.

In the *Presentation*, the CTIs that this TDA addresses are mentioned, which will be discussed in detail in *Chapter 4*.

In what is referred to as the Legal-Institutional Framework, in *Chapter 3.2* there will be an overview of global and regional agreements; national norms[4]; regional, national, and interjurisdictional institutions; and national plans applicable to all or various CTIs. *Chapter 3.3* will include those that are more specifically related to each CTI, and *Chapter 4* will present considerations on legal and institutional aspects about each topic in order to complement the diagnostic.

TDA Meeting in Foz do Iguazu, Brazil, in 2015.

4 Only national standards are considered. Both Argentina and Brazil—because they are countries organized federally—also have norms at the provincial or state level, respectively.

3.2 General Characteristics

3.2.1 Agreements at the Global Level

- Rasmar Convention on Wetlands of International Importance (1971), ratified by the five countries.
- Convention on Protection of World Cultural and Natural Heritage (1975), ratified by the five countries.
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989), ratified by the five countries.
- United Nations Framework Convention on Climate Change (1992), ratified by the five countries.
- Convention on the Biological Diversity (1992), ratified by the five countries.
- United Nations Convention to Combat Desertification (1994), ratified by the five countries.

3.2.2 Agreements at the Regional Level

- Convention on the Utilization of the Rapids of the Uruguay River in the Salto Grande Area (Argentina-Uruguay) (1946).
- La Plata Basin Treaty (signed by the five countries) (1969).
- Convention to Study the Use of the Paraná River's Resources (Argentina-Paraguay) (1971).
- Treaty of Itaipú for hydroelectric exploitation of the hydraulic resources of the Paraná River (Brazil-Paraguay) (1973).
- Treaty of Yacyretá (Argentina-Paraguay) (1973).
- Treaty between Uruguay and Argentina concerning the La Plata River and the Corresponding Maritime Boundary (Argentina-Uruguay) (1973).
- Statute of the Uruguay River (Argentina-Uruguay) (1975).
- Agreement for the regularization, channeling, dredging, beaconing, and maintenance of the Paraguay River (Argentina-Paraguay) (1979).
- Uruguay River and the Pepirí-Guazú River Treaty (Argentina-Brazil) (1980).
- Quaraí River Natural Recourses Use and Development Cooperation Agreement (Brazil-Uruguay) (1991).
- Agreement on River Transport Through the Paraguay-Paraná Waterway (signed by the five countries) (1992).
- Environmental Cooperation Agreement between Argentina and Bolivia (1994).
- Statute of the Binational Administrative Commission of the Lower Basin of the Pilcomayo River (Argentina-Paraguay) (1994).
- Tri-national Commission for the Development of the Pilcomayo River Basin Treaty (Argentina-Bolivia-Paraguay) (1995).
- Binational Commission for the Development of the upper Bermejo River and Grande de Tarija River Basins (Argentina-Bolivia) (1995).
- Agreement between Bolivia and Para-

guay regarding natural resources and environment (1995).

- Environmental Cooperation Agreement between Argentina and Brazil (1996).
- Mercosur Environmental Framework Agreement (Argentina-Brazil-Paraguay-Uruguay) (2001).
- Cooperative Agreement between Brazil and Paraguay for the Sustainable Development and Integrated Management of the Hydrographic Basin of the Apa River Agreement (2006).
- Sub-Regional Action Program for the Sustainable Development of the Great Chaco Americano (Argentina-Bolivia-Paraguay) (2007).

3.2.3 National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Law N° 25675 (2002). General Environmental Law	Law Nº 1333 (1992). Environment Law	Law N° 6938 (1981). National Environmental Policy. Creation of the National Environmental System	Law N° 294 (1993). Environmental Impact Assessment (EIA) (modified by the Law N° 345/94 and regulated by Decree 453/13)	Law N° 16466 (1994). Environmental Impact Assessment (EIA)
Law Nº 25688 (2002). System of Environmental Management of Waters	Law Nº 300 (2012). Mother Earth Law (incorporates framework on climate change)	Federal Law N° 9433 (1997). The Water Law	Law N° 3239 (2007). Water Resources Act	Law N° 17.283 (2000). Environmental Protection
		Law N° 9985 (2000). National System of Conservation Units		Law N° 18.610 (2009). National Water Policy
		Law N° 12187 (2009). National Policy on Climate Change		Water Code

3.2.4 Regional Institutions

Table 3.2.4.1 details the multilateral organizations that act within the LPB.

Table 3.2.4.1

Multilateral organizations in the La Plata Basin

Year of Creation	Name	AR	BO	BR	PY	UY
1946	Joint Technical Commission of Salto Grande (CTM)	X				X
1967	Intergovernmental Coordinating Committee of the Countries of La Plata Basin (CIC)	X	X	X	X	X
1971	Paraguayan-Argentinian Joint Commission of the Paraná River (COMIP)	X			X	
1973	Binational Itaipú			X	X	
1973	La Plata River Administrative Commission (CARP)	X				X
1973	Joint Technical Commission of the Maritime Front (CTMFM)	X				X
1973	Yacyretá Binational Entity (EBY)	X			X	
1975	Administrative Commission of the Uruguay River (CARU)	X				X
1976	La Plata Basin Financial Development Fund (FONPLATA)	X	X	X	X	X
1989	Intergovernmental Committee of the Paraguay-Parana Waterway (CIH)	X	X	X	X	X
1991	Common Market of the South (MERCOSUR / MERCOSUR)	X		X	X	X
1991	Brazilian-Uruguayan Joint Commission for the Development of the Cuareim-Quaraí River Basin (CRC)			X		X
1993	Binational Commission of the Basin Lower Pilcomayo River	X			X	
1995	Trinational Commission for the Development of the Pilcomayo River Basin	X	X		X	
1995	Binational Commission for the Development of the Upper Bermejo River Basin and the Río Grande de Tarija (COBINABE)	X	X			
2006	Brazilian-Paraguayan Joint Commission for the Sustainable Development and Integrated Management of the Apa River Basin (CRA)			X	X	

3.2.5 National and Interjurisdictional Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Ministry of Environment and Sustainable Development (MAyDS)	Ministry of Environment and Water (MMAyA)	Ministry of Environment (MMA)	Secretary of Environment (SEAM)	National Directorate of Water (DINAGUA) (Ministry of Housing, Land Use, and Environment MVOTMA)
Secretariat of Environmental Policy, Climate Change, and Sustainable Development (MAyDS)	Vice Ministry of Environment, Biodiversity, Climate Change, and Forestry Development Management (MMAyA)	Secretary of Urban Environment and Water Resources (SRHU) (MMA)	Direction of Meteorology and Hydrology (DMH) (National Directorate of Civil Aviation)	National Environment Directorate (DINAMA) (MVOTMA)
Under-Secretariat of Water Resources (SSRH) (Ministry of Interior, Public Works, and Housing)	National Meteorology and Hydrology Service (SENAMHI) (MMAyA)	National Water Agency (ANA)		Uruguayan Institute of Meteorology (INUMET) (Ministry of Housing, Use of the Land, and Environment-MVOTMA)
Federal Water Council (COHIFE)	National Naval Hydrography Service (SNHN) (Ministry of Defense)	National Water Resources Council (CNRH)		
Federal Environment Council (COFEMA)		National Environmental Council (CONAMA)		
National Water Institute (INA)		National Institute of Meteorology (INMET)		
National Weather Service (SMN) (Ministry of Defense)		National Spacial Research Institute (INPE) (Ministry of Science, Technology, and Innovation)		
Naval Hydrography Service (SHN) (Ministry of Defense)		Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)		

3.2.6 National Plans

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Federal National Plan for Water Resources (2007)	National Watershed Plan (2006)	National Water Resources Plan	Master Environmental Management Plan for the Yacyretá Binational Entity (EBY)	National Water Plan

3.3 Legal-institutional Framework: Specific Characteristics

3.3.1 Extreme Hydrological Events

Agreements

- Combat Desertification in Those Countries Experiencing Serious Drought (1994).
- Cooperation of the Upper Basin of the Paraguay River (Brazil-Bolivia). Objective: hydrological monitoring in the region (2001).
- Additional Protocol on Environmental Emergencies (2004) from the Mercosur Agreement on the Environment (Argentina-Brazil-Paraguay-Uruguay) (2001).

National Standards

Argentina	Brazil
Law N° 25675 (2002). General Environmental Act. Art. 4. Mitigation of Transboundary Environmental Emergencies	Federal Law N° 9433 (1997). Water Law (establishes a National Water Resources Plan, which contemplates “Preventing and defending against critical hydrological events”) Law 12608 (2012). National Policy of Protection and Civil Defense (creates the disaster information and monitoring system)

National plans

Argentina
National Flood Insurance Program (relaunched in 2003)

3.3.2 Water Quality Degradation

Agreements

- Stockholm Convention on Persistent Organic Pollutants (1989), ratified by the five countries.
- Convention to Cooperate in Preventing Incidents of Water Pollution by Hydrocarbons and other Harmful Substances. (Argentina-Uruguay) (1987).
- Additional Protocol on environmental emergencies (2004) from the Mercosur Agreement on the Environment (Argentina-Brazil-Paraguay-Uruguay) (2001).

National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Decree 674 (1989), incorporates the polluter pays principle into the Mining Code	Law Nº 318 (2012), declares the improvement of water quality for human consumption by means of proper technology throughout the territory a national priority	CONAMA 357 (2005). Classification of bodies of water and environmental guidelines for effluent discharge Decree N° 440 (2005). Water quality control in water supply systems. CONAMA 396 (2008). Framework for groundwater, areas of well protection, and control of potential sources of pollution CNRH 140 (2012). Grants rights for effluent discharge	Resolution SEAM Nº 222/05, establishes the water quality standard Law Nº 1614 (2000). Regulatory and Tariff Framework for the Public Provision of Drinking Water Sewer Systems	Decree 253 (2009) and its amendments. Protection of the Environment

National plans

Brazil
ANA. National Water Quality Evaluation Plan

3.3.3. Sedimentation of Water Bodies and Watercourses

National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Law N° 13273 (1995). The Forest Wealth Defense Act	Law N°1700 (1996). Forest Law	Law N° 12651 (2012). Forest and Native Vegetation Protection Act (modified by Law ° 12727/12)	Law N° 4241 (2012). Restoration Act for Protected Forests of the Watercourses within the Eastern Region Law 3239/07 Water Resources Act.	CWater Code Law N° 15239 (1981) Soil and Water Conservation Laws Forest Law (1987)

National plans

Brazil
National Agriculture-Livestock-Forestry Policy, The Brazilian Agricultural Research Corporation (EMBRAPA). Adoption of integration systems to recuperate degraded pastures

Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
National Observatory of Land Degradation and Desertification (ONDTyD) (MAyDS)	Vice Ministry of Lands (Ministry of Rural Development and Lands)	Secretariat of Biodiversity and Forests of the Ministry of the Environment (MMA) Brazilian Agricultural Research Corporation (EMBRAPA)	Secretariat of the Environment (SEAM) National Forestry Institute (INFONA)	General Department of Renewable Natural Resources (Ministry of Livestock, Agriculture, and Fisheries) DINAMA (MVOTMA) DINAGUA (MVOTMA))

3.3.4 Alteration and Loss of Biodiversity

Agreements

- Convention on International Trade of Endangered Species from Wild Flora and Fauna (1973), ratified by the five countries.
- Cartagena Protocol on Biosafety (2003), ratified by Argentina, Bolivia, Paraguay, and Uruguay.
- Rasmar Convention on Wetlands of International Importance (1971), ratified by the five countries.

National Standards

Brazil	Paraguay	Uruguay
National Biodiversity Policy Law N° 6902 (1981). Creation of Ecological Stations and Environmental Protection Areas Law N° 9985 (2000). National System of Environmental Conservation Units CONAMA 303 (2002). Protected Areas	Law Nº 96. Wildlife Law Nº 352. Protected Wildlife Areas	LLaw N° 16408. Biological Diversity Law N° 19175. Hydrobiological Resources

Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
MAyDS COFEMA	Vice-Ministry of Environment, Biodiversity, Climate Change, and Forest Management, National Service of Protected Areas (SERNAP), decentralized entity of MMAyA	Secretariat of Biodiversity and Forestry (MMA) CONAMA Chico Mendes Institute for Biodiversity Conservation (MMA)	SEAM	DINAMA (MVOTMA)

3.3.5 Unsustainable Use of Fishery Resources

Agreements

- Uruguay River Statute (Argentina-Uruguay) (1975).
- Convention on the Conservation and Development of Fish Resources in the Paraná and Paraguay Rivers (Argentina-Paraguay) (1996).
- Agreements between Brazil and Paraguay for the conservation of aquatic fauna in the bordering rivers (1994 y 1999).

National Standards

Uruguay
Law N° 19175 (2013). Hydrobiological Resources and Ecosystems

Plans

Brazil	Paraguay
Plan SAFRA on Fishing and Aquaculture	National Fishing Plan

Institutions

Regional institutions
Paraguayan-Argentinian Mixed Commission of the Paraná River (COMIP)

National institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Undersecretary of Fisheries and Aquaculture (SPA) (Ministry of Agroindustry)	Decentralized Public Institute of Fisheries and Aquaculture (PACU) (Ministry of Rural and Land Development-MDRT)	Ministry of Fisheries and Aquaculture	SEAM	National Directorate of Aquatic Resources (DINARA) (MGAP)

3.3.6 Unsustainable Use of Aquifers in Critical Areas

Agreements

- Guaraní Aquifer Agreement (2010) (Argentina-Brazil-Paraguay-Uruguay) (Ratified by Argentina and Uruguay, has not come into effect).

National Standards

Brazil	Paraguay	Uruguay
CNRH 16 (2001). Grants of rights of use of groundwater resources CNRH 22 (2002). Considers the multiple uses of groundwater, hydrogeological characteristics, and the qualitative aspects of resource development and sustainability CONAMA 357 (2005). Classification and framework of the bodies of water CNRH 92 (2008). Protection and conservation of groundwater CONAMA 396 (2008). Framework of groundwater, protected well areas, and controlled sources of possible contamination CNRH 153 (2013). Artificial recharge of aquifers	Resolution SEAM 2155 (2005). Technical specifications for the construction of tubular wells intended for capturing groundwater	Decree N° 214 (2000). Guaraní Aquifer System Management Plan Decree N° 86 (2004). Technical Standard for Constructing Perforated Wells for Groundwater Capture

Plans

Argentina	Brazil
Federal National Groundwater Plan (PNFAS) (First Phase of Implementation)	National Groundwater Program (SRHU)

Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
SSRH	MMAyA Geological and Mining Service (SERGEOMIN)	MMA-SRHU ANA Brazilian Geological Service (CPRM)	SEAM	DINAGUA (MVOTMA) Guaraní Aquifer System Commission

3.3.7 Conflicts Over Water Use and the Environmental Impact of Irrigated Crops

National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Law N° 25688 (2002). Law on Minimum Standards for the Environmental Management of Water	Law Nº 1333 (1992). Environmental Law	Federal Law N° 9433 (1997). Water Law CNRH 16 (2001). Grant of rights for groundwater. ANA 135 (2002). Grant of rights for use ANA 425 (2004). Volume measurement of water captured in bodies of water CNRH 65 (2006). Articulation of the rights and use of water resources with environmental licensing procedures Law N° 12787 (2013). National Irrigation Policy	Resolution SEAM 170 (2006). Approval of the Regulation of the River Basin Water Council Law N° 3239 (2007). Water Resources Law Law Nº 294/93 Evaluation of Environmental Impact	Decree-Law N° 14859 (1978). Water Code Law N° 15239 (1981). Conservation of Soil and Water Ley N° 16466 (1994). Regulation of the Evaluation of Environmental Impact Ley N° 18610 (2009). National Water Policy Water Code

Plans

Argentina	Bolivia	Brazil	Uruguay
Federal National Water Resources Plan (2007)	National Watershed Plan (PNC) (2006) National Irrigation Plan to Live Well (PNDR) (2007)	National Policy for recuperation of degraded pastures with the adoption of agriculture-livestock-forestry integration.	National Water Plan

Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
SSRH COHIFE National Institute of Agricultural Technology (INTA)	Vice Ministry of Watersheds and Water Resources (MMAyA) Vice Ministry of Water Resources and Irrigation (MMAyA) Ministry of Rural and Land Development (MDRT), Vice Ministry of Land (VT) National Irrigation Service (SENARI) (decentralized organization of MMAyA)	MMA-SRHU ANA CNRH Water Basin Committees Brazilian Agricultural Research Corporation (EMBRAPA)	SEAM Water Council for Basins	DINAGUA (MVOTMA) MGAP- General Direction of Renewable Natural Resources (DGRNR)

Signing the Agreement on the Guaraní Aquifer. Meeting of the Mercosur Ministers of Foreign Affairs and Associated States, San Juan, Argentina, August 2, 2010.

3.3.8 Lack of Disaster Contingency Plans

National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Law N° 25675 (2002). General Environmental Law. Art. 4: Mitigation of Transboundary Impacts from Environmental Emergencies Laws N° 23879 and N° 24539. Environmental Impact Assessment of Hydroelectric Dams	Law Nº 13338 (1992). Environmental Law Law N° 2140 (2000). Risk Reduction and Disaster and Emergency Assistance Law N° 2335 (2002). Creation of the Trust Fund for Risk Reduction and Disaster Assistance (FORADE)	Federal Law N° 9433 (1997). Water Law Law N° 12608 (2012). National Policy of Civil Defense and Protection (PNPDEC) and the Disaster Information and Monitoring System Law N° 12334 (2010). National Policy on Dam Safety and creation of National Dam Safety System Resolution CNRH 143 (2012). Classification of Dams Resolution CNRH 144 (2012). Establishes guidelines for the implementation of the National Policy on Dam Safety	Law Nº 2615, Creation of the Secretary of National Emergencies (SEN) Decree Nº 11632 regulates SEN	Decree-Law N° 14.859 (1978) Water Code Law N° 18621. National Emergency System (SINAE)

Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
SSRH COHIFE Dam Security Regulatory Agency (ORSEP) (SSRH)	MMAyA	MMA-SRHU ANA Ministry of Integration	Secretary of National Emergencies (SEN)	SINAE DINAGUA (MVOTMA)

3.3.9 Water Quality Degradation and Deterioration of Environmental Health

Agreements

- Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (2004), ratified by the five countries.
- Stockholm Convention on Persistent Organic Pollutants (2004), ratified by the five countries.

National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Law N° 25675 (2002). General Environment Law	Law Nº 1333 (1992). Environmental Law	Law N° 6938 (1981). Creation of National Environmental System	Law N° 3239 (2007). Water Resources Law	Decree 253 (1979). Control of Water Contamination
Law N° 25.688 (2002). Environmental Management of Water Law	Law Nº 300 (2012). Mother Earth Law	Federal Law N° 9433 (1997). Water Law	Law N° 294 (1993). Evaluation of Environmental Impact Law (EIA) (modified by Law N° 345/94 and regulated by Decree 453/13)	Law N° 18610 (2009). National Water Policy
Penal Code	Law Nº 318 (2012). Improvement of drinking water quality for human consumption	Decree N° 440 (2005). Quality control of water supply systems	Penal Code	EIA: Law N° 16466 (1994). Environmental Impact Assessment
		CONAMA 357 (2005). Classification of the bodies of water	Resolution N° 222. Secretariat for the Environment	Law N° 17283 (2000). Environmental Protection
		CNRH 140 (2012). Granting of the rights of effluent discharge	Law Nº 2459/04, creation of the National Service for Plant and Seed Quality and Health (SENAVE)	Water Code
			Law Nº 3742, Agricultural Pesticide Control	Penal Code

Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
MAyDS	Ministry of Health	Ministry of Health	SEAM	DINAGUA (MVOTMA)
SSRH		Ministry of Cities	National Directorate of Drinking Water and Sanitation (DINAP) (Ministry of Public Works and Communications)	Administration of State Sanitary Works (OSE) (decentralized service related to the Executive Power through MVOTMA)
Ministry of Health		IBAMA	Potable Water and Sanitary Services Regulatory Entity (ERSSAN)	Ministry of Public Health
			National Environmental Sanitation Service (SENASA) (Ministry of Public Health and Social Welfare MSPBS)	
			National Directorate of Environmental Health (DIGESA)	
			SENAVE	

3.3.10 Navigation

Agreements

- Treaty of Yacyretá
- Regularization, Channeling, Dredging, Marking, and Maintenance of the Paraguay River Agreement (Argentina-Paraguay) (1979).
- Agreement on River Transport Through the Paraguay-Paraná Waterway (signed by the five countries) (1992).

National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Civil Code Law N° 20094 (1973). Navigation Law	Decree (17.01.1853). (Bolivian rivers can be navigated freely by ships of all flags)	Law N° 9432 (1997). River Transport Law N° 9537 (1997). River Transport Security Law N° 9611 (1998). Multimodal Cargo Transport	Civil Code Law N° 475 (1957). Sanction of the River and Maritime Code	Law Nº 12.091 (1954). Law on Navigation and Coastal Trade Decree-Law N° 14859 (1978). Water Code

Institutions

Regional Institutions

Intergovernmental Committee of the Paraguay-Paraná Waterway (CIH)

National Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Ministry of Transport	Ministry of Defense	Ministry of Defense-Naval Command Ministry of Transportation	National Administration of Navigation and Ports (ANNP) Ministry of Foreign Affairs, Secretary of Environment, Naval Prefecture of the Paraguayan Navy, Paraguayan Ship Owners' Association, National Water Commission	onal Hydrographic Directorate (Ministry of Transportation and Public Works-MTOP) National Transport Directorate (MTOP)

3.3.11 Hydroelectricity

Agreements

- Convention on the Utilization of the Uruguay River Rapids in the Salto Grande Area (Argentina-Uruguay) (1946).
- Convention to Study the Use of the Paraná River's Resources (Argentina-Paraguay) (1971).
- Itaipú Treaty for the Hydroelectric Utilization of the Water Resources of the Paraná River (Brazil-Paraguay) (1973).
- Treaty of Yacyretá (Argentina-Paraguay) (1973).
- Treaty for the Utilization of Shared Water Resources of the Boundary Stretches of the Uruguay and Pepirí-Guazú Rivers (Argentina-Brazil) (1980).
- Tri-national Commission for the Development of the Pilcomayo River Basin (Argentina-Bolivia-Paraguay) (1995).
- Binational Commission for the Development of the upper Bermejo River and Grande de Tarija River Basins (Argentina-Bolivia) (1995).

National Standards

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Law N° 24065 (1991). Regulatory Framework on Electricity	Law N° 1604 (1994). Electricity Law	Law N° 3890 (1961). Constitution of the Brazilian Electric Company formed Centrais Elétricas Brazileiras S.A. (ELETROBRAS) Law N° 7990 (1989). Financial compensation for the use of water resources to generate electric energy and other aspects for the federal, state, and municipal governmental organizations. Law N° 9427 (1996). Brazilian Electricity Regulatory Agency (ANEEL) and regulation of the system of concession for the public energy sector ANEEL (2013). Electric Sector Regulation	Law N° 3009 (2006). Independent Production and Transport of Electric Power Law	Law N°16832 (1997). Updating the National Electric System and the framework of the Energy Regulation Unit

Institutions

Regional Institutions

Mixed Technical Commission of Salto Grande (CTM)

Paraguayan-Argentinian Mixed Commission of the Paraná River (COMIP)

Itaipú Binational Entity

Yacyretá Binational Entity (EBY)

National Institutions

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Ministry of Mines and Energy SSRH (Ministry of the Interior, Public Works, and Housing)	Ministry of Hydrocarbons and Energy	Ministry of Mines and Energy Brazilian Electricity Regulatory Agency (ANEEL)	National Electricity Administration (ANDE)	Ministry of Energy, Industry, and Mining

Chapter 4:
Critical Transboundary Issues

4.1 Introduction

The Macro- Transboundary Diagnostic Analysis (Macro TDA), developed over a period of two years from 2003 to 2005, identified, on a scientific and social basis, the critical transboundary issues (CTI) present and emerging in the LPB and their causal chains.[5] The process of drawing up the Macro TDA (as a preliminary version) was carried out through national and regional workshops.

The critical issues identified were as follows:

- Extreme hydrological events linked to climate variability and change, particularly more prolonged, recurrent, and intense floods and widespread drought periods that cyclically affect parts of the Basin, with catastrophic social, economic, and environmental effects. Gaps in information and climate knowledge were identified, with the consequent inability to more efficiently prevent the effects of climate variability and change.

- Water quality degradation, a problem caused by organic and chemical pollutants from specific sources without adequate treatment, such as mining and industrial activity; wastewater and solid waste from urban centers; diffuse pollution sources, mainly agricultural crops with intensive use of agrochemicals. The lack of common standards and instruments for mutually determining the quality parameters and constraints of the five countries' control and monitoring network was identified, making it impossible to carry out a coherent and encompassing diagnostic on the quality of the waters of the rivers in the Basin.

5 EThe causal analysis was carried out through national and regional workshops, with the participation of specialists designated by each country for the different topics. The CTI causes were classified as follows: i) Technical causes: causes that refer to poor management of scarce natural resources, such as water and land, to the use of inadequate technologies, lack of monitoring systems or the improper operation thereof; ii) Economic-managerial causes: causes that derive from the inadequate economic projections or inadequacy of managerial approaches; iii) Political-institutional causes: causes derived from the institutional environment, that is, from the legal and organizational framework of a region or country; and iv) Socio-cultural causes: those based on the foundations on which society is formed, such as its behavioral norms, ethics, customs, traditions, religion, etc.

- The sedimentation of bodies of water and watercourses in the Basin, which limits the capacity of waterways and ports, with important maintenance costs, and which fills the dam reservoirs and modifies the quality of their waters; these processes are caused by greater erosion and land degradation that has been increasing because of changes in land use and loss of vegetation.

Other critical issues of interest were also highlighted:

- The alteration and loss of biodiversity, in particular of river and coastal ecosystems—including wetlands—problems mainly caused by the loss and fragmentation of habitats.

- Unsustainable use of fishery resources, whether due to overfishing or lack of protective capture methods, which alters the structure and functioning of aquatic communities.

- The unsustainable use of aquifers in critical areas, the conservation of which makes it necessary to manage them in an integrated way, together with surface resources and the climate, taking sustainable development needs into account.

- Water use conflicts and the environmental impact of irrigated crops, without an overall vision and capacity to generate participatory processes for the stakeholders involved to reach a fair resolution.

- The lack of disaster contingency plans, including dam safety and problems associated with the prevention of accidents and catastrophes mainly related to navigation and transport of hazardous and polluting materials.

- Poor water health and the deterioration of environmental health and its effects on human health, resulting from contamination and changes in water quality. The incidence of urban development with insufficient sanitation services and the advance of cyanobacteria, among other things, was highlighted, recognizing that it is a problem that requires significant primarily national investment, but which also involves cross-border aspects.

It should be noted that in Stage 1, which began in March 2011, it was decided that limitations on navigation and hydropower be incorporated as CTIs, as they are two socio-economic sectors that are fundamental to regional integration.

As part of the initial activities of that stage, a Regional Workshop on Working Groups was held (June 2011), where the project document was revised and updated, taking into account the time elapsed since the formulation of the proposal (2005). As a result of the review process, not only were the Mac-

A bird of the Pantanal, Jaburu Tuiuiu.

ro TDA and the causal chains of each problem updated, but also the baseline and work elements (objectives, outputs, results, and activities) of the components and subcomponents of the project.

During the period from 2011 to 2016, the project's execution included the implementation of activities aimed at deepening the knowledge base of the different topics, which allowed for the consolidation and updating of the diagnostic. The process was carried out with the involvement of the Working Groups (WG), through the participation of representatives with competence in each of the topics from governmental and academic institutions from the five Basin countries (water quality, hydraulic balance, groundwater, land degradation, hydrometeorology, ecosystems, etc.).

The work of the WGs was complemented with specific studies aimed at obtaining knowledge on critical and priority issues for the Basin, not included in the project components. This includes studies on navigational limitations and measures to overcome them; the analysis of the hydroelectric potential and the possible use of alternative sources of energy; and the problems associated with the environmental sanitation of the Basin, the impact on human health, and the transboundary effects.

Demonstrative Pilot Projects and priority projects related to critical problems of the Basin were also developed in selected areas and sub-basins, and carried out by local actors and by the principal governmental and non-governmental organizations. The projects were implemented with the objective of providing information for the preparation of this TDA and providing local management experiences for replication as part of the Strategic Actions Program (SAP), catalyzing existing initiatives in the countries involved.

The Demonstrative Pilot Projects are:

Regulated conservation of biodiversity in the Paraná River

Countries involved: Argentina, Brazil, and Paraguay

Its purpose is to contribute to improving the management capacity of aquatic resources in the Paraná River stretch between the confluence of the Paraná and Paraguay rivers and Guayrá falls, an area where two of the most important transboundary reservoirs of the Basin are located: Itaipú and Yacyretá. An updated baseline was generated and guidelines were formulated that could contribute to the development of a management plan for the conservation of aquatic resources, and a set of recommendations was prepared to harmonize legislation and to train local actors. It contributes to the knowledge base of the CTIs regarding alteration and loss of biodiversity and unsustainable use of fishery resources.

Hydro-environmental alert system. Floods and droughts in the confluence zone of the Paraguay and Paraná rivers

Countries involved: Argentina and Paraguay

Its purpose is to develop a hydro-environmental monitoring and warning system for risk management (prevention, contingency, and rehabilitation) in the metropolitan axis of Resistance-Corrientes (Argentina) and Pilar (Paraguay), also contemplating adaptations or actions to to address the hydrological effects of climate variability and change, to prevent flood and drought disasters, and to implement mitigation measures in collaboration with civil defense authorities. The alert system includes notification of extreme hydrological phenomena and contaminant spills and the preparation of

Parque Nacional El Palmar - Argentina.

contingency plans. It contributes to knowledge base on the CTIs related to extreme hydrological events, lack of disaster contingency plans, and water quality degradation.

Resolution of water use conflicts - Cuareim / Quaraí river basin

Countries involved: Brazil and Uruguay

Its purpose is to execute a localized project that contributes to improving the integrated management capacity of the water resources of the Basin, seeking their harmonious use among national users and in the transboundary area. It promotes the involvement of local actors and the existing Binational Commission for the development of the Basin and the conservation or improvement of environmental quality, guiding decision-making processes toward a rational use of water, with an aim to resolve current conflicts, including the issue of irrigated crops, particularly rice. It contributes to the knowledge base of CTIs on "water use conflicts and the environmental impact of irrigated crops."

Pollution and erosion control in the Pilcomayo River Basin

Countries involved: Argentina, Bolivia, and Paraguay

Its purpose is to generate a local management experience, contributing to the reduction of both the risk of environmental liabilities and mining pollution, such as soil erosion, sedimentation, and silting in the Pilcomayo River watercourses. It includes a set of actions at the local level (Cotagaita basin in Bolivia). The aim is to preserve the integrity of the water resource system of the Pilcomayo sub-basin by improving water quality and erosion control through non-structural measures in order to create the possibility of replicating actions to control and mitigate pollution and erosion. The project contributes to the knowledge base of the CTI on water quality degradation and sedimentation of bodies of water and watercourses, considering the transboundary effect on Argentina and Paraguay.

There are also two priority projects dedicated to the Selva Misionera Paranáense (SMP) and to the Yrendá-Toba-Tarijeño Aquifer System (YTTAS) (see *Chapters 1.3.11* and *1.4.1.3*, respectively). A third project is based on the experience of the Cultivating Good Water (CGW) program, initiated in 2003 by Binational Itaipú to mitigate environmental liabilities and work toward a new culture, one of socio-environmental sustainability, including the implementation of appropriate technologies and best practices with the participation of the different social actors that influence quality of life and the environment: companies, governments, schools and universities, civil society organizations, and the media.

The CIC expanded the CGW Program in the La Plata Basin, initially in the zones of influence of the other two binational hydroelectric power stations in the region, operated by the Yacyretá Binational Entity (EBY) and the Mixed Technical Commission of Salto Grande (CTM-SG). The Bolivian FP delegation (with no binational hydroelectric power stations in its territory) was invited to send representatives from the agencies or institutions that they considered appropriate to learn the methodology of the work in order to potentially replicate it.

The results of the various works and studies, summarized in the previous chapters and in this chapter, form the basis of this analysis.

The following section presents a summary of the results for each CTI, in order to better understand the problems presented and their social and economic impacts. Special consideration will be given to the likely effects of climate variability and change, based on the results outlined in *Chapter 2*.

The summary is presented considering the entire basin and, depending on available information, the sub-basins mentioned in *Chapter 1.3*. It should be noted that the identification of a problem in a sub-basin is not necessarily indicative of its occurrence in all of its extension, and it may be in fact be treated as a local problem that occurs in a certain area of that sub-basin, a point which will be clarified in each case.

The analysis includes some considerations on legal and institutional aspects and the identification of the main causes (technical, economic-managerial, political-institutional, and socio-cultural) that were detected for each CTI in the preparation of the Macro TDA. Based on these elements, recommendations are made for the preparation of the Strategic Actions Program (SAP).

4.2 Extreme Hydrological Events

4.2.1 Flooding

4.2.1.1 Presentation of the Topic

Floods are the greatest natural threat in the LPB. They are caused by three main factors: the natural increase of river flows in rainy seasons, disorganized urban sprawl that occupies flood plains, and the increase in groundwater levels.

Most of the rivers in the Basin have large floodplains that have been occupied by both the population and agricultural activities. The Paraguay River has large plains with a slow-flowing runoff when flooding occurs on its banks. On the banks of the Paraná River and its tributaries, such as the Iguazú River, there are important cities that are flooded with great frequency. This is the case with the cities of Resistencia, Corrientes, Rosario, and Santa Fe, which suffer major impacts. The Uruguay River also has significant flooding, mainly in São Borja, Itaquí, and Uruguaiana. In the lower part of the Basin shared by Argentina and Uruguay, flooding downstream of the Salto Grande dam was observed at the end of 2015, coinciding, in turn, with the historical flood of Artigas and Quaraí, cities included in the pilot project carried out in the Cuareim/Quaraí river basin.

Since 1970, floods have been occurring more frequently, on average every four years. The greater frequency is associated with the El Niño phenomenon and the impact of land use on the upper basins.

On the other hand, in recent years there has been an increase in the groundwater level in the Pampa region of Argentina, associated with natural and anthropogenic causes. In urban and suburban areas, the increase in the water table causes damage to the underground infrastructure and increases the possibility of groundwater contamination. In rural areas, the reduced depth and upwelling of water cause flooding in large areas intended for agricultural use.

Although this problem is associated, above all, with natural causes (mainly the increase in rainfall since 1970), there are anthropogenic causes such as inadequate territorial planning and the construction of infrastructure works, such as roads which obstruct surface runoff and increase infiltration as a consequence of increased irrigated area.

4.2.1.2 Environmental, Social, and Economic Impacts

No systematic studies have been implemented in the Basin to assess losses or damages due to flooding. According to specific studies (FP, 2016b), during the El Niño event of 1982 to 83, the estimated losses in the La Plata Basin were more than a billion dollars.

In Argentina, the direct and intangible damages of the floods between 1987 and 1998 were estimated at 2,640 million dollars, with more than 235,000 people evacuated. In the period from 1991 to 1992, flooding created a loss of 513 million dollars, more than 3 million hectares flooded, and 122,000 people evacuated.

Recent studies undertaken in Paraguay within the framework of the Strategic Planning and Institutional Development of the Pluvial Drainage Sector Support Program estimated that the baseline cost of a flood in an intermediate city is in the neighborhood of 5 million dollars, a value that arose from considering, among other variables, losses in GDP due to hours of work stop-

Montevideo Port, Uruguay.

page, loss of workers' income per hour of work stoppage, temporary shelters, provision of emergency facilities, reconstruction of average housing, reconstruction of social housing, rehabilitation of waterways and waterworks, and operations to return victims to their homes (FP, 2016b).

4.2.1.3 Activities Developed

In 2005, gaps were identified in information and knowledge of present and future climate, which required improving the capacity to model the phenomena of climate variability and change to identify hazards and vulnerabilities, as well as to plan adaptation measures for the new climatic and hydrological scenarios.

In response, a detailed diagnosis of the hydrometeorological monitoring systems (meteorological and hydrological observations as well as meteorological satellites and radar) and of the existing warning systems at the national and regional levels was advanced.

For example, in Argentina, the SINARAME project was implemented in two stages. In the first, the first two radars (the MR A0 prototype and the MR A1 operation) were developed and manufactured, and then the project proceeded to the design and the preliminary implementation of the LPB Operations Center and the integration of existing radar with transmission into the LPB. In 2015, the MR A0 was put into operation at the San Carlos de Bariloche airport, while the MR A1 was installed at the National University of Cordoba (UNC). During the period from 2015 to 2016, the second stage of the project will be carried out, with the installation of 10 meteorological radar units at different sites, five regional processing centers, and 55 automatic meteorological stations. In this second stage, the Argentine sector of the LPB would have five new meteorological radars: Las Lomitas (Formosa), Resistencia (Chaco), Bernardo de Irigoyen (Misiones), Chajarí (Entre Ríos), and Ezeiza (Buenos Aires).

On the other hand, activities related to hydroclimatic modeling and adaptation allow hydroclimatic scenarios generated by a model selected by the countries (ETA-INPE) and a hydrological model (MGB-IPH) installed in the five countries to analyze the current situation and the future scenarios.

In order to visualize the effects of flooding, maps of flooding vulnerability, occurrence, and impact were carried out at the sub-basin scale, including a regional analysis of the results. Subsequently, for each of the sub-basins analyzed, urban and rural critical areas were identified. This provides a vulnerability map for flooding (**Figure 4.2.1.3.1**), as well as vulnerability assessments for different socio-economic sectors.

This issue is emphasized in the Demonstrative Pilot Project *Hydro-environmental alert system. Floods and droughts in the confluence zone of the Paraguay and Paraná rivers, mentioned in Chapter 4.1.*

4.2.1.4 Knowledge Expansion and Updating

Among the main results of the work on floods are the following:

Vulnerability to river flooding

Based on the GIS mapping of the La Plata Basin and applying the methodology proposed by the ANA (2011), the main watercourses were studied and those with high, medium, and low vulnerability to flooding were identified. Only 7.2 percent (67,820 km) of the watercourses of the Basin were

Figure 4.2.1.3.1

La Plata Basin. Flood Vulnerability

Vulnerability to floods

- High (significant damage)
- Medium (rassonable damage)
- Low (localized damage)

analyzed. It should be noted that although the same methodology was used for the whole Basin, when applied in different countries by different experts, the results could present some differences between countries and sub-basins, so they should be taken as merely a first approximation to the problem. Based on the applied methodology, the following results were obtained: of the watercourses analyzed in the whole Basin, 41 percent (27,806 km) presented high vulnerability to flooding, 35 percent (23,737 km) medium vulnerability, and 24 percent (16,276 km) low vulnerability. The detail by sub-basin is presented in **Table 4.2.1.4.1.**

Urban floods

Background studies indicate that one of the main problems in the La Plata Basin is urban flooding. This was analyzed in particular by first identifying the preliminary populations with potential flood problems. For this purpose, populations with more than 50,000 inhabitants were identified, as well and those with between 10,000 and 50,000 inhabitants, all with a nearby watercourse with high vulnerability to riparian flooding. The results that are presented should be considered a first approximation to the problem. When considering the entire Basin, 92 cities were identified with more than 50,000 inhabitants and 226 populations between 10,000 and 50,000 inhabitants with a high likelihood of having problems with river flooding. The sub-basin details are presented in **Table 4.2.1.4.2**.

Flood occurrence maps and flood impact maps were generated for both the Basin (**Figures 4.2.1.4.1** and **4.2.1.4.2**) and the sub-basins.

The vulnerability analysis also identified 87 cities of more than 50,000 inhabitants and 226 with between 10,000 and 50,000 inhabitants with a high vulnerability to flooding. In the rural areas of each sub-basin,

Table 4.2.1.4.1

Vulnerability to riparian floods in major sub-basins

		Flood Vulnerability		
Sub-basin	**Extension analyzed** (km)	**High** (%)	**Medium** (%)	**Low (%)**
Upper Paraguay	4,579	65	25	10
Lower Paraguay	17,417	38	41	21
Upper Paraná	11,939	23	40	37
Lower Paraná	12,946	73	24	3
Upper Uruguay	4,454	55	19	26
Lower Uruguay	13,334	27	39	34
La Plata River (*)	3,150	6	45	49

(*) The La Plata River sub-basin was only partially studied.

land use associated with high vulnerability (with a return period of less than five years) to flooding was identified (**Table 4.2.1.4.3**).

4.2.1.5 Influence of Climate Variability and Change

In general terms, there is an increase in rainfall mainly in the south and south-western areas of the LPB (although there is a decrease in the northern area), an increase in the frequency of intense rains, an increase in river flows, and an increase in dry periods. All these factors indicate a current trend towards an increase in riparian flooding in the LPB.

In terms of the analysis of possible future scenarios, according to the available precipitation studies (FP, 2016c), the following conclusions can be drawn:

- For the period 2011 to 2040, there is an increase of up to 1 mm/day in the south-

Table 4.2.1.4.2

Number of populations per sub-basin likely to have problems due to riparian flooding

	Nº Populations	
Sub-basin	**> 50.000 inhabitants**	**10.000 - 50.000 inhabitants**
Upper Paraguay	3	15
Lower Paraguay	9	17
Upper Paraná	39	66
Lower Paraná	22	77
Upper Uruguay	4	18
Lower Uruguay	7	18
La Plata River (*)	8	15

(*) The La Plata River sub-basin was only partially studied.

Table 4.2.1.4.3

Number of cities with high and medium vulnerability to floods

	High		Medium	
Sub-basin	**> 50.000 inhabitants**	**10.000-50.000 inhabitants**	**> 50.000 inhabitants**	**10.000-50.000 inhabitants**
Upper Paraguay	3	15	3	19
Lower Paraguay	34	66	42	98
Upper Paraná	4	18	1	8
Lower Paraná	9	17	12	31
Upper Uruguay	22	77	8	21
Lower Uruguay	7	18	5	9
La Plata River	8	15	13	10
Total	**87**	**226**	**84**	**196**

Figure 4.2.1.4.1

La Plata Basin. Flood occurrence

Occurrence of floods

- Low: return periods greater a 10 years
- Medium: return periods between 5 and 10 years
- High: return periods of less than 5 years

Figure 4.2.1.4.2

La Plata Basin. Flood impacts

Impact of floods

- Low
- Medium
- High

High impact: high risk of damage to human lives, significant damage to essential services, facilities and public infrastructure and residential areas.

Average impact: reasonable damage to essential services, public and residential infrastructure and facilities.

Low impact: localized damage.

SINARAME radar, Argentina.

ern area and a decrease of up to 3 mm/day in the northern part of the Basin.

- For the period 2041 to 2070, there is an increase of up to 1 mm/day in the south, southwest, and western zones, while in the north and northeast there is a decrease of up to 1 mm/day.

- In the period 2071 to 2099, the increase continues for the southern, western, and northern areas and there is a decrease in the eastern zone for the December-January-February quarter. Subsequently, this signals a moderate or neutral increase for the rest of the months of the year.

If the current trend continues, the southern and southwestern part of the Basin could have greater river flooding problems, while in the northwest zone, even with less precipitation, this problem will depend on whether the seasonal distribution is homogeneous or if, on the contrary, the current trend continues, where the rains accumulate in fewer days.

4.2.2 Droughts

4.2.2.1 Presentation of the Topic

Drought is a hydrological extreme with low precipitation and flow for a long enough period to affect populations and environments. Unlike flooding, it has a slow and progressive nature. Available data on droughts and, in particular, their effects on the environment and the economy are often scarce.

When discussing droughts, it is possible to distinguish the case in which the lack or reduction in precipitation affects areas with different magnitude—by reducing the availability of water, in quantity and quality, to satisfy the demands for domestic and agricultural uses, among others—from the case where such lack or reduction is reflected in the reduction of flows and river levels—what is sometimes known as "low water"—affecting in particular hydroelectric generation and navigation.

In much of its territory, the Basin does not present significant water deficiencies for current uses. In some of the largest urban centers, low levels of water are commonly found in sources used for human consumption. This is because some of these cities are located in the headwaters of the tributaries of the main rivers, which limits the availability of sources. San Pablo and Curitiba are two good examples of this situation.

Argentina devotes a large part of its territory to agricultural, livestock, and forestry activities, generating strong pressure on its natural resources, particularly on the soil. In the province of Buenos Aires, the most severe droughts occurred in the early 1970s, with a reduction in extreme events after 1972. This trend towards a reduction in the risk of severe droughts and an increase in precipitation, particularly in the western part of the Pampa plain, has led to a shift from agriculture and ranching to a primarily agricultural system.

In the Gran Chaco region (shared by Argentina, Bolivia, Brazil, and Paraguay) the semi-arid zone is subject to erosive processes and loss of fertility resulting from over-ranching and unsustainable agriculture. This situation is aggravated towards the west, where the arid Chaco region presents the most extreme conditions of aridity, observing a process of desertification.

4.2.2.2 Environmental, Social, and Economic Impacts

There is a general consensus on the existence of significant adverse economic consequences due to the occurrence of droughts, and these consequences are reflected on a national scale, as they affect important sectors of the economies of LPB countries, such as agriculture and livestock production, agribusiness, hydropower generation, and navigation, among others. However, it is a complex task to quantify the effects of drought economically, taking into account all its direct and indirect implications. In the framework of the Project's activities, the incidence of drought was analyzed by relating the occurrence of a dry year to the variation in the GDP growth of the sub-basin affected by drought.

Although the GDP growth value in each of the sub-basins depends on the economies of the countries that make them up, as well as on many other factors that are independent of the drought situation, it is also a constant in most regions that the economic sectors related to the availability of water resource have a large influence on the GDP. On average, the dry years identified have meant an average GDP decrease of 5 percent (between 3 and 7 percent).

4.2.2.3 Activities Developed

A study was carried out on vulnerability to drought; a temporal space characterization of the periods with water deficit at the sub-basin level and with an annual time scale was performed.

In addition, a characterization of the water deficit periods in the sub-basins was performed, based on the SPEI (Standardized Precipitation-Evapotranspiration Index), with a monthly step for different time scales (one, three, six, and 12 months) and an analysis of evapotranspiration potential (ETP) and precipitation (P) variables for the current and future scenarios. The current scenario (1961 to 2005) and future scenarios

(2007 to 2040, 2041 to 2070, 2071 to 2099) were analyzed.

4.2.2.4 Knowledge Expansion and Updating

For the study of vulnerability to drought events, monthly rainfall series from 46 pluviometric stations were used. Dry years were identified in the series with complete data (a period from 1861 to 2014 in some stations) and the average recurrence of those periods. The average time between dry years for the entirety of the LPB was six years, varying between five and nine years depending on the sub-basin analyzed.

In order to evaluate a possible change in current climate trends with respect to the complete historical series, the dry periods for the period of 1961 to 2014 were identified. The mean time between dry years for the entirety of the LPB was nine years, varying between six and 16 years depending on the sub-basin analyzed.

It was observed that in those areas where the mean time of recurrence of dry years is high, variation is minimal in the two periods analyzed, whereas in areas where the mean dry-season recurrence time is low, in the reduced series, the time between droughts increases considerably.

Subsequently, an initial assessment of the spatial-temporal distribution of droughts was carried out. It was observed that for periods with a good spatial representation of the pluviometric network in operation, the surface area with water deficit varies between five and 20 percent of the total area of the Basin annually, with some unique years, such as 1962 with 55 percent, the years 1968 and 1988 with 33 percent, and the year 2008 with 48 percent. When analyzing the situation by sub-basins, it was noticed that there is an important variability between them, reaching values of 70 to 80 percent surface area in a dry year, although in those same years the situation differs in the other sub-basins.

4.2.2.5 Influence of Climate Variability and Change

Among the main results of the characterization of water deficit periods in the sub-basins, based on the calculation of the SPEI index for each of them, the following stand out:

Upper Paraguay and upper Paraná: There is an increase in dry periods, both in their duration and in their magnitude and average intensity. The same applies to the spatial coverage of dry periods. In the period from 2007 to 2040, the worst situation occurred, gradually improving but not reaching the levels of the control period (1961 to 2005).

Lower Paraguay: Dry periods increase considerably in duration, magnitude, and spatial coverage for the period from 2007 to 2040, but without reaching the levels of the upper Paraguay and upper Paraná basins. From the period from 2041 to 2070 the situation improves, although the situation of the control period is not reached. The spatial coverage of drought also begins to decline, although it remains above the levels of the control period.

Lower Paraná: In the control scenario, the basin presents a normal to slightly humid climate, with brief dry periods of low intensity. In future scenarios, the climate gradually becomes more humid over time, decreasing the dry periods and their magnitude, intensity, and spatial coverage. Therefore, future scenarios would present greater water resources than the control scenario.

Upper Uruguay: The climate in the period from 1961 to 2005 alternates between dry and wet periods. In the period from 2007 to 2040, there are fewer dry periods, although with longer duration and intensity. In the 2041 to 2070 scenario, the humid climate predominates, decreasing the number of dry periods, their duration, intensity, and coverage.

Lower Uruguay: The signal clearly indicates an increase in water resources as the most distant scenarios are analyzed over time. Dry periods decrease in quantity, duration, intensity, and spatial coverage.

La Plata River: The period from 1961 to 2005 was characterized by the alternation of dry and wet periods. In the future scenario from 2007 to 2040, there is a strong decrease in dry periods, their duration, and magnitude, as well as their spatial coverage. In the rest of the scenarios, although with a predominance of normal to humid climates, short dry periods are observed. In all cases, dry periods are fewer than those observed in the control scenario.

4.2.3 Legal and Institutional Considerations

While the issue is poorly developed at the country level, there is a broad national and regional umbrella consisting of several treaties—that include all or some of the five countries—that support the adoption of a harmonized framework that regulates this CTI. In Paraguay, there is a national policy on disaster prevention and risk management and reduction, carried out by the Secretariat of National Emergencies and the National Commission, composed of several institutions. The treaty of San Ramón de la Nueva Oran (1995) between Argentina and Bolivia establishes a system of hydrological alert that could be taken as a model. There is an WMO-CIC Agreement (2000) that could relate to the WIGOS project at the development stage. Harmonization of regulations is required; the countries could start from a common base and adjust their legislation to the additional protocol of the Mercosur Framework Agreement on Environment in the area of cooperation and assistance in the event of environmental emergency.

Drought in the western region of the Chaco.

4.2.4 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Deforestation and loss of vegetation cover. • Inadequate hydro-meteorological monitoring and prediction systems, and insufficient studies on extreme events. • Lack of defined risk areas. • Lack of urban and territorial planning. • Changes in land use.	• Poor coordination of information on extreme events. • Insufficient economic resources. • Lack of operational capacity for the management and dissemination of territorial planning plans associated with extreme events. • Lack of regional economic criteria for the management of extreme events. • Lack of sustainable management of the basin.

Political-Institutional Causes	Social and Cultural Causes
• Lack of coordination between countries for the implementation of common management. • Lack of enforcement mechanisms for existing regulations. • Lack of legal framework for managing transboundary water resources. • Lack of regional disaster prevention policies. • Insufficient technical institutional capacity in local areas.	• Lack of education and awareness processes. • Historical trend of occupation of flooded areas. • Lack of environmental awareness. • Lack of culture for seeking collective solutions.

4.2.5 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Consolidate, expand, and improve coordination between the various systems of monitoring, information, climate prediction, and early warning.
- Develop support systems for decision-making at basin and sub-basin levels.
- Improve the urban and territorial planning to increase resilience and reduce vulnerability to extreme events.
- Promote agro-ecological zoning to reduce the impact of extreme events.
- Promote the development of regional policies and the strengthening of the legal framework for the prevention and management of extreme events.
- Implement territorial planning and integrated water resource management policies.
- Harmonize legal frameworks for the management of transboundary water resources.
- Promote institutional cooperation and coordination at the basin level, including the consolidation of the CIC as the coordinating and institutional implementation body.
- Establish and manage water management plans in conjunction with the meteorological and geological services of the Basin countries.
- Promote joint monitoring of shared water resources.
- Seek sources of funding for joint activities.
- Exchange experiences on adaptation measures to extreme events.
- Promote the integration of surface and groundwater.
- Develop and apply at the sub-basin and sectoral levels methodologies for the quantification of economic losses caused by the extreme events.
- Strengthen national agencies for the management of extreme events.
- Exchange risk management experiences among national, bilateral, and multilateral agencies.
- Develop regional contingency plans for urban and rural areas for floods and droughts.
- Develop and exchange experiences on research, awareness-building, and environmental education programs related to extreme events.

4.3 Water Quality Degradation

4.3.1 Presentation of the Topic

In relation to the loss of or threat to the water quality of the water bodies in the LPB, a common problem is observed, mainly due to point source and diffuse pollution of terrestrial origin, in addition to the pollution sources originating from aquatic activities linked to navigation.

4.3.2 Activities Developed

The five countries prepared a preliminary methodological guide on water quality and quantity. Between 2011 and 2015, they produced national water quality reports as a guide for monitoring, and two water quality and water monitoring campaigns were carried out in the five countries of the Basin using that guide. An inventory of pollution sources (point-source and diffuse) was prepared with estimates of the main pollutant loads in the LPB. Special emphasis is placed on this topic in the Demonstrative Pilot Projects *Hydro-environmental alert system. Floods and droughts in the confluence zone of the Paraguay and Paraná rivers and Pollution and erosion control in the Pilcomayo River Basin*, mentioned in *Chapter 4.1*.

4.3.3 Knowledge Expansion and Updating

The main threats to water quality are point-source pollution—a consequence of sewage and industrial effluent discharge and, in some specific areas, mining and oil production—and diffuse pollution, resulting from agricultural and livestock activity, in addition to the municipal solid waste that is discharged by drainage networks to the main river courses. It should be noted that water pollution by urban solid waste is a topic that, in many international water bodies, is considered critical and transboundary.

On the other hand, sewage effluents contribute a great deal of what have been called emerging pollutants, such as antibiotics, tranquilizers, and other pharmaceutical drugs that are ingested daily by the population and whose metabolites in the end are discharged to surface water bodies by sanitation networks, posing a threat to aquatic ecosystems.

Regarding pollution as result of aquatic activities, one of the main problems is biological contamination by invasive species (for example, the golden mussel).

Throughout the LPB as a whole, it can be observed in general terms that diffuse organic contamination—mainly as a consequence of agricultural/livestock activities—predominates over that of point sources. However, they have parity in the case of the Paraná sub-basin, and the predominance is inverted in the La Plata River sub-basin. This can be explained by the presence in these sub-basins of a large metropolis, like São Paulo and Buenos Aires, respectively.

The impact generated by organic matter is more relevant in the case of point sources in low flow courses, typical of the headwaters of the basin, in contrast with the large rivers, which are characterized by their high capacity of self-purification.

However, the appearance of harmful cyanobacteria algae blooms—for example, in the waters of the Uruguay River, the Uruguayan banks of the La Plata River, and the Santa Lucía River sub-basin (Uruguay)—as a consequence of nutrient inputs from agricultural/livestock activities is increasingly recurrent. The tambos, pig and chicken farmers, also represent another important source of organic matter inputs, their impacts depending on the sub-basin or area under consideration.

In terms of heavy metals, the contributions are mainly a consequence of industrial and mining activity. For example, contamination due to the presence of heavy metals in the Pilcomayo and Bermejo rivers has as its origin in the strong mining activity in the headwaters of their respective basins in Bolivian territory. It is an emblematic case considering that it is an activity that has been taking place since pre-colonial times.

Beyond the above, given the large land area of the LPB and the various anthropogenic activities and their degree of development, each sub-basin presents its own particularities in terms of loss or threat to water quality.

Paraná River

The Paraná River is characterized by its great power of dilution and capacity for self-purification. However, degradation or water quality degradation is observed in the riparian areas of urban-industrial conglomerates and in the rivers and streams of the sub-basin, such as in the areas of São Paulo, Brasilia, and Curitiba, with great demand for water and the corresponding increase in the load of contaminant discharges.

It is also observed that industrial effluents from industries linked to agricultural/ranching activities, such as livestock, sugar cane, and pig and chicken farms represent important organic matter contamination contributions, with the consequent decrease of dissolved oxygen levels in water bodies.

In the lower Paraná basin, pollution problems are observed, mainly in large urban conglomerates, such as the cities of Rosario and Santa Fe, and areas with industrial development, such as the city of Esperanza, which is characterized by the presence of tanneries that pour their effluents into the northern part of the Salado river basin, a tributary of the Paraná.

Paraguay River

Particular attention should be given to mining activity in the upper basin of the Paraguay River in Bolivia and Brazil. There are tin deposits in the form of cassiterite and acid drainage, a consequence of mining activity and its environmental liabilities. Discharges of water used in extraction and processing, as well as the erosion and dissolution of mining waste, contaminate rivers and groundwater. The information on aquifer impact is still preliminary and the information relating to surface water pollution as a result of acid drainage from open-pit mining is not entirely accurate. Hence, the importance of actions to prevent and control post-closure pollution from a mining enterprise.

On the other hand, in the Brazilian sector of this high basin, water resources are also contaminated as a result of mining activities, mainly in the state of Mato Grosso, and also from pesticides used in annual crops in the Planalto region.

Downstream, in Paraguay, the highest contaminant load comes from agricultural activity (crops and pastures) and, mainly, from domestic and industrial effluent discharges in areas close to large urban centers, such as Concepción, Asunción, and Pillar.

A high concentration of phenols was observed—indicating probable contamination from industries, including timber—in the course of the Paraguay River in Humaitá and one of its tributaries, the Apa River. Phenols are compounds highly toxic to aquatic species that cannot be degraded biologically.

In one of the main tributaries of the Paraguay River, the Bermejo River, there is a certain degree of pollution caused by oil discharge, originating in the oil wells that discharge the water used in oil exploitation—which has high salinity, high temperature, and traces of hydrocarbons—into different tributaries of the basin.

In the Pilcomayo River, which has a predominance of detritus fish species, high levels of heavy metals have been detected. At Mision La Paz (province of Salta), high concentrations of lead, arsenic, copper, mercury, zinc, and silver were found.

Uruguay River

In the upper basin of the Uruguay River, the largest sources of industrial pollution are found in the tributaries, the Peixe and Canoas rivers, which receive high pollution loads of point source and diffuse origin due to the industrial activity in the state of Santa Catarina.

Effluents from the paper, tannery, and food industries from the cities of Cacador and Videira (the Peixe River basin) and Lages (the Canoas River basin) represent an important source of contamination by heavy metals and other substances, as well as organic matter. These loads have increased due to the growth in production, the outsourcing of industrial production, and the difficulty in treating small loads, which leads to the production of diffuse loads for the basin.

Most urban-industrial effluents are discharged into river systems with little or no prior treatment, which generates inadequate environmental conditions in most of the urban rivers that drain from these cities.

In this sub-basin there is an increase in the occurrence of noxious algae blooms (cyanobacteria) resulting from eutrophication processes associated with increases in nutrient spillage. In some cases these blooms may pose a threat to drinking water sources, since conventional treatments do not remove cyanotoxins. These events of harmful algal blooms also move to the Uruguayan banks of the La Plata River.

La Plata River

More than 97 percent of the freshwater inflow to the La Plata River comes from the Paraná and Uruguay rivers, with the rest corresponding to numerous rivers and streams that dump their waters into the coastal strip.

Three sources of pollution have been identified as responsible for the pollution in the La Plata River coastal strip: sewage effluent discharge, the dumping of industrial effluents, and urban solid waste discharge. The first two are declining due to the extension of the sewage network and to greater control of industrial effluents. The presence of solid urban waste in various urban and suburban streams is a growing problem, mainly due to an increase in waste generation and a low acceptance rate into the waste collection system, in addition to the use of watercourses as a container for waste not recycled and discarded by the collectors, which are dragged, especially when it rains, through the drainage network to the surface watercourses that discharge their waters in the coastal zone of the La Plata River.

The asymmetry in urban and industrial development between the two coastal zones (Uruguay and Argentina) is reflected in the quality of water and the sediments. As an example, while on the western banks of the La Plata River there are more than 15,000 industries, on the eastern banks there are about 200. Thus, the greatest contamination of urban-industrial origin comes from the city of Buenos Aires and its suburban area, and from La Plata and Gran La Plata. The river basins of Matanza-Riachuelo and Reconquista, as well as numerous streams and channels, stand out due to their high degree of contamination.

In the case of Uruguay, the most affected are urban watercourses, the Carrasco, Miguelete, Pantanoso, Colorado, and Las Piedras streams, and many of their tributaries, as well as the Montevideo Bay and the Santa Lucia River sub-basin, which is the source of potable water for the city of Montevideo.

In both countries, the rivers and streams mentioned have nearly permanent low levels of oxygen (levels of hypoxia or anoxia). These low levels of oxygen generate situations of anaerobiosis, with the consequent emanation of unpleasant odors and environmentally degraded areas.

As in other transition systems, there is a turbid or "maximum turbidity" zone of water where there is interaction between the freshwater of the La Plata River and the salt water of the Atlantic Ocean, where sediments accumulate (many of them contaminated, for example, with heavy metals and persistent organic compounds) and solid waste from coastal sources in the metropolitan area of Buenos Aires and the La Plata Basin. This is caused by two simultaneous processes: (i) some natural substances (organic and inorganic) carried by the freshwater of the La Plata River (either dissolved or adsorbed by the suspended material) that condense and precipitate when salinity suddenly increases, and (ii) salt water from the sea enters deeply because of its greater density and weight and acts as a wedge, forcing the light material seated in the bottom to enter again in suspension, increasing the bioavailability of contaminants "trapped" in the sediments.

Since the "maximum turbidity" zone is an area of high biological activity, there is a danger that, if the observed levels continue to increase, the accumulated contaminants may enter the food chain with harmful consequences. In this area, several species of demersal and pelagic fish group together to feed, spawn, and develop in their first stages of life.

Finally, it is important to consider that the problems of coastal pollution, except at the height of the maximum turbidity zone, are not reflected in the main body of the La Plata River. Therefore, the impact of urbanized coastal areas on the water quality and sedimentation is generally restricted to a transverse section not exceeding two km from the coast. This is explained by the type of circulation in the La Plata River, wherein three longitudinal corridors converge in the main axis of the river (mainly in the interior and middle of the La Plata River), which prevents, on average, mixture and transverse diffusion.

Estimate of Contaminant Loads

The main source considered when estimating point source pollutant loads was that of domestic or cloacal origin. It was assumed that effluents discharged into the sewage system receive at least one primary treatment. The existence of plants with secondary treatment was not considered since, if they existed, these plants would treat a very small portion of the effluents, so that in the LPB, their impacts would be insignificant.

On the other hand, it was considered that inputs from industrial activity were not relevant for the determination of pollutant loads since, in principle, industries should comply with the regulations established by each of the five countries. However, the detection of substances, such as the phenols mentioned above, should not be overlooked. With regard to mining activity, no information was available to estimate the point source contaminants resulting from this activity.

Furthermore, the importance of including agricultural/ranching enterprises such as pig farms, livestock breeding, etc., was highlighted, and were treated as contributors to the nutrients of animal origin based on the number of cattle.

The applied methodology presents constraints, and it is a first approximation with respect to the quantification of point source and diffuse contaminant contributions. In addition, it was applied considering the available information, so the results have an important degree of uncertainty.

Estimation of point source and diffuse pollutant loads (nutrients)

Quantitatively, in relation to estimated diffuse discharges in the sub-basins of the Paraná and Paraguay rivers, the type of soil cultivation is significant for Nitrogen (N) and Phosphorus (P) parameters, with the highest levels for these sub-basins in Brazil and Argentina and, to a lesser extent, Paraguay (at a scale of 700,000 tons/year for Brazil, 200,000/year for Argentina, and 20,000/year for Paraguay in terms of nitrogen in the Paraná river basin.

The applied methodology considers the contributions made by animals from urine and manure. As a reference, the information corresponding to the national agricultural censuses was considered, indicating the number of heads of cattle by department/municipality. The contributions of three parameters (Biological Oxygen Demand—5 days of reaction—BOD5, Nitrogen, and Phosphorus) are considered for the different types of livestock.

In the case of cattle, their contribution is significant in the sub-basins of the Paraná and Uruguay rivers and, to a lesser extent, in the La Plata River, with ranges between 670 and 1,175 tons/day contributing to the BOD5. With regard to sheep, the sub-basins that receive the greatest organic load contributions are the Uruguay River and the Pilcomayo River. Regarding goats, the Pilcomayo sub-basin received the greatest contribution, followed by the Bermejo River basin. Finally, in the case of pigs, the largest significant contributions are found in the sub-basin of the Pilcomayo River, followed by the Paraná River and, to a lesser extent, the Uruguay River.

In relation to domestic inputs, the contributions to the Paraná sub-basin in relation to the other sub- basins is significant for the three parameters (BOD5, P, and N), with three different orders in the contribution scale for the BOD5, and two orders for the remaining parameters. Domestic contributions continue to be important in the sub-basin of the La Plata River.

4.3.4 Legal and Institutional Considerations

This issue is addressed in all of the national legislations with varying degrees of intensity, so that there is a broad national and regional umbrella constituted by several treaties—some that include all five countries and others with just some of them—that support the adoption of a harmonized framework to regulate this CTI.

There is a methodology guide approved in 1991 by the five countries and a further update is in process. Argentina and Uruguay have carried out joint monitoring in the common area of the La Plata River within the framework of the FREPLATA project; some qualitative objectives were agreed upon for that area. In addition, Argentina, Bolivia, and Paraguay carry out joint monitoring in the Pilcomayo river basin, having defined reference values for metals between the three countries, given the priority of this problem for the sub-basin.

There is no coordination between central and local governments, nor municipalities that have jurisdiction within their territory. Institutions are weak and there are insufficient human resources.

The contamination of the Basin's waters constitutes a potential risk to human health and biodiversity.

4.3.5 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes

- Inadequate use of agrochemicals in agricultural/livestock and agro-industrial activities.
- Inadequate wastewater treatment (domestic and industrial).
- Discharge of heavy metals resulting from mining activity (Pilcomayo).
- Inadequate management of hazardous substances.
- Nutrient contribution to water bodies.
- Inadequate disposal of solid waste in flood valleys.
- Inadequate waste management in cross-border transport.

Political-Institutional Causes

- Lack of vision and integrated management policy in the basin.
- Heterogeneity of water quality norms and standards.
- Lack of development policies that encourage the use of clean technologies and the minimization of waste.
- Different degrees of development of regulations on water quality management, and deficiencies in their application.
- Different degrees of consideration of water quality in state policies.
- Difficulties integrating environmental and water resource agencies.

Economic-Managerial Causes

- Poor monitoring and control.
- Lack of investment in sewage and industrial effluent treatment plants, and poor maintenance of existing treatment plants.
- Insufficient resources for adequate water quality management.
- Lack of resources for the mitigation of mining pollution (Pilcomayo).
- Inadequate management of agricultural/livestock activity.
- Lack of quantification and valuation of environmental liabilities.
- Mining activity without environmental adaptation.
- Lack of non-structural measures for erosion control.
- Lack of economic valuation of water as a strategic natural resource.
- Lack of training of environmental managers.

Social and Cultural Causes

- Poverty and its particular consequence on the capacity to sustainably manage water resources.
- Deficiency in compliance with existing regulations.
- Deficiency in environmental and water education.
- Lack of awareness about the valuation of environmental goods and services.

4.3.6 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Harmonize regulations and develop consensual criteria for water quality assessment and monitoring.
- Seek sources of funding for the construction and operation of domestic and industrial wastewater treatment plants.
- Seek financing sources for the implementation of best practices for the monitoring and management of environmental quality in mining enterprises.
- Promote the implementation of sustainable agricultural practices and the rational use of agrochemicals.
- Exchange experiences on disposal and recycling of solid urban waste.
- Exchange experiences on waste disposal in cross-border transport.
- Strengthen agencies responsible for water quality management.
- Develop joint programs for monitoring water quality and quantity among countries.
- Develop training programs for environmental managers.
- Develop environmental education and training programs.
- Promote citizen participation in the prevention of domestic and urban pollution.
- Develop plans for valuation and implementation of environmental services.

4.4 Sedimentation of Water Bodies and Courses

4.4.1 Presentation of the Topic

The sedimentation process alters and compromises the structure and functioning of ecosystems, and thus of the environmental goods and functions they provide. In the La Plata Basin, as a result of the large-scale development of agriculture and agro industries, about half of the natural vegetation has been changed to fields. Deforestation caused by agriculture has reduced the ability of the land to capture and store carbon and water and to anchor the soils, leading to increases in erosion rates in some sites and sedimentation in others, causing changes in water availability.

Large-scale farming practices, due to the intensification of soybean production since the early 1990s and the development of one of the world's largest cattle breeding industries, have also led to compaction of the soil, reduction in water infiltration, increased surface runoff, and sedimentation problems.

The high production of fine sediments in the upper basin is the characteristic feature of the Bermejo River, which contributes approximately 100 million tons of sediment per year to the Paraguay-Paraná Delta and La Plata River systems. The fine sediments are transported to and deposited in areas with very calm waters, from the Lower Paraná to the La Plata River.

The sediment production in the upper basin of the Pilcomayo River is somewhat larger than that of the Bermejo River. With mean annual flow rates of 210 m^3/s and an annual contribution of sediments of the same magnitude as the Bermejo, it does not have enough energy to transport its solid cargo to the Paraguay River, so it deposits the sediments in the wetlands of the Gran Chaco plain in the vicinity of the border between Argentina and Paraguay. This solid contribution of 110 million tons annually causes morphological changes in the channels, in the bodies of water, and in the annual altimetry of the floodplain.

4.4.2 Environmental, Social, and Economic Impacts

The increase in the predicted sediment yield implies an increased risk of morphological changes in the lower Bermejo riverbed, an increase in water clarification costs in potable water plants throughout the river way to the La Plata River, and an increase in dredging volumes in transverse channels of the Paraná River, channels of the La Plata River, and in ports and port accesses.

4.4.3 Activities Developed

As inputs for updating the diagnostic, there are national reports on existing information on land use and degradation, projects, cartography, and publications; an integrated document with identification of critical degraded areas; maps of current land use and soil types, as well as an estimate map of sediment production; a diagnostic on land degradation in the Selva Misionera Paranaense; and an inventory of best practices and technologies for the use and sustainable management of soils. This topic is given special emphasis in the *Demonstrative Pilot Project Pollution and erosion control in the Pilcomayo River Basin*, mentioned in *Chapter 3.1.*

4.4.4 Knowledge Expansion and Updating

Among the main results of the completed work, the following stand out:

- The highest specific production of sediment is verified in the Andean sector of the Basin. The most notable sources of sediment are the high basins of the Bermejo and Pilcomayo rivers. In the rest of the Basin, erosion and sedimentation problems resulting from agricultural/livestock activities also deserve special consideration because they cause productivity losses and deterioration of the porous structure and space.

- The Bermejo River discharges an average annual flow of 446 m³/s, representing 2.5 percent of the section of the Paraná River in Corrientes. In contrast, the contribution of solid flow to the Paraguay-Paraná Delta system of the Paraná-La Plata River is very important, since the 100 million tons/year of suspended sediment constitutes about 75 percent of the total present in the Paraná River. In recent decades this percentage was increasing due to the construction of dams in Brazil in the upper basin of the Paraná River, which retain the sediments.

- The Pilcomayo River has an average annual flow of 203 m³/s and an annual sediment contribution of the same magnitude as the Bermejo, but it lacks sufficient energy to transport its solid cargo to the Paraguay River.

The Iruya River basin generates a large proportion of sediments which are then deposited into the Paraná and La Plata River.

- The average annual concentration of sediments in the LPB (150 mg/l) is moderate for a river in a basin in a tropical zone, but it is a decisive parameter for the potabilization of river water and in the sedimentation of navigation channels with very low speeds (below 30 cm/s).

- The average annual concentration of 500 mg/l has been recorded in the Paraguay River tributaries in the Pantanal region, corresponding to an average erosion rate of 146 t/km²/year in watersheds with an average area of 17,000 km².

- In southwestern Brazil near the border with Argentina, which covers the middle and lower reaches of the left bank tributaries of the Paraná River from the Paranápanema River downstream and a substantial part of the Uruguay river basin, the average annual concentration is around 100 mg/l and the specific production of sediments is around 95 t/km²/year.

Sub-basin analysis

Based on an analysis carried out on the seven sub-basins to identify the principal critical issues related to sediment production and transport, it was concluded that the following sub-basins require more attention:

Upper Paraguay:

The Parapetí River begins in the eastern range of the sub-Andean Sierras and forms an alluvial fan of several dozens of square kilometers in Bolivia and Paraguay. Its current permanent channel empties into the Izozog swamps, but during the rainy season there is an important transfer which forms the Timané River, which runs eastward and flows into the Paraguay River. In exceptionally wet years, the swamps overflow and feed the springs of the San Julián River, which, downstream, is transformed into the São Paulo River to finally end up in the Iténez River on the border with Brazil. Under the current dynamics, in the Parapí riverbed one can observe fluvial sedimentation processes, which occur due to the change in slope of the river course. In the rainy season the river carries sedimentary material by dragging and suspension. The coarser materials are deposited near the exit of the sub-Andean mountain range and the thinner materials are deposited as they travel along the plain, until arriving in the Izozog swamps, where very fine material accumulates.

Lower Paraguay:

The sediment production of the upper Pilcomayo River Basin is somewhat greater than that of the Bermejo River, but this load is deposited in the swamps of its alluvial cone in the Chaco plain and consequently does not reach the Paraguay-Paraná River. Conflicting transboundary river processes linked to water resources have been identified: (i) use of water in an area with water deficit, (ii) the changing morphology of the channel due to erosion and sediment transport, (iii) fishery and fish fauna, particularly the migration of shad from the lower basin to the upper basin, and (iv) the risk of contamination due to mining in the upper basin, from environmental liabilities and current activities. The total sedimentation of the channel to levels higher than the floodplain is a morphological problem that affects the management of the basin. Consequently, the river flows over the plateau forming new swamps annually.

The contribution of silt and clay from the Bermejo River constitutes 90 percent of the fine sediment transported by the Paraná River, which is deposited predominantly in the La Plata River.

The area with the greatest fluviomorphological activity is the upper La Plata River, adjacent to the Delta, where the annual amount of silt and clays dredged in the navigation channels is equivalent to 23 percent of the total contribution of the Bermejo River. Management measures in the upper Bermejo basin that substantially affect the amount of sediment generated for the entire basin have been identified. The areas that produce the most sediment in the upper Bermejo basin are not significantly affected by current anthropogenic actions, but specific sediment production problems in the basin could be resolved through structural and nonstructural measures.

4.4.5 Influence of Climate Variability and Change

Changes in temperature and precipitation will manifest in variations in sediment production and transport rates in the Bermejo and Pilcomayo river basins. There is a tendency to maintain current rates for the next 30 years, and a decrease for the period from 2041 to 2070 in both basins, which is of greater importance in the Pilcomayo River basin.

On the other hand, erosion and sedimentation problems resulting from agricultural and livestock activity cause an increase in runoff or flooding—in addition to productivity loss—depending on the slope of the land and whether or not the soil transported and transformed into sediment reaches the surface waters, producing contamination with organic matter, nutrients, and agrochemicals.

4.4.6 Legal and Institutional Considerations

There is little regard for the joint management of land and water use. However, there are already accepted international regulations, such as the Conventions on Biodiversity, Desertification, and Climate Change ratified by all countries at the 1992 Rio Earth Summit. The Environmental Handbook for the Gran Chaco Americano, considering soil resources, biodiversity, and water, among other aspects, was also validated through various workshops. This environmental framework could be applicable to other areas of the Basin. Internal legislation has been created in some countries, which should be taken as a model for harmonization among them; and land and water management plans, such as those in Uruguay, have been implemented, which could be taken as a guide for their application in the remaining countries of the Basin.

4.4.7 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Improper use and management of soils (expanding agricultural activity, use of marginal soils, removal of natural pastures, overgrazing). • Excessive expansion of the agricultural frontier. • Soil compaction. • Deforestation of coastal and native forests (Uruguay River). • Inadequate construction and maintenance of infrastructure. • Erosion generated by mining activity (Pilcomayo and Bermejo rivers). • Coastal erosion by fluctuation marked by the operation of large dams.	• Weakness in management and administration. • Inadequate implementation and insufficient economic resources for monitoring, control, and mitigation. • Lack of application and supplementation of territorial planning, especially at the basin level. • Extensive livestock activity and monoculture agriculture, mainly soybeans • Lack of incentives and widespread training to apply sustainable farming techniques. • Institutional weaknesses to ensure compliance with environmental legislation.

Political-Institutional Causes	Social and Cultural Causes
• Technical-economic weaknesses of state agencies. • Insufficient institutional coordination: poor application and inadequate regional harmonization of standards for the protection and use of natural resources. • Institutional decisions based on short-term profitability and not on sustainable land use. • Bureaucracy and centralism.	• Limited political and citizen awareness. • "Chaqueos" or fires. • Excessive profit for landowners (producers). Short-term vision in leases. • Perception that natural resources are inexhaustible.

4.4.8 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Promote the development and harmonization of standards for the protection and use of natural resources.
- Develop plans for territorial planning and agro-ecological zoning.
- Strengthen institutional capacities for land use management.
- Strengthen institutional coordination at national and regional levels.
- Develop programs for monitoring, research, and applied studies on erosion and sediment generation and transport.
- Implement soil recovery and erosion control programs in priority areas.
- Develop comprehensive management plans for priority basins.
- Develop programs for the preservation and restoration of forests and riparian vegetation.
- Develop sustainable agriculture programs.
- Develop training and extension programs in soil management and conservation techniques.

The turbid waters of the La Plata River. On the left, the Paraná Delta.

4.5 Alteration and Loss of Biodiversity

4.5.1 Presentation of the Topic

The LPB is a region of extraordinary ecological value. Its wide climatic and geological variety, coupled with the great availability of water in much of its territory has allowed for a great diversity of ecosystems and species. However, there is great concern about the threat to ecosystem integrity as a result of the advancement of human activities.

4.5.2 Activities Developed

Contributing to the deepening of knowledge about this subject, the joint work of the five countries provides: an inventory of protected areas and wetlands of the Basin—by country and all together—following a common methodology; an evaluation of natural habitat loss, including the reduction of the Selva Misionera Paranaense (SMP); an identification of the impacts and control measures on exotic species living in the countries; an integration document containing guidelines for a biodiversity conservation strategy, a proposal for ecological corridors and wetland conservation and management, and replicas of the Cultivating Good Water program currently being implemented in micro-watersheds near the influence areas of dams with binational hydroelectric centers (Itaipú, Yacyretá, and Salto Grande). This topic is given special emphasis in the *Demonstrative Pilot Project Regulated conservation of biodiversity in the Paraná River* mentioned in *Chapter 4.1.*

Tea cultivation in the Selva Misionera Paranaense region.

4.5.3 Knowledge Expansion and Updating

The work carried out has allowed for the identification of the following problems:

- Habitat loss/alteration, fragmentation, and loss of connectivity, which may be aggravated by the effects of climate change on critical or more vulnerable areas by rising water levels.

- Loss of integrity (goods and services) due to environmental risk, with impacts on biodiversity throughout the LPB, especially in the Pantanal and in the SMP.

- The low percentage of protected areas, including those with some type of protection, endangers the environmental goods and services that ecosystems provide.

- Dams have affected some floodplains and interrupted migratory corridors.

- The bivalve molluscs of the genus *Corbicula* and the golden mussel *Limnoperna fortunei* are some of the species that demand the most attention for their remarkable distribution throughout the Basin and their proven impacts on the native fauna, the ecosystem, infrastructure works (such as water intakes), and other human activities.

Selva Misionera Paranaense (SMP)

The topography of the SMP comprises relatively flat areas with deep soils near the Paraná and other main rivers, with altitudes between 150 and 250 masl, to a relatively flat plateau with altitudes between 550 and 800 masl. The areas that are between the main rivers and plateau, with altitudes between 300 and 600 masl, have relatively steep slopes and are very exposed to soil erosion when forest cover is removed.

Their soils are relatively rich in nutrients. The red soils, which are deep near the rivers, become less deep and rockier at higher altitudes. There is a great difference in soil types, which vary in texture, chemical composition, and acidity.

The ecoregion has a subtropical climate (with an average temperature of 16-22°C). In the southern part, frost is common (June-August), especially in the highlands. Precipitation in the region ranges from 1,000 to 2,200 mm per year, generally with less precipitation in the north than in the south.

Rainfall is not uniformly distributed throughout the year, and some areas have up to five dry months. Increased rainfall during El Niño events produces large inter-annual variations. Precipitation and high seasonality of temperature and light determine a seasonal pattern of primary forest productivity and an associated seasonality in the availability of food for folivore, frugivore, and insectivore animal species.

More than 3,000 species of vascular plants, numerous mammals, a rich diversity of amphibians, reptiles, invertebrates, and marsupials have been registered in the SMP, as well as more than

550 species of birds, with a large concentration of endemic species. The predominant vegetation is the semi-deciduous subtropical forest. Variations in the local environment and soil type allow for the existence of different plant communities, gallery forests, bamboo forests, palmetto forests (*Euterpe edulis*), and Paraná pine forests (*Araucaria angustifolia*). Most of the forests have been exploited to obtain wood; some sec-

ondary forests are recovering from deforestation. Thus, forest fragments are composed of primary and secondary forests at different stages of succession.

The main issues associated with land degradation also affect the populations of the three countries that share this ecosystem: loss of soils as a result of deforestation and conversion to agricultural or livestock land, alteration of biodiversity, water quality loss, and the socio-economic conflicts associated with these processes. Add to this climate variability and change and the consequent alteration of the rainfall system, which can increase water erosion, resulting in a greater impoverishment of the soils, an increase in sedimentation in the river beds (with the water quality degradation), and desertification.

These processes of land degradation in the SMP have been addressed by different countries through different action and response strategies. Conservation measures for SMP sections focus mainly on the implementation of a network of conservation areas.

Analysis by sub-basin

Upper Paraguay:

The Pantanal is located in this sub-basin, one of the most transcendent wetlands for the Basin's aquatic biodiversity. This sub-basin has suffered a considerable loss of terrestrial ecosystems (40 percent) and presents an environmental risk of loss of integrity. Sixty-one protected areas covering 12.6 percent of its area have been created. There are six Ramsar sites (46,500 km²), two MAB Biosphere Reserves (326,492 km²), and 19 important bird areas (IBA). It is the least populated sub-basin, with 2.4 million people.

Lower Paraguay:

This sub-basin has suffered a 15 percent loss of terrestrial ecosystems. Three important water reservoirs have been planned in the sources of the Bermejo River. It is one of the least-populated sub-basins (2.8 million inhabitants). Sixty-six protected areas have been set up covering 7.4 percent of its area, representing a low level of protection since it does not meet the 10 percent target set by the CBD by 2010. The designation of nine Ramsar sites (11,384 km²), six Biosphere Reserves (21,097 km²), and 94 important bird areas (IBA) is a clear indication of the high international priority received by this sub-basin.

Upper Paraná:

This sub-basin has suffered a very high loss of terrestrial ecosystems (75 percent). There are no Ramsar sites, which indicates the absence of major wetlands of international relevance. The upper Paraná and its tributaries have undergone major modifications to control flooding and hydroelectric power generation (43 large reservoirs), which affect the respective floodplains. It is the most populated sub-basin, with 61.8 million inhabitants, with a high population density (6.9 inhabitants/km²) and six important cities, including the capital of Brazil, Brasilia. There are many protected areas (313), but they cover only 7.7 percent of the sub-basin area. The Biosphere Reserve (MAB-Unesco), Mbaracayú Forest (2,800 km²), is partly included within this sub-basin. There are 32 IBA within its limits.

Lower Paraná:

There are several important wetlands, such as the Ramsar Lagoons and Iberá

Wetlands, the Chaco Wetlands, Jaaukanigás, Otamendi Reserve, and the lower Paraná floodplain, Paraná Delta (Argentina) in this sub-basin. It has suffered a considerable loss of terrestrial ecosystems (40 percent) and presents environmental risk due to loss of integrity.

Three reservoirs associated with dams have been built, one in the Juramento River (Cabra Corral, Salta, Argentina) and two in Paraná: the Yacyretá and Itaipú dams. Other works that impact the ecosystem are the Rosario-Victoria road connection, the real estate expansion over wetlands, and their loss to the construction of hills for the use of agriculture and cattle breeding. The population amounts to 9.5 million (1.6 inhabitants/km²), with seven major cities. Eighty-two protected areas covering only 5.6 percent of the area have been created, a level of protection well below the CBD's 10 percent target for 2010. The designation of five Ramsar sites (10,950 km²), two Biosphere reserves (10,619 km²), and 78 IBAs show that it is a high international priority.

Upper Uruguay:

There are no noteworthy wetlands. This sub-basin has suffered a considerable loss of terrestrial ecosystems (60 percent). Three large reservoirs associated with dams with hydroelectric power plants have been built on the Uruguay River (Machadinho, Itá, and Passo Fundo) and there are plans for the construction of three new ones, which will increase the respective alteration of the fluvial environments. It is a sub-basin with a relatively small population, with 1.7 million inhabitants and without any large cities. Twenty-nine protected areas have been created covering only 4.4 percent of the sub-basin area, a low level of protection with regard to the 10 percent target imposed by the CBD. While there are important wetlands, such as the Moconá Falls, there are no Ramsar sites. There is a Biosphere Reserve, Yabotí (2,366 km²), and 12 IBAs have been identified.

Lower Uruguay:

The most important wetlands are: Uruguay River plains and islands, Farrapos Estuary Ramsar site, Villa Soriano, and Palmar de Yatay Ramsar Site. The sub-basin has suffered a significant loss of terrestrial ecosystems (60 percent). There are four large reservoirs associated with dams with hydroelectric power stations, one on the Uruguay River (Salto Grande) and three on the Negro River (Palmar, Rincón del Bonete, and Baygorria), with their respective alterations of river environments. It is a sub-basin with an intermediate population level, with 3.8 million inhabitants and a population density of 1.6 hab/km²), with three important cities. Thirty-nine protected areas covering only 1.8 percent of its area have been created, well below the CBD’s 10 percent target for 2010. Three Ramsar sites (849 km²), a Biosphere Reserve (997 km²), and 20 IBAs have been identified.

La Plata River:

The important wetlands are Samborombón Bay and the Santa Lucía swamps. This sub-basin has suffered a considerable loss of terrestrial ecosystems (35 percent), concentrated in the coastal strip of the La Plata River, mainly in the metropolitan areas associated with the cities of Buenos Aires and Montevideo. It is the second most populated sub-basin, with 24.9 million inhabitants, five major cities, including the capitals of Argentina and Uruguay—Buenos Aires and Montevideo, respectively. Eleven protected areas covering only 0.8 percent of the sub-basin area have been created, the lowest of the entire LPB and well below the CBD's 10 percent target for 2010 and even further away from the 2011 to 2020 Aichi target of 17 percent. Two Ramsar sites (Costanera Ecological Reserve and Samborombón Bay, 4,883 km²) and two MAB Biosphere Reserves (1,289 km²) have been designated on the Argentine banks, and nine IBAs have been identified.

4.5.4 Influence of Climate Variability and Change

Loss or alteration of habitats and fragmentation and loss of connectivity may be aggravated by the effects of climate change in critical areas or those more vulnerable to rising water levels.

4.5.5 Legal and Institutional Considerations

Biodiversity issues still have little presence on the political agenda. The LPB countries have signed the Convention on Biological Diversity, which would make it easier to legislate or implement lines of action by having a common standard. This legislative text should be the basis for regional regulation. Although there has been progress in recent decades, the systematic implementation of international commitments is very heterogeneous or disjointed. The problem should be dealt with in an integrated manner at the regional level, which would allow them to strengthen measures, give them solidity and territorial support, and promote their sustainability over time, so as not to encourage the development of specific, isolated measures without continuity.

The Moconá Falls in the Uruguay River, Argentine-Brazilian border.

4.5.6 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Entry of invasive species (golden mussel, among others) and displacement of native species. • Loss of ecological flows for wetland maintenance. • Loss of physicochemical water quality. • Alteration of peak flows. • Interruption of the migratory flow of fish. • Replacement of natural ecosystems by productive activities. • Alteration of water dynamics by infrastructure works. • Illegal hunting, fishing, and extraction of flora. • Illegal trafficking of animals and plants (smuggling).	• Lack of financial and material resources for studies and monitoring. • Lack of strategic planning for biodiversity conservation. • Lack of integration of the concept of biodiversity protection into integrated watershed management. • Coordination deficiencies in research programs. • Lack of incentives for the care and conservation of natural systems. • Absence of regional environmental assessments.

Political-Institutional Causes	Social and Cultural Causes
• Auditing deficiencies and lack of coordinated institutional decisions. • Technical-economic weakness of state agencies. • Lack of protocols for the control of invasive species. • Lack of training, awareness-raising, and human resources training programs. • Little presence of biodiversity on the political agenda. • Deficiencies and heterogeneity of country regulations.	• Lack of social awareness about the value of water resources and biodiversity. • Irrational exploitation of the fishing resource. • Lack of willingness in civil society to seek collective solutions.

4.5.7 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

Special Recommendation

Proposal for ecological/fluvial corridors: Landscapes along riverbeds act as naturally interconnected ecological units. The three main rivers of the LPB (Paraná, Paraguay, and Uruguay) establish a continuous strip of landscape organization with a vertical axis (north-south), cross-cutting different biogeographic patterns (biodiversity, climate, temperature, precipitation, etc.) depending on the latitude.

Thus, the valley of these large rivers in the north-south direction, associated with tributaries on the horizontal (east-west) axis, can serve as a linear element connecting landscape fragments and natural areas with some kind of protection (parks, protected areas, biosphere reserves, Ramsar sites).

This type of strategy would serve to generate large-scale spatial connectors, with the valleys of the Paraná, Paraguay, and Uruguay rivers playing a central role in a priority conservation network, which would include lateral extensions formed by tributaries to be selected and other areas in current protection status, etc.

Even if it is not possible to construct a continuous corridor in the river valley because of the difficulty of reconciling with areas already occupied by humans, a conservation network formed by the restoration of landscapes can be provided, and currently spatially fragmented species have a greater probability of displacement between conserved matrices. **Figure 4.5.7.1** presents an outline of connection corridors through the large rivers and tributaries of the LPB associated with the protected areas close to them.

Recommendations generales

- Strengthen and harmonize the regional legal framework for the protection of aquatic biodiversity.
- Develop and apply protocols for the control and management of invasive species.
- Establish mechanisms for cooperation among countries in the field of biodiversity conservation.
- Develop joint bioprospecting programs.
- Develop river and coastal ecological corridors and other forms of participatory conservation.
- Promote the development of transboundary protected areas.
- Exchange experiences on methodologies for the determination of ecological flows.
- Integrate information, research, and monitoring systems at the basin level.
- Conduct regional environmental impact assessments (EIAs).
- Promote the adoption of regional minimum budgets for biodiversity conservation.
- Develop awareness and training programs on water resources and biodiversity.

Figure 4.5.7.1

Ecological corridor strategy on a large spatial scale in La Plata Basin

Ecological corridors strategy

- Great rivers (main corridor)
- Affluents (secondary corridors)
- Protected areas

4.6 Unsustainable Use of Fishery Resources

4.6.1 Presentation of the Topic

The unsustainable use of fishery resources alters the structure and functioning of aquatic communities, and can compromise them.

4.6.2 Activities Developed

Contributing to the deepening of knowledge about this subject, the joint work of the five countries provides: an inventory of fish, habitats, and protected areas, especially those that include aquatic ecosystems; a description of some of the major fisheries (species, gear, number of fishers, catch volumes), including commercial and subsistence fisheries and sport-recreational fisheries as the foundation for tourism. However, there are many information gaps that need to be filled in. This topic is given special emphasis in the Demonstrative Pilot Project *Regulated conservation of biodiversity in the Paraná River* mentioned in *Chapter 4.1*.

4.6.3 Knowledge Expansion and Updating

The main results of the work carried out indicate:

- As noted in *Chapter 1.3.7*, 40 percent (367) of fish species have socio-economic relevance as a resource for commercial, artisanal, subsistence, recreational, and aquaculture fisheries. The number of relevant species presents an east-west gradient, suggesting that the use and valuation of the native fauna is more relevant in the sub-basins of the Paraguay River (upper and lower) and the lower Paraná, which also have a high fishing pressure.
- The predominant native fauna, belonging to the orders *Characiformes* and *Siluriformes*, present adaptations that optimize reproductive success through the use of separate areas for the spawning, breeding, and feeding, among which they move by active migration (adults) and by drifting in the current (eggs and larvae), giving them, consequently, a transboundary character. Most of the whitefish species of the fisheries belong to these two orders.
- About 53 percent (480) of fish species are considered to be endemic in any of the seven sub-basins, indicating that the conservation of fish biodiversity requires differentiated efforts. Endemism is highest in the upper Paraná, it is intermediate in the sub-basins on the western edges of the Basin, and lowest in the lower Uruguay and the La Plata River.
- Thirteen species of exotic fish were registered in the La Plata Basin, several of them with invasive capacity. The most widespread exotic species are: Asian carp (*Cyprinus carpio*) (present in five sub-basins), herbivorous carp (*Ctenopharyngodon idella*), and bighead carp (*Hypophthalmichthys nobilis*), registered in four of the seven sub-basins. Also important are tilapia (*Tilapia rendalli*), Nile tilapia (*Oreochromis niloticus*), rainbow trout (*Oncorhynchus mykiss*), and African catfish (*Clarias gariepinus*). The greatest diversity of exotic species was recorded in the sub-basins of the Paraná River (eight species in the upper Paraná, seven species in the lower) and La Plata River (eight species). In the upper Uruguay there is no record of exotic species, while there are intermediate levels in the remaining sub-basins.

- In Argentina, about 90 percent of inland fisheries are in the LPB, where they work with 367 fish species of commercial and/or sport value, the most important of which are tarpon (*Prochilodus lineatus*), dorado (*Salminus brasiliensis*), surubí (*Pseudoplatystoma*), gilded catfish (*Zungaro zungaro*), pacú (*Piaractus mesopotamicus*), patí (*Luciopimelodus pati*), and boga (*Leporinus obtuidens*). Commercial artisanal fisheries employ more than 10,000 people, while subsistence fisheries are important for the food security of vulnerable sectors of the local population. The most important commercial species are tarpon, of which some 14,000 tons per year are exported. Recreation-sport fisheries are also important throughout the Basin, with more than 70,000 annual licenses, and bait fishing is carried out by the inhabitants of the riverbanks. Fish farming is an incipient activity, but it is increasing, especially in Formosa, Misiones, and Corrientes, with a native species, the pacú. The closed seasons in the border areas between Paraguay and Argentina are fixed through an agreement signed between both countries.

- In Bolivia, subsistence fishing is a traditional activity and constitutes an important source of protein for riparian populations –mainly indigenous peoples– along the Bolivian section of the Pilcomayo River, where tarpon fishing predominates. This is a fundamental activity in this river, and it is one of the most important activities in Villa Montes between May and September. Tarpon, dorado, surubí, and pacú are the main fish exploited. In the lower basin there is recreational fishing of dorado, surubí, and catfish (*Pimelodus*).

- In all of Brazil, continental fisheries account for about 24.8 percent of the country's fish production. Subsistence fishing is traditional in the Pantanal and constitutes an important source of protein for riparian populations. Recreational fishing, with more than 57,000 licenses, represents 75 percent of all fish officially shipped in the State of Mato Grosso do Sul. The capture and marketing of live bait is an important related activity. Aquaculture fish production is 73,200 tons per year, with the state of Paraná the largest producer.

- In Paraguay, the number of artisanal fishers is 7,877 (2015). The fisheries are very similar to those in Argentina and are mainly located in the Paraguay River. In the Chaco Paraguayo, the aboriginal communities carry out subsistence fishing, mainly capturing tarpon in the middle basin of the Pilcomayo River. The most coveted commercial white species is the surubí, which is followed by gilded catfish, dorado, and pacú. During the annual closed season, which is shared with Argentina in the border sections of the Paraguay and Paraná rivers (from the beginning of November until approximately December 20), the fishermen receive a subsidy from their respective governments.

- In Uruguay, artisanal fishing is carried out mainly in the Uruguay, Negro, and La Plata rivers. In the Uruguay River there are 250 to 300 boats with around 500 fishermen. Captures are estimated at 4,500 tons annually, bringing in mainly tarpon, patí, boga, dorado, various species of catfish (*Pimelodus albicans, Pimelodus maculatus*), manduvá (*Ageneiosus brevifilis*), armado (*Pectoras granulosus*), manduví (*Ageneiosus valenciennesi*), tiger barb (*Gnidens barbus*), pejerrey (*Odontesthes bonariensis*), tiger fish (*Hoplias malabaricus*), and suckermouth catfish (*Hy-*

postomus). Tarpon accounts for more than 70 percent of catches, and is also the main freshwater species exported, reaching around 4,300 tons in 2008.

- In some areas, fish stocks have been retracted because of high fishing pressure.
- There is a high risk of an increase in invasive alien species (IAS), by escape from their farming centers.
- The low level of protection and the loss of terrestrial habitats impact fish biodiversity.

Analysis Diagnostic by sub-basin

Las subcuencas que requieren mayor atención son:

Upper Paraguay:

Exotic fish farming is underdeveloped.

Upper Paraná:

Nine species of threatened fish inhabit this sub-basin, and there is a high degree of invasion of exotic species. The cultivation of exotic fish is highly developed.

Lower Paraná:

In this sub-basin there are 13 native threatened species and a high degree of invasion, with seven species of invasive exotic fish; the herbivorous carp, Asian carp, rainbow trout, and tilapia present the greatest risk. The cultivation of exotic fish is highly developed.

Upper Uruguay:

No significant exotic fish have been recorded.

Lower Uruguay:

Six species of threatened fish and five species of exotic fish have been recorded.

La Plata River:

This sub-basin presents a rich population of native fish, with five threatened species. The degree of invasion detected was classified as high, with eight species of invasive exotic fish, the herbivorous carp and Asian carp presenting the greatest risk.

4.6.4 Influence of Climate Variability and Change

High vulnerability to climate change is anticipated for riparian habitats in the major fishing communities.

4.6.5 Legal and Institutional Considerations

There are inconsistencies in some regulations related to fishing in different countries regarding the same rivers (closed season dates, prohibited species for fishing, different criteria for net use, among other things). There is a lack of harmonization in the regulations (for example, the closed season on the Paraguay is different in Brazil and Argentina with respect to the same river).

4.6.6 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Overexploitation of target species. • Interruption of target species migrations from fisheries by civil works in general. • Disruption and loss of habitats due to alterations in the hydraulic system. • Contamination. • Improper handling of aquaculture tanks (nets and excavated).	• Lack of technical and political coherence in the design and implementation of fishery policies. • Lack of fisheries statistics and environmental and biological monitoring. • Low incentive for technology of native species production. • Increased fishing pressure from fixed prices set by the external market and overexploitation. • Inadequate design or absence of systems to mitigate the impact of works. • Increased fishing pressure because of the loss of economic profitability for fishermen.

Political-Institutional Causes	Social and Cultural Causes
• Lack of harmonized and integrated policies for the protection of aquatic life at the Basin level. • Asymmetry of norms and criteria for natural resource use. • Lack of economic management tools. • Failure to comply with current legislation and poor controls. • Lack of participatory management.	• Unsustainable techniques and difficulties in accepting new technologies. • Increased poverty that increases fishing pressure. • Little awareness of the importance of abiding by fisheries regulations and ensuring compliance.

Artisanal fishing, an important activity for the subsistence of many communities in the Basin.

4.6.7 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Promote integrated policies, standards, and compatible criteria for the protection and sustainable use of fishery resources at the Basin level.
- Harmonize fisheries legislation and regulations.
- Consolidate sport fishing standards at the sub-basin level.
- Implement a code of conduct for responsible fishing.
- Strengthen tools and mechanisms for management and control.
- Implement environmental monitoring networks.
- Develop preventive programs for the control of fisheries and aquaculture.
- Develop actions to prevent and reverse the reduction of fish stocks.
- Implement mechanisms to reduce the impact of hydraulic works on migrations of target species.
- Monitor and control exotic species.
- Promote natural tourism by incorporating plans for the regulation of fishing activity.
- Carry out vulnerability studies of priority riverine habitats.
- Development of conservation programs for supporting species. Implementation of training and capacitation programs in sustainable production techniques.

4.7 Unsustainable Use of Aquifers in Critical Areas

4.7.1 Presentation of the Topic

At the regional level, there has been an increase in the use of groundwater resources due to urban and rural population development and the sharp increase in agricultural and industrial activities in the LPB region.

Several causes have led to an unsustainable use of groundwater: There is a lack of knowledge about the vulnerability of recharge areas, and there are deficiencies in well inventories, as well as their monitoring and exploitation. As an exception, it should be noted that Brazil has some monitoring networks, mainly in the state of São Paulo, and Paraguay monitors the Patiño aquifer, which is of great importance at the local level.

4.7.2 Activities Developed

Through the joint work of the countries, progress has been made in the characterization of select transboundary aquifers at the Basin level (Serra Geral, Baurú-Caiuá-Acaray, Pantanal, and Agua Dulce), as well as in the elaboration of a hydrogeological synthesis map of the Basin at a scale of 1: 2,500,000, presented in *Chapter 1.* In addition to the hydrogeological map, thematic maps were elaborated as a diagnostic for groundwater and its exploitation in the Basin.

At the local level, progress has been made in the knowledge of the Yrendá-Toba-Tarijeño Aquifer System (YTTAS) in the territories of Argentina, Bolivia, and Paraguay. Available information has been revealed, and field work with well monitoring and sampling for physical-chemical and isotopic analysis has been carried out. A geological report has been prepared delineating the aquifer zone, and a geological map has been elaborated in each country, to later be integrated. Similarly, hydrogeological maps have been created in each country, to later be integrated by all three countries.

4.7.3 Knowledge Expansion and Updating

Figure 4.7.3.1 shows the distribution of salinity in groundwater, and **Figure 4.7.3.2** shows the density of information on drilling available from the FP, based on information from official agencies of each country, per sub-basin.

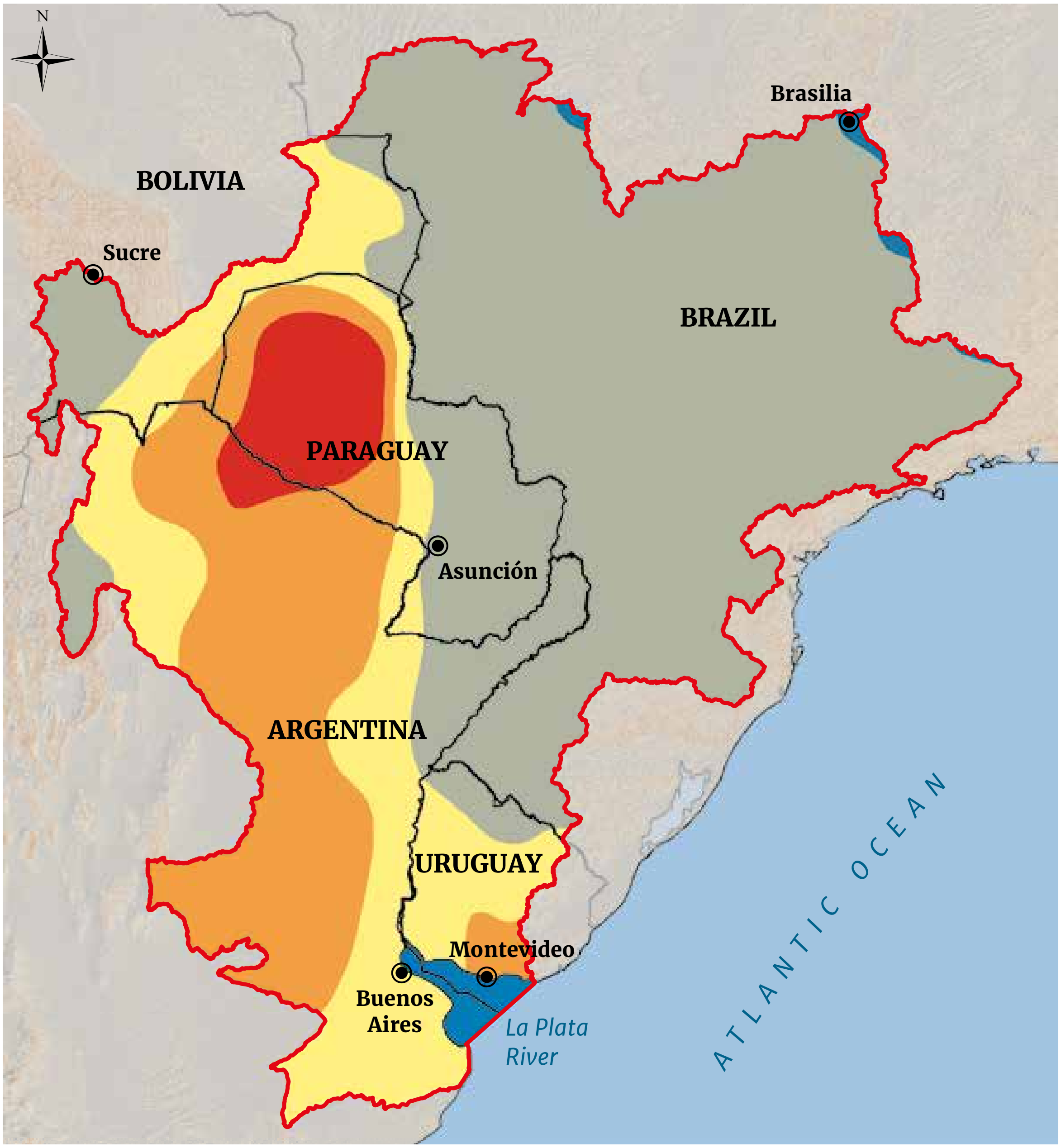
In the lower Paraná sub-basin, the lowest well density of the Basin is observed, with only 1.5 wells/ 10 km², corresponding to the Mesopotamian area of Argentina, an area with low demographic density and an abundance of surface water. At the same time, the La Plata River sub-basin, after the confluence of the Paraná and Uruguay rivers, and also with low population density and good surface water availability, has a density of 1.8 wells/10 km².

The area with the highest level of groundwater exploitation today is the upper Uruguay sub-basin, where a density of 70 wells/10 km² is observed.

With regard to vulnerability (**Figure 4.7.3.3**), low to medium natural vulnerability is observed for the area comprising the Paraná sedimentary basin, and high vulnerability for the YTTAS. For the Gran Chaco area, high vulnerabilities predominate, while those in the Pantanal are low. On the other hand, the Andes display a low vulnerability index.

Figure 4.7.3.1

La Plata Basin. Distribution of groundwater salinity



Electric conductivity (µS/cm)

- 0 to 100
- 100 to 500
- 500 to 1,000
- 1.000 to 3,000
- > 3,000

Figure 4.7.3.2

Drilling density for groundwater extraction by sub-basin

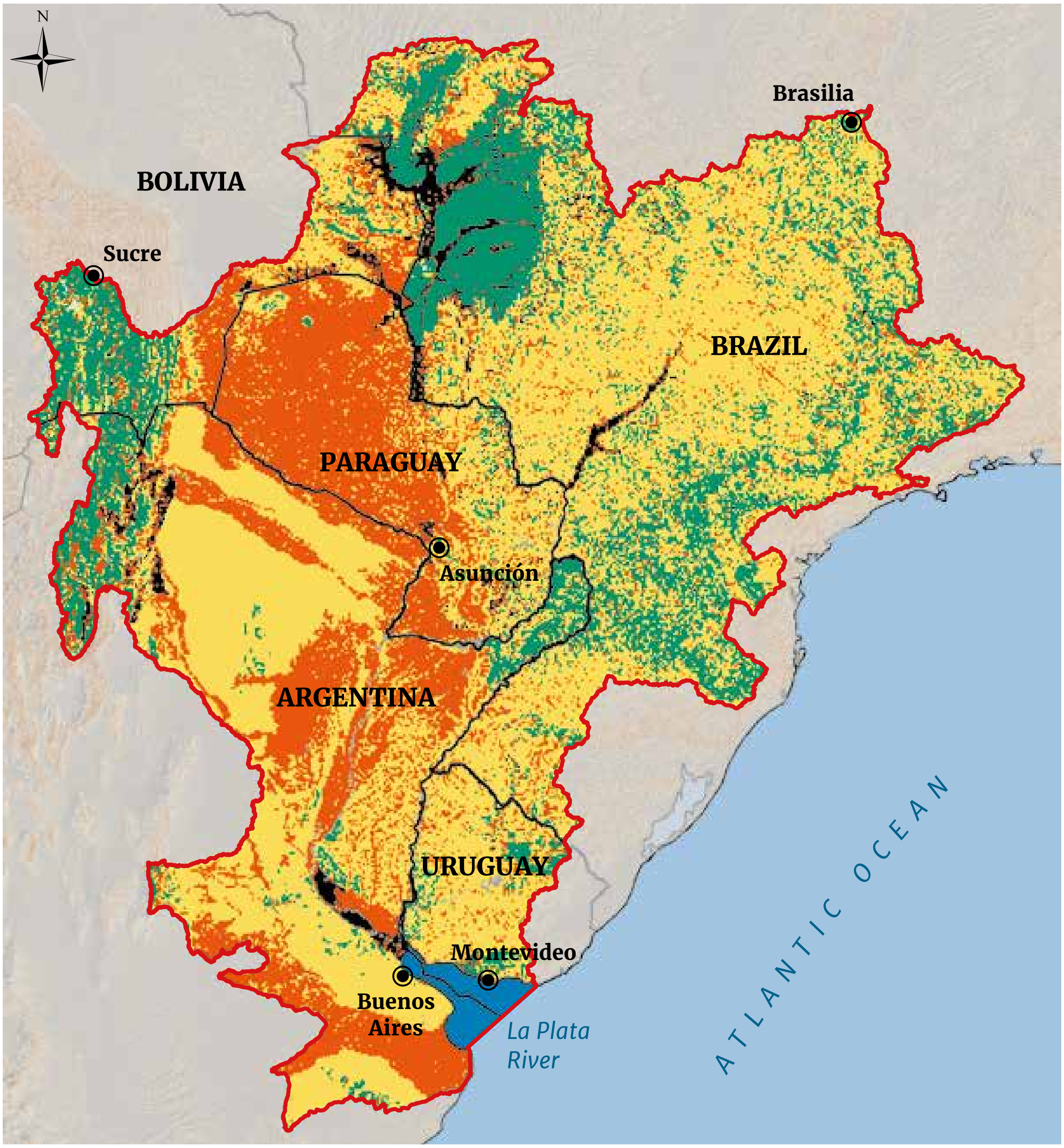
Nº of wells/10 km² (per sub-basin)

- Upper Paraguay – 4.5
- Upper Paraná – 3.7
- Lower Paraguay – 2.4
- Lower Paraná – 1.5
- Upper Uruguay – 70
- Lower Uruguay – 18
- La Plata River itself – 1.8

Information on the number of wells available in the FP, supported by the official organisms of each country.

Figure 4.7.3.3

La Plata Basin. Natural vulnerability of groundwater to pollution



Vulnerability

- Negligible
- Low
- Medium
- High
- Extreme

Yrendá-Toba-Tarijeño Aquifer System (YTTAS)

YTTAS is an aquifer system of great regional importance due to the expectations that exist in a region with water scarcity, a semi-arid climate, and other brackish or saltwater aquifers not suitable for human consumption or agricultural production. It represents one of the most important transboundary freshwater and groundwater reservoirs in this region, and one of the most significant in the South American continent.

It has been studied in greater detail than other aquifers due to lack of existing information on drilling and the quality and quantity of water in addition to a lack of maps and the delimitation of the area. In this context, a geological map of YTTAS was elaborated and studies were carried out to create national hydrogeological maps.

In the YTTAS, the geology is manifested throughout the geological provinces of the Sub-Andean Sierras of Bolivia and Argentina and the Cretaceous basins of the Northwest (Argentina), the Bolivian Chaco, Western Paraguay, and the Paranaense Chaco (Argentina). It is also delineated by the geological provinces of the Central and Eastern Cordillera (Bolivia), Eastern Paraguay and the Brazilian Shield and the Paraná Basin (Brazil), where the main aquifers were formed: GAS, Serra Geral, Baurú and Caiuá, among others.

From a geological point of view, the GAS consists of a sequence of predominantly sandy rocks, whose sedimentation occurred in fluvio-lacustrine and windy environments in the Triassic and Jurassic periods. These rocks saturated with water were later covered extensively by basaltic laminar flows of the Upper Cretaceous, coverage that can exceed 1,000 m. In the uppermost part of this sequence, under a desert climate system, eolic-fluvial sands have been deposited, giving rise to layers of thick, porous, and permeable sandstones with a wide geographic distribution.

4.7.4 Influence of Climate Variability and Change

The climatic variations modeled for a period of almost 80 years would be insignificant from the point of view of groundwater, since geological time periods are very broad. However, in some locations where recharge is affected by precipitation (more restricted aquifers such as Raigon), variation may affect this recharge.

4.7.5 Legal and Institutional Considerations

The countries have a distinct level of legal progress on the subject, and also in its implementation and compliance. On both the constitutional and legal levels, the five countries have established the initial steps toward sustainable groundwater management, but the subject is still not well developed in terms of regulation in some countries. It is therefore important that guidelines for groundwater use and protection in the LPB respect the singularities of the institutional and regulatory framework of each country, so it is necessary to define guidelines as recommendations for local management.

4.7.6 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Lack of knowledge on the vulnerability of the system (risk areas, recharge areas). • Identification of contaminating focal points from agricultural uses and domestic and industrial discharges. • Lack of monitoring of the state of exploitation of the aquifer, supply, and demand. • Lack of complete and effective monitoring systems. • Deficiencies in aquifer inventories, studies, and research. • Improper construction of drilling holes, with risk of contamination.	• Lack of management of groundwater use. • Ineffectiveness of environmental management instruments.

Political-Institutional Causes	Social and Cultural Causes
• Lack of regulatory framework for the construction and use of drilling. • Lack of integration of soil, water, and environmental legislation in each country and between countries. • Lack of cross-border institutional coordination for shared control and management. • Lack of exchange of information.	• Poor culture, social awareness, and training on the use of groundwater. • Lack of economic-environmental valuation by society. • Lack of integrated vision of the water resource. • Poor social participation.

4.7.7 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Establish a normative and regulatory framework for the sustainable use of aquifers.
- Harmonize legislation on soil, water, and environmental resources in each country and between countries.
- Develop a normative framework for the construction and use of drilling.
- Strengthen management capacity and institutional coordination.
- Strengthen and articulate institutions and services with competence in groundwater management.
- Develop integrated and participatory management tools.
- Develop a program for the sustainable management of YTTAS.
- Implement the actions resulting from the Environmental Protection and Sustainable Development of the Guarani Aquifer System project.
- Promote research and information exchange.
- Conduct vulnerability studies for the identification of risk areas at the regional and local levels.
- Develop inventories and regional data banks.
- Implement education and awareness programs.
- Strengthen information dissemination systems.
- Promote greater social participation.

4.8 Conflicts Over Water Use and the Environmental Impact of Irrigated Crops

4.8.1 Presentation of the Topic

The main reason for the conflict lies in the permanent and sustained growth of irrigated areas in the LPB. As a reference, there are currently about 4 million hectares of irrigated land in the LPB, while in the 1960s there were only 1.85 million in the total territory of Argentina, Brazil, Paraguay, and Uruguay.

The growth of the irrigated area has accelerated in the last three decades by increasingly technically advanced commercial production and due to the persistent occurrence of droughts and the probable effects of climate change, as well as the need to ensure economic performance and survival of agricultural enterprises and producers.

This expansion of irrigation has created a growing conflict and shows the lack of overall vision and capacity to generate participatory processes amongst the actors involved for a balanced resolution; that is, there is a great need to implement Integrated Water Resources Management (IWRM).

4.8.2 Activities Developed

The five countries of the Basin have advanced in the deepening of knowledge regarding water availability, including the preparation of a Surface Water Balance Calculation Manual for the LPB; the implementation of surface water balance in each country; advances in Integrated Water Balance (IWB) in pilot basins; and an evaluation of water use and demand at the national level in each of the five countries, to be integrated later.

An opportunity has been identified for transferring knowledge on best practices in irrigated rice cultivation to support production and significantly reduce water consumption for irrigation through cross-border cooperation from the more developed to the more incipient regions. Special emphasis is placed on this topic in the Demonstrative Pilot Project *Resolution of water use conflicts - Cuareim/Quaraí river basin.*

4.8.3 Knowledge Expansion and Updating

The estimation of water demands corresponding to the various uses was carried out as follows:

Population demand includes domestic use, provision of public services, and water services for shops and industries located in the municipal area that are connected to the supply network. In general, there is no discrimination between each service for most municipalities and provinces. As much as possible, urban demand was estimated from real data obtained through measurements and censuses. But in the case of not having data, the starting data for the estimation of total urban demand was the population and the *per capita* endowment. Estimated consumption included urban and rural potable water, as well as water extracted for potable water production that was not consumed.

Agricultural demand includes agriculture, forestry, and livestock demand. With respect to agriculture, only production under irrigation was estimated. No correlation was calculated for forest use. The number of crops considered for the area exceeded twenty and there was no discrimination between annually irrigated crops and perennials.

The concepts that characterize agricultural demand under irrigation are: 1) The net demand for irrigated crops (water consumed by crops); gross demand was not taken into account (total derived water, taking into account transport efficiency, distribution, and application); 2) The surface under irrigation, and 3) The difference between gross and net demand, corresponding to the return or losses. No information is available on the relationship at the country level.

The estimation of agricultural demand was obtained by means of indirect methods (estimated net demands), as the sum of water consumption by the crops under irrigation plus the extracted water not consumed.

The estimation of livestock demand is generally done in terms of the daily consumption of water from the heads of cattle in a certain place or region. It was quantified by setting differentially applied consumption modules in the production chain. In this way, the volume of water used in all stages of growth, termination, and slaughter was taken into account, considering cattle, goats, equines, pigs, sheep, poultry, and others part of the livestock population.

As far as industrial demand is concerned, the data available generally refers to the large industry, which has its own supply sources. Small and medium-sized industries, however, are often included in the urban supply sector, which in general leads to an underestimation of industrial demand. Water used in industrial or processing activities is included as a further input for the intermediate consumption associated with the ex-

Rice cultivation by flooding, a major use of water in the Basin traction, retention, or processing of raw or mineral materials, product finishing, construction, and heat transfer processes.

The industrial uses of establishments supplied by potable water networks and discharged into the sewage system are not discriminated against, nor are a large number of establishments which are supplied directly from underground sources and are not accounted for by the municipalities.

In relation to mining demand, the water consumed in this activity has many uses, especially during the process of separation of minerals. It is also used for cooling, cleaning, lubrication of drillings, and as a cutting tool (drills, bits, and diamond drills). Surface mining requires water to avoid dust in the quarry paths, especially when there is heavy traffic of drilling, loading, and transport machinery. Groundwater mining needs it to cool environments and machines, to clean rock dust off of tools, and to avoid excess dust, watering the soil to protect operators and machines. When groundwater work generates the emergence of natural water, it is necessary to anticipate its catchment, canalization, and pumping to avoid flooding. Water is also used for transportation of minerals, for leaks, and processes for the restoration of land and revegetation of areas. There is little information on this use, and only estimates from Argentina and Uruguay are included.

Among the main results of the work carried out, there is an important concentration of water use for rice irrigation in the area near the Cuareim/Quaraí and Ibucuy rivers on the Brazilian and Uruguayan banks, respectively, and in the contributing basin to the Uruguay River on the Argentine side.

Considering that irrigation will consolidate its dominant position as the main water consumer in all the countries of the Basin in the future, transforming growth into development should increase and regulate the water supply and increase its efficiency by optimizing the relation of kg of product per m^3 of irrigation water consumed.

4.8.4 Influence of Climate Variability and Change

Rice flooding uses a high volume of water, which can create conflicts with the water supply and the environmental maintenance of the channels. In the event of a drought, this problem would be very serious if private reservoirs built by the rural owners accumulated all available water.

4.8.5 Legal and Institutional Considerations

At the national level, all the countries establish in their laws the main guidelines for the sustainable use of water resources and the granting of rights of use. While all countries contain provisions for water use, the reach and extent of implementation varies. In some countries no permits are granted, although they are foreseen, but the application is registered. There are also rights granted on a temporary basis but without a deadline. With regard to water charges, although almost all legislation provides for the possibility, in few cases is it applied.

4.8.6 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Little or no available information on shared water resources (inventory of uses and availability). • Lack of knowledge of water demands for different uses. • Lack of hydrological studies of the basin. • Asymmetries in the granting of rights of use. • Construction of hydraulic works for exploitation without the proper authorization. • Unsustainable agricultural practices placing demands on the resource.	• Lack of integration and asymmetric application of water, land, and environmental legislation. • Lack of joint management bodies for shared water resources. • Little research on the topic of water resource use optimization.

Political-Institutional Causes	Social and Cultural Causes
• Asymmetries in the control and administration of the use of the resource. • Asymmetries in public policies. • Asymmetries in legal-institutional structures for integrated shared resource management.	• Poor culture, social awareness, and training on water use. • Lack of knowledge of social actors about the value of resources and their limited availability. • Lack of knowledge of users about regulations for the exercise of water use. • Lack of a culture to seek collective solutions and shared management.

4.8.7 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Promote agreements and the development of common legal frameworks for the management of water uses.
- Develop measures to increase the uptake and storage of water and improve the efficiency of irrigation.
- Develop and exchange experiences on technologies to increase the availability and efficient use of irrigation water.
- Joint use of surface and groundwater in areas under water stress.
- Strengthen the management and institutional coordination capacities of competent bodies in the five countries.
- Consolidate and expand the Cuareim-Quarai pilot project.
- Generate information and facilitate public access to data of interest for the management of supply and demand.
- Conduct water demand studies in selected basins.
- Establish communication, dissemination, and awareness of public opinion on management strategies.

4.9 Lack of Disaster Contingency Plans

4.9.1. Presentation of the Topic

The rivers of the Basin and their riparian areas are subject to the risk of disasters due to extreme natural events and human error that can cause accidents of various kinds, such as toxic spills and the breakdown of infrastructure works. Hence, the need for preparation to prevent or confront such events.

4.9.2 Activities Developed

Progress was made on a detailed diagnostic of hydro-meteorological monitoring and alert systems nationally (in each of the five countries of the Basin) and regionally, as the basis for strengthening contingency plans in the event of disaster. Progress is being made in coordinating the five countries in the hydro-meteorological network. Special emphasis is placed on this topic in the Demonstrative Pilot Projects *Hydro-environmental alert system. Floods and droughts in the confluence zone of the Paraguay and Paraná rivers and Resolution of water use conflicts - Cuareim/Quaraí river basin.*

4.9.3 Knowledge Expansion and Updating

From the analysis carried out, it follows that:

There are hydrological and hydraulic studies associated with the hypothetical breakages of the principal dams of the Uruguay and Paraná rivers in Argentina, since the Dams Safety Regulatory Agency (ORSEP) exists in that country since the 90s, which inspects dam safety studies and, more specifically, the development of so-called Emergency Action Plans (EAPs).

Brazil enacted Law 12334/2010 establishing the National Policy on Dam Safety and creating the National Dam Safety System.

There is still a need to establish common agreements to facilitate the exchange of data and information and the establishment of homogeneous criteria (defining maximum probable rises, probable breakage scenarios, etc.) to allow for more detailed safety studies (fundamentally for the analysis of domino effects in waterfall dams).

Contingency plans for riverine and rainfall floods are currently being developed globally throughout the Matanza-Riachuelo river basin (2,470 km²), Buenos Aires, Argentina. This activity can be taken as a frame of reference, along with similar ones that have been executed in the province of Santa Fe, Argentina.

4.9.4 Legal and Institutional Considerations

The accidents and disasters recorded in the Basin have highlighted the lack of prevention plans and, above all, contingency plans for accidents. The Basin countries confront them with isolated measures, often extemporaneous and insufficient and subject to a plurality of jurisdictions. On a national scale, in general, specific regulations are scarce.

4.9.5 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Risk of dam breakage due to operating errors.	• Lack of contingency plans for the section of the river potentially affected. • Lack of common standards for emergency operation and dam safety. • Failure to review dam safety criteria, considering the impacts of climate change.

Political-Institutional Causes	Social and Cultural Causes
• Lack of transnational contingency plans. • Lack of national and transnational regulations for dam safety. • Lack of communication and coordination between countries to provide information on dams existing upstream of possibly affected countries.	• Lack of awareness of the risks of populations located downstream of the dams and the operating companies themselves.

4.9.6 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Establish common safety standards and criteria, considering the incidence of climate variability and change.
- Elaboration and adoption of national and transnational safety and operational standards in the event of emergency.
- Promote the exchange of information and experiences on safety of works and operation of reservoirs.
- Institutionally articulate the organizations that operate binational hydroelectric power plants.
- Develop or update contingency plans and programs in the event of dam breakage.
- Develop contingency plans for accidents and disasters.
- Develop citizen awareness measures on prevention and risk reduction.
- Develop citizen awareness programs for vulnerable areas.

4.10 Unhealthy Water and Deterioration of Environmental Health

4.10.1 Presentation of the Topic

This is a critical issue for all the countries of the Basin, which mainly involves all urban areas -typical sources of domestic and industrial pollution- and agricultural and mining activities. There is a serious situation in the urban and rural settlements of the Basin caused by biological contamination due to the lack of sanitation facilities and adequate wastewater treatment services.

4.10.2 Activities Developed

As outlined in *Chapter 4.3.3*, the work carried out provides an inventory of both diffuse and point sources of pollution, with an estimation of the main pollutant loads in the LPB. Progress was also made with regard to human health, with a report containing universal information for the Basin as a whole and by region of each country. This analysis was conducted jointly with the sanitation studies.

4.10.3 Knowledge Expansion and Updating

Episodes of waterborne diseases, such as diarrhea, cholera, malaria, and dengue, are common in certain regions, particularly where there are households without access to safe drinking water or sanitation. Diarrhea is by far the largest water-related epidemic disease that mainly affects children, and in particular those from households without access to improved sources of drinking water or sanitation. Other diseases of lesser occurrence are leptospirosis, leishmaniasis, and yellow fever.

With regard to potential health risks in drinking water sources, in recent years a number of blue-green algae blooms or toxigenic cyanobacteria have been recorded in different river systems. These belong to the oldest organisms on the planet and have characteristics that are common to other bacteria and eukaryotic algae, which gives them unique qualities in terms of their physiology, tolerance to extreme conditions, and adaptive flexibility. These blooms, which generally occur in low-depth bodies of water with low water circulation, are also associated with high temperatures, pH changes, prolonged water retention times, and low turbulence, have successfully colonized aquatic ecosystems and are currently dispersed in inland water bodies (rivers, lakes, reservoirs) and marine environments, either as single-cell or multi-cell organisms (colonial or filamentous).

Its natural development has been modified by human action, mainly by the excessive contribution of nutrients, especially nitrogen and phosphates, from sewage discharges and the increasing use of fertilizers. This phenomenon can also be aggravated by climate variability and change, as the increase in the temperatures of water bodies favors the development of cyanobacteria masses—called algae blooms—as a competitively successful group in comparison with other phytoplankton.

As they grow disproportionately, depending on the genus and species concerned, these organisms produce cyanotoxins, which, when present in ambient water, can affect the health of the population, of domestic and wild animals, and of livestock.

As for schistosomiasis, a parasitic disease originating in Africa, it was discovered in South America at the beginning of the 20th century in Brazil, which is now an endemic country. It has spread mainly in the populations along the Atlantic coast of that country, reaching the state of Rio Grande do Sul in the 1990s. The most efficient preventive measure is the control of people who come from endemic areas for different reasons (work, tourism, etc.).

Another serious problem is the presence of arsenic. Water is contaminated by contact with the layers of rocks with a high content of this carcinogenic mineral. Arsenic is also used in some industrial processes and can be filtered into water bodies if not treated with care.

4.10.4 Legal and Institutional Considerations

In some areas there are no conditions for effective control of contamination. There is a lack of coordination between central and local governments. The topic is mentioned in all national legislations with varying degrees of intensity, so there is a good foundation for adopting a harmonized framework to regulate this CTI in its various aspects.

4.10.5 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Inadequate disposal of solid waste. • Untreated wastewater. • Inadequate disposal of agrochemical packaging. • Lack of treatment of water supply. • Inadequate urban drainage. • Lack of information on waterborne diseases.	• IInefficiency in the control of industrial dumps and agrochemicals. • Lack of an integrated information system on water resources. • Lack of capacity of local sanitation and health managers. • Lack of local health data banks.

Political-Institutional Causes	Social and Cultural Causes
• Lack of harmonized and integrated policies for surveying public health problems related to water. • Lack of coordination between governments (local and central) and social, technical, and economic actors on water pollution. • Asymmetry of legal and technical criteria for the management of water resources and public health.	• Resistance to changing habits.

4.10.6 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Strengthen research and the generation and dissemination of data on waterborne diseases.
- Promote health plans associated with the treatment of waterborne morbidity.
- Promote policies and programs for the treatment of solid waste, industrial waste, and agrochemical management.
- Strengthen the capacity of local managers and the institutional coordination of organizations and institutions in the water and sanitation sectors of the countries.
- Promote education and citizen awareness programs on environmental hygiene and health.

4.11 Limitations on Navegation

4.11.1 Presentation of the Topic

Navigation is one of the key socioeconomic sectors in the integration of the LPB, because it provides the connection between production centers, storage, and ports from which the main products are exported to the world. Currently, transport between the regions is primarily of agricultural products.

Navigation is the most economical means of transport, although it depends on connections with other modalities, the development of ports, investments in the maintenance of roads and ports, and agreements between countries. The integrated assessment of all elements within the institutional framework of countries, particularly associated with economic potential, is the great challenge for the expansion and modernization of navigation in the Basin.

4.11.2 Activities Developed

Based on the work of national specialists from the Basin countries, the state of knowledge of river navigation on the main waterways was updated.

4.11.3 Knowledge Expansion and Updating

The Paraguay River presents characteristics of a plain river, subject to erosion and sedimentation, so that morphological changes occur in the bed that in the course of time modify the navigation channel. Variable water levels on the river, subject to the precipitation system in its basin, determine the coming hydraulic cycle on the Paraguay: low waters (from November to February), high waters (from May to August), and medium waters (from March to April and September to October).

In the low-water periods, there are generalized difficulties in navigation and, more specifically, the appearance of critical steps. The Paraguay River does not have artificial regulation of its flow, so the dynamic process of the river necessitates permanent monitoring of the effective depths of the navigation channel in order to determine the critical steps and, through dredging, to facilitate the navigation of boats of up to 10 feet throughout the year.

The section that presents the greatest difficulties for navigation is that which lies between the mouths of the Apa and Pilcomayo rivers, due to the existence of a rock bed. Poor drainage, poor channel signaling, and lack of satellite navigation charts make navigation difficult.

The main risk for navigation in the Paraguay River is associated with the inter-annual conditions presented by its water levels and flows. For example, during the years 1960 to 1973, the levels of the Paraguay River were much lower than in the previous and subsequent periods. With low flows such as those recorded during this period, the stretch between Puerto Caceres and Asunción offers very low drainage, compromising navigation. This problem triples the cost of navigation because of the need for a larger number of barges to carry the same cargo. Therefore, the greatest risk to navigation in the Basin is due to the probable consequences of climate variability and change.

The Paraná River is a plain river that changes its course. This mobile bed feature, which is very susceptible to tides, results in obvious changes in the position of the navigation channel and in the setting of critical steps. It is a river that receives sediments, especially from the Bermejo River, which causes silting in some areas. At the same time, however, the river flows generating a process of self-dredging, which means dredging is not required in those places. The stretch from Santa Fe over the Paraná River, to Asuncion, over the Paraguay River is one of the most beneficial since, for the most part, it is navigable throughout the year at eleven feet of draft. The Apipé rapids used to exist in the Posadas-Corrientes section, but they disappeared with the construction of the Yacyretá dam, whose sluice and reservoir now allow navigation without any draft problems until the confluence of the Paraná River with the Iguazú.

The Uruguay River, which is commercially navigable only in a stretch of approximately 200 km from its outflow, has historically offered navigational conditions inferior to those prevailing in the Paraná River. In addition, it has not been systematically maintained. The Uruguay River Administrative Commission (CARU), a binational organization responsible for the planning and control of activities carried out in the section of shared jurisdiction between Argentina and Uruguay, has carried out a study that resulted in the drainage project necessary to make it possible to sail with drafts up to 7.0m to the Argentine port of Concepción del Uruguay (km 187) and up to 5.17m to the Uruguayan port of Paysandú (km 207). The governments of both countries have committed the necessary financial contributions for the execution of the projected works, and have begun to take pre-dredging (bathymetry) and effective dredging actions in some parts of the lower section of the river.

The Tieté River currently has an inland transportation waterway in Brazil and, due to the lack of a lock in the Itaipú dam, as mentioned above, it does not have a transport flow in the Paraná River downstream. In 2014, this hydroelectric power plant suffered an interruption due to a long period of drought, which also led to conflicts with other water uses, such as urban water supply, irrigation, and hydroelectricity.

The principal results associated with the main navigation sections were:

The navigation network of the Basin has been favored with regional agreements that allow its commercial exploitation. The Paraguay-Paraná Waterway alone reached the mark of 13 million tons of goods transported in 2004, a value that is growing rapidly each year.

Paraguay-Paraná Waterway. This waterway is 3,442 km long from Nueva Palmira, on the left bank of the Uruguay River in Uruguay, to Puerto Cáceres, at the north end on the Paraguay River. The busiest segment of traffic is between Puerto Caceres and Corumbá. The Paraguay River between Puerto Caceres and its confluence with the Cuiabá River presents a sinuous, wide, and shallow bed, which makes it difficult to navigate ships that require a certain draft. In order to expand the transport capacity of the waterway, works have been planned to increase the draft of the channel; despite this, the project may have an important environmental impact that has been questioned by environmental groups and requires careful technical evaluation.

Table 4.11.3.1 presents the main physical characteristics of the Paraguay-Paraná Waterway, considering its different sections.

Tietê-Paraná Waterway. The Tietê River runs through a highly industrialized region of Brazil, which accounts for 35 percent of Brazil's GDP. There are multiple uses of energy and navigation in this system. There are currently eight locks and nine dams with hydroelectric power plants. This waterway runs from the Tietê (which crosses the city of São Paulo) to the Itaipú dam, which does not yet have a lock.

Uruguay Waterway. The Uruguay River is navigable in its lower section, shared by Uruguay and Argentina, downstream from the Salto Grande dam. Upstream from Salto Grande, the river is navigable from Salto to São Borja, although traffic is scarce. In 2002, the Administrative Commission of the Uruguay River (CARU) promoted the completion of full studies on the navigation of this river.

Some 11 million tons are moved through the Port of Nueva Palmira (Uruguay), of which only 5 million correspond to the Uruguayan cargo of cereals and pulp. The rest is estimated to come mainly from Paraguay, by way of the Paraguay-Paraná Waterway.

The access canal to the port of Montevideo has a length of 42 km, dredged to 11m. To maintain these depths, it is necessary to dredge between 10 and 12 million m³/year.

Table 4.11.3.1

Paraguay-Paraná Waterway

Section	**Length** (km)	**Draft** (m)	**Barge train** (m)
Paraguay River			
Cáceres – Corumbá	672	2.10	24 x 80
Corumbá – Porto Murtinho	538	2.10	50 x 290
Porto Murtinho – Asunción	602	2.10	60 x 319
Asunción – Confluencia	390	3.65	60 x 319
Paraná			
Encarnación – Itaipú	360		
Yacyretá – Incarnation	115		
Confluencia – Yacyretá	225		
Confluencia – Santa Fe	616	3.65	released
Santa Fe – Rosario	170	7.65	released
Rosario – New Palmira	420	10.36	

4.11.4 Influence of Climate Variability and Change

Recalling the period of very low flows in the upper basin of the Paraguay River between 1960 and 1973 and its effect on the shipping costs and on increased environmental impacts, it is important to verify the potential effects in the future, taking climate change into consideration. The reduction in levels, as in the period mentioned, would increase navigation costs by about 300 percent due to the need to increase the number of vessels for the same tonnage.

4.11.5 Legal and Institutional Considerations

The Waterway Agreement is a law in all the countries and requires a political commitment to enforce it, as there are protocols and regulations that are not met. There is agreement between the countries to improve the waterways, but resources are needed to reach effective navigability. There is little coordination between the CIC and the CIH. At the national level, specific regulations exist but have not been harmonized between countries.

The lock on the Yacyretá binational dam permits navigation in the section of the Paraná River shared by Argentina and Paraguay.

4.11.6 Primary Detected Causes

When elaborating the Macro TDA, the following causes were detected for this CTI:

Technical Causes	Economic-Managerial Causes
• Lack or insufficiency of infrastructure to overcome natural critical points. • Lack of maintenance of the waterway. • Lack of navigation locks. • Insufficient infrastructure for access to ports and for the operation of navigation.	• Inadequate joint institutional management. • Lack of agreement for the joint financing of works. • Lack of resources to maintain navigability. • Lack of multimodal transport planning. • Lack of information on the socio-environmental impacts of navigation on civil society

Political-Institutional Causes	Social and Cultural Causes
• Asymmetries and weaknesses in country regulations. • Lack of transport policy. • Lack of instrumentation of international treaties and conventions.	• Lack of planning culture. • Preference for ground transportation.

4.11.7 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Harmonize regional policies for river transport.
- Adapt the legal and institutional framework for river navigation.
- Promote structural, maintenance, and operations improvements in ports.
- Promote actions to reduce the vulnerability of river transport.
- Agree on safety standards in the transport and handling of dangerous cargoes.
- Strengthen institutional capacities for joint planning and management.
- Develop cross-border plans for maintenance and dredging of inland waterways.
- Strengthen information systems for navigation.
- Promote an integrated transportation system.

4.12 Development of Hydroelectric Potential

4.12.1 Presentation of the Topic

Hydropower is one of the core activities for the socio-economic integration of the LPB, where much of the hydroelectricity generated in the countries is concentrated. In the energy matrix, hydroelectric power is the main generator in at least three countries of the Basin: Brazil, Paraguay, and Uruguay, and it is also important for Argentina. An important part of the power associated with this energy is found in the transboundary sections of the Basin. Hydroelectric production offers opportunities for synergy between countries in production and also in the transmission and distribution of electricity.

4.12.2 Activities Developed

Based on the work of national specialists from the Basin countries, the state of knowledge on hydropower was updated, with a broad vision focused on deepening the integration of existing systems and those predicted in the future.

4.12.3 Knowledge Expansion and Updating

The countries of the Basin have a large potential for renewable energy sources, particularly in regards hydropower, which is estimated at around 93,000 MW, of which 66 percent is already being exploited. More than 150 hydroelectric power plants have been installed, of which 72 are operating at levels above 10 MW.

Twenty percent of the hydroelectric energy in the Basin countries is generated in the transboundary stretches. A significant part of the hydroelectric potential is concentrated in the Paraná and Uruguay rivers, due to their geological and hydrological characteristics. The number of planned power plants is important, both internally and across transboundary courses.

Argentina has the highest untapped potential (2,650 MW), equivalent to 66 percent of its total potential in the Basin (4,000 MW). Bolivia has planned, together with Argentina, works in the Bermejo River basin. Brazil has the largest hydroelectric potential, with around 74,000 MW (80 percent of the Basin's potential), of which about 67 percent is being exploited. Paraguay accounts for approximately 14 percent of the hydroelectric potential of the Basin, of which 67 percent (around 9,000 MW) is already being exploited. Uruguay has almost all its hydroelectric potential in operation, which constitutes approximately 1.5 percent of the Basin total (1,515 MW).

Interaction through electrical interconnections is associated with the use of transmission lines connecting the electrical systems of two or more nations. The great advantage of electrical interconnection is the possibility of transmitting electrical energy from one country to another, taking advantage of the differences and complementarities of electrical systems, consumption habits, seasonality, and temperature variations. In addition, the possibility of being compensated for structural problems in a particular country also exists. The integration of the hydroelectric sector is currently carried out through binational hydroelectric plants, among which Itaipú stands out.

Depending on the distance to the load centers and the size of the inventoried potential, the construction of new hydroelectric plants may not be economically viable if the market is much smaller than the power of the plant. However, electrical integration allows large-scale companies located in countries with more protected internal markets to be economically viable by meeting the demand for integrated electrical energy from several countries in a much more reliable way, compensating for any electric disparities or shortcomings with surplus energy from other countries.

In this sense, the electrical integration between the countries creates greater reliability of the energy systems to cope with adverse meteorological conditions, technical problems, and consumption peaks. On the other hand, since electrical systems must be designed not only to meet the average demand, but above all to be able to face consumption peaks, the possibility of compensating and complementing the facilities of several regions is a better use of the investments made.

4.12.4 Influence of Climate Variability and Change

The LPB has a privileged position with respect to the availability of water resources in much of its territory. However, climate variability and change can affect the production of hydroelectric power. The operation of the power plants depends on the annual or multi-annual rainfall cycle and, consequently, on the associated river flow. Phenomena such as El Niño and La Niña—mentioned in *Chapter 2*—and variations in water surface temperature in the Tropical and Southern Atlantic can lead to climatic anomalies.

It will be necessary to continue the studies in order to have a clear vision of the impacts of climate change on the water resources of the Basin and, consequently, to reduce the uncertainty, which constitutes an obstacle to operational planning and the management of hydroelectric plants.

4.12.5 Legal and Institutional Considerations

Given the degree of hydroelectric development in the countries of the LPB, there is a great deal of legal experience, which provides a special basis for harmonization at the level of the Basin, facilitating energy integration.

It should be noted, however, that the integration process of the hydroelectric sector must address a complex context, conditioned by multiple variables, such as the political and institutional diversity of the countries, differences of interests, legal security, the regulatory system, the energy trading system, and the integrated operation of electrical systems.

4.12.6 Primary Detected Causes

As this CTI was incorporated after the preparation of the Macro TDA, the respective analysis of its causes is not available.

4.12.7 Recommendations

In the search for answers for the CTI analyzed, based on the results of the studies carried out during Phase 1 of the Framework Program (FP, 2016b and 2016c) and taking into account the different causes of the various problems that the topic entails and the actions proposed to solve them, the following recommendations are proposed, as a contribution to the preparation of the SAP:

- Make agreements for energy integration among the countries of the Basin.
- Promote inter-institutional transboundary meetings between technical teams from the main dams in the Basin, favoring the multiple use of shared dams.

Piracema Canal in the Itaipú dam.

- Strengthen relations between the binational hydroelectric power plants (Itaipú, Yacyretá, and Salto Grande) in various work areas, particularly in the transfer of experiences and lessons learned by their operators.

- Encourage agreements with the navigation sector to manage variable flows.

- Incorporate information from hydro-meteorological monitoring systems and studies on climate projections into energy planning.

- Integrate hydro-meteorological monitoring networks for hydraulic exploitation into other information systems.

Carry out actions to take advantage of the communications of the interconnected regional system in order to improve the transmission of information for early warning hydrological systems.

4.13 Main Problems Detected by Sub-basin

This section summarizes the main problems identified in each sub-basin for most of the Critical Transboundary Issues covered in the chapters above, with the purpose of highlighting and providing a foundation on which to relate them. Some of these main problems are featured in **Figure 4.13.1**, while the description of each presents their respective figures.

Figure 4.13.1

Characteristic problems of each sub-basin

Upper Paraguay

(to its confluence with the Apa river)

The Pantanal is located in this sub-basin, one of the most transcendent wetlands for the Basin's aquatic biodiversity. This sub-basin has suffered a considerable loss of terrestrial ecosystems (40 percent) and presents an environmental risk of loss of integrity. Sixty-one protected areas covering 12.6 percent of its area have been created. There are six Ramsar sites (46,500 km²), two MAB Biosphere Reserves (326,492 km²), and 19 important bird areas (IBA). It is the least populated sub-basin, with 2.4 million people.

In terms of navigation, it boasts the tract of the Paraguay-Paraná Waterway with the greatest difficulty of traffic, between Puerto Caceres and Corumbá. Between Puerto Caceres and the confluence with the Cuiabá River, the bed is sinuous, wide, and shallow, which makes it difficult to navigate boats that require a certain draft. In order to expand the waterway's transport capacity, works have been planned to increase it, a project that may involve a significant environmental impact requiring careful technical evaluation.

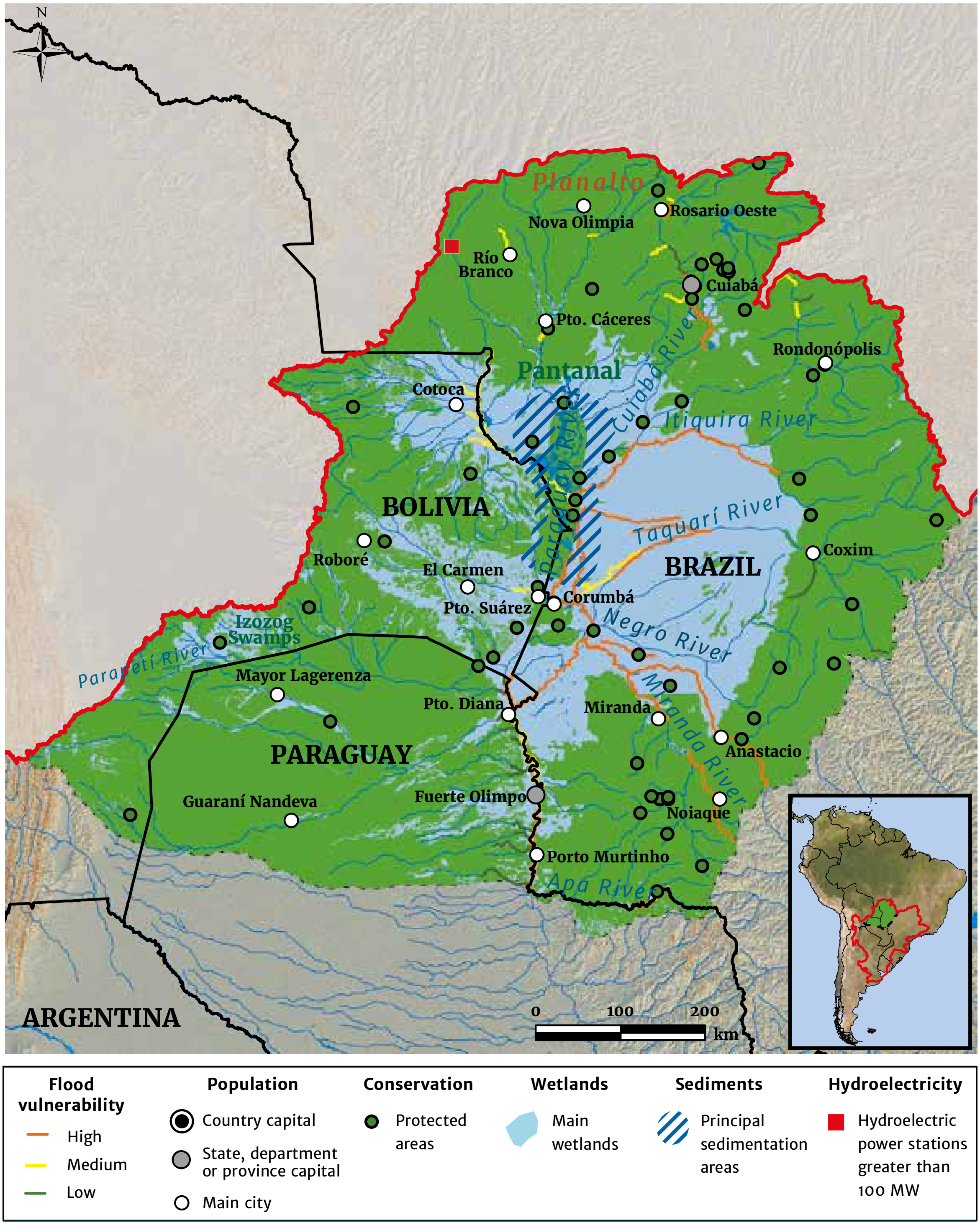
With respect to sediment production and transport, the Parapetí River requires more attention, as sedimentation processes can be observed in its channels that occur due to the change of slope of the river course. In the rainy season, the river carries sedimentation by drag and suspension. The coarser materials are deposited near the exit of the sub-Andean mountain range and the thinner materials are deposited as they travel along the plain, until arriving in the Izozog swamps, where very fine material accumulates.

Based on the analysis of 4,579 km of the upper section of Paraguay River, it was estimated that 65 percent of the course has a high vulnerability to floods, 25 percent a medium vulnerability, and 10 percent low vulnerability. As for the number of populations likely to have problems with riverine floods, three were identified with more than 50,000 inhabitants and 15 between 10,000 and 50,000 inhabitants.

In terms of droughts, the characterization of future periods of water deficit shows an increase in dry periods, in terms of duration, magnitude, and average intensity, as well as spatial coverage.

In relation to pollution, the mining activity in Bolivia and Brazil stands out. There are tin deposits in the form of cassiterite and acid drainage as a result of this activity and its environmental liabilities. On the other hand, in the Brazilian sector, water resources are contaminated by pesticides used in annual crops in the Planalto region.

Figure 4.13.2 **Upper Paraguay sub-basin**



Estimated Population	2.4 million people	The second least populated
Protected areas	61 (12,6% of the area)	
Loss of terrestrial ecosystems	40% of area	Considerable

Lower Paraguay

(to its confluence with the Paraná River)

This sub-basin is characterized by sediment production, which is somewhat greater in the upper basin of the Pilcomayo River than in the Bermejo River basin. However, the load on the Pilcomayo River is deposited in the swamps of its alluvial cone in the Chaco plain, and it consequently does not reach the Paraguay River. The total sedimentation of the channel to levels higher than the floodplain is a morphological problem that affects watershed management. As a consequence, the Pilcomayo River floods overflow over the plain, forming new swamps annually. For its part, it should be noted that the contribution of silt and clays from the Bermejo River constitutes 90 percent of the fine sediment transported by the Paraná River.

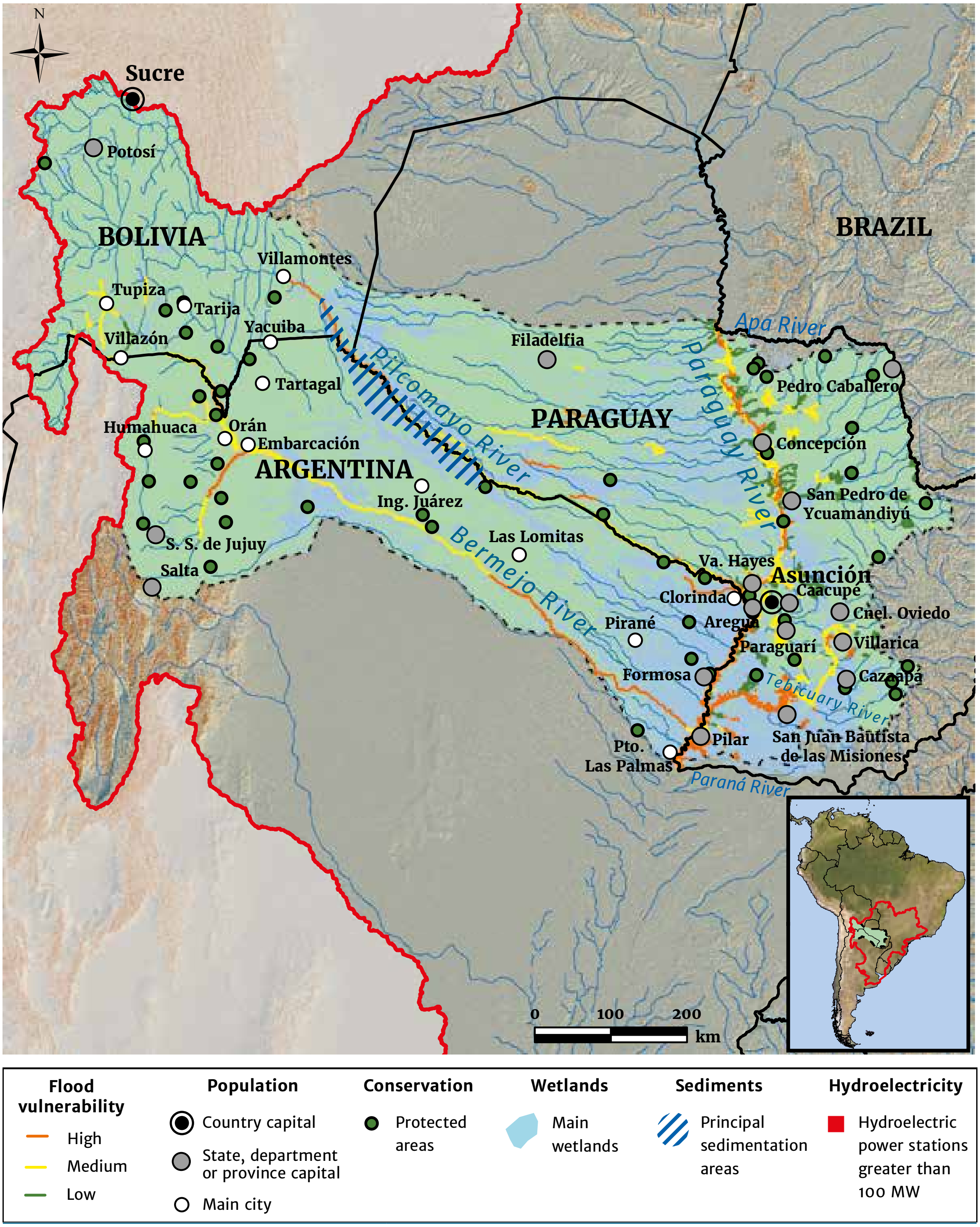
As far as pollutant loads are concerned, the major ones come from agricultural activity (crops and pastures) and, mainly, discharges of domestic and industrial effluents in areas close to large urban centers such as Concepción, Asunción—the capital of Paraguay—and Pilar. Likewise, there is a high concentration of phenols—indicating probable contamination from industries, including timber—in the course of the Paraguay River and one of its tributaries, the Apa River. There is also a heavy metal presence in the Pilcomayo and Bermejo rivers, originating from the mining activity in the headwaters of their respective basins on Bolivian territory.

It is one of the least populated sub-basins, with 2.8 million inhabitants, also including the constitutional capital of Bolivia, Sucre. It has suffered a 15 percent loss of terrestrial ecosystems. Three important reservoirs have been planned in the sources of the Bermejo River, and 66 protected areas have been created covering 7.4 percent of its area. There are nine Ramsar sites (11,384 km^2), six Biosphere reserves (21,097 km^2) and 94 IBA.

On the other hand, based on the analysis of 17,417 km of the lower section of the Paraguay River, it was estimated that 38 percent of the course has a high vulnerability to flooding, 41 percent an average vulnerability, and 21 percent low vulnerability. As for the number of populations likely to have problems with river floods, nine were identified with more than 50,000 inhabitants and 17 between 10,000 and 50,000 inhabitants.

In terms of droughts, the characterization of future periods of water deficit shows an increase in dry periods—both in duration, magnitude, and spatial coverage—but without reaching the levels of the upper Paraguay and upper Paraná sub-basins.

Figure 4.13.3 **Lower Paraguay sub-basin**



Estimated Population	2.8 million inhabitants	One of the least populated
Protected areas	66 (7,4% of the area)	
Loss of terrestrial ecosystems	15% of the area	The least affected

Upper Paraná

(to its confluence with the Iguazú Rive)

This is the most populated sub-basin, with 61.8 million inhabitants and six major cities, including Brasilia, the capital of Brazil. Upper Paraná and its tributaries have undergone major modifications for flood control and hydropower generation (43 large reservoirs and eight dams with locks). The Tietê-Paraná Waterway encompasses the Tietê River, which runs through a highly-industrialized region of Brazil, and the Paraná River to the Itaipu dam, which still does not have a sluice.

In terms of contamination, degradation or water quality degradation is observed in riparian areas of the urban-industrial conglomerates and in the rivers and streams of the sub-basin, for example, in the areas of São Paulo, Brasilia, and Curitiba, with great demand for water and a corresponding increase in the load of contaminants discharged. It is also observed that the industrial effluents of industries linked to agricultural activities represent important contributions of contamination by organic matter, with a consequent decrease in dissolved oxygen levels in water bodies.

This sub-basin has suffered a very high loss of terrestrial ecosystems (75 percent). There are no Ramsar sites, which indicates the absence of large wetlands of international relevance. There are many protected areas (313), although they cover only 7.7 percent of its area. The Mbaracayú Forest Biosphere Reserve (2,800 km^2) is part of this sub-basin. There are 32 IBAs within its limits. Nine species of threatened fish inhabit this sub-basin, and there is a high degree of invasion of exotic species. The cultivation of exotic fish is highly developed.

In terms of floods, 11,939 km of the high Paraná River stretch were analyzed, with 23 percent of the course considered to have high vulnerability to floods, 40 percent average vulnerability, and 37 percent low vulnerability. With regard to the number of populations likely to have problems with river floods, 39 were identified with more than 50,000 inhabitants and 66 between 10,000 and 50,000 inhabitants.

In terms of droughts, the characterization of future periods of water deficit shows an increase in dry periods, in terms of duration, magnitude, and average intensity, as well as spatial coverage.

Figure 4.13.4 **Upper Paraná sub-basin**

Flood vulnerability	Population	Conservation	Wetlands	Sediments	Hydroelectricity
High	Country capital	Protected areas	Main wetlands	Principal sedimentation areas	Hydroelectric power stations greater than 100 MW
Medium	State, department or province capital				
Low	Main city				

Estimated Population	61.8 million people	The most populated
Protected areas	313 (7,7% of the area)	
Loss of terrestrial ecosystems	75% of the area	Very high

Lower Paraná

(to its mouth in the La Plata River)

There are several important wetlands, such as the Ramsar Lagoons and Iberá Wetlands, the Chaco Wetlands, Jaaukanigás, Otamendi Reserve, and the lower Paraná floodplain, Paraná Delta (Argentina) in this sub-basin. It has suffered a considerable loss of terrestrial ecosystems (40 percent) and presents environmental risk due to loss of integrity. There are 82 protected areas covering only 5.6 percent of the total area. There are five Ramsar sites (10,950 km^2), two Biosphere Reserves (10,619 km^2), and 78 IBAs. Thirteen species of threatened fish inhabit this sub-basin, and there is a high degree of invasion with seven species of exotic fish. The cultivation of exotic fish is highly developed.

The population amounts to 9.5 million inhabitants, with seven major cities. Three dam reservoirs have been built with power plants producing more than 100 MW, one in the Juramento River and two in the Paraná. Other works that impact the ecosystem are the Rosario-Victoria road connection, the real estate expansion over wetlands, and their loss to the construction of hills for the use of agriculture and cattle breeding.

In terms of floods, from the analysis of 12,946 km of the lower section of the Paraná River, it emerged that 73 percent of the course presents a high vulnerability to floods, 24 percent an average vulnerability, and 3 percent low vulnerability. As to the number of populations likely to have problems with riverine flooding, 22 were identified with more than 50,000 inhabitants and 77 between 10,000 and 50,000 inhabitants.

Regarding droughts, the characterization of future periods of water deficit shows that the climate becomes gradually more humid for the most distant scenarios in time, decreasing dry periods and their magnitude, average intensity, and spatial coverage.

In terms of pollution, problems are observed mainly in large urban conglomerates such as the cities of Rosario and Santa Fe and areas with industrial development, such as the city of Esperanza, with tanneries that pour their effluents into the Salado River, an affluent of the Paraná.

Figure 4.13.5 **Lower Paraná sub-basin**

Flood vulnerability	Population	Conservation	Wetlands	Sediments	Hydroelectricity
High	Country capital	Protected areas	Main wetlands	Principal sedimentation areas	Hydroelectric power stations greater than 100 MW
Medium	State, department or province capital				
Low	Main city				

Estimated Population	9.5 million people	Intermediate level
Protected areas	82 (5,6% of the area)	
Loss of terrestrial ecosystems	40% of the area	Considerable

Upper Uruguay

(To the section planned for the Garabí dam)

This is the least populated sub-basin, with 1.7 million inhabitants, with no large cities. It has suffered a significant loss of terrestrial ecosystems (60 percent). Three large reservoirs associated with dams with hydroelectric power plants have been built on the Uruguay River, and there are plans for the construction of three new ones. Twenty-nine protected areas have been created, covering only 4.4 percent of its area. Although there are important wetlands, such as the Moconá Falls, there are no Ramsar sites. There is a Biosphere Reserve, Yabotí (2,366 km^2), and 12 IBAs have been identified.

As for industrial pollution, the largest sources are found in the tributaries, the Peixe and Canoas rivers, which receive high pollution loads of both point source and diffuse origin, coming from the paper and food industries and tanneries of, respectively, the cities of Cacador and Videira.

Regarding flooding, 4,454 km of the upper stretch of the Uruguay River were analyzed, estimating that 55 percent of the course has a high vulnerability to floods, 19 percent has average vulnerability, and 26 percent low vulnerability. As for the number of populations likely to have problems with river floods, four were identified with more than 50,000 inhabitants and 18 between 10,000 and 50,000 inhabitants.

In terms of droughts, the characterization of future periods of water deficit shows fewer dry periods, although with longer duration and intensity. Later, the humid climate predominates, decreasing the number of dry periods, their duration, intensity, and coverage.

Figure 4.13.6 **Upper Uruguay sub-basin**

Flood vulnerability	Population	Conservation	Wetlands	Sediments	Hydroelectricity
High	Country capital	Protected areas	Main wetlands	Principal sedimentation areas	Hydroelectric power stations greater than 100 MW
Medium	State, department or province capital				
Low	Main city				

Estimated Population	1.7 million people	The least populated
Protected areas	29 (4,4% of the area)	
Loss of terrestrial ecosystems	60% of the area	Important

Upper Uruguay

(to its mouth in the La Plata River)

It is a sub-basin with an intermediate population level, with 3.8 million inhabitants and three important cities. It presents some conflicts over the alternative use of water between rice irrigation, the supply of cities, and the conservation of ecological flows in rivers. In terms of contamination, there is a reoccurrence of harmful cyanobacteria algae blooms as a consequence of nutrient inputs from agricultural activity.

The Planicie wetlands and islands of the Uruguay River, the Farrapos Estuary Ramsar Site, Villa Soriano, and the Palmar de Yatay Ramsar Site stand out. The sub-basin has suffered a significant loss of terrestrial ecosystems (60 percent). There are four large reservoirs associated with dams with hydroelectric power stations, one on the Uruguay River and three on the Negro River. Thirty-nine protected areas have been created, covering only 1.8 percent of its area. There are three Ramsar sites (849 km^2) and a Biosphere Reserve (997 km^2), and 20 IBAs. Six species of threatened fish and five species of exotic fish have been recorded.

In terms of floods, the analysis of 13,334 km of the lower section of the Uruguay River shows that 27 percent of the course has a high vulnerability to floods, 39 percent an average vulnerability, and

34 percent a low vulnerability. For its part, seven populations were identified with more than 50,000 inhabitants, and 18 between 10.000 and 50.000 inhabitants, which have the probability of facing problems with riverine floods.

In terms of droughts, the characterization of future periods of water deficit shows an increase in water resources in the more distant future scenarios. Dry periods decrease in quantity, duration, and intensity, as well as in spatial coverage.

The Uruguay River is navigable in its lower section, shared by Uruguay and Argentina, downstream of the Salto Grande dam. Upstream from Salto Grande, it is navigable from Salto to São Borja, although traffic is scarce.

Figure 4.13.7 **Lower Uruguay sub-basin**

Flood vulnerability	Population	Conservation	Wetlands	Sediments	Hydroelectricity
High	Country capital	Protected areas	Main wetlands	Principal sedimentation areas	Hydroelectric power stations greater than 100 MW
Medium	State, department or province capital				
Low	Main city				

Estimated Population	3.8 million people	Intermediate level
Protected areas	39 (1,8% of the area)	
Loss of terrestrial ecosystems	60% of the area	Important

La Plata River Sub-basin

It is the second most populated sub-basin, with 24.9 million inhabitants, and five major cities, including Buenos Aires and Montevideo, the capitals of Argentina and Uruguay, respectively.

The largest pollution of urban-industrial origin in Argentina comes from the cities of Buenos Aires and its suburban area, and from La Plata and Gran La Plata, the sub-basins of the Matanza-Riachuelo and Reconquista rivers, as well as numerous streams and channels. In the case of Uruguay, the urban courses are the most affected, the Carrasco, Miguelete, Pantanoso, Colorado and Las Piedras streams and many of their tributaries, as well as the Bay of Montevideo and the Santa Lucía River sub-basin. Likewise, there is a recurrent occurrence of harmful cyanobacteria algae blooms on the Uruguayan banks of the La Plata River and in its sub-basin, as a result of nutrient inputs from agricultural/livestock activities.

The fine sediments of the Bermejo River, transported by the Paraná River, settle predominantly in the upper section of the La Plata River, contiguous to the Paraná Delta, the area with the greatest fluviomorphological activity.

Based on the analysis of 3,150 km in the La Plata River sub-basin, it was estimated that 6 percent of the courses have a high vulnerability to floods, 45 percent an average vulnerability, and 49 percent low vulnerability. As for the number of populations likely to have problems with riverine floods, eight were identified with more than 50,000 inhabitants and 15 between 10,000 and 50,000 inhabitants.

In the case of droughts, the characterization of future periods of water deficit shows a strong decrease of the dry periods, their duration and magnitude, as well as their spatial coverage.

In this sub-basin, the Samborombón Bay and Santa Lucía swamps stand out as important wetlands. The sub-basin has suffered a considerable loss of terrestrial ecosystems (35 percent), concentrated in the coastal strip of the La Plata River. Eleven protected areas have been created, covering only 0.8 percent of its tota area. There are two Ramsar sites (4,883 km^2) and two Biosphere Reserves (1,289 km^2) in the Argentine section, and nine IBAs have been identified. There is a considerable wealth of fish fauna, registering five threatened species. The degree of invasion is high, with eight recorded species of exotic fish.

Figure 4.13.8 **La Plata River sub-basin**

Flood vulnerability	Population	Conservation	Wetlands	Sediments	Hydroelectricity
High Medium Low	Country capital State, department or province capital Main city	Protected areas	Main wetlands	Principal sedimentation areas	Hydroelectric power stations greater than 100 MW

Estimated Population	24.9 million people	The second most populated
Protected areas	11 (0,8% of the area)	
Loss of terrestrial ecosystems	35% of the area	Considerable

Chapter 5: TDA Conclusions as Contributions to the SAP

The implementation of the Framework Program during the period from 2011 to 2016 deepened the information available on the Critical Transboundary Issues (CTI) of the La Plata Basin, particularly in relation to the characteristics of each problem and related impacts. The work developed by the national institutions of each country, through the Thematic Groups, was consolidated through technical consultations, seeking to provide an overview of the different problems and their importance in the Basin, considering the environmental, social, and economic aspects associated with them. In some cases, specialized technical consultations were carried out, dealing with issues unrelated to a particular component. In this respect, health, navigation, and energy issues were addressed, among others. A particularly important aspect of this phase of the project was the generation and incorporation of data and information on climate variability and climate provided by Component III on Hydroclimatology, which allowed for a qualitative visualization of the predicted impacts on the identified problems and the economic sectors of interest to the Basin.

The development of each of the CTIs shown in *Chapter 4*—supported by *Chapters 1* through 3—makes it possible to understand the hydrological behavior of the La Plata Basin, both historically and as projected for the future.

From such analysis it emerges that more knowledge of the anthropic activities that affect hydrological behavior must be added to the current understanding of natural phenomena, particularly regarding change in land use, especially driven by the development of agriculture and livestock and growing urbanization. Such hydrological behavior, modified by the actions of man, is the direct or relatively less indirect basis for the analysis of each CTI.

Based on the analysis of the main causes identified for the CTIs and the recommendations arising from the execution of this phase of the project, the following are the general recommendations to be considered for the Strategic Action Program (SAP), grouped into technical, economic-managerial, political-institutional, and socio-cultural points:

Technical Recommendations

- Promote joint monitoring of shared water resources in quantity and quality.
- Encourage coordination between observation and warning systems in the face of extreme events (floods and droughts) in the Basin countries.
- Promote agro-ecological zoning to reduce the impact of extreme events.
- Improve urban and territorial planning to increase resilience and reduce vulnerability to extreme events.
- Exchange experiences on risk management among national, bilateral, and multilateral agencies.
- Develop regional contingency plans for urban and rural areas in the face of floods and droughts.
- Promote the exchange of best practices for drought management.
- Develop and apply, at both the sectoral and sub-basin levels, methodologies for the quantification of economic damages caused by extreme events.
- Promote the implementation of sustainable agricultural practices and the rational use of agrochemicals.
- Exchange experiences on cleaner industrial production.
- Exchange experiences on waste disposal in cross-border river transport.
- Implement mechanisms to reduce the impacts of hydraulic works on migrations of different fish species.
- Develop or update contingency plans and programs in case of broken dams and other accidents.
- Promote structural, maintenance, and operations improvements in ports.
- Promote actions to reduce the vulnerability of river transport.
- Develop cross-border plans for the maintenance and dredging of waterways

Economic and Managerial Recommendations

- Develop agreed-upon criteria and harmonize regulations for the monitoring and evaluation of water quality.
- Seek funding sources for the construction and operation of domestic and industrial wastewater treatment plants.
- Seek funding sources for the implementation of best practices for the monitoring and management of environmental quality in mining enterprises.
- Develop river and coastal ecological corridors and other forms of participatory conservation.
- Establish cooperation mechanisms on biodiversity conservation among the countries.
- Consolidate standards for sport fishing at the sub-basin level.
- Implement a code of conduct for responsible fishing.
- Establish common safety standards and criteria, considering the incidence of climate variability and change.
- Promote the exchange of information and experiences on reservoir operation and safety of works.

Political and Institutional Recommendations

- Promote institutional cooperation and coordination at the Basin level, including the consolidation of the CIC as the institutional coordinating and planning body at the Basin level.
- Harmonize legal frameworks for managing transboundary water resources.
- Harmonize environmental legislation on water resources and soil.
- Promote the development of regional policies and the strengthening of legal frameworks for the prevention and management of extreme events.
- Promote the adoption of regional minimum budgets for biodiversity conservation.
- Strengthen and harmonize the regional legal framework for the protection of aquatic biodiversity.
- Develop and apply protocols for the control and management of invasive species.
- Harmonize legislation and regulations for fisheries.
- Establish a regulatory framework for the sustainable use of aquifers.
- Elaborate and adopt national and transnational safety standards in case of broken dams and other emergencies.
- Harmonize regional policies and adjust the legal and institutional frameworks for river navigation.
- Harmonize regional policies for hydroelectricity development.
- Promote regional policies for the development of ecotourism projects.

Socio-cultural Recommendations

- Promote greater social participation in actions aimed at solving the Basin's problems.
- Develop and exchange experiences on research, education, and public awareness programs on water resources and respective environmental considerations.
- Promote education and public awareness programs about specific environmental problems in the Basin.
- Promote a culture of cooperation to address collective action

Appendix: Complementary Information

Table A.1

Population of the states/provinces/departments that are part of La Plata Basin

Country (*)	State/Province/Department	Population (inhab)
Argentina	Buenos Aires, Catamarca, Ciudad de Buenos Aires, Chaco, Córdoba, Corrientes, Entre Ríos, Formosa, Jujuy, Misiones, Salta, Santa Fe, Santiago del Estero, Tucumán.	29.030,719 26.1%
Bolivia	Chuquisaca, Oruro, Potosí, Santa Cruz, Tarija.	2.,064,348 1.8%
Brazil	Brazilia (Distrito Federal), Goiás, Minas Gerais, Mato Grosso, Mato Grosso do Sul, Paraná, Río Grande do Sul, Santa Catarina, San Pablo.	70,527,416 63.3%
Paraguay	The whole country.	6,672,631 6.0%
Uruguay	Artigas, Canelones, Colonia, Durazno, Flores, Florida, Montevideo, Paysandú, Río Negro, Rivera, Salto, San José, Sorlano, Tacuarembó.	3,105,368 2.8%
Total		**111,400,482** **100%**

The calculation of the population of the La Plata Basin was made from the sum of the population of the second and third level units whose territory is within the basin. Provinces and departments in Argentina were considered; states and municipalities in Brazil; departments and provinces in Bolivia; and departments and census tracts in Uruguay. In the case of Paraguay, the total data per country was considered, since it is included in its entirety the Basin. In all cases, any administrative territorial unit with 5 percent or more of its area included in the Basin was considered representative.

(*) The data correspond to the years 2010 in Argentina and Brazil, 2011 in Uruguay, and 2012 in Bolivia and Paraguay. In the latter case the census was conducted but the results are not yet available on the website; the data corresponds to a projection calculation made by the General Directorate of Statistics, Surveys and Censuses of Paraguay.

Sources: National Institute of Statistics and Censuses (INDEC, Argentina); National Institute of Statistics (INE, Bolivia); Brazilian Institute of Geography and Statistics (IBGE, Brazil); General Directorate of Statistics, Surveys and Censuses (DGEEC, Paraguay) and National Institute of Statistics (INE, Uruguay).

Table A.2

Sectoral participation in % of GDP

Sectors	Argentina [1]	Bolivia [2]	Brazil [3]	Paraguay [4]	Uruguay [5]
Agriculture	9.0	12.3	5.3	18.1	10.1
Mining	3.8	18.4	4.3	0.2	0.3
Industry	19.5	12.8	13.0	12.2	22.6
Energy / Water	1.0	2.4	3.1	10.2	4.8
Construction	5.9	3.3	5.7	7.8	4.1
Servicies	15.7	11.1	12.7	16.8	13.4
Transportation and communications	7.9	10.0	8.3	6.5	9.1
Financial sector	16.0	10.8	15.4	8.9	18.5
Social services and government	21.2	18.9	32.3	19.4	17.1

Base year: [1] 1993; [2] 1990; [3] 2000; [4] 1994; [5] 1983.
The data in the table refer to the countries of the Basin as a whole, not only to the portion corresponding to the La Plata Basin.

Source: Statistical Yearbook of Latin America and the Caribbean. ECLAC, 2013.

Table A.3

Human Development Index (HDI) by country and by state, province, or department in La Plata Basin

Country	HDI country	State/Province/Department
Argentina (2011)	0.848	Buenos Aires 0.838, Catamarca 0.836, City of Buenos Aires 0.889, Chaco 0.807, Córdoba 0.862, Corrientes 0.828, Entre Ríos 0.839, Formosa 0.806, Jujuy 0.829, Misiones 0.817, Salta 0.832, Santa Fe 0.846, Santiago del Estero 0.807, Tucuman 0.843.
Bolivia (2001)	0.641	Chuquisaca 0.563, Oruro 0.618, Potosí 0.514, Santa Cruz 0.689, Tarija 0.641.
Brazil (2010)	0.727	Brasilia (Federal District) 0.824, Goiás 0.735, Minas Gerais 0.731, Mato Grosso 0.725, Mato Grosso do Sul 0.729, Paraná 0.749, Rio Grande do Sul 0.746, Santa Catarina 0.774, Sao Paulo 0.783.
Paraguay (2011)	0.659	The entire territory of Paraguay is included in the La Plata Basin.
Uruguay (2010)	0.790	Artigas 0.738, Canelones 0.706, Colonia 0.775, Durazno 0.762, Flores 0.772, Florida 0.769, Lavalleja 0.750, Maldonado 0.767, Montevideo 0.841, Paysandú 0.748, Rio Negro 0.753, Rivera 0.710, Salto 0.742, San Jose 0.732, Soriano 0.748, Tacuarembó 0.745.

Sources:

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Table A.4

Percentage of illiteracy by country and by state, province, or department

Country	% Country	State/Province/Department
Argentina (2010)	7.5	Buenos Aires 6.2. Catamarca 7.4. Ciudad de Buenos Aires 3.6. Chaco 11.0. Córdoba 6.0. Corrientes 9.5. Entre Ríos 7.1. Formosa 9.7. Jujuy 8.3. Misiones 10.3. Salta 9.0. Santa Fe 6.1. Santiago del Estero 9.9. Tucumán 7.9.
Bolivia (2012)	12.6	Chuquisaca 11.8. Oruro 6.2. Potosí 11.9. Santa Cruz 1.6. Tarija 7.8.
Brazil (2010)	9.2	Brazilia (Distrito Federal) 4.7. Goiás 8.0. Minas Gerais 8.3. Mato Grosso 8.5. Mato Grosso do Sul 7.7. Paraná 6.3. Rio Grande do Sul 4.5. Santa Catarina 4.1. San Pablo 4.3.
Paraguay (2012)	4.7	The entire territory of Paraguay is included in the La Plata Basin.
Uruguay (2010)	1.3	Artigas 2.8. Canelones 1.4. Colonia 1.3. Durazno 2.1. Flores 1.8. Florida 1.9. Lavalleja 1.9. Maldonado 1.1. Montevideo 0.9. Paysandú 1.7. Río Negro 2.2. Rivera 3.5. Salto 2.1. San José 1.6. Soriano 2.1. Tacuarembó 2.7.

Note: The data correspond to all departments, states, and provinces; In the case of the countries the partial totals were added, and the percentage of the total population of each was calculated.

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Table A.5

Life expectancy at birth by country and by state, province, or department

Country	Life expectancy country (in years)	State / Province / Department
Argentina (2008 - 2010)	75.3	Buenos Aires 75.2. Catamarca 76.0. Ciudad de Buenos Aires 77.2. Chaco 72.8. Córdoba 75.7. Corrientes 74.4. Entre Ríos 75.0. Formosa 73.9. Jujuy 74.8. Misiones 74.2. Salta 74.9. Santa Fe 75.1. Santiago del Estero 70.9. Tucumán 75.1.
Bolivia (2005-2010)	67.1	Chuquisaca 66.3. Oruro 64.4. Potosí 62. Santa Cruz 69.4. Tarija 69.5.
Brazil (2011)	74.2	Brazilia (Distrito Federal) 76.2. Goiás 74.4. Minas Gerais 75.6. Mato Grosso 74.2. Mato Grosso do Sul 74.8. Paraná 75.2. Rio Grande do Sul 76.0. Santa Catarina 76.2. San Pablo 75.3.
Paraguay (2010-2015)	72.5	The entire territory of Paraguay is included in the La Plata Basin.
Uruguay (2006-2010)	75.9	Artigas 75.8. Canelones 76.0. Colonia 77.2. Durazno 76.5. Flores 76.8. Florida 77.0. Lavalleja 75.9. Maldonado 76.7. Montevideo 75.9. Paysandú 76.2. Río Negro 76.5. Rivera 75.3. Salto 75.2. San José 75.1. Soriano 75.9. Tacuarembó 75.5.

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Table A.6

Infant mortality rates by country and by state, province, or department

Country	Infant mortality by country (en %)	State/Province/Department
Argentina (2013)	10.8	Buenos Aires 11.0. Catamarca 9.7. Ciudad de Buenos Aires 8.9. Chaco 11.6. Córdoba 9.6. Corrientes 14.9. Entre Ríos 9.2. Formosa 14.2. Jujuy 11.8. Misiones 10.4. Salta 14.1. Santa Fe 9.8. Santiago del Estero 11.5. Tucumán 13.1.
Bolivia (2005-2011)	61.1	Chuquisaca 48.3. Oruro 55.1. Potosí 65.5. Santa Cruz 37.8. Tarija 37.2.
Brazil (2014)	14.4	Brazilia (Distrito Federal) 11.0. Goiás 15.8. Minas Gerais 12.0. Mato Grosso 17.7. Mato Grosso do Sul 14.9. Paraná 10.1. Rio Grande do Sul 10.2. Santa Catarina 9.8. San Pablo 10.5.
Paraguay (2011)	15.2	La totalidad del territorio de Paraguay se encuentra comprendido en la La Plata Basin.
Uruguay (2013)	8.9	Artigas 9.4. Canelones 10.0. Colonia 7.5. Durazno 6.0. Flores 5.8. Florida 5.4. Lavalleja 11.4. Maldonado 5.4. Montevideo 7.5. Paysandú 8.9. Río Negro 11.1. Rivera 10.2. Salto 10.4 San José 9.8. Soriano 9.7. Tacuarembó 7.1.

The data correspond to the totality of each department, state, or province and to the entirety of each country.

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Table A.7

National parks in the territory of La Plata Basin

Argentina 13	Bolivia 3	Brazil 8	Paraguay 13	Uruguay 1
Campos del Tuyú National Park	National Park and Natural Area of Integrated Management Area Kaa-lya of Gran Chaco	Chapada dos Guimarães National Park	Cerro Corá National Park	Farrapos Estuary and Islands of the Uruguay River National Park
Predelta National Park	National Park and Natural Area of Integrated Management Otuquis	Das Emas National Park	Ñacunday National Park	
Santa Fe Islands National Park	National Park and Natural Area of Integrated Management Serrania del Aguaragüe	Brasilia National Park	Ybycui National Park	
El Palmar National Park		Ilha Grande National Park	Caazapa National Park	
Chaco National Park		Pantanal Matogrossense National Park	Paso Bravo National Park	
Copo National Park		Iguaçu National Park	Serrania de San Luis National Park	
Mburucuyá National Park		Araucarias National Park	Defensores del Chaco National Park	
Pilcomayo River National Park		Campos Gerais National Park	Tinfunqué National Park	
Iguazu National Park			Teniente Agripino Enciso National Park	
National Park			Medanos del Chaco National Park	
National Park			Rio Negro National Park	
National Park			Lake Ypoá National Park	
The Impenetrable National Park			Chovoreca National Park	

Glossary

Activity
Practice or set of practices taking place in a defined area during a given period.

Adaptation
Adjustment in human or natural systems with regard to new or changing environments.

Biodiversity
Quantity and relative abundance of different families (genetic diversity), species, and ecosystems (communities) in a given area.

Biogeographic Corridor
Structural component of an ecosystem whose characteristics—breadth, connectivity, narrowing, cuts, nodes, etc.—constitute an important regulating function of the flow of species, genes, nutrients, energy, and water.

Biome
Set of related ecosystems that show similarities both in their appearance and in their internal structure because they are influenced by the same climate, soil, and type of relief. Biomes are characterized mainly by their dominant plant and animal species.

Change in Land Use
Change in the use or management of land by humans, which may lead to a change in soil cover.

Climate
Average weather state over a period of at least 30 years in a specific region. In a broader sense, it can also be said that climate refers not only to the atmosphere, but to the description of climate systems as a whole, which comprises the atmosphere, ocean, earth, cryosphere (snow and ice), and biosphere. It is generally said that weather is what you have and the climate is what you expect.

Climate Change
Change in the state of the climate that can be identified –for example, with statistical evidence– by changes in the average climate or the variability of its properties and which persists for an extended period of time, usually for decades or longer periods. Climate change may be due to internal natural or external forceful processes, such as solar cycle modulations or volcanic eruptions, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (special report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, IPCC, 2012).

Change of climate attributed directly or indirectly to human activity that changes the composition of the global atmosphere and which adds to the natural variability of the climate observed during certain periods. A distinction is made between "climate change," attributed to human activities that alter atmospheric composition, and "climate variability," attributed to natural causes (United Nations Framework Convention on Climate Change - UNFCCC) (See *Climatic variability*).

Climate Model (in spectrum or hierarchy)
Numerical representation of the climate system, based on the physical, chemical, and biological properties of its components, their interactions, and their feedback processes, and which collects all or some of their known properties. The climate system can be represented by models of varying degrees of complexity; in other words, for each component or set of components it is possible to identify a spectrum or hierarchy of models that differ in such aspects as the number of spatial dimensions, the degree to which they explicitly represent physical, chemical, or biological

processes, or the degree of use of empirical parameterizations. The coupled atmospheric and oceanic general circulation models (AOGCM) provide the most complete representation of the climate system currently available. There is movement towards more complex models incorporating interactive chemistry and biology. Climate models are used as a research tool to study, and simulate the climate and for operational purposes, in particular monthly, seasonal, and inter-annual climatic predictions (IPCC, 2013).

Climate Prediction

A climatic prediction or climatic prognosis is the result of an attempt to obtain—from a particular state of the climate system—an estimate of actual future climate changes, for example, on seasonal, inter-annual, or regional time scales. As the future evolution of the climate system can be very sensitive to the initial conditions, these predictions are usually probabilistic.

Climate Projection

Simulated response of the climate system to various emissions scenarios or to concentrations of greenhouse gases and aerosols, often based on simulations using climate models. Climate projections differ from climate predictions because of their dependence on the emissions/concentration/radiative forcing scenarios, based on relative assumptions, for example, on a socio-economic and technological development that may or may not materialize (IPCC, 2013).

Climate Scenario

A plausible and sometimes simplified representation of the future climate, based on an internally coherent set of climatological relationships, explicitly defined to investigate the possible consequences of anthropogenic climate change, and which can be introduced as incoming data in impact models. Climate projections are often used as a starting point for defining climatic scenarios, although these usually require additional information, for example on the current observed climate. A climate change scenario is the difference between a climate scenario and the current climate.

Climate Variability

Variations in the mean state and other climate data and statistics—such as standard deviations, occurrence of extreme phenomena, etc.—at all temporal and spatial scales, beyond specific meteorological phenomena. The variability may be due to natural internal processes within the climate system (internal variability), or to variations in external anthropogenic forces (external variability) (IPCC, 2007). (See also *Climate Change*).

Community

All populations of individuals who inhabit and interact in a common environment.

Conservation

Protection, maintenance, management, sustainable use, restoration, and strengthening of the natural environment.

Deforestation

Action to permanently eliminate the forest for non-forest use, with a reduction of crown cover to less than 10 percent.

Degradation

The process in which a system moves from a certain degree of organization and composition to a simpler one with fewer components.

Desertification

Degradation of soils in arid, semi-arid, and dry sub-humid areas that are the result of several factors, including climatic variations and human activities.

Diversity

General term for designating the variability of living organisms of any kind, including terrestrial and marine ecosystems and other aquatic ecosystems, and the ecological complexes of which they form part.

Ecosystem
Dynamic complex where communities of plants, animals, fungi, and microorganisms and their physical environment interact as a single unit.

Emission Scenario
Future greenhouse gas emissions are the product of very complex, dynamic systems, determined by forces such as population growth, socioeconomic development, or technological change. Its future evolution is very uncertain. Scenarios are alternative images of what might happen in the future and are an appropriate instrument for analyzing how determining forces will influence future emissions, and for assessing the margin of error in that analysis. Emission scenarios are useful for climate change analysis, and for climate modeling in particular, for impact assessment, and for adaptation and mitigation initiatives.

Endangered Species
Species whose survival is unlikely if causal factors continue to operate. In this category are species whose numbers have been reduced to a critical level or whose habitats have been dramatically reduced.

Endemic
In biology, referring to a species or taxon restricted to a specific region or location.

Environmental Education
Permanent learning process that targets the community as a whole with a global and nterdisciplinary approach to the environmental reality.

Environmental/Ecosystem Services
Functions (processes) provided by forests, other natural ecosystems, and forest plantations which have a direct impact on the protection and improvement of the environment and quality of life.

Extinction
The total disappearance of whole species.

Fragmentation
Division of an area, landscape or habitat into separate and defined parts, often as a consequence of change in land use.

Functions of Ecosystems
The ability of ecosystems to provide services that satisfy society.

Global Warming
Gradual increase in the temperature of the Earth's atmosphere and oceans that has been detected in the present, in addition to its continued projected increase in the future.

Greenhouse Effect
Infrared radiative effect of all the components of the atmosphere that absorb the infrared radiation. Greenhouse gases and clouds and, to a lesser extent, aerosols, absorb the radiation emitted by the Earth’s surface and by any point in the atmosphere. These substances emit infrared radiation in all directions but, under equal conditions, the net amount of energy emitted into space is generally less than would have been emitted in the absence of such absorbers due to the decrease in temperature with altitude in the troposphere and the consequent weakening of the emission. A higher concentration of greenhouse gases increases the magnitude of this effect, and the difference is generally referred to as an intensified greenhouse effect. Modification of the concentration of greenhouse gases due to human emissions contributes to an increase in the surface temperature and in the troposphere induced by an instantaneous radiative imposition in response to that forcing, which

gradually restores the radiative balance in the upper part of the atmosphere.

Greenhouse Gas

Gaseous component of the atmosphere, natural or anthropogenic, which absorbs radiation at certain wavelengths on the terrestrial radiation spectrum emitted by the surface of the Earth, by the atmosphere itself, and by the clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases of the Earth's atmosphere. In addition, the atmosphere contains a certain number of entirely anthropogenic greenhouse gases, such as halocarbons or other chlorine- and bromine- containing substances, which are covered by the Montreal Protocol. In addition to CO_2, N_2O, and CH_4, the Kyoto Protocol covers additional greenhouse gases like sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

Habitat

The particular environment or place where an organism or species lives; a part of the total environment but circumscribed more locally.

Intertropical Convergence Zone (ITCZ)

Equatorial zonal strip of low pressure, strong convection, and large quantities of rainfall near the equator, where the trade winds of the northeast meet those of the southeast. This strip moves seasonally.

Land Degradation

Understood as the reduction or loss of biological or economic productivity and the complexity of rain fed agricultural land, irrigated arable land, pasture lands, forests, and woodlands, caused in arid zones, semi-arid and dry sub-humid areas, by land use systems or by a process or a combination of processes, including those resulting from human activities and patterns of settlement.

Mitigation

All activities tending to reduce the effects as a result of an impact.

Native Forest

Forest that has evolved and has been naturally renewed from organisms that were already in a particular biogeographic region.

Population

A group of individuals of the same species in an arbitrarily defined space/time and which are much more likely to come together with one other than with individuals from another group.

Protected Natural Areas

Territory comprised within certain well-defined limits, of natural or semi-natural characteristics, which is subject to the management of its resources to achieve established conservation objectives. Normally, the territory belongs to a nation or to one of the nation’s public sector organisms, but it can also be private property, managed according to norms set by national or sub-national authorities.

Resources

Any biotic or abiotic element that can be exploited, whether mercantile or not.

Scenario

Plausible description of a realistic future, based on a consistent and coherent set of assumptions about driving forces (for example, the rate of technological evolution and prices) and the most important relationships. Note that scenarios are neither predictions nor prognoses, but they are useful, as they provide an overview of the consequences of the evolution of certain situations and measures.

Soil Degradation
Any process of partial or total loss of land productivity.

Territorial Planning
Process of planning the distribution and spatial location of the components of the territorial structure, as a means of implementing the strategies of a regional development proposal, with special emphasis on economic aspects, population distribution, and environmental management.

United Nations Framework Convention on Climate Change (UNFCCC)
Adopted in New York on May 9, 1992, and ratified the same year at the Earth Summit held in Rio de Janeiro by more than 150 countries plus the European Community. Its ultimate goal is to "stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system." It contains clauses that involve all Parties. Under the Convention, Parties included in Annex I (all OECD countries and countries in transition) proposed to return, by the year 2000, greenhouse gas emission levels not controlled by the Montreal Protocol to the levels that existed in 1990. The Convention took effect in March 1994. In 1997 the UNFCCC incorporated the Kyoto Protocol. In December 2015, the Paris Agreement was signed.

Weather
Description of the state of the atmosphere at a given time (for example, at noon). It is defined by variables such as temperature, atmospheric pressure, wind direction and strength, quantity of clouds, and humidity, among other things. It can be said that weather is instantaneous, changing, and somewhat unrepeatable. It is not the same at noon as at six in the afternoon.

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Appendix I

List of Acronyms

AMC	Annual Mean Concentration (*Concentración Media Anual, CMA*)
ANA	National Water Agency (*Agência Nacional de Águas / Agencia Nacional de Aguas de Brasil*)
ANAC	National Civil Aviation Administration (*Administración Nacional de Aviación Civil de Argentina*)
ANDE	National Electricity Administration (*Administración Nacional de Electricidad de Paraguay*)
ANEEL	Brazilian Electricity Regulatory Agency (*Agência Nacional de Energia Elétrica / Agencia Nacional de Energía Eléctrica de Brasil*)
ANNP	National Administration of Navigation and Ports (*Administración Nacional de Navegación y Puertos de Paraguay*)
AOGCM	Atmosphere-Ocean General Circulation Model / *Modelos Globales Acoplados Océano-Atmósfera*
CARP	La Plata River Administrative Commission (*Comisión Administradora para el Río de la Plata*)
CARU	Administrative Commission of the Uruguay River (*Comisión Administradora del Río Uruguay*)
CBD	Convention on Biological Diversity (Convenio sobre Diversidad Biológica, CDB)
CC	Climate Change (Cambio Climático)
CEDLAS	Socioeconomic Database for Latin America and the Caribbean (Base de Datos Socio-Económica para Latinoamérica y el Caribe)
CEMADEN	National Center for Natural Disaster Monitoring and Alert (*Centro Nacional de Monitoramento e Alertas de Desastres Naturais / Centro Nacional de Monitoreo y Alerta de Desastres Naturales de Brasil*)
CGW	Cultivating Good Water (*Cultivando Agua Boa / Cultivando Agua Buena, CAB*)
CIC	Intergovernmental Coordinating Committee of the Countries of La Plata Basin (*Comité Intergubernamental Coordinador de los Países de la Cuenca del Plata*)
CIH	Intergovernmental Committee of the Paraguay-Parana Waterway (*Comité Intergubernamental de la Hidrovía Paraguay-Paraná*)
CIMA	Center for Marine and Atmospheric Research (*Centro de Investigaciones del Mar y la Atmósfera, Argentina*)
CNRH	National Water Resources Council (*Conselho Nacional de Recursos Hídricos / Consejo Nacional de Recursos Hídricos de Brasil*)
COBINABE	Binational Commission for the Developemtn of the Upper Basin of the Bermejo River and Rio Grande de Tarija (*Comisión Binacional para el Desarrollo de la Alta Cuenca del Río Bermejo y el Río Grande de Tarija, Argentina-Bolivia*)
COFEMA	Federal Environment Council (*Consejo Federal de Medio Ambiente, de Argentina*)
COHIFE	Federal Water Council (*Consejo Hídrico Federal, de Argentina*)

COMIP	Paraguayan-Argentinian Joint Commission of the Paraná River (*Comisión Mixta Argentino-Paraguaya del Río Paraná*)
CONAMA	National Environmental Council (*Conselho Nacional do Meio Ambiente / Consejo Nacional de Medio Ambiente de Brasil*)
CONAMA	National Environmental Council (*Consejo Nacional de Medio Ambiente de Uruguay*)
CONICET	National Scientific and Technical Research Council (*Consejo Nacional de Investigaciones Científicas y Técnicas de Argentina*)
COP	Conference of the Parties (*Conferencia de las Partes*)
CPC	Climate Prediction Center
CPRM	Brazilian Geological Service (*Serviço Geológico do Brasil / Servicio Geológico de Brasil*)
CPTEC	Center for Weather Forecasting and Climate Studies (*Centro de Previsão de Tempo e Estudos Climáticos / Centro de Predicción del Tiempo y Estudios Climáticos de Brasil*)
CRA	Brazilian-Paraguayan Joint Commission for the Sustainable Development and Integrated Management of the Apa River Basin (*Comisión Mixta Brasileño-Paraguaya para el Desarrollo Sustentable y la Gestión Integrada de la Cuenca del Río Apa*)
CRC	Brazilian-Uruguayan Joint Commission for the Development of the Cuarein-Quaraí Basin (*Comisión Mixta Brasileño-Uruguaya para el Desarrollo de la Cuenca del Río Cuareim-Quaraí*)
CRC-SAS	Regional Climate Center for Southern South America (*Centro Regional de Clima para el Sur de América del Sur*)
CRU	Climatic Research Unit / *Unidad de Investigación del Clima, Universidad de East Anglia, Reino Unido*
CTI	Critical Transboundary Issue
CTM	Joint Technical Commission of Salto Grande (*Comisión Técnica Mixta de Salto Grande, Argentina-Uruguay*)
CTMFM	Joint Technical Commission for the Maritime Front (*Comisión Técnica Mixta del Frente Marítimo, Argentina-Uruguay*)
DAAE	São Paulo Department of Water and Electricity (*Departamento de Águas e Energia Elétrica do Estado de São Paulo / Departamento de Aguas y Energía Eléctrica del Estado de São Paulo*)
DACC	Department of Agriculture and Climate Contingencies of Mendoza (*Dirección de Agricultura y Contingencias Climáticas de Mendoza, Argentina*)
DDP	Demonstrative Pilot Projects (*Proyectos Piloto Demostrativos, PPD*)
DECEA	Brazilia Department of Air Space Control (*Departamento de Contro le do Espaço Aéreo / Departamento de Control del Espacio Aéreo de Brasil*)
DGEEC	General Directorate of Statistics, Surveys, and Censuses (*Dirección General de Estadísticas, Encuestas y Censos de Paraguay*)
DGRNR	General Directorate of Renewable Natural Resources (*Dirección General de Recursos Naturales Renovables de Uruguay*)
DIGESA	National Directorate of Environmental Health (*Dirección General de Salud Ambiental de Paraguay*)
DINAC	National Directorate of Civil Aeronautics (*Dirección Nacional de Aeronáutica Civil de Paraguay*)

DINAGUA	National Directorate of Water (*Dirección Nacional de Aguas de Uruguay*)
DINAMA	National Environment Directorate (*Dirección Nacional de Medio Ambiente de Uruguay*)
DINAP	National Directorate of Drinking Water and Sanitation (*Dirección de Agua Potable y Saneamiento de Paraguay*)
DINARA	National Directorate of Aquatic Resources of Uruguay (*Dirección Nacional de Recursos Acuáticos de Uruguay*)
DMH	Direction of Meteorology and Hydrology (*Dirección de Meteorología e Hidrología de Paraguay*)
DNVN	National Directorate of Waterways (*Dirección Nacional de Vías Navegables de Argentina*)
DSS	Decision-making Support System (*Sistema Soporte para la Toma de Decisiones, SSTD*)
EAP	Emergency Action Plan (*Plan de Acción Durante Emergencias, PADE*)
EBY	Yacyretá Binational Entity (*Entidad Binacional Yacyretá, Argentina-Paraguay*)
ECLAC	Economic Commission for Latin America and the Caribbean (*Comisión Económica para América Latina y el Caribe, CEPAL*)
EIA	Environmental Impact Assessment (*Evaluación de Impacto Ambiental*)
EMBRAPA	The Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária / Empresa Brasileña de Investigación Agropecuaria*)
ENSO	El Niño Southern Oscillation (*El Niño-Oscilación del Sur- ENOS*)
ERSSAN	Potable Water and Sanitary Services Regulatory Entity (*Ente Regulador de Servicios de Agua Potable y Saneamiento de Paraguay*)
ETP	Evapotranspiration potential (*Evapotranspiración Potencial*)
FAO	Food and Agriculture Organization of the United Nations (*Organización de las Naciones Unidas para la Alimentación y la Agricultura*)
FONPLATA	La Plata Basin Financial Development Fund (*Fondo Financiero para el Desarrollo de la Cuenca del Plata*)
FORADE	Trust Fund for Risk Reduction and Disaster Assistance (*Fondo de Fideicomiso para la reducción de riesgos y atención de desastres de Bolivia*)
FP	Framework Program for the Sustainable Management of La Plata Basin's Water Resources, with respect to the effects of climate variability and change (*Programa Marco para la Gestión Sostenible de los Recursos Hídricos en la Cuenca del Plata, en relación con los efectos de la variabilidad y el cambio climático, PM*)
FPPP	Fund for Promoting Public Participation (*Fondo para la Participación Pública, FPP*)
FREPLATA	Environmental Protection of the La Plata River and its Maritime Front (*Proyecto de Protección Ambiental del Río de la Plata y su Frente Marítimo, Argentina-Uruguay*)
GAS	Guaraní Aquifer System (*Sistema Acuífero Guaraní*)
GCM	General Circulation Model / *Modelo General de Circulación*
GDP	Gross Domestic Product (Producto Bruto Interno, PBI)
GEF	Global Environment Facility (*Fondo para el Medio Ambiente Mundial, FMAM*)
GHG	Greenhouse gases (*Gases de Efecto Invernadero, GEI*)
GFCS	Global Framework for Climate Services (*Marco Mundial para los Servicios Climáticos- MMSC*)

HDI	Human Development Index
IAS	Invasive alien species (Especies exóticas invasoras, EEI)
IB	Binational Itaipú (Itaipú Binacional, Brasil-Paraguay)
IBA	Important Bird and Biodiversity Area / *Área Importante para la Conservación de las Aves*
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis/Instituto Brasileño de Medio Ambiente y Recursos Naturales Renovables*)
IBD	International Development Bank (*Banco Interamericano de Desarrollo, BID*)
IBGE	Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística / Instituto Brasileño de Geografía y Estadística de Brasil*)
IGAM	Mineiro Institute for Water Management (*Instituto Mineiro de Gestão das Águas / Instituto Mineiro de Gestión de Aguas del Estado de Minas Gerais, Brasil*)
INA	National Water Institute (*Instituto Nacional de Aguas, Argentina*)
INDC	Intended Nationally Determined Contributions / *Contribuciones Determinadas a Nivel Nacional*
INDEC	National Institute of Statistics and Censuses (*Instituto Nacional de Estadística y Censos de Argentina*)
INE	National Institute of Statistics (*Instituto Nacional de Estadística de Bolivia*)
INE	National Institute of Statistics (*Instituto Nacional de Estadística de Uruguay*)
INIA	National Institute of Agricultural Research (*Instituto Nacional de Investigación Agropecuaria de Uruguay*)
INMET	National Institute of Meteorology (*Instituto Nacional de Meteorologia / Instituto Nacional de Meteorología de Brasil*)
INPE	National Spacial Research Institute (*Instituto Nacional de Pesquisas Espaciais / Instituto Nacional de Investigaciones Espaciales de Brasil*)
INTA	Institute of Agricultural Technology (*Instituto Nacional de Tecnología Agropecuaria de Argentina*)
INUMET	Uruguayan Institute of Meteorology (*Instituto Uruguayo de Meteorología*)
IPCC	Intergovernmental Panel on Climate Change / *Panel Intergubernamental de Cambio Climático*
IPTA	Paraguayan Institute of Agrarian Technology (*Instituto Paraguayo de Tecnología Agraria*)
ITCZ	Intertropical Convergence Zone (*Zona de convergencia intertropical, ZCIT*)
IWB	Integrated Water Balance (*Balance Hídrico Integrado, BIH*)
IWRM	Integrated Water Resource Management (*Gestión Integrada de los Recursos Hídricos, GIRH*)
JAXA	Japan Aerospace Exploration Agency
LDN	Land Degradation Neutrality / *Neutralidad de la Degradación de la Tierra*
LEAS	Leading Environmental Analysis and Display System
LPB	La Plata Basin (*Cuenca de la Plata- CdP*)

MAB	Man and the Biosphere Programme / *Programa El Hombre y la Biósfera - Reservas de la Biósfera de Unesco*
MAyDS	Ministry of Environment and Sustainable Development (*Ministerio de Ambiente y Desarrollo Sustentable de Argentina*)
MCS	Mesoscale Convective Systems (*Sistemas Convectivos de Mesoescala, SCM*)
MCTI	Ministry of Science, Technology, and Innovation (*Ministério da Ciência, Tecnologia e Inovação do Brasil / Ministerio de Ciencia, Tecnología e Innovación de Brasil*)
MDRT	Ministry of Rural and Land Development (*Ministerio de Desarrollo Rural y Tierras de Bolivia*)
Mercosur	Mercado Común del Sur
MMA	Ministry of Environment (*Ministério do Meio Ambiente do Brasil / Ministerio de Medio Ambiente de Brasil*)
MMAyA	Ministry of Environment and Water (*Ministerio de Medio Ambiente y Agua de Bolivia*)
MPA	Ministry of Fisheries and Aquaculture (*Ministério da Pesca e Aquicultura do Brasil / Ministerio de Pesca y Acuicultura de Brasil*)
MR	Meteorological radar (*Radares meteorológicos, RM*)
MTOP	Ministry of Transportation and Public Works (*Ministerio de Transporte y Obras Públicas de Uruguay*)
MVOTMA	Ministry of Housing, Land Use, and Environment (*Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente de Uruguay*)
NASA	National Aeronautics and Space Administration / *Administración Aeronáutica y del Espacio de Estados Unidos*
NOAA	National Oceanic and Atmospheric Administration
NWI	National Water Institute (*Instituto Nacional del Agua de Argentina- INA*)
OAS	Organization of American States (*Organización de los Estados Americanos, OEA*)
ONDTyD	National Observatory of Land Degradation and Desertification (*Observatorio Nacional de Degradación de Tierras y Desertificación de Argentina*)
ORSEP	Dam Safety Regulatory Agency (*Organismo Regulador de Seguridad de Presas de Argentina*)
OSE	Administration of State Sanitary Works (*Administración de las Obras Sanitarias del Estado de Uruguay*)
PACU	Decentralized Public Institute of Fisheries and Aquaculture (*Institución Pública Desconcentrada de Pesca y Acuicultura de Bolivia*)
PCU	Project Coordination Unit (*Unidad de Coordinación de Proyecto*)
PMAE	Framework Program for Strategic Actions for the Sustainable Development of Water Resources in the La Plata Basin (*Programa Marco de Acciones Estratégicas para la Gestión Sostenible de los Recursos Hídricos de la Cuenca del Plata*)
PNAS	National Groundwater Program (*Programa Nacional de Águas Subterrâneas / Programa Nacional de Aguas Subterráneas de Brasil*)
PNDR	National Irrigation Plan to Live Well (*Plan Nacional de Riego para Vivir Bien de Bolivia*)
PNFAS	Federal National Groundwater Plan (*Plan Nacional Federal de Aguas Subterráneas de Argentina*)

PNFRH	National Water Resources Plan (*Plan Nacional Federal de Recursos Hídricos de Argentina*)
PNPDEC	National Policy of Civil Defense and Protection (*Política Nacional de Proteção e Defesa Civil /Política Nacional de Protección y Defensa Civil de Brasil*)
PNUMA	United Nations Environment Program (*Programa de las Naciones Unidas para el Medio Ambiente*)
RCM	Regional Climatic Models / *Modelos Climáticos Regionales*
RCP	Representative Concentration Pathways / *Trayectorias de Concentración Representativas*
RMA	Argentine Meteorological Radar (*Radares Meteorológicos Argentinos*)
SACZ	South Atlantic Convergence Zone (*Zona de Convergencia del Atlántico Sur, ZCAS*)
SALLJ	South American Low-Level Jet / *Jet de Bajo Nivel de Sudamérica*
SAP	Strategic Action Program (*Programa de Acciones Estratégicas, PAE*)
SAT	Early Flood Warning System (*Sistema de Alerta Temprana de Inundación, Durazno, Uruguay*)
SEAM	Secretary of the Environment (Secretaría del Ambiente de Paraguay)
SEGEMAR	Argentine Geological Mining Service (*Servicio Geológico Minero Argentino*)
SEN	Secretary of National Emergencies (*Secretaria de Emergencia Nacional de Paraguay*)
SENAMHI	National Meteorology and Hydrology Service (*Servicio Nacional de Meteorología e Hidrología de Bolivia*)
SENARI	National Irrigation Service (*Servicio Nacional de Riego de Bolivia*)
SENASA	National Environmental Sanitation Service (*Servicio Nacional de Saneamiento Ambiental de Paraguay*)
SERGEOMIN	Geological and Mining Service (*Servicio Nacional Geológico de Minas de Bolivia*)
SHN	Naval Hydrography Service (*Servicio de Hidrografía Naval de Argentina*)
SIMEPAR	Paraná Meteorological System (*Sistema Meteorológico do Paraná / Sistema Meteorológico del Estado de Paraná, Brasil*)
SINAE	National Emergency System (*Sistema Nacional de Emergencias de Uruguay*)
SINARAME	National System of Meteorological Radar (*Sistema Nacional de Radares Meteorológicos de Argentina*)
SIyAH	Hydrological Information and Alert System of the La Plata Basin (*Sistema de Información y Alerta Hidrológico de la Cuenca del Plata, Instituto Nacional del Agua, Argentina*)
SMHN	National Weather and Hydrologival Service (*Servicio Meteorológico e Hidrológico Nacional de Bolivia*)
SMN	National Weather Service (Argentina) (*Servicio Meteorologico Nacional- SMN*)(cited in the text with the Spanish acronym)
SMP	Selva Misionera Paranaense
SNATD	National Disaster Early Warning System (*Sistema Nacional de Alerta Temprana de Desas tres de Bolivia*)
SNHN	National Naval Hydrography Service (*Servicio Nacional de Hidrografía Naval de Bolivia*)

SNIRH	National System of Information on Hydraulic Resources (*Sistema Nacional de Informações sobre Recursos Hídricos/Sistema Nacional de Informaciones sobre los Recursos Hídricos de Brasil*)
SPA	Undersecretary of Fisheries and Aquaculture (*Subsecretaría de Pesca y Acuicultura de Argentina*)
SPEI	Standardized Precipitation-Evapotranspiration Index (*Índice estandarizado de precipitación-evapotranspiración*)
SRHU	Secretary of Urban Environment and Water Resources (*Secretaria de Recursos Hídricos e Ambiente Urbano / Secretaría de Recursos Hídricos y Ambiente Urbano de Brasil*)
SSRH	Under-secretariat of Water Resources (*Subsecretaria de Recursos Hídricos de la Nación de Argentina*)
TCP	La Plata Basin Treaty (*Tratado de la Cuenca del Plata*)
TDA	Transboundary Diagnostic Analysis
TRMM	Tropical Rainfall Measuring Mission
UBA	University of Buenos Aires (*Universidad de Buenos Aires, Argentina*)
UDELAR	University of the Republic (*Universidad de la República*)
UFAL	Federal University of Alagoas, Brazil (*Universidade Federal de Alagoas / Universidad Federal de Alagoas, Brasil*)
UN	United Nations (Organización de las Naciones Unidas, ONU)
UNC	National University of Córdoba (Universidad Nacional de Córdoba, Argentina)
UNEP	United Nations Environment Programme / *Programa de las Naciones Unidas para el Medio Ambiente – PNUMA* (cited in the text with the Spanish acronym)
Unesco	United Nations Educational, Scientific and Cultural Organization (*Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura*)
UNESP	Paulista State University (*Universidade Estadual Paulista "Júlio de Mesquita Filho"/ Universidad Estatal Paulista "Julio de Mesquita Filho"*)
UNFCCC	United Nations Framework Convention on Climate Change (*Convención Marco de las Naciones Unidas sobre el Cambio Climático, CMNUCC*)
UTE	National Power Plant and Electric Transmission Administration (*Administración Nacional de Usinas y Transmisiones Eléctricas de Uruguay*)
WIGOS	WMO Integrated Global Observing System / *Sistema Integrado de Observación Global de la Organización Meteorológica Mundial*
VIDECI	Vice Ministry of Civil Defense (*Vice Ministerio de Defensa Civil de Bolivia*)
WMO	World Meteorological Organization (*Organización Meteorológica Mundial – OMM*)
WTO	World Tourism Organization (*Organización Mundial de Turismo, OMT*)
YTTAS	Yrendá-Toba-Tarijeño Aquifer System (*Sistema Acuífero Yrendá Toba Tarijeño-SAYTTT*)

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Institutional References

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Political Representative	Technical Representative	Second Technical Representative
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National Units of the Framework Program

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Argentina	Bolivia	Brazil	Paraguay	Uruguay
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National Units of the Framework Program

Thematic Groups of the Framework Program

Argentina*	Bolivia	Brazil	Paraguay	Uruguay
Legal and Institutional Framework				
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Decision-making Support System				
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Public Participation, Communication and Education				
Secretaría de Ambiente y Desarrollo Sustentable de la Nación (Silvia Freiler, Daniela García)	Ministerio de Relaciones Exteriores (María del Sagrario Urgel Aguilar, Consuelo Ponce) Ministerio de Educación	Ministerio de Medio Ambiente/ Secretaría de Recursos Hídricos y Ambiente Urbano (Franklin de Paula Júnior)	Universidad Nacional de Pilar (Ernilda Vera); Secretaría de la Información y Comunicación (César Palacios); Secretaría del Ambiente (Maria Coronel)	MVOTMA (Luján Jara); Ana Laura Martino; Ministerio de Educación y Cultura (Laura Barcia); Secretaría Comunicación Presidencia (Carolina Echavarría)
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*Consejo Hídrico Federal Argentina (2011- 2016).
Dirección de Hidráulica de Entre Ríos (Oscar Duarte). Instituto Correntino del Agua y del Ambiente (Mario Rujana).

Thematic Groups of the Framework Program

Argentina	Bolivia	Brazil	Paraguay	Uruguay
Water Quality				
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Groundwater				
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Aquatic Ecosystems				
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Environmental Degradation				
Secretaría de Ambiente y Desarrollo Sustentable de la Nación (José Cuevas; Pablo Viegas Aurelio)	Ministerio de Desarrollo Rural y Tierra	Empresa Brasileña de Investigación Agropecuaria (Celso Vainer Manzatto)	Secretaria del Ambiente (David Fariña, José Silvero)	Ministerio de Ganadería, Agricultura y Pesca MGAP (Carlos Clerici); Facultad de Agronomía de la Universidad de la República - UDELAR (Mario Pérez Bidegain, Fernando García Prechac)
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National Units of the Framework Program

Thematic Groups of the Framework Program (continuation)

Argentina	Bolivia	Brazil	Paraguay	Uruguay
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PPD Confluence				
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PPD Cuareim				
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PPD Pilcomayo				
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Thematic Groups of the Framework Program

Argentina	Bolivia	Brazil	Paraguay	Uruguay
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GLOBAL ENVIROMENT FACILITY - GEF

The GEF promotes international cooperation and fosters actions to protect the environment of our planet. Since its inception, it has become a catalyst and source of funding to consider global environmental issues in the development process in an integrated way, which is crucial to achieving a sustainable balance between man and nature. It provided the grants which funded the Framework Program.

UNITED NATIONS ENVIRONMENT PROGRAMME - UN ENVIRONMENT

UN Environment directs and encourages participation in caring for the environment by inspiring, informing and giving nations and peoples the means of improving their quality of life without endangering future generations. In the organizational structure of the Framework Program, it has been the GEF implementing agency, and its goal has been to ensure that the project is implemented for the benefit of the global environment. Member of the Project Board.

ORGANIZATION OF AMERICAN STATES - OAS

The OAS has maintained a historical relationship of technical cooperation with the La Plata Basin and the CIC on issues related to sustainable development, natural resources and management of water resources. For the preparation of the Framework Program for the La Plata Basin, it was the regional organization selected both by UN Environment and by the CIC, as the executing agency with technical and administrative responsibility for GEF funds. Member of the Project Board.

Framework Program

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Publications of the Framework Programme

Main Documents

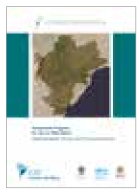
Versions in Spanish, Portuguese and English

Transboundary Diagnostic Analysis for the La Plata Basin
TDA

Strategic Action Program for the La Plata Basin
SAP

Transboundary Diagnostic Analysis (TDA) and Strategic Action Program (SAP) for the La Plata Basin

Executive Summary



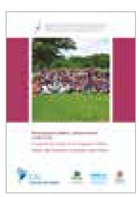
Framework Program for the La Plata Basin

Implementation Process and Primary Outcomes

Thematic Documents

Sistema soporte para la toma de decisiones de la Cuenca del Plata

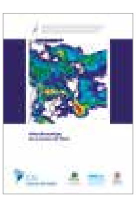
Marco institucional y legal para la gestión integrada de los recursos hídricos en la Cuenca del Plata



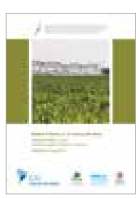
Participación pública, comunicación y educación

Proyectos del Fondo de Participación Pública

Réplica del Programa Cultivando Agua Buena



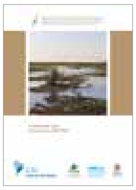
Hidroclimatología de la Cuenca del Plata



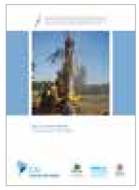
Balance hídrico en la Cuenca del Plata

Disponibilidad y usos, considerando escenarios futuros

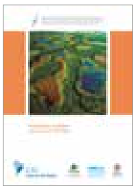
Modelos de gestión



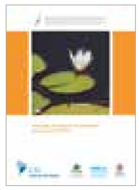
Calidad del agua
en la Cuenca del Plata



Aguas subterráneas
en la Cuenca del Plata

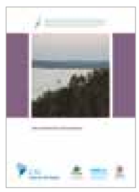


Ecosistemas acuáticos
en la Cuenca del Plata



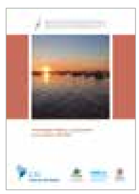
Inventario de Regiones
de Humedales de
la Cuenca del Plata

Degradación de tierras
en la Cuenca del Plata



Selva Misionera
Paranaense

Hidroelectricidad
y navegación en
la Cuenca del Plata



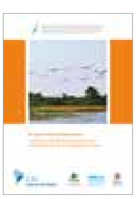
Tecnologías limpias
y ecoturismo
en la Cuenca del Plata

Buenas prácticas
en el uso del suelo
en la Cuenca del Plata

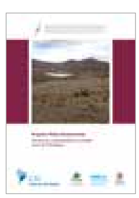
Boas práticas
para o cultivo do arroz
na Bacia do Prata

Proyecto Piloto Demostrativo
Conservación de la biodiversidad
íctica en una zona regulada
del río Paraná

Proyecto Piloto Demostrativo
Resolución de conflictos por
el uso del agua en la cuenca
del río Cuareim/Quaraí



Proyecto Piloto Demostrativo
Sistema de alerta hidroambiental
en la confluencia de los ríos
Paraguay y Paraná



Proyecto Piloto Demostrativo
Control de contaminación
y erosión en el río Pilcomayo

The Framework Program for the Sustainable Management of La Plata Basin's Water Resources, with respect to the effects of climate variability and change

ISBN 978-987-4187-01-7

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