PROJECT FOR THE ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT OF THE GUARANÍ AQUIFER SYSTEM

TRANSBOUNDARY DIAGNOSTIC ANALYSIS (TDA)

Version for the startup of the formulation

of the Strategic Action Plan

MONTEVIDEO, 29 MARCH 2007

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1. BACKGROUND

In accordance with the Terms of Reference - ToR, "the Governments of Argentina, Brazil, Paraguay and Uruguay have agreed to move forward with a project for the 'Environmental Protection and Sustainable Development of the Guarani Aquifer System' (the Project), with the support of the Global Environmental Facility (GEF) and the World Bank (WB) as the GEF Implementation Agency.

The Project is based on the following 7 components:

1 - expansion and consolidation of the scientific and technical knowledge base of the Guarani Aquifer System (GAS);
2 - joint development and implementation of a management framework;
3 - strengthening of stakeholder participation, social communication and environmental education;
4 - monitoring and evaluation and dissemination of Project results;
5 - development of aquifer management and mitigation measures for the identified hot spots or critical issues;
6 - assessment of the aquifer's geothermal potential and,
7 - project coordination and management.

Within the framework of the development of the Guarani Aquifer System Project, Activity 2e, as described in the Project Implementation Plan (PIP), refers to the "preparation of a Transboundary Diagnostic Analysis (TDA) of the GAS, the first step towards defining the main current and emerging problems of the aquifer, their effects and the underlying root causes to be addressed by an efficient management program, with a view to its sustainable use and protection, followed by a Strategic Action Program (SAP)."

2. OBJETIVES

In short, a Transboundary Diagnostic Analysis - TDA document must be formulated, containing:

1 - the main current and emerging problems affecting the Guarani Aquifer System,
2 - their effects on the resource and their root causes,
3 - an analysis of the cause and effect chain, and
4 - a priority analysis of the problems for an effective protection and sustainable use of the aquifer system.

This document will identify and provide the technical and scientific grounds for the main problems as perceived by the institutional and social stakeholders of the GAS region.

3. GUIDELINES FOR PREPARING THE TDA

INFORMATION

The ToR determine that the TDA should take into account and include:

- Information on the project development stage, including the information contained in the PAD (The World Bank. PAD: Project Appraisal Document - Document of the World Bank, Report No. 23490-LAC dated May 17, 2002. Available at: http://www.sg-guarani.org) and the PIP (Project Implementation Plan - the Project Operation Manual);
- Preliminary results of the Universities Fund projects (knowledge on system structure and geometry, water flow and quality) and of the Guarani Citizenship Fund projects (aspects on socio-economic, gender, cultural and customary use issues);
- Progress to date of the four (4) Pilot projects, including the BGR experience;
- Progress and results to date of the consultancy agreements and bids in execution;
- Lessons learned by the GS-GAS staff and regional experts; and
- Lessons learned from the specific experience and work of the legal experts team and others supporting the Project.

REQUIREMENTS

The ToR also specify that this first version of the TDA should contain:

- "The known technical and scientific aspects of the GAS;
- the current legal and institutional GAS-related structure in the countries;
- the socio-economic situation of the region and uses of GAS water, including groundwater assessment in terms of education, culture and gender".

Other requirements are "identification of other projects and actions under way in the aquifer region and their interrelations and impacts on the Project and the aquifer".

In full compliance with the ToR, the present Preliminary TDA Document should provide an account of the main current and emerging problems of the GAS that stem from the area's economic, social and environmental situation and from the existing legal and institutional conditions. Special attention should be paid to issues of transboundary interest and to the most vulnerable areas. Once the main current and emerging problems are detected, their effects on the GAS and root causes will be identified and addressed in a Strategic Action Program-SAP in realistic terms and in order of priority.

PROCESS OF PREPARING THE TDA

The ToR establish that the TDA will be prepared on the basis of a process of consultation and participation at the country level, involving each National Project Execution Unit (NPEU)

and key stakeholders (such as stakeholders from affected states and provinces, civil society organizations, Pilot Project Local Committees, etc.). This interaction will help to adjust the Preliminary TDA Document and to find the technical foundations of the identified and perceived problems, with the support of the General Secretariat.

Consolidation of the TDA will be based on a consultative and participative process at the multi-country level, in a workshop that integrates the recommendations of 4 previous regional workshops. This will result in an adjusted TDA which will be discussed by the Coordination Group (CC) before final review and approval by the CSDP (Steering Committee).

CONTENTS OF THE TDA

The TDA will identify and rank priority areas with critical problems and propose an evaluation system. Among others, the document will take into account the following:

- population by gender;
- population income brackets;
- whether it is a recharge area or not;
- whether it is an at-risk area or not;
- current and future pollution levels;
- number and magnitude of the area's critical issues;
- potential aquifer use;
- other issues to be proposed.

OTHER GUIDELINES FOR THE TDA

The preparation process of the TDA will be *preventive* in nature, and identify potential development scenarios, possible risks, negative effects on use for drinking water, irrigation and other uses, and an efficient exploitation and sustainable management of the resource. Aspects inherent to groundwater operation, current uses and the scope of potential local and regional problems found in the aquifer region shall also be contemplated.

In more general terms, as well as identifying critical areas and zones, the TDA should dedicate part of its content and focus to defining topics and issues of transboundary interest with significant impact on the GAS management and protection. This means that the TDA will generate a series of technical and institutional requirements, which will be prioritized and then classified in terms of their transboundary impact. Two groups of essential activities will arise from this analysis, one which is essentially transboundary, and another which is mainly national, i.e., activities which must become priorities for each country. The overall analysis should be discussed at length and be consensual.

The GS-GAS will disseminate the TDA among the stakeholders or interested parties, including institutional, scientific, technical, social, economic and cultural actors. Workshops will be conducted to discuss and adjust it, ensuring through each NPEU that representation is broad-based.

4. CONCEPTUAL AND METHODOLOGICAL FRAMEWORK

BACKGROUND ON GEF OPERATIONAL PROGRAM 8 – WATER BODIES

Operational Program Number 8-OP 8 finances the agreed incremental cost of additional measures to solve transboundary environmental problems that affect certain water bodies, based on countries' commitment to reform sectoral policies and activities and to finance the required baseline investments. Environmental problems include pollution, over-exploitation of biological and non-biological resources, degradation of habitats and non-indigenous species. Annex 1 displays the short and long-term objectives of this operational program.

TDA METHODOLOGY

The TDA is a tool that helps to identify and assess the main existing and emerging environmental problems (critical issues) in a basin or region, and to determine direct, indirect and root causes. It also identifies cause and effect chains and seeks interrelations with the degradation of water resources. Additionally, it also undertakes the detection of information gaps and actions that are required to mitigate or prevent problems. The TDA focuses on the transboundary aspects of a basin or region and its potential, contributing to the implementation of the GEF operational strategy for international waters.

Methodologically, the TDA is a technical and scientific document structured in two main pillars:

- **available information and experience** on the target area and the GAS, its physical characteristics, composition and behavior; on the use of the resource and regional socio-economic development; on the legal framework, the existing legislation and regulations, as well as institutional information, particularly vis-à-vis capacities and competences; and
- **stakeholder participation** and their perception of the main problems and their causes, including the institutional instances in each of the participating countries and their NPEUs.

To achieve the objectives, certain guidelines should be followed. These directives for the TDA and SAP were proposed in a document formulated for the GEF (Mee, 2003) as follows:

- **Broad-based stakeholder participation**: all the parties involved in or affected by an environmental problem or its solution should be involved in preparing the TDA and consulted for the SAP formulation.
- **Joint fact-finding**: an independent specialist(s) selected by stakeholder representatives should conduct the TDA by means of a broad-based consultative process, to ensure the process and its products' suitability to the region.
- **Transparency**: the TDA should be a public-access document; during preparation and data gathering, stakeholders should agree on the free dissemination of the resulting information and products.
- **Eco-systemic approach**: this approach is based on the application of the appropriate scientific methodologies, focused on the levels of biological organization involved in the essential processes and interactions between organisms and the environment - therefore, it should recognize that human beings are part of the ecosystem; furthermore, systems should be defined by their natural limits and not by their political limits, which, however, should be incorporated into the analysis.
- **Adaptive management**: TDAs and SAPs should be formulated in a series of pragmatically defined stages; previously defined performance indicators should be monitored at each stage, and pursuant to the results, joint planning should be developed for progress monitoring and planning of the next stage.
- **Actions should take into account the economic and social causes of a problem**: an analysis of the causal chains of transboundary problems and identification of social and economic causes are of crucial importance in the formulation of the TDA; it should be acknowledged that actions taken with the root causes in view have greater possibilities of having long-term impacts on the problem.
- **Accountability**: The parties involved in SAP implementation should be entirely accountable for their actions; the social stakeholders who are responsible for SAP implementation should be clearly and unambiguously identifiable.
- **Building of inter-sectoral policies**: sectoral approaches should be avoided, as they obstruct the inclusion of multiple purposes, application of economies of scale and an eco-systemic approach.
- **Step-by-step consensus-building**: consensus-building at each stage of the TDA and SAP preparation is essential to ensure the long-term sustainability of the process and its results.
- **Local strengthening**: the SAP should propose practical solutions for transboundary issues that require regional, national and local actions; the concept of local strengthening implies that any issue that may be solved locally should not be taken to the highest levels for solution; as a corollary, when a problem cannot be solved locally, then solutions should be sought at higher levels of action, whether national or regional.
- **Incremental costs**: The SAP should detect any actions that generate incremental costs as agreed by the parties, and separate them from those that refer to purely national interests ("baseline actions").
- **Donor partnerships**: The process of formulating the SAP is intended to strengthen cooperation among the development partners so that the identified problems are taken into account and, whenever necessary, to assist the governments in covering the costs of baseline actions, to encourage joint responsibility in SAP implementation and to avoid overlapping of the donor community efforts.

- **Intergovernmental commitments**: approval and startup of the SAP as a contractual agreement between governments should be a significant management objective of its formulation process.

All the guidelines were accepted save the last one. On the contrary, the countries understood that project results do not imply any such commitment or the actual execution of the SAP; rather, they viewed it as the cornerstone for a Management Framework to be proposed to the Parties so that they can eventually decide what type of sovereign agreement they will subscribe.

In short, the TDA will provide identification of the main current and emerging problems that were identified and perceived as priorities, the causes of the problems arising from the economic, social and environmental conditions in the area, and the prevailing legal and institutional conditions, with particular emphasis on issues of transboundary interest and (most) vulnerable areas. It will lead to a logical development of the SAP based on a reasonable, holistic and multisectoral assessment of the problems associated with transboundary water systems.

Annex 2 provides summaries of TDAs designed for similar GEF projects.

CONCLUSIONS

The TDA and the SAP stem from an analytical and participative process, where the different instances include broad-based stakeholder participation and information gathering and assessment by means of pilot projects and sub-projects. A lesson learnt from the consulted literature (see Annex 2) is that there is no single methodology for TDA preparation. On the contrary, there are methodological adaptations to each project based on existing data and the nature of problems and their causes. These aspects will be studied in depth in the presentation of the proposed methodology for the preparation of the GASP TDA.

A significant aspect of the GEF methodology for TDA design is the paradigmatic change that is required: from an approach defined as “rationalistic or realistic” to a “constructivist” approach. Roy, Landry and Oral (1993) state that in counterpoint to the realistic or rationalistic approach, the purpose of the constructivist approach is not to find a “truth that is external” to the stakeholders involved in a process, but rather to develop a “set of keys” that will open the doors to these stakeholders so that they continue to make progress in accordance with their objectives and systems of values. This approach, states the author, does not involve “prescriptions”, but rather “recommendations”. Each stakeholder builds on a problem problem using his own set of values, and therefore solutions should be negotiated

by all the stakeholders, focusing on consensus. For this reason the GEF methodology relies on participative workshops, where the TDA is developed on a step-by-step basis.

In the realist approach, the task of the consultant hired for the TDA preparation, is to "extract" the stakeholders' preferences according to his own analysis of the submitted information. The constructivist approach implies that the stakeholders build the solution/s, with the consultant acting as the process "facilitator" and avoiding as far as possible to induct his own values into results. For this reason, interaction among stakeholders in the process of designing solutions is crucial. Table 1 displays some other basic differences between the realistic and constructivist approaches, with comments on the preparation requirements of a TDA.

All these factors should be considered in the preparation process of the Guarani Aquifer System Project TDA.

Table 1 – Differences between the rationalist and constructivist paradigms in decision-making

Issue	Rationalist Paradigm	Constructivist Paradigm	Related aspects of TDA and SAP design
Decision-making	Moment of choice of the optimal solution	Lengthy process involving interaction among decision-making social stakeholders	Approval of TDA and SAP and subsequent implementation
Characteristics of decision-makers	Totally rational and objective	Endowed with their own set of values, that are patent in their subjective preferences	Countries, with their respective social stakeholders in the design process of the TDA and SAP
Problem to be solved	A real problem, which may be defined objectively	Problem to be constructed: each decision-maker builds his own vision of the problem, subjectively	Definition of the Transboundary Diagnostic Analysis and the Strategic Action Program
Models	Represent objective reality	They are accepted tools, useful in the support of decisions by decision-making social stakeholders	Causal chains as models for the dynamics of identification of critical issues
The results of the models	Optimal situations	Recommendations that focus on respecting the values of the decision-making social stakeholders, in negotiated decisions	Proposal and evaluation of mitigation actions for the critical issues
Purpose of model construction	Finding the optimal solution	Generating knowledge on a problem so that decision-making social stakeholders can negotiate a satisfactory decision reached by consensus	Identification of root causes and analysis of mitigation actions, one of the cornerstones for the SAP formulation
Validation of the model	The model is valid when it represents reality objectively	The model is valid when it serves as a tool for supporting a decision	Causal chains are valid when they help to reach consensus in the identification of information gaps and proposals for mitigation actions
Preferences of the decision-makers	Extracted by the consultant / analyst	They are constructed by the decision-making social stakeholders with the support of the consultant / facilitator	Consultants facilitate the TDA preparation process, on the basis of respect towards the preferences revealed by the decision-making social stakeholders

Source: Adapted from Ensslin, Montibeller Neto and Noronha (2001)

5. METHODOLOGY FOR THE PREPARATION OF THE GASP TDA

Figure 1 shows a diagram of the methodology that was applied in preparing the GASP TDA.

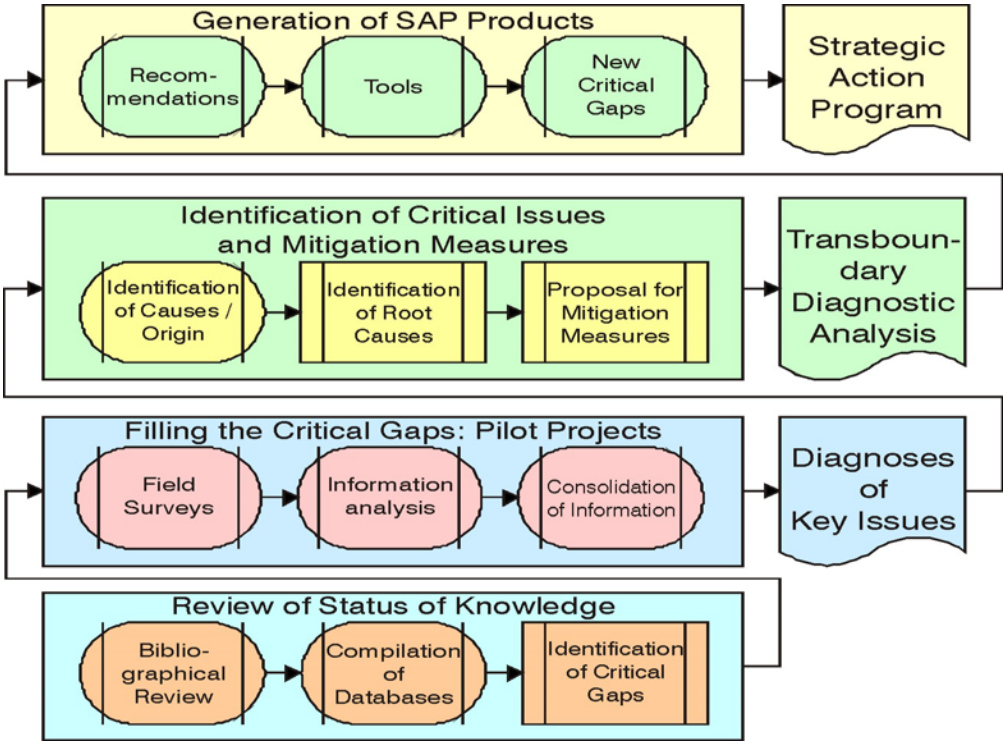


Figure 1 – Methodology used in the preparation of the GASP TDA and SAP

Review of the knowledge base was and is being carried out as a GASP activity. The pilot projects were implemented to obtain management experience in specific GAS areas with typical problems and to help fill certain previously identified critical information gaps. Their results will assist in the diagnosis of key issues, which in turn will enable the identification of new critical issues. Annex 3 summarizes the current status of the GAS knowledge base.

The TDA was prepared with a view to identifying the causes of each critical issue; consequently, mitigation measures were proposed. Therefore this final TDA document is a guideline for the formulation of the Strategic Action Program - SAP, which is the final document of the GASP.

ACTIVITIES

Figure 2 shows a diagram of the activities that were performed in compliance with the Terms of Reference and the resulting documents.

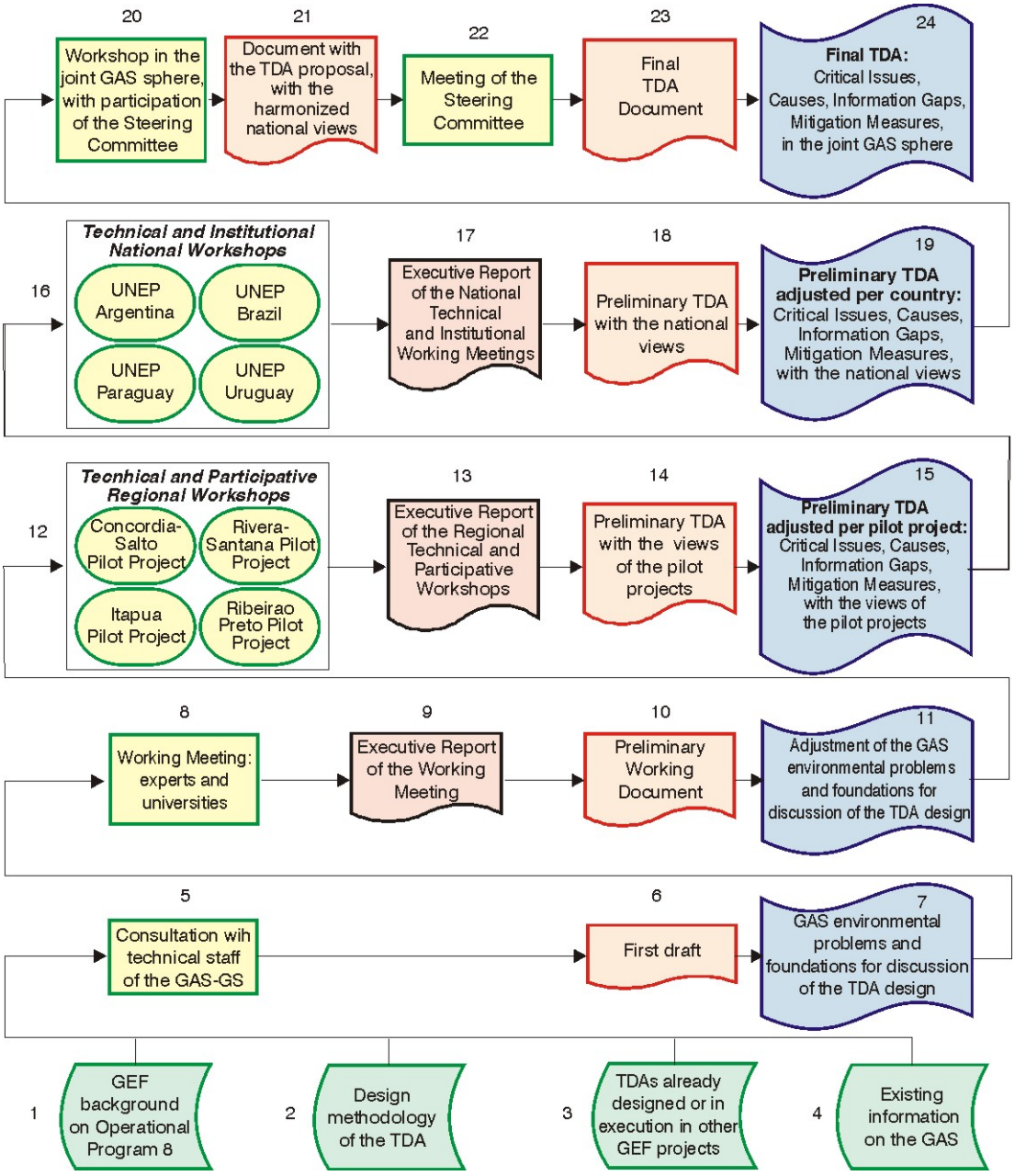


Figure 2 – Preparation stages of the GAS TDA

In further detail, the activities were:

1 - Review of the background on GEF Operational Program Number 8 (Water Bodies) which is the basis for this project;
2 - Review of the methodology for these instruments;
3 - Review of the TDAs under way or completed for other GEF projects, to obtain guidelines and models to be taken into account;

4 - Review and analysis of the existing information on the GAS;
5 - In consultation with the technical staff of the GAS-GS;
6 - Preparation of the first draft …
7 - … containing a preliminary view of the GAS environmental problems and the grounds for discussion for the preparation of the TDA;
8 - Organization and moderation of a working meeting with the participation of experts from the countries, the pilot projects and the universities participating in the Universities Fund surveys, in coordination and with the support of the GAS-GS and DSD/OAS;
9 - Preparation of an executive report of the experts' working meeting, and inclusion of the information and analysis obtained at the meeting in the TDA document;
10 - Integration of the overall work in a single TDA document called Preliminary Document …
11 - … which is an adjustment of the GAS environmental problems and the grounds for discussion of TDA preparation, and a preliminary identification of the Critical Issues to be addressed;
12 - Conduction of four (4) Regional Participative Technical Workshops - RPTWs based on each Pilot Project (PP), with the participation of key regional stakeholders. The workshop dynamics led the participants to identify, discuss and agree on critical issues, information gaps, direct, indirect and root causes of the issues, and on proposals for mitigation actions;
13 - Preparation of a RPTW executive report …
14 - … in the form of a new preliminary TDA version …
15 - … containing PP views on the GAS environmental problems, a Preliminary TDA with the views of the Pilot Projects;
16 - Conduction of four (4) National Technical and Institutional Workshops - NTIWs based on the NPEUs of each country involved in the GASP, including key country stakeholders, with participants from states, provinces and local pilot project committees. The preliminary TDA with the pilot projects' views was reviewed, in order to adjust, prepare and submit the Preliminary TDA adjusted to the national views;
17 - Preparation of NTIW executive reports …
18 - …incorporating the information and analysis by the NTIWs in the the TDA document …
19 - … resulting in a Preliminary TDA with the national views;
20 - Conduction of a workshop at the multi-country level of the GAS, with key representatives from the 4 countries and their competent bodies and institutions;
21 - Addition of the adjustments approved in this meeting, producing the TDA with the consensual national views, or the TDA proposal from the joint GAS sphere;
22 - Support to the GAS-GS and DSD/OAS in the Steering Committee and CSDP meetings which evaluated the TDA proposal at the overall GAS level;
23 - Production of the final TDA document …
24 – … with the critical issues, information gaps, mitigation measures, at the overall GAS level.

WORKING MEETINGS

Four types of meetings were held:

1) a technical meeting with experts, with the aim of improving a preliminary TDA document prepared by the consultant, which summarized the main aspects of the GAS to inform the participants of the regional workshops, which were carried out sequentially;
2) regional workshops in the pilot projects, to obtain the contribution of local views to the TDA, for consideration of the critical issues for which these projects were selected;
3) national workshops, for the design of a national proposal from each country to the TDA, once the local views of the pilot projects were known;

4) the joint meeting, with representatives from all the countries, for a harmonized Transboundary Diagnostic Analysis of the Guarani Aquifer System.

Further information on these meetings is supplied below. The results of each meeting in are shown in more detail in Chapter 6 of this report.

Working meeting with experts from the countries, pilot projects and universities participating in the surveys of the Universities Fund

The objectives of this meeting were:

1 – To analyze, discuss, and improve the Preliminary Document, particularly with reference to the summary on GAS information;
2 – To propose the critical issues to be analyzed in the RTPWs, with detailed descriptions, taking into account the proposal of Table 17, Framework for the GAS management needs in Annex 3.

Regional Participative Technical Workshops - RPTWs

Four (4) Regional Participative Technical Workshops - RPTWs were held, with the participation of regional key stakeholders. In these workshops the dynamics led the participants to identify, discuss and reach a consensus on critical issues, information gaps, direct, indirect and root causes of these issues, and to make proposals for mitigation actions.

The RPTWS dynamics were:

1 - The Support Document, containing essential information on the GAS and the methodology to be adopted, was submitted in advance in electronic form to workshop participants;
2 - Presentation of the Support Document, summarizing the information and introducing the key issues for the design of the TDA;
3 - Selection of the critical issues of interest of the pilot project;
4 - For each critical issue of interest, proposal and discussion of the causes, on the basis of a ranking that will be presented later in this document, and identification of information gaps that prevent identification of critical issues;
5 - Proposals for mitigation actions for the causes and information gaps that prevent proposal or implementation of actions.

Causes, information gaps and mitigation actions were identified by means of a participation technique involving the use of placards, by means of which participants submitted their proposals and shared them with other participants. In some cases, it was necessary to create working groups for reviewing specific critical issues.

National Technical and Institutional Workshops - NTIWs

Four (4) National Technical and Institutional Workshops – NTIWs were conducted, on the basis of the indications of each National Project Execution Unit - NPEU involved in the PGAS, attended by key stakeholders from each country and participants from the states, provinces and local committees of the pilot projects.

The dynamics proposed for the NTIWs was:

1 - The Preliminary TDA Document with the views of the pilot projects was submitted in advance to workshop participants in electronic format;
2 - Presentation of the Preliminary TDA Document, summarizing the information and introducing the key issues for the preparation of the TDA with the national views;
3 - Selection of the critical issues of interest for the country;
4 - For each critical issue of interest, evaluation of the causes submitted by the RTPWs, followed by proposals for improvement;
5 - Evaluation of the information gaps submitted by the RTPWs, and proposals for improvement;
6 - In view of the causes, evaluation of mitigation actions and information gaps that may obstruct proposal or implementation of actions, as submitted by the RTPWs, and suggestions for improvement;
7 - If there was time, prioritize the causes, information gaps and mitigation actions for each critical issue of interest.

The NPEUs adapted this dynamics to their interests and to the time available for the workshops.

Joint Meeting

The main goal of the Joint Meeting - the last participative stage for the TDA preparation - was to submit a joint country proposal for the GAS TDA to the Steering Committee-CSDP.

Preparation of this joint proposal required consensus-building on:

- the Causal Chains for each critical issue of the GAS, with detailed definitions that identify the main causes existing in each country;
- the information gaps on each critical issue of the GAS, with detailed definitions that identify the main information gaps existing in each country; and,
- particularly, a definition of the nature of the Action Programs reflecting the needs and interest in joint and individual actions by each country for a sustainable use of the GAS.

The outcome of the Joint Meeting was a proposal by the four countries - with clear, concise and non-redundant definitions - of the causes and information gaps for each Critical Issue, and of proposals for action to mitigate the identified problems. The following were prepared:

- Causal chains for the GAS critical issues and their degree of relevance;
- Major information gaps to be filled by programs of action that include the generation of strategic information on the GAS;
- Programs of action that are to be implemented jointly by the countries, with substantial impact on the common asset that is the GAS;
- Priority ranking of actions, based on the interests of each country.

It is important to emphasize that the Programs of Action are a useful reference for the design of the Strategic Action Program – SAP, which will conclude the preparation process of the Guarani Aquifer System Project–GASP.

GUIDELINES FOR THE DESIGN OF THE CAUSAL CHAINS

For the design of causal chains all the workshops adopted the following guidelines on the identification of critical issues, causes, mitigation actions and information gaps.

Critical issues to be considered - preliminary list

The critical issues proposed in Table 2 were approved by the experts working meeting. The 7 critical issues were discussed at the Regional Participative Technical Workshops, and were amended to depict the local critical problems more clearly.

Classification of the causes

The definitions shown in Table 3 were used to classify the causes in the causal chain.

An example that illustrates a causal chain is the lack of a Water Resource Policy, instituted by a Water Law - which would qualify as a political and institutional cause - which may result in the absence of a system to issue permits for water use - an economic and management cause - which generates excessive use or use in low-priority activities - a technical cause - leading to the critical issue of conflicts or non-sustainable use of water, whether of a transboundary nature or not. Another example: presupposing that there is a Water Law in place, an Information System on Water Resources is found to be lacking - an economic and management cause - that enables adequate management decision-making regarding the granting of rights of use. This cause would be classified as a secondary or economic-management cause and the solution to conflicts arising from the use of water lies in its mitigation.

Table 2 - Management Framework for the GAS

Typology	Situations with local transboundary effects in pilot areas	Potential situations with regional transboundary effects
I - Protection of the GAS against pollution and quantity-related aspects II - Use of groundwater and geothermal resources III - Sustainable management of the GAS	1 – Pollution of drinking water wells due to inadequate sanitation and unplanned land use *(R-P PP and R-S PP)* 2 – Impacts on wetlands (mainly in the Esteros de Ibera (AR) and Niembucú (PY), as well as on the Rio Uruguay, respectively) and decline of the rivers' baseflows, possibly as a consequence of potential intensive exploitation of groundwater for agricultural irrigation *(GASP Component 1)* 3 - Impacts on the quality and recharge rate of the aquifer as a result of extensive changes in the use of agricultural soil as well as in farming types and systems *(PP IT)* 4 - Impacts on the water balance of water consumption caused by afforestation and its effect on the recharge *(GASP Comp. 1)* 5 – Salinization caused by deep unsealed wells; it is unknown whether they are located in the GAS area *(C-S PP)* 6 - Decline of aquifer artesianism and geothermalism due to uncontrolled exploitation of geothermal wells *(C-S PP)*	7 - Growth of impacts to a greater scale if intensive land use and/or groundwater use is encouraged, considering a) the current ecologic role of the aquifer discharge and b) the hydraulic continuity of the aquifer system in the relevant areas (GASP Comp. 1)

Notes: RP PP: Ribeirão Preto Pilot Project; R-S PP: Rivera-Santana do Livramento Pilot Project; IT PP: Itapúa Pilot Project; C-S PP: Concordia-Salto Pilot Project.

Source: Based on FOSTER; KEMPER; GARDUÑO (2004)

Table 3 – Classification and example of causes of the Critical Issues, and mitigation actions

Causes	Description	Examples	Possible mitigation actions
Natural Causes	These are not dependent on human action and are inherent to the natural environment.	- Vulnerability to pollution of the GAS recharge areas; - Topography and soil type; - Climate change and extreme weather; - etc.	In general, there are no possible mitigation actions. Even when mitigation is possible, coexistence with or adoption of precautionary or protective measures vis-a-vis these causes is more viable than any intention to change them.
Primary or Technical Causes	They include inadequate handling of limited natural resources like water and soil, use of inadequate technologies, lack of monitoring systems, resource over-exploitation; inadequate system operation; introduction of exotic plant species, etc. One way to identify them as primary causes is their direct relation with environmental impacts.	- Over-exploitation or pollution of wells; - Inadequately well design; - Very little or non-existent sanitation coverage; - Inadequacy of land use vis-a-vis GAS vulnerability; - Lack of diversification of uses and energy misuse; - Destruction of vegetation cover and overgrazing; - etc.	They may be prevented in the short term by means of the dissemination of knowledge, investments in non-structural measures (regulations, for example) and structural measures (hydraulic works, for example), among others.
Secondary or Economic and Management Causes	They arise from inadequate economic signs or inadequate management approaches. Examples of the former are the lack of resources for proper environmental monitoring and management and that resource prices do not reflect the real costs for the ecosystem in the medium to long-term, etc. Therefore, in this case there is a direct or indirect economic link (lack of resources or inadequate prices, respectively) between the secondary cause and the consequent primary causes. In the second case, the	- Absence of uses with higher added value; - Environmental costs or costs that count in the long term are not considered in decision-making; - Water use by future generations is not considered in decision-making; - Uncontrolled water use, without permits; - Undefined or incorrect use priorities; - Poor and untimely assignment of human resources, infrastructure and budgets for adequate management; - Absence of systems of management information and dissemination; - Non-existent or inadequate exploitation	These causes are addressed by means of economic regulation measures and measures to improve management and management information systems; results are achieved in the short and medium-term

Causes	Description	Examples	Possible mitigation actions
	examples are the non-existence of an adequate system of environmental permits or granting of water use rights, lack of knowledge or consideration of the ecosystem's vulnerability, etc. In this situation, there is a physical or technological relation between the secondary causes and the consequent primary cause.	plans; - Deficient human resources training; - etc.	
Tertiary or Political / Institutional Causes	They arise from the institutional setting, in other words, from the legal and organizational framework of a region or country. It is the case of legislation deficiencies, lack of effective organization of the entities promoting sustainable development, governance difficulties or – in a broad sense – from governments' financial and administrative ability to implement policies.	- Low level of government and social organization; - Absence of legal regulations; - Non-existence of institutions for water resource management; - Lack of policies on social integration and gender issues; - etc.	The institutional improvements that may lead to mitigation of this kind of deficiency require political negotiations and agreements, which may be achieved by means of legislation in the medium and long term.
Basic or social and cultural causes	They refer to the foundations of a society: its rules of conduct, ethics, customs, traditions, religion, etc. There are several examples of these causes, among which we may mention refusal to participate in public policies, limited political and citizen awareness, difficulty in implementing community actions, lack of respect or consideration towards minority rights, gender issues,	- Very little or non-existent stakeholder participation; - Lack of adequate capacities in the population; - Inadequate habits of certain ethnic groups (e.g. uncontrolled burning) - Lack of social insertion; - Lack of consideration towards gender issues, as part of the current culture; - etc.	Due to their level of inertia, mitigation of these causes may only be achieved in the long term.

Causes	Description	Examples	Possible mitigation actions
	difficulties in democratic coexistence, lack of environmental ethics, etc. Their existence hinders governance or the political capacities that arise from the relationship between the legitimacy of a state and its government with society.		

Information Gaps

Two types of information gaps were considered: 1) knowledge gaps on the causes of critical issues and 2) gaps that prevent formulation of proposals for mitigation actions. The first category includes cases where the absence of information prevents detection of the possible causes of a specific critical issue. In the second case, the cause of a specific critical issue is known, but the conditions to determine mitigation action are unknown.

Mitigation Actions

Three types of mitigation actions were considered: 1) mitigation of the main causes that act against a sustainable use of the GAS, 2) actions to achieve financial sustainability of the project in the future, and 3) actions to fill the information gaps.

FINAL GUIDELINES

A few final guidelines that were used in the formulation of the TDA are presented below:

Problems to be addressed

Management of the GAS should be intended to address only existing or emerging groundwater problems - exclusively within its geographical range and notwithstanding aquifer size; for this reason, it is necessary to:

- keep the framework of joint management within realistic limits, with the aim of minimizing transaction costs; and
- trim down international coordination requirements to the minimum indispensable levels.

Dynamics between pilot projects and the TDA/SAP

It was important to preserve a dynamic relationship between pilot projects and the TDA/SAP, which emphasizes:

- the dual nature of the Local Action Programs - LAPs, 1) as management units for groundwater and 2) as information centers to provide “experience” to the TDA diagnoses and SAP actions; and
- the convenience of making progress in action implementation, both at pilot and at national and regional levels before making proposals to modify the legal and institutional frameworks.

Actions to be proposed

Given the nature of the GAS, the mitigation actions to be approved in the TDA and that may be considered as proposals for the SAP, should have the following characteristics:

- they should strengthen the basis for a common understanding of the GAS and promote its sustainable exploitation and management;
- “*services*” should be obtained from the GAS as agreed by the four countries, ensuring minimum negative effects;

- they should strengthen the approach of making good use of the opportunities that the sustainable exploitation of the GAS has to offer, based on common understanding and pragmatic cooperation mechanisms;
- they should anticipate emerging conflicts affecting more than one country and propose approaches to their solution;
- they should have the support of social stakeholders and other interested groups.

CONCLUSIONS ON THE TDA PREPARATION METHODOLOGY

The proposed preparation process of the TDA was conducted in three spheres of consensus-building: 1) regional, in the sphere of the pilot projects, 2) national, in each country, and 3) joint, in the four GAS countries, at two levels:

- **a participative level**, within the regional sphere of the pilot projects, by means of four Regional Technical Participative Workshops;
- **an institutional level**, within the national spheres, by means of four National Technical Institutional Workshops, and at the Joint Meeting.

Regional, national and international consensus-building took place in these spheres. As national and international consensus-building took place after regional consensus-building, the result was the projection of regional harmonization over national interests, as shown in Figure 3.

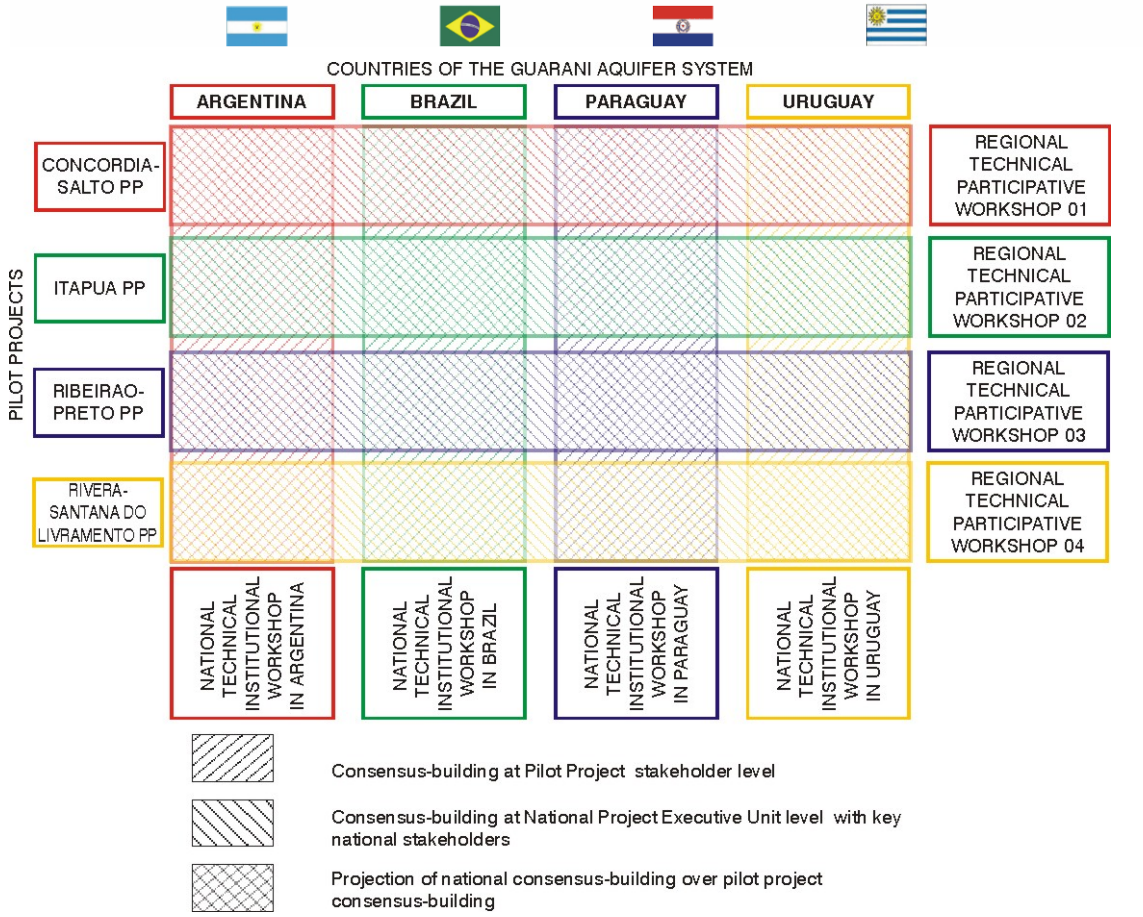


Figure 3 - Consensus-building levels to be considered in the preparation of the TDA

The last consensus-building instance at the overall level GAS was the Joint Meeting of country representatives, held in Montevideo from 18 to 20 October, and at the GASP Coordination Group meeting in Curitiba on November 23, 2006, with the participation of representatives from the National Project Execution Units.

This ensures that the TDA document includes the input of the regional level (Pilot projects), the national sphere (NPEUs) and the overall GAS sphere (Joint meeting and Coordination Group meeting), and consequently so do the proposals for mitigation actions for the critical issues which are the basis for the SAP formulation.

6. SUMMARY OF THE MEETINGS HELD IN PREPARATION OF THE TDA

The results of each meeting conducted for the preparation of the TDA will be reviewed sequentially. A specific report was submitted after each meeting with detailed information.

EXPERTS MEETING

The Experts Meeting was held in Montevideo on 16 and 17 February 2006. 12 experts attended, among them 2 GASP experts, 2 GASP trainees, and 2 pilot project facilitators. 3 experts are from Argentina, 4 from Brazil and the rest are from Uruguay. No Paraguayan experts were present for force majeure reasons. The meeting achieved its objective of supporting the TDA consultant in the formulation of the preliminary document, refining its content and structure.

SUMMARY OF THE REGIONAL WORKSHOPS

The main objective of the regional workshops (RTPWs) was to evaluate the perceptions of key stakeholders from the pilot projects of the current or emerging critical transboundary issues of the GAS region and their causes, related information gaps and required mitigation actions. These workshops were part of a fact-finding process that was intended to support the national proposals, and the results were systematized and sent to the NPEUs for their information before the national workshops took place.

The RTPWs were held in the pilot projects on:

Rivera - Santana do Livramento RTPW: 3 and 4 April 2006;

Concordia-Salto RTPW: 6 and 7 April 2006;

Itapúa RTPW: 10 and 11 April 2006;

Ribeirão Preto RTPW: 12 and 13 April 2006.

Table 4 contains a summary of the critical issues that were identified in each pilot project for subsequent formulation of their causal chains. They can be classified into 5 groups: the first group deals with water pollution; the second deals with depletion of phreatic levels; the third considers the impacts caused by inadequate use of water and soil; the fourth tackles the problems arising from the growth of the described impacts; at the end there is a mention of, the issue of the difficulty of implementing the Local Management Unit of GAS.

Table 4 – Summary: Critical Issues identified in the Pilot Projects

Critical issues	RS	CS	It	RP
Pollution of drinking water wells due to inadequate sanitation and unplanned use of soil		X	X	X
Pollution of drinking water wells from inadequate sanitation and solid waste disposal, population increase and unplanned use.	X			
Depletion of phreatic levels, possibly as a consequence of intensive potential exploitation of groundwater	X			
Reduction of artesianism or of GAS water levels				X
Non-sustainable use of the aquifer (decrease of artesianism and geothermalism and increase of salinization) caused by uncontrolled exploitation of geothermal wells and by deep unsealed wells		X		
Impacts on the balance of water consumption caused by afforestation and its effects on recharge			X	X
Impacts on the balance of water consumption vis-a-vis quality and quantity caused by extensive changes in the use of soil and in types and systems of soil cultivation, and by afforestation and its effect on recharge	X			
Impacts on the quality and rate of a aquifer recharge as a result of extensive changes in the use of agricultural soil and in types and systems of soil cultivation			X	
impacts on the quality and rate of a aquifer recharge as a result of extensive changes in the use of agricultural soil, and in types and systems of soil cultivation and urbanization				X
Growth of the impacts described above if the regional agricultural policies and the market should favor the intensive and extensive use of the local soil and/or the groundwater resources			X	
Difficulties in the implementation of a Local Management Unit	X	X	X	

Note: RS: Rivera-Santana do Livramento; CS: Concordia-Salto; It: Itapúa; RP: Ribeirão Preto.

SUMMARY OF THE NATIONAL WORKSHOPS

The national workshops had the main object of submitting a national TDA proposal for the GAS. A summary of the results of the Regional Technical-Participative Workshops held in the four pilot projects was provided beforehand to the countries. Each region's critical issues were described, as well as their causal chains, identification gaps and proposals for mitigation actions. Therefore it could be said that the pilot projects submitted their TDA proposals to the national workshops.

There was no analysis of these proposals to avoid influencing the countries - they received only the critical issues detected in each pilot project, their causal chains, identification gaps and proposals for mitigation actions. They were forewarned that it was likely that each country would be interested not only in the results of the pilot projects in its own territory but

in all the results, as the pilot projects are located in regions with typical GAS real or emerging problems and the countries would benefit from the information obtained in any one of them.

The NTIWs were held in each GAS country on:

Brazil: 29 and 30 May 2006;

Paraguay: 1 and 2 June 2006;

Argentina: 12 and 13 June 2006;

Uruguay: 15 and 16 June 2006.

In the first workshop, which was held in Brazil, the participants decided to summarize the five critical issues shown on Table 4 into three main issues:

1) GAS pollution problems: wells and the aquifer;
2) Quantitative problems arising from intensive over-exploitation; decline in GAS water availability; and
3) Macro strategies: challenges to the sustainable management of the GAS

This was proposed to each workshop to maintain a certain degree of coherence and help the final meeting to reach a consensus. Participants were free to accept it or to propose alternatives. The results agreed to a certain extent with the Brazilian proposal, with a few adjustments to the national situation by Argentina, as shown on Table 5. This country's final proposal, which was submitted after its NPEU's analysis, can be found in Annex C of the National Workshops Reports.

The National Project Execution Units - NPEUs selected the participants to the National Technical and Institutional Workshops, which included NPEU members and other key stakeholders.

SUMMARY OF THE JOINT MEETING

The Joint Meeting was held in Montevideo on 18, 19 and 20 October 2006, in the MERCOSUR building where the Guarani Aquifer System Project has its headquarters. The main references for this meeting were the National Technical and Institutional Workshops and the systematized information submitted to the Joint Meeting by the TDA consultant. Guidelines on the dynamics to be adopted at the meeting were sent to the NPEUs in advance.

The meeting's main objective was to submit to the Project Steering Committee - CSDP a joint proposal by the countries for the Transboundary Diagnostic Analysis of the Guarani

Aquifer System. The formulation of this joint proposal complied with consensus-building requirements on:

- the causal chains for each GAS critical issue and its detailed definition as displayed on Table 5, that identify the main causes which exist in each country;
- the information gaps on each critical issue and detailed descriptions, to define the main information gaps which occur in each country; and
- definition of the nature of the mitigation actions, reflecting the requirements and interest in joint and individual actions by each country regarding the sustainable use of the GAS.

Table 5 - Critical issues listed by each country

Types of critical issue	Argentina	Brazil	Paraguay	Uruguay
1 - Pollution	Degradation of the quality of the GAS water in general, and in particular as a result of salinization from over-exploitation of geothermal wells, deep unsealed wells and surface water bodies, due to inadequate handling of effluents from thermal use.	Pollution of GAS water	Pollution and use of soil	Pollution problems: wells and the aquifer
2 - Over-exploitation	Reduction of water availability in general, and in particular quantitative and qualitative problems (reduction of artesianism and geothermalism) and interferences between perforations.	Reduction of GAS water availability	Over-exploitation (in the future)	Quantitative problems arising from intensive over-exploitation: decline of GAS water availability
3 - Management	Challenges to the sustainable management of the GAS	Macro strategies: challenges to a sustainable management of the GAS	Macro strategies for the sustainable management of the GAS	Macro strategies: challenges to a sustainable management of the GAS

The result of the Joint Meeting is a common proposal by the four countries - with clear, concise and non-redundant definitions - of the causes and information gaps for each critical issue and the proposals for actions to mitigate the identified problems. It contains:

- Causal chains for the GAS critical issues and their degree of relevance: these are displayed on Figure 4 for the pollution issue, Figure 5 for the over-exploitation issue, and Figure 6 for the management issue;
- Major information gaps to be filled by programs of action that include the generation of strategic information on the GAS; these are shown on Figures 7 to 9 as identified for each critical issue;
- Proposals for actions to be implemented jointly by the countries, with substantial impact on the shared asset - the GAS; also a proposal for ranking the priorities to be assigned to the actions from the point of view of the common interests of the countries, shown for each critical issue on Figures 10 to 12.

It is important to emphasize that the proposals for actions are a useful reference for the formulation of the Strategic Action Program - SAP, which will conclude the design process of the Guarani Aquifer System Project–GASP.

The detailed results of the Joint Meeting are submitted in a specific report. This final TDA report contains a summary and analysis of these results, which are part of the TDA proposal for the GAS.

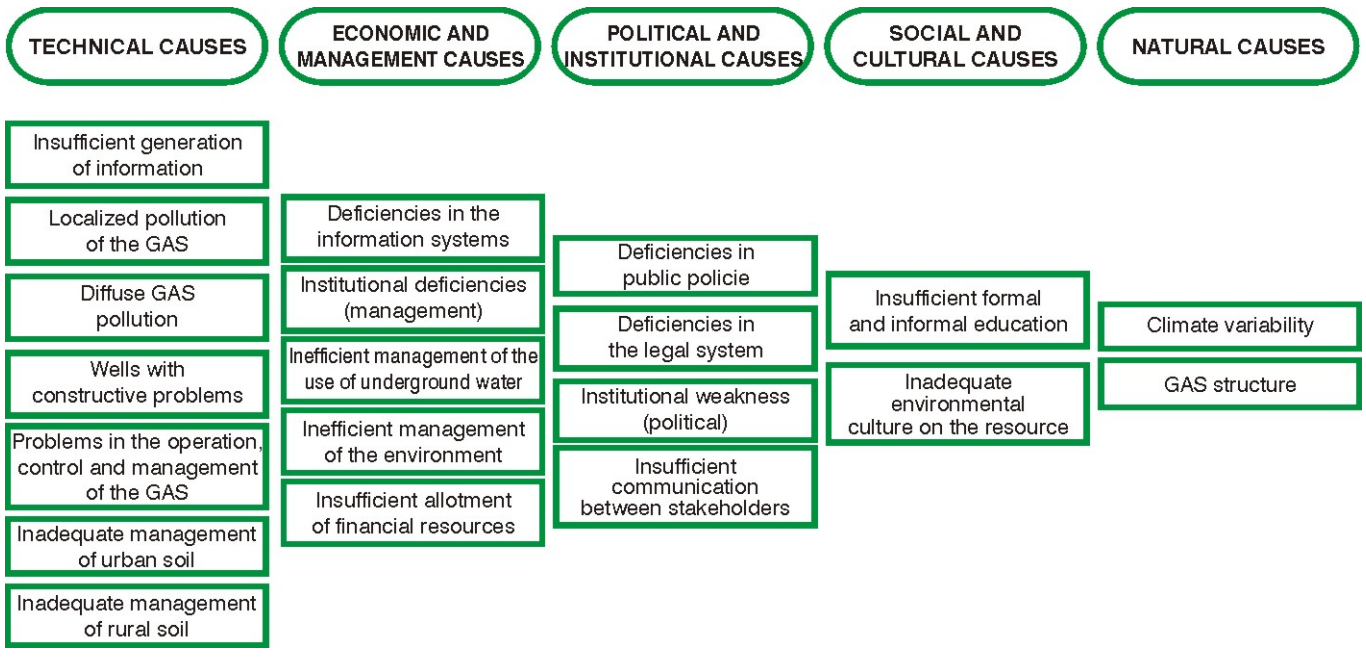


Figure 4 - Causal chain of the critical issue of pollution

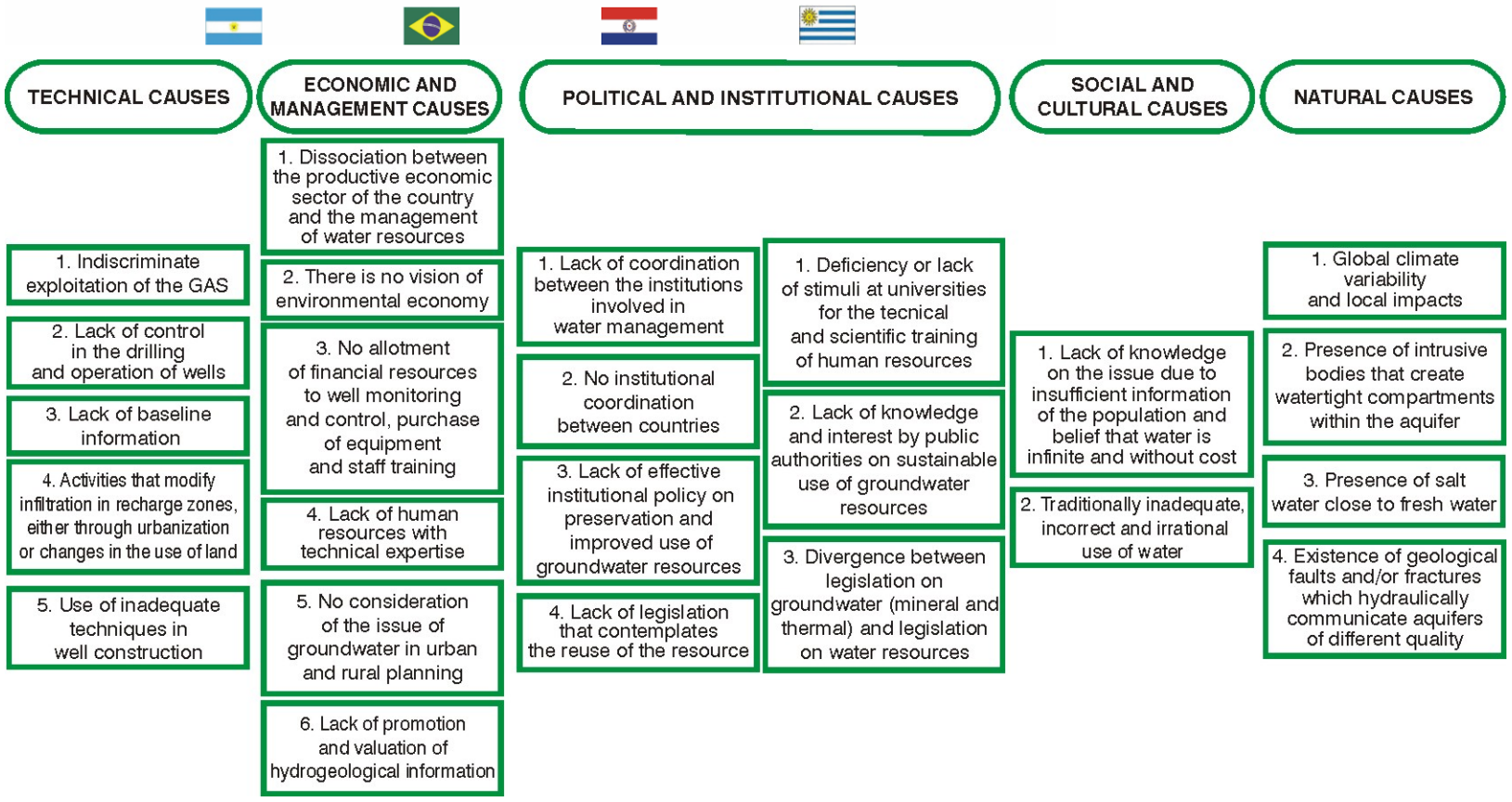


Figure 5 – Causal chain of the critical issue of over-exploitation

(causes are organized into each category by their relative relevance regarding over-exploitation)

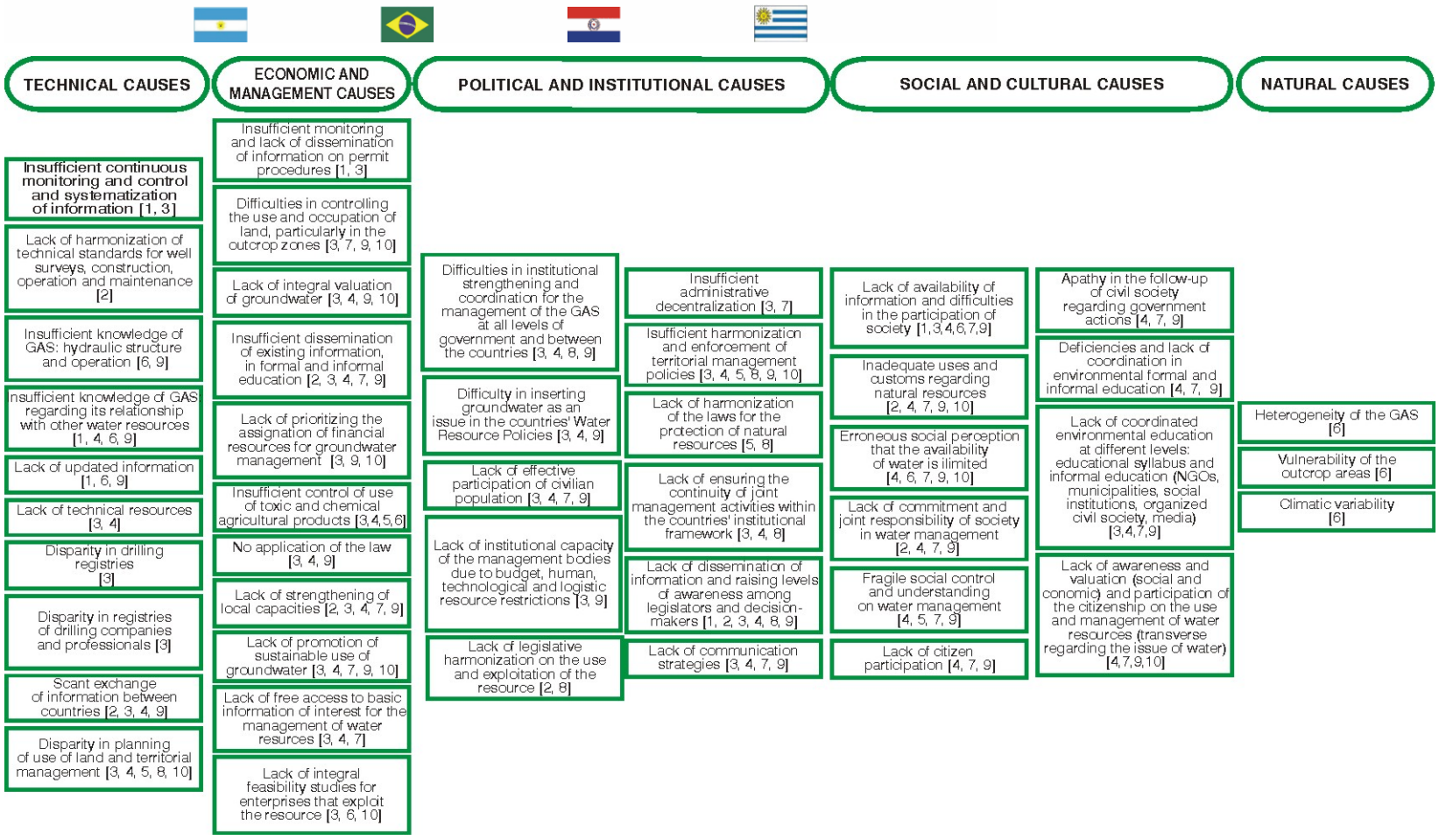


Figure 6 - Causal chain of the critical issue of management

(The numbers between square brackets refer to the actions shown on Figure 13, which mitigate the causes)

Figure 7 - Information gaps on the critical issue of pollution

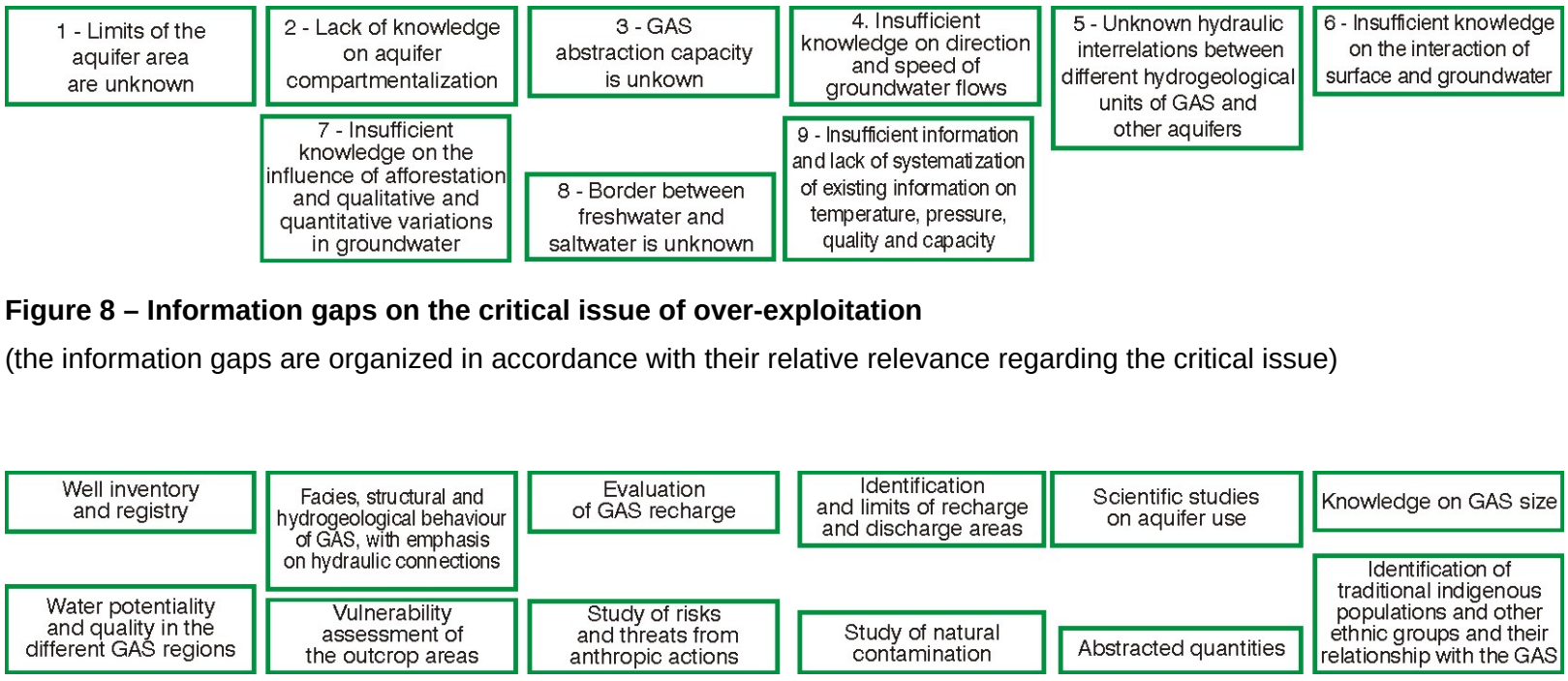


Figure 8 – Information gaps on the critical issue of over-exploitation

(the information gaps are organized in accordance with their relative relevance regarding the critical issue)

Figure 9 - Information gaps on the critical issue of Management

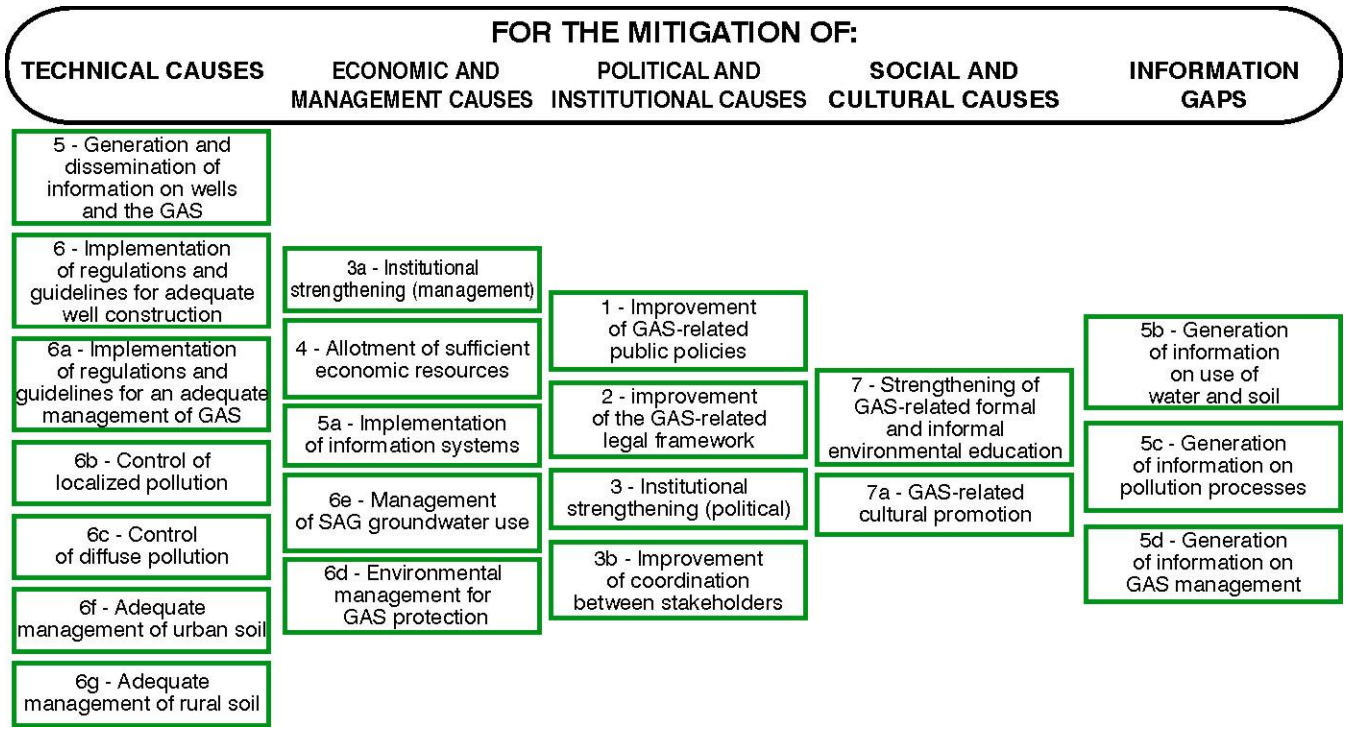


Figure 10 - Mitigation actions for the critical issue of Pollution

(The numbers refer to the relative priority of the actions)

Figure 11 - Mitigation actions for the critical issue of Over-exploitation

(the mitigation actions are ranked in each category by their relative relevance vis-à-vis the critical issue)

Figure 12 – Mitigation actions for the critical issue of Management

(The numbers between square brackets refer to the relative priority of the actions according to the number of causes that would be mitigated by their implementation)

7. TDA PROPOSALS FOR EACH CRITICAL ISSUE

This proposal consists in the identification of causes, information gaps and mitigation actions for each critical issue that is presented in Table 5, with the country views on each. The presentation, which is set out sequentially, contains an aggregate analysis of the causes, information gaps and mitigation actions proposed for each critical issue, as a way of establishing links between the root causes of the problems, the information needs and in particular, with the proposals for action.

CONSOLIDATION AND ANALYSIS OF RESULTS

One of the possible consolidations of the results of the Joint Meeting is the classification of the root causes of the critical issues, of the information gaps and the mitigation actions in the main categories with which they were identified. This will contribute to the development of proposals for action, which is the main focus of the GASP in the following phase, the formulation of the Strategic Action Plan-SAP that the TDA is to support. This classification is set out below.

CAUSES OF THE CRITICAL ISSUES

A general classification was proposed in the formulation of the causal chains, namely technical, economic and management, political and institutional and social and cultural causes. Sub-categories were created - as per Figure 13 - taking into consideration the causes identified in the Joint Meeting. There are 5 subcategories for the technical causes, 4 subcategories for economic and management causes, 3 for political and institutional causes, 2 for social and cultural causes and 3 for natural causes. Figure 14 sets out the causes identified in the Joint Meeting for the three critical issues, organized according to this classification and providing an overview of the results. As ascertained during the Joint Meeting, it is not possible or useful to draw links between causes, as it was concluded that almost all the causes influence the others, which would make the result uninformative and the figure too confusing.

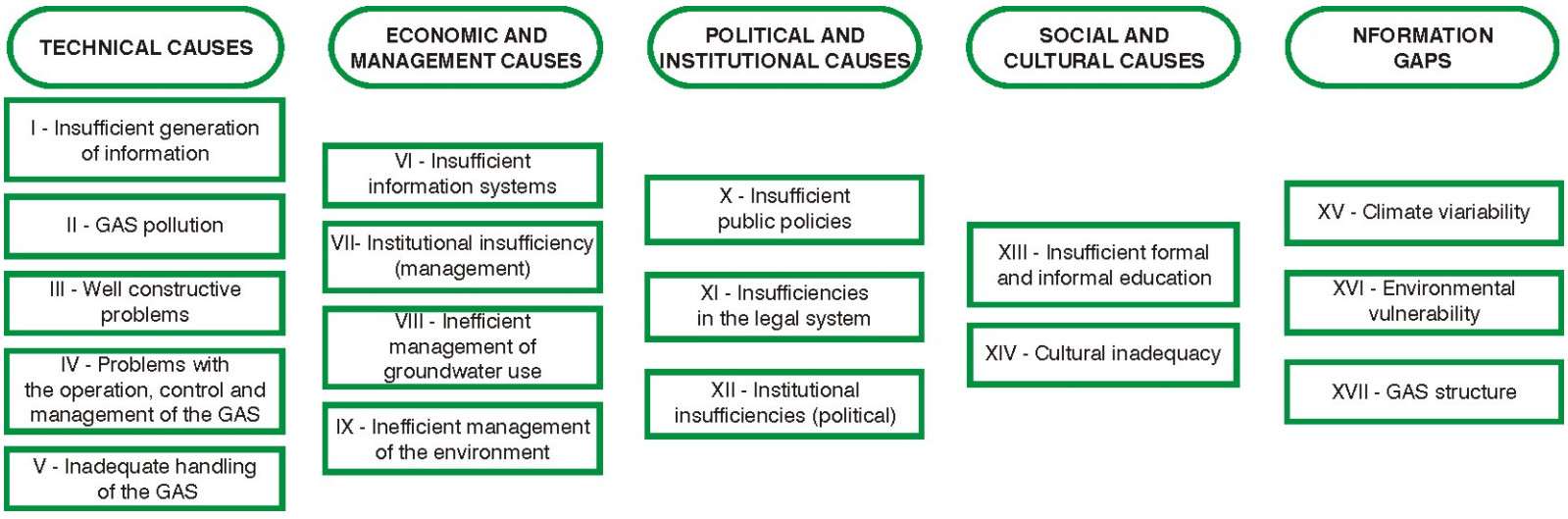


Figure 13 – Diagram of the causal chains of the GAS critical issues

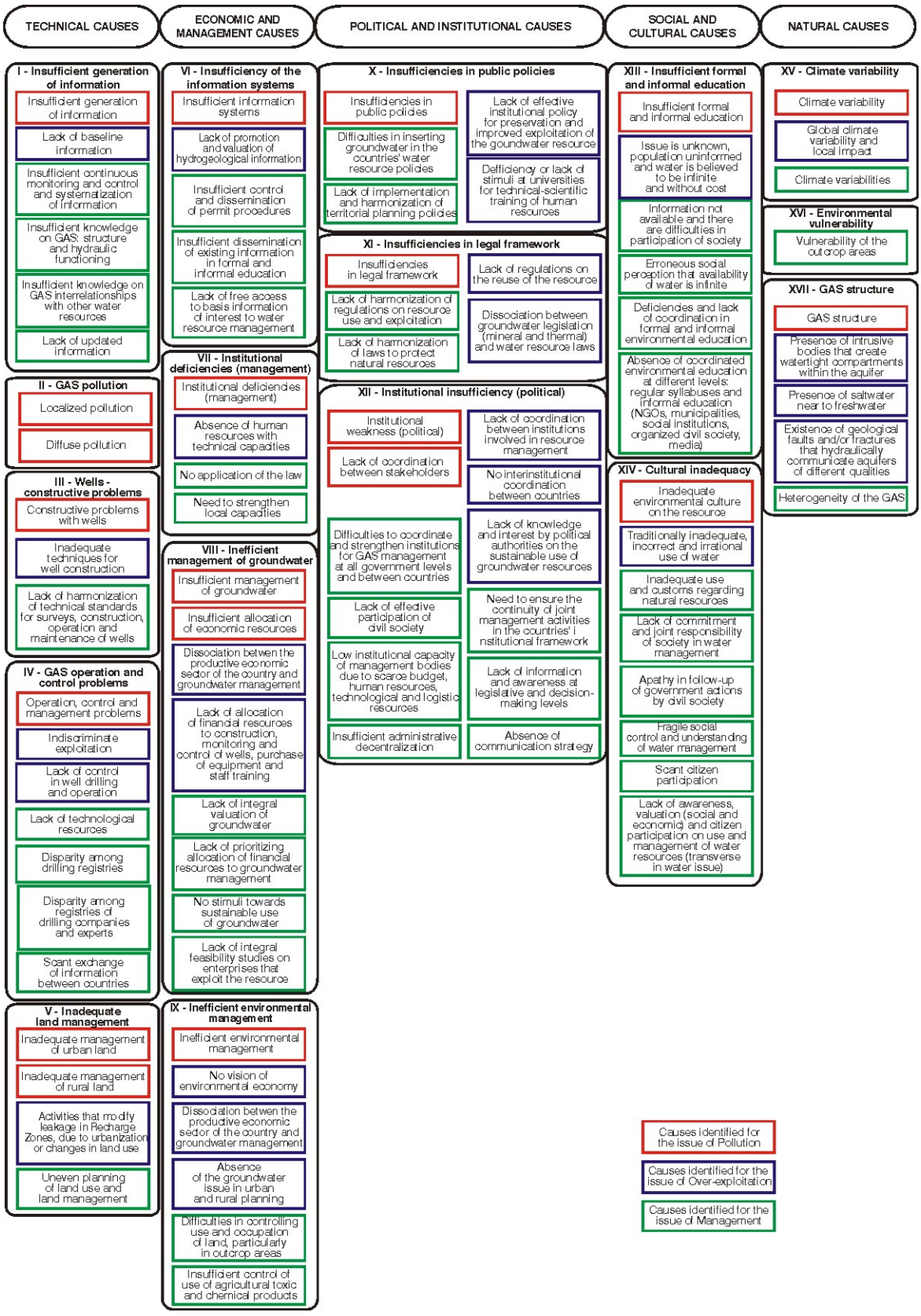


Figure 14 – Identified Causes of the Critical Issues, classified

Figure 14 exhibits many contrasts between the results for each critical issue, which may be a consequence of the essence of the issue and also of the professional training and experience of the members of the group that identified the causes. For instance, it should be noted that the results for the critical issue Pollution are presented in a very concise manner, and using for the most part the denomination for the subcategory. One of the reasons for this may be the professional training of the group members, mostly hydrogeologists, who are not necessary specialists in water pollution. This may result in a lack of precision or definition of the pollution problems. On the other hand, it may be a result of the nature of the pollution problem itself, which has such heterogeneous spatial dynamics that it limits the possibilities for precise definitions, and therefore requires more generalization.

At the opposite end are the causes of the Management issue, which are much more abundant than the other issues. The reason for this may be the broader education of the group members, who were experts, diplomats and environmentalists among others, in consideration of the issue's complexity. It may be noted that strictly speaking Management is not limited to political, legal, institutional and management aspects, but must also take into account aspects of pollution and over-exploitation that were assessed in the other critical issues.

An important note is that most of the identified causes do not refer to one single critical issue - rather, most of them are adequate to explain the root of all the critical issues. This conclusion leads to the simplification of causal chains by the aggregation of similar causes, and will be presented later in this report.

INFORMATION GAPS ON THE CRITICAL ISSUES

The same attempt towards consolidation was applied to information gaps. The initial idea of classifying them as gaps preventing the identification of causes and gaps which prevent proposals for mitigation actions did not prove to be practical. This was due to the fact that many of them have both consequences. Thus, they were classified into 6 categories, as shown below in Figure 15.

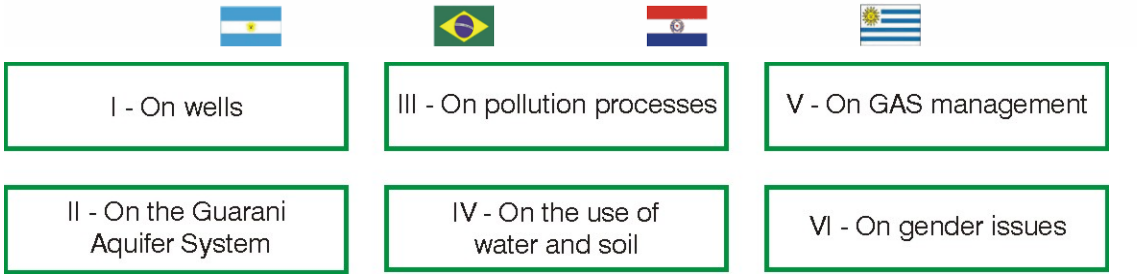


Figure 15 – Synopsis of the information gaps on the GAS critical issues

Figure 16 shows the information gaps that were identified for the three critical issues, organized as per the above classification. It may be noted that most of them refer to the composition, structure and processes of the Guarani Aquifer System.

The same comments that were made above on the causes apply to this case as regards the possibility of considering one single figure for the critical issues and eliminating the existing redundancies. In this case, however, the identifications found for the critical issue Over-exploitation have almost the same detail as those for the critical issue of Management.

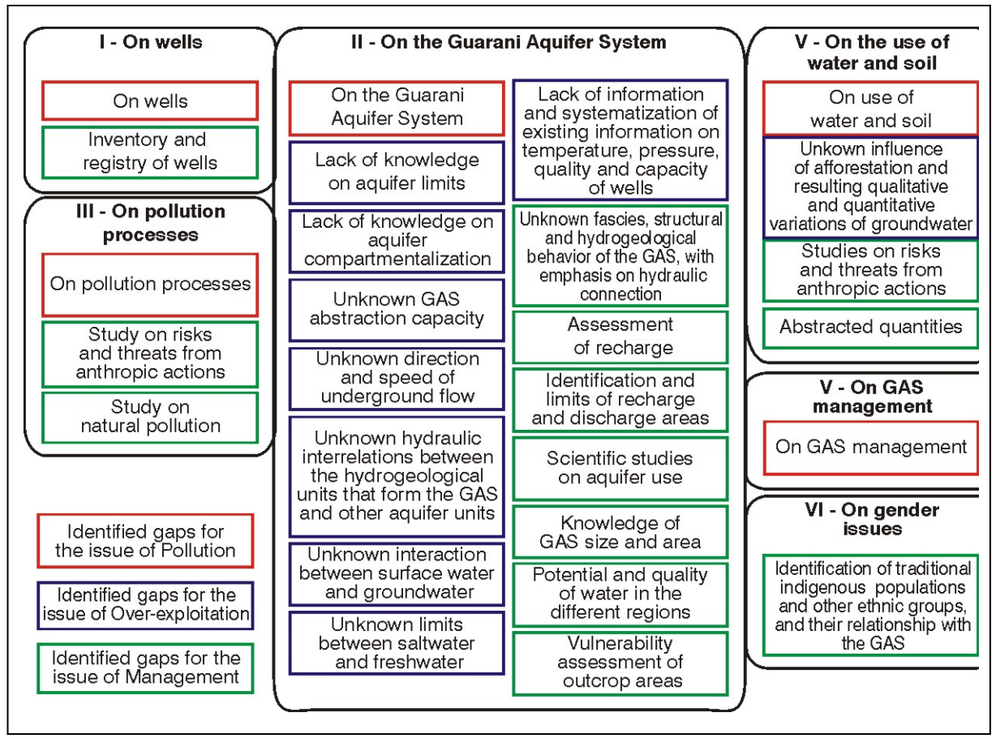


Figure 16 – Identified information gaps on the critical issues, classified

MITIGATION ACTIONS FOR THE CRITICAL ISSUES

The proposal for actions is of the greatest interest for the results of the TDA, as it is the basis for the formulation of the Strategic Action Plan - SAP. There are two types of actions: actions to mitigate the causes of critical issues and actions to fill the information gaps. To be consistent with the classification of the causes and to help formulate the proposal for actions, the same subcategories were used as for the causes. This will make it easier to link a proposal for action with the causes it should mitigate or with the information gaps it must fill.

One exception was the subcategory of natural causes, which was not expressly considered and the actions for which are presented in the subcategories of the other causes. There are also mitigation actions to fill the information gaps, but those on wells and the GAS that pertain to the two first subcategories were added to the subcategory “Generation and dissemination of data on wells and the GAS”, under Technical Causes.

The resulting 18 action categories are summarized in Figure 17. Figure 18 shows the results of the Joint Meeting.

The former comments regarding the scant details on the critical issue of Pollution also apply to the actions. In this case however, there is roughly the same amount of proposals for mitigation actions for the critical issues of Over-exploitation and Management, as in the information gaps.

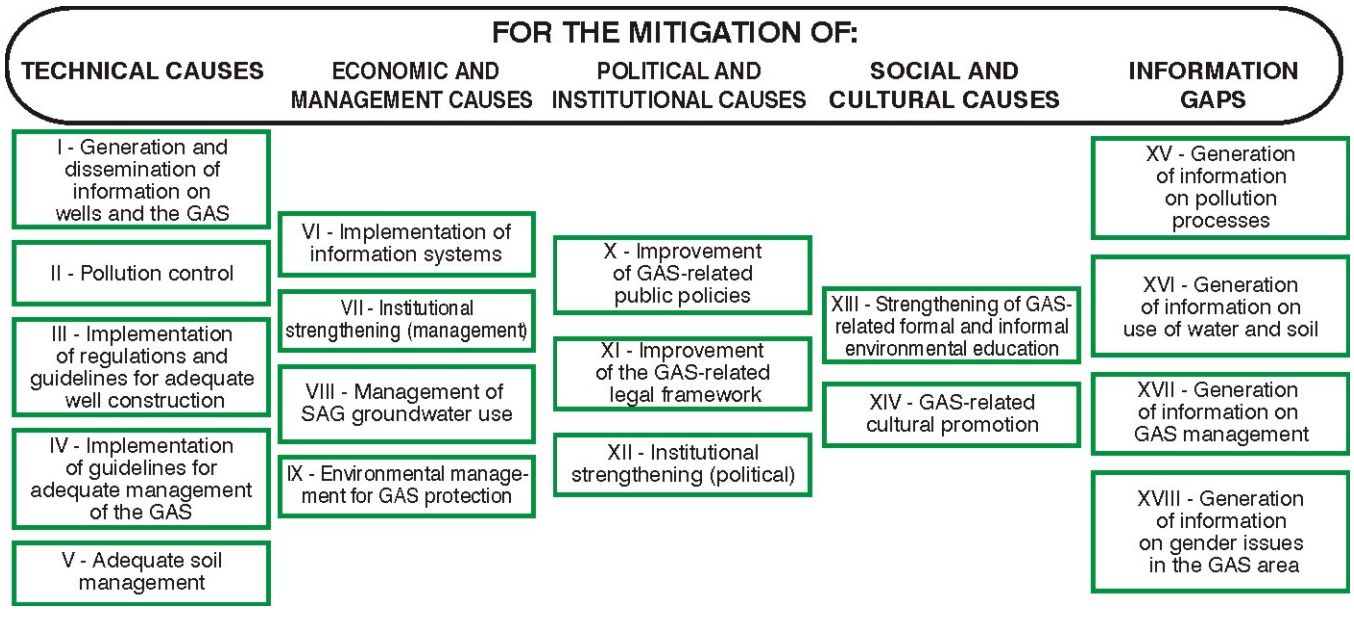


Figure 17 - Diagram of the types of action required to mitigate the causes and fill the information gaps.

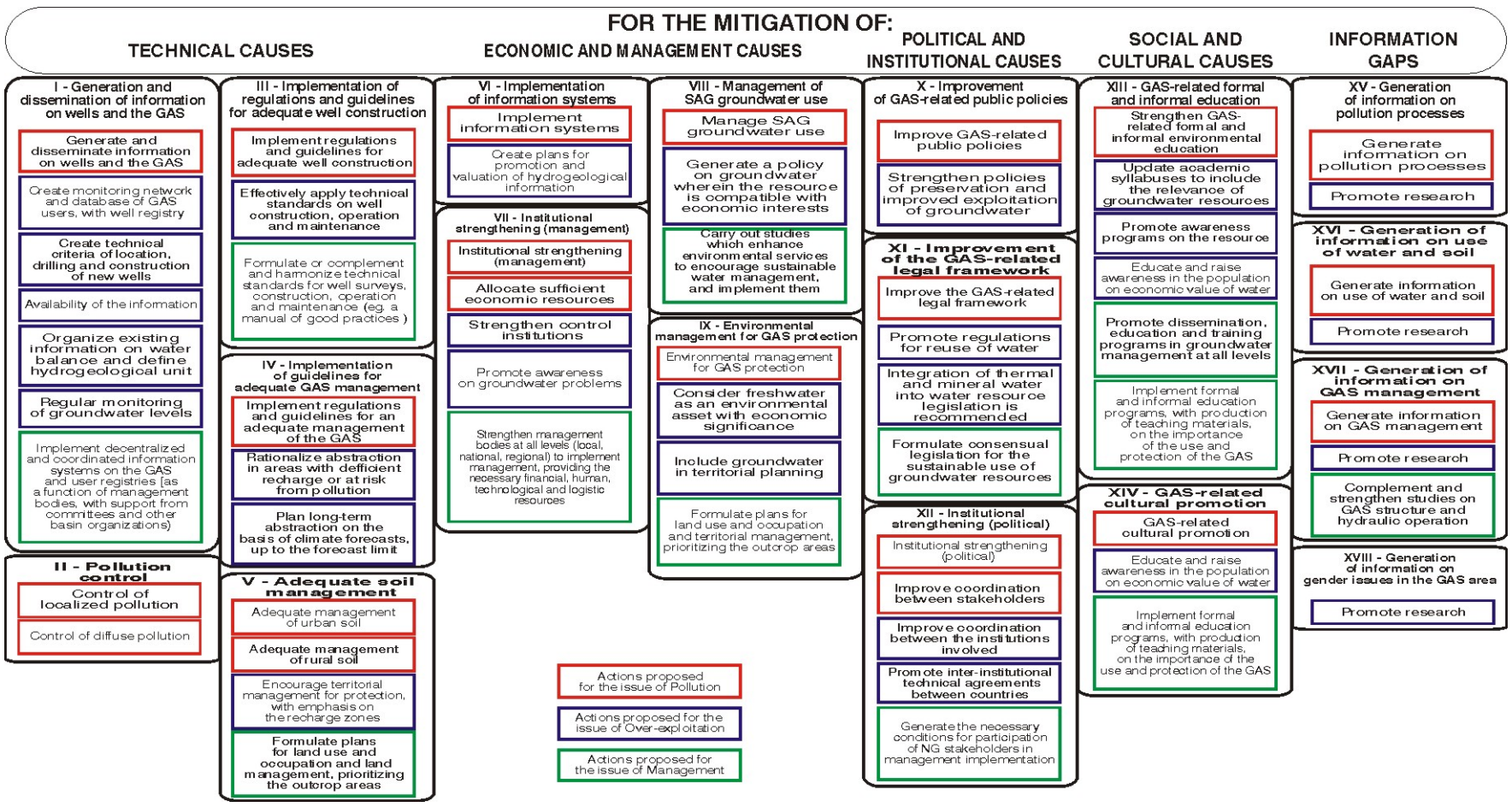


Figure 18 – Mitigation actions proposed for the critical issues, classified

8. FINAL TDA PROPOSAL

A final proposal containing the causes, information gaps and mitigation actions for the critical issues of the GAS is shown on Figures 14, 16 and 18 and takes into account the TDA proposals for each critical issue as presented in the Joint meeting. This final proposal, consolidated and classified, arrived at after eliminating redundancies and reorganizing the figures. The results refer to all the critical issues, since, as noted above, there are no clear dividing lines between causes, gaps and actions, with the sole exception of the pollution control program.

CAUSES, INFORMATION GAPS AND PROPOSALS FOR MITIGATION ACTIONS

As a result, Figure 19 displays the causes of the GAS critical issues, namely 10 technical causes organized in 5 subcategories; 12 economic and management causes organized in 4 subcategories; 12 political and institutional causes organized in 3 subcategories; 7 social and cultural causes organized in 2 subcategories and 6 natural causes organized in 3 subcategories. Figure 20 shows the information gaps in 6 categories, among which those referred to GAS outnumber the rest. Figure 21 displays mitigation actions for technical causes, 10 actions organized in 5 subcategories; 5 actions are suggested for economic and management causes, organized in 5 subcategories; 7 actions organized in 3 subcategories are proposed for political and institutional causes; 5 actions for social and cultural causes; and 2 actions for information gaps, in one specific subcategory.

To achieve these results there was a reorganization of the mitigation actions for social and cultural and natural causes. Actions regarding formal and informal education were added to the first group. In the cultural aspects, actions were added in a single subcategory described as “Formal and informal education, and cultural promotion on the GAS”. The reason is that many of the mitigation actions for the critical issues in one subcategory also mitigate the problems of another.

TECHNICAL CAUSES

I - Insufficient generation of information

Insufficient continuous monitoring and control, systematization and update of information

II -GAS pollution

Localized and diffuse pollution of the GAS

III - Wells-constructive problems

Use of inadequate techniques for well construction
Lack of harmonization of technical standards for well surveys, construction, operation and maintenance

IV - GAS opeeration and control problems

Lack of technological resources

Indiscriminate exploitation and lack of control in well drilling and operation

Disparity in drilling registries and registries of drilling companies and experts

Lack of information exchange between countries

V - Inadequate soil handling

Activities that modify infiltration in Recharge Zones due to urbanization or changes in soil use

Uses of urban and rural soil that promote GAS pollution

ECONOMIC AND MANAGEMENT CAUSES

VI - Poor information systems

Lack of promotion and valuation of hydrogeological information, insufficient dissemination of existing information in formal and informal education, added to the lack of free access to basic information of interest on water resources

VII - Institutional insufficiency (management)

Lack of human resources with technical capacities

Need to strengthen local capacities

Poor monitoring and dissemination of permit procedures

Lack of application of the law

VIII - Inefficient management of groundwater

Dissociation between the productive economic sector of the country and water resource management

Lack of integrated valuation and stimulus for sustainable usee of groundwater, resulting in absence of allocation of financial resources for implementation of monitoring and control of wells, equipment purchase, staff training and groundwater management

No integrated feasibility studies for enterprises that exploit the resource

IX - Inefficient environmental management

Nonexistence of a vision of environmental economics results in dissociation between the productive economic sector of the country and water resource management

Diverse planning in use of land and territorial planning in urban and rural areas

Difficulties in controlling use and occupation of land, particularly in outcrop areas

Insufficient control of use of agricultural toxic and chemical products

POLITICAL AND INSTITUTIONAL CAUSES

X - Insufficiencies in public policies

Absence of effective institutional policies for preservation and improved exploitation of groudwater resources, and difficulties in including them in countries' water resource policies

Lack of implementation and harmonization of territorial planning policies

Defficiencies or lack of stimuli at universities for technical and scientific training of human resources

XI - Insufficiencies in the legal framework

Lack of harmonization of regulations on use and exploitation of the resource, and dissociation between legislation on mineral and thermal groundwater and legislation on water resources

Lack of harmonization of laws on protection of natural resources

Lack of regulations on reuse of the resource

XII - Institutional insufficiencies (political)

Lack of knowledge and interest in political authorities on sustainable use of groundwater

Scant institutional capacity in management bodies due to budget, human resources, technological and logistic restrictions

Difficulties in institutional coordination and strengthening for GAS management, at all government levels and between the countries

Insufficient administrative decentralization

Continuity of joint management activities in institutional framework of the countries must be ensured

Lack of communication and information and awareness dissemination strategies at legislator and decision-maker levels

Lack of effective participation of civil society and insufficient stakeholder coordination

SOCIAL AND CULTURAL CAUSES

XIII - Insufficient formal and informal education

Issue is unknown due to lack of information and difficulties in population participation, and belief that water is unlimited and without cost

Defficiencies and lack of coordination between f ormal and informal environmental education

Lack of coordinated environmental education at different levels: academic syllabuses and informal education (NGOs, municipalities, social institutions, organized civil society, media)

XIV - Cultural inadequacy

Inadequate use and customs vis-a-vis natural resources linked to groundwater result in its incorrect and irrational use

Low citizen participation, and lack of commitment and joint responsibility of society in water management

Fragile social control and understanding of water management

Lack of awareness, valuation (social and economic) and participation of citizens on use and management of water resources (transverse for water issue) result in apathy by civil society regarding follow-up of government actions

INFORMATION GAPS

XV - Climate variability

Global climate variability and its local impact

XVI - Environmental vulnerability

Vulnerabilities of the outcop areas

XVII - GAS structure

Heterogeneity of the GAS

Presence of intrusive bodies that create watertight compartments in the aquifer

Existence of geological faults and/or fractures that hydraulically communicate aquifers of different qualities

Presence of saltwater close to freshwater

Figure 19 – Causes of the critical issues of the Guarani Aquifer System

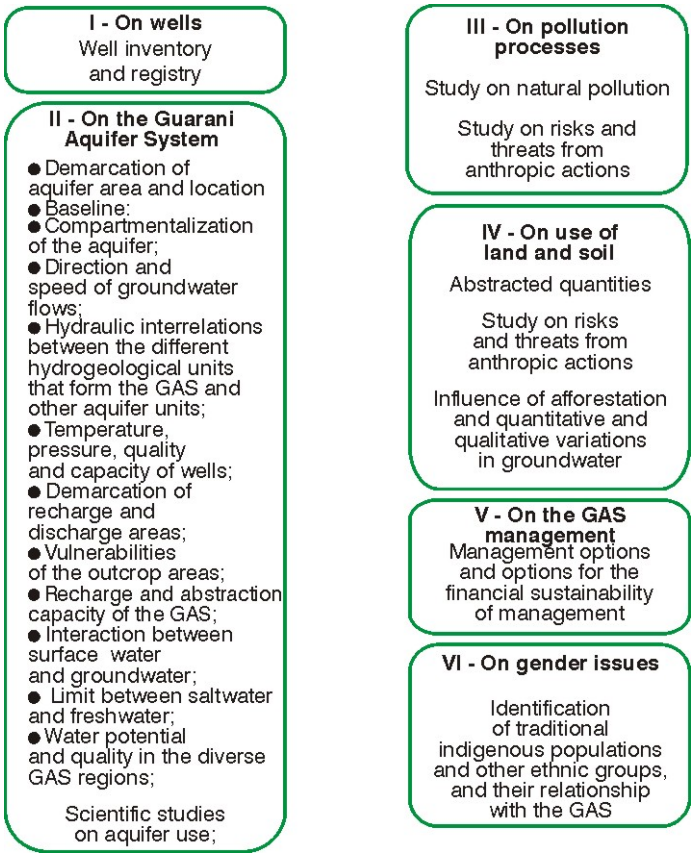


Figure 20 – Existing Information gaps on the critical issues of the Guaraní Aquifer System

Regarding natural causes it was understood that mitigation actions for other causes act preventively in such a way that natural causes, that by definition cannot be mitigated, may be mitigated too. Finally, it was understood that an action described as “Generation of Information for GAS management” would fill the information gaps.

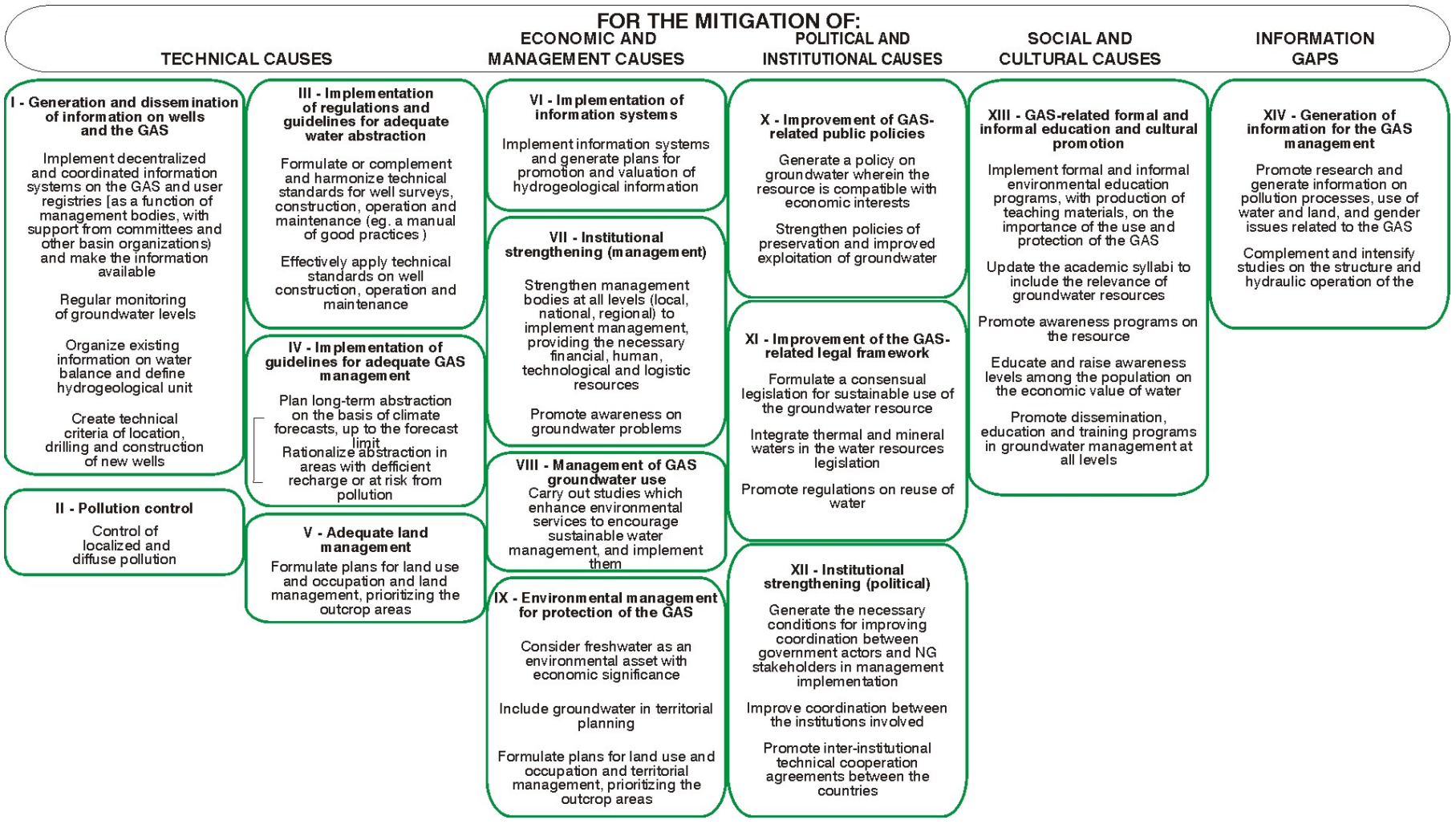


Figure 21 – Proposals for Mitigation Actions for the critical issues of the Guaraní Aquifer System

ANALYSIS OF THE RESULTS

In order to analyze the actions and propose the preliminary priorities, the indications of the Joint Meeting are available on Figures 10, 11 and 12. However, the working groups that dealt with the critical issues of Pollution, Over-exploitation and Management used different criteria for establishing priorities. The Over-exploitation group ranked actions in accordance to each kind of cause: technical, economic and management, political and institutional and cultural. The groups that handled the issues of Pollution and Management ranked actions as a whole, but the first group considered that certain actions have equal priority.

To deal with this difference in criteria the approach was the following. Considering the 14 Proposals for Mitigation Actions displayed on Figure 21, an evaluation was made of which proposed actions for the mitigation of each critical issue were involved in a program and with what kind of priority. For example, in the sub-group of actions 1 - “Generation and dissemination of data on wells and the GAS” there is a proposed action for the critical issue of Pollution with priority 5; 3 actions for the critical issue of Pollution with priorities 1, 1 and 3 respectively regarding the cause to be mitigated; finally, for the Critical issue of Management, a mitigation action with priority 9 was proposed. Table 6 displays the results.

In the critical issue of Pollution, column R displays the priority for the actions. The top priority subgroup is X - “Improvement of GAS-related Public Policies”, because the action with the highest priority pertains to this program. When there is more than one action in a subgroup, as in VII - “Institutional strengthening (management)” and XII - “Institutional strengthening (political)” the second has higher priority, because actions were ranked with priority 3 and 3, while in the other group they have priorities 3 and 4. The same criterion was applied to the remaining critical issues and the relative priority for each is displayed under the heading ‘R’ in Table 6.

It is worthwhile to note that this priority ranking is not and should not be considered as conclusions by the countries, but rather as one of the results of the consultant’s analysis which is presented for information purposes to the countries and to be taken into account in the preparation of the SAP.

Table 6 – Indications of priorities for the proposals for mitigation actions for each critical issue

Proposals for Action	Critical Issues												
	Pollution			R	Over-exploitation					R	Management		R
I - Generation and dissemination of information on wells and the GAS	5			6	1	1	3			2	9		8
II - Pollution control	6	6		7						10			10
III - Implementation of standards and guidelines for adequate well construction	6			8	1	5				4	8		7
IV - Implementation of standards and guidelines for adequate GAS management	6			8						10			10
IX - Environmental management for the protection of the GAS	6			8						10			10
V - Adequate land management	6	6		7	4	5				7	10		9
VI - Implementation of Information Systems	6			8	6					9			10
VII – Institutional strengthening (management)	3	4		4						10	1		1
VIII - Management of GAS groundwater use	6			8	3	4				6			10
X - Improvement of GAS-related Public Policies	1			1	1	2	1	2	3	1	6		5
XI - Improvement of GAS-related legislation	2			2	4	7				8	7		6
XII - Institutional strengthening (political)	3	3		3						10	2		2
XIII- Formal and informal education, and cultural promotion on the GAS	7	7		9	5	6	1			3	3	4	3
XIV - Generation of information for GAS management	5	5	5	5	2					5	5		4

Note: the columns rank the priorities as set out by each working group that tackled each critical issue. The last column, R, displays the relative priority of the proposal for action, for each group.

The subgroups of actions were assigned Number 1 when the priority for a certain critical issue is very high, and number 2 for the second-highest priority, as shown on Table 7. For the final classification, the first place was given to subgroups with top priority for a critical issue, followed by those with the second-highest priority, and so on.

This criterion is the same as the one used to rank countries in the Olympic Games: first are those who won the most gold medals; next those who obtained the most silver medals, etc. The advantage of this criterion is that it avoids the “dictatorship of the majority”, by which only those actions that a significant number of voters consider important are given priority, and an action with maximum priority for one single voter, if it does not have priority for the rest, may end up ranked as without relevance. With this criterion, if there are N voters, an action that is considered as having maximum priority by only one of them will at least be assured of having priority N in the general computation.

The relative priorities of the subgroups of actions, proposed by the consultant by means of this criterion, are displayed in Table 7. The three subgroups with the highest priority are: X – “Improvement of GAS-related Public Policies”; VII – “Institutional strengthening (management)” and XII – “Institutional strengthening (political)”. Oddly enough, program VI – “Implementation of Information Systems” obtained a low priority ranking, as it had low priority for all the critical issues.

From these results it may be interpreted that the social stakeholders of the GAS perceive improvement of public policies and institutional strengthening (both management and political) as the highest priorities for the Guarani Aquifer System Project: two subgroups of political and institutional mitigation actions, and one from the economic and management category. Generation and dissemination of information on wells and the GAS is ranked as fourth, followed by improvement of GAS-related legislation: one subgroup of mitigation actions with technical causes, and another of a political and institutional nature. Finally, formal and informal education and GAS-related cultural promotion also obtained a significant ranking, a subgroup of mitigation actions of social and cultural origin. This ranking leads to the conclusion that priorities are focused on the root causes, because they are those that are displayed on the right hand side of the causal chain, and for this reason they generate more permanent changes in the organization of society and its relationship with the environment and the GAS.

Table 7 – Tentative priority ranking of the Proposals for Mitigation actions

Proposals for Mitigation Actions	Pollution	Over-exploitation	Management	Final Priority
X - Improvement of GAS-related Public Policies	1	1	5	1
VII – Institutional strengthening (management)	4	11	1	2
XII - Institutional strengthening (political)	3	10	2	3
I - Generation and dissemination of data on wells and the GAS	6	2	4	4
XI - Improvement of GAS-related legislation	2	8	6	5
XIII- Formal and informal education, and cultural promotion on the GAS	14	3	3	6
III - Implementation of standards and guidelines for adequate well construction	9	4	7	7
XIV - Generation of data for the management of the GAS	5	5	4	8
VIII - Management of the use of GAS groundwater	12	6	9	9
V - Adequate use of land	8	7	8	10
II - Pollution control	7	12	11	11
VI - Implementation of information systems	11	9	10	12
IV - Implementation of standards and guidelines for an appropriate management of the GAS	10	13	12	13
IX - Environmental management for the protection of the GAS	13	14	13	14

Once more, it is important to note that this ranking is merely indicative of the perceptions of the social actors from the four countries, as interpreted by the consultant. The countries, on the other hand, understand that the program is indivisible, and therefore must be addressed as a whole when formulating the SAP. However, the countries believe that the deep concern voiced at the Joint Meeting regarding the issue of improving public policies and an efficient strengthening of the water management institutions in the four countries should be taken into account at the time of designing the SAP. These should be instrumental in generating changes in the organization of society, and consequently, in its relationship with the environment in general and the GAS in particular.

9. FINAL CONSIDERATIONS - EVALUATION OF THE FORMULATION PROCESS OF THE TDA OF THE GUARANI AQUIFER SYSTEM

To sum up, it is important to evaluate the formulation process that was used for the TDA, following the guidelines provided by Mee (1983). Pursuant to these, the following factors must appear:

- Broad-based stakeholder participation - all the parties involved or affected by an environmental issue or its solution should be involved in the preparation of the TDA: 142 social stakeholders took part in the design of the TDA via the regional workshops, 148 via the national workshops and 33 in the Joint Meeting. The first were selected by the facilitators of the Pilot Projects, prior approval of the GASP General Secretariat; the rest were selected by the National Project Execution Units - NPEUs. This allowed for a broad-based participation, in compliance with the guidelines, as arises from the reports of the regional and national workshops.

- Joint fact-finding - the TDA should be directed by an independent expert or experts, appointed by representatives of the social stakeholders through broad-based consultation, to ensure that the process and its products are suitable for the region; the consultation process consisted of 4 regional workshops in the context of the pilot projects, 4 national workshops in the GAS countries and one Joint Meeting. The consultant acted as a facilitator in the meetings, making only the necessary interventions to ensure that the meetings had the appropriate dynamics. He was careful to avoid inducement or influence on results, displaying them exactly as they were produced in the workshops, with small corrections regarding form and classification but not contents. This enabled a process of regional appropriation of the TDA to occur: it is not the consultant's TDA, or that of GASP experts, or even a TDA by the experts or representatives of the regional public agencies. The TDA is, up to now, the result of successive broad-based discussions, and it began at the baseline of the process - the pilot projects - reaching the national spheres. Now it will reach the joint level, after a sequence of successive appropriations which involved the broadest geographic areas and stakeholder interests.

- Transparency: the TDA must be a public access document; both during design and fact-finding by the stakeholders; the resulting products should be freely disseminated. The TDA documents were made available on the GASP webpage by the GASP General Secretariat with no access restrictions. The participants of the various workshops were informed and therefore were easily able to access these documents.

- Eco-systemic approach: this approach is based on the application of the appropriate scientific methodologies, focused on the levels of biological organization that involve the essential processes and interactions between organisms and the environment - therefore it must be recognized that human beings are a part of the ecosystem; also, the systems should be defined by their natural limits and not their political ones, though these must be recognized in the analysis. The classification of causes (technical, economic and management, political and institutional, social and cultural and natural causes) made it possible to make an eco-systemic analysis. Border issues were considered in the contributions of the 11 experts that analyzed the Preliminary Document and assisted in the formulation of this document, which guided the participants of the several workshops.

- Adaptive management: the TDA and the SAP should be formulated in a series of pragmatically defined stages; at each stage, previously defined performance indicators must be monitored, and depending on results, joint planning must be put into place to evaluate progress and plan the following stage. The adaptive approach was defined in the permanent discussions between the consultant and SG-GAS experts, NPEU coordinators and experts from the OAS, World Bank and GW-Mate, who contributed significant guidelines. The regional workshops were organized and evaluated jointly with the GASP General Secretariat so that the guidelines for the national workshops were approved. In the workshops, the consultant ensured that the participants established the appropriate dynamics. However, objective performance indicators were not used, in the understanding that they do not exist. Subjective performance indicators were adopted, based on workshop attendance, participation of social stakeholders and results, analyzed jointly with the General Secretariat of the GASP.
- Actions should take into account the economic and social causes of a problem: an analysis of the causal chains of the transboundary problems and identification of social and economic causes is of critical importance for the formulation of the TDA; it must be admitted that actions taken in close proximity to the root causes have greater possibilities of having long-term effects on problems. The classification that was used for the causes led to an emphasis on social (social-cultural) and economic (economic-management) causes. Among the mitigation actions that were proposed at the Joint Meeting, emphasis was on those with direct action on root causes.
- Strengthening of intersectoral policies: sectoral approaches are to be avoided, as they prevent the inclusion of multiple purposes, economies of scale and the eco-systemic approach itself. This approach was ensured by the intersectoral origin of participants at the workshops and the Joint Meeting.
- Gradual consensus-building: Consensus must be reached at each stage of TDA and SAP formulation in order to ensure the long-term sustainability of the process and its results. At the 8 workshops and 1 Joint Meeting results were always reached by consensus and widely disseminated.

In this way, preparation of this TDA followed the required guidelines.

Regarding the constructive approach that was adopted - as indicated by the GEF methodology itself - please note that, as with all paradigm shifts, there may be difficulties in its application and understanding. Notwithstanding this, the design process of the TDA complied strictly with the guidelines of this new GEF paradigm, and accordingly:

- There was constant interaction with stakeholders throughout 10 meetings, one of them with experts, 4 of them regional in the pilot projects, 4 of them national and one of them a joint meeting;
- Their values were respected and taken into account, by means of broad-based participation, and joint construction of results based on feedback;
- The visions and perceptions of the stakeholders were incorporated into the TDA;

- Causal chains were regarded not as representations of objective reality, but rather as tools to build consensus on the proposals for mitigation actions to be taken in the GASP sphere;
- Information gaps and mitigation actions were taken not so much as critical information failings and optimal solutions to solve the GAS problems, but rather as socially constructed recommendations; for this very reason they have better chances of being considered at the political level and actually implemented, and socially accepted and supported.

ANNEX 1 - GEF OPERATIONAL PROGRAM 8 - WATER BODIES

Operational Program 8 – OP8 finances the agreed incremental cost of additional measures to solve transboundary environmental problems which affect certain water bodies, based on countries' commitment to reform policies and sectoral activities and to fund expected baseline investments. Environmental problems include pollution, over-exploitation of biological and non-biological resources, degradation of habitats and exotic species.

This program "may fund the transaction costs of neighboring countries collaborating on defining the priority transboundary environmental concern of the waterbody and determining expected baseline and additional actions needed to resolve each priority concern" (GEF – 2006).

The long-term objective of OP 8 is to "undertake a series of projects that involve helping groups of countries to work collaboratively with the support of implementing agencies in achieving changes in sectoral policies and activities so that transboundary environmental concerns degrading specific waterbodies can be resolved".

The short-term objectives of OP 8, towards which the GAS may contribute, are to:

- "undertake a series of projects that utilize a spectrum of interventions for addressing different transboundary environmental concerns in different types of waterbodies that are representative of diverse geographic settings across the world;
- derive lessons learned from experiences in using various types of institutional arrangements at the national and regional levels for collaboration in addressing transboundary priority environmental concerns; provisions will be included for periodic stock-taking and review of lessons learned as projects are implemented;
- assess the usefulness of Strategic Action Program formulation in leveraging national / donor actions at the policy/investment levels, in coordinating support of regular implementing agency programs, and in serving as a logical framework for monitoring and evaluation;

- initiate actions toward resolving transboundary environmental concerns for a variety of waterbody settings with at least one freshwater basin project and one large marine ecosystem project in each of the world's five development regions: 1) Sub-Saharan Africa, 2) Asia, 3) Latin America/Caribbean, 4) Middle East/North Africa, and 5) Eastern Europe/Former Soviet Union.

The view of the GEF is that projects for waterbodies encompass a wide range of transboundary problems, geographic contexts and regions. The following GEF criteria are applicable to the GAS:

- transboundary concerns are defined by neighboring countries in a transboundary diagnostic analysis;
- transboundary concerns create significant threats to the functioning of the ecosystems and a focus is placed on the highest threats;
- most countries contributing to the problems wish to collaborate;
- resources are programmed to support projects in many different development regions rather than being clustered on one continent;.

Assistance may be provided by GEF to:

- conduct a transboundary diagnostic analysis to identify priority transboundary environmental concerns;
- formulate a Strategic Action Program of actions each country needs to take to address the priority transboundary concerns (including differentiation of agreed expected baseline actions and those that would be additional in nature) and to leverage non-GEF resources for implementing both baseline and additional actions;
- support the incremental cost of technical assistance, capacity building, limited demonstrations, and certain investments needed to address the priority transboundary concerns as outlined below under "Types of Activities".
- encourage the use of sound science and technological innovations for management.
".

Other GEF guidelines are:

- "Rather than addressing all the environmental problems GEF seeks to focus on the top priority problems that are transboundary in nature so that sectoral policies and activities that create the problems are changed:
- Joint actions among nations and regional cooperative institutional arrangements are often key features of these projects;
- The projects run the range from capacity building and technical assistance to specific investments with incremental costs;
- Institutional elements such as water quality standards/regulations, permit processes or water minimization/pollution requirements are harmonized among countries;
- If applicable, institutional arrangements such as commissions are often Developer or strengthened to provide mechanisms for countries to sustain actions after the GEF projects end."

ANNEX 2 - OTHER GEF PROJECT TDAS

Several similar experiences were reviewed to find guidelines on how to apply the GEF methodology to the GAS. The following studies, carried out in the Plata Basin, were of particular interest:

- Strategic Action Program for the Bermejo Basin (Argentina and Bolivia) – (SAP Bermejo). Source: Comisión Binacional para el Desarrollo de la Alta Cuenca del Río Bermejo y Grande de Tarija, OAS, UNEP, GEF (2000) Strategic Action Program for the Binational Basin of the Bermejo River. 94p. Website: http://www.cbbermejo.org.ar/docs.htm
- Integrated Watershed Management Program for the Pantanal and Upper Paraguay River Basin (Brazil) - (Pantanal/Alto Paraguay): Source: ANA/GEF/UNEP/OAS (2003) Diagnostic Analysis of the Pantanal and Upper Paraguay River Basin. Executive Summary. 103 p.
- Environmental Protection of the Rio de la Plata and Its Maritime Front: Pollution Prevention and Control and Habitat Restoration. Source: Transboundary Diagnostic Analysis of the Rio de la Plata and its Maritime Front – Technical Document. Project: UNDP/GEF RLA/99/G31. Montevideo, June 2005. Website: http://www.freplata.org/documentos/TDA/default.asp, obtained on 30/01/2006.
- Framework for the Sustainable Development of the Water Resources of the Plata Basin regarding the Hydrological Effects of Variability and Climate Change. Transboundary Diagnostic Analysis. Final consultancy report, 17 January 2005

Other sources on GEF projects in other regions are:

- Brazil, Organization of American States (2004). Proposal for the Integrated Management of Land-based Activities in the São Francisco River Basin: Strategic Action Program for the Integrated Management of the São Francisco River Basin and its Coastal Zone Transboundary Diagnostic Analysis: SAP: GEF São Francisco; Final Report, 336 p.
- Formulation of the Strategic Action Program for the Integrated Management of the Water Resources of the San Juan River Basin and its Coastal Zone (PROCUENCA SAN JUAN). Report available at: http://www.oas.org/sanjuan/spanish/documentos/TDA/introduccion.html

Specific GEF documents were also consulted, namely:

- DUDA, A (2002). Monitoring and evaluation Indicators for GEF International Water Projects, Monitoring and Evaluation Working paper 10, GEF. 11p.
- MEE, L. (2203) The GEF IW TODA/SAP Process – Notes on a proposed best practice approach. Revision 5/6/2003. Mimeo.
- GONZALEZ, P (2004) La formulación del Programa Estratégico de Acción (PEA) y el Análisis Diagnóstico Transfronterizo (TDA). La metodología del Fondo para el Medio Ambiente Mundial en sus programas operacionales de Aguas Internacionales. 12p.
- BEWERS, J. M, UITTO, J. I. (s/d) International Waters Program Study – Final Report. Global Environment Facility 52p. (mimeo).

Below is a summary of the results of the above projects' TDAs.

GEF Bermejo

The TDA for this project took into account baseline studies, thematic cartography, zonification and regionalization, and the pilot studies. It identified the problems, their causes, transboundary effects and root causes.

Causal chains were formulated in terms of (1) identified environmental problems, (2) effects and symptoms (or ways to identify the effect), (3) direct causes and (4) basic causes, which would be the root causes. (5) Strategic Actions were proposed.

Figure 22 shows the Causal Chain for the top priority environmental problems.

GEF Pantanal/Alto Paraguay

This Project adopted a methodology that enhanced stakeholder participation in the formulation of the TDA and SAP and was supported by 44 previous sub-projects. The causal chains were set out in terms of (1) critical issues, (2) their primary causes (technical), (3) the secondary and tertiary causes (economic and institutional, respectively), and finally (4) the root causes. These led to (5) the proposal of Top priority actions. Figure 23 shows an example of one of the causal chains, water pollution.

It is worthwhile to note that in comparison with the Bermejo TDA, this project shows more detail in the definition and classification of the causes which lead to the root of the problems. On the other hand, the GEF-Bermejo deals better with aspects of environmental fragility and sensitivity of the Direct Causes of natural origin in the formulation of the causal chain.

GEF FREPLATA

The methodology of the GEF-FREPLATA project was innovative in the use of the causal analysis Pressure-State-Response - PSR model of the Organization for Economic Cooperation and Development (OECD, 2004) to identify the root causes of the critical issues. This approach provides for a classification of environmental indicators into 3 types:

Pressure - P: information on human activities that affect the environment; they do not necessarily cause negative impacts, as they may be managed correctly;
State - S: information on the state or condition of the environment, i.e., the quality of the environment and the operation of the more relevant environmental processes;
Response - R: information on preventive or corrective measures to mitigate environmental impacts.

By applying the PSR model, the project identifies: (1) root causes. Subsequently, (2) the immediate negative consequences of the root variables and (3) the negative impacts on the ecosystem, and (4) on society. This data led to the causal chain that was used to formulate proposals for (5) top priority actions. Additionally, it makes a vulnerability analysis of the uses and services of the water environment and, by examining the trends of the root variables, presents future scenarios for the environment. Figure 24 illustrates the process, and Figure 25 shows the chain that arises from the root variable Agro-industrial Activity.

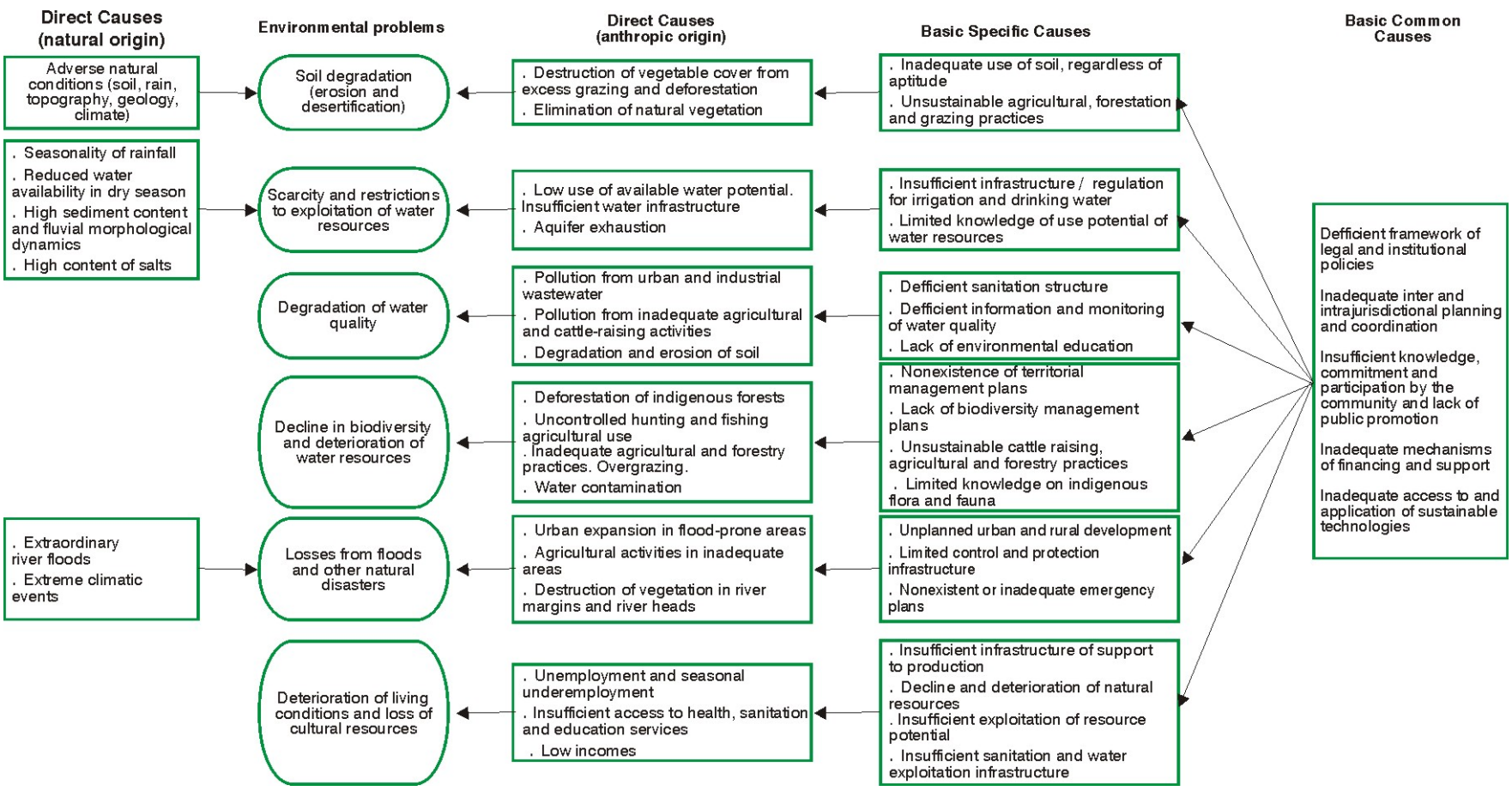
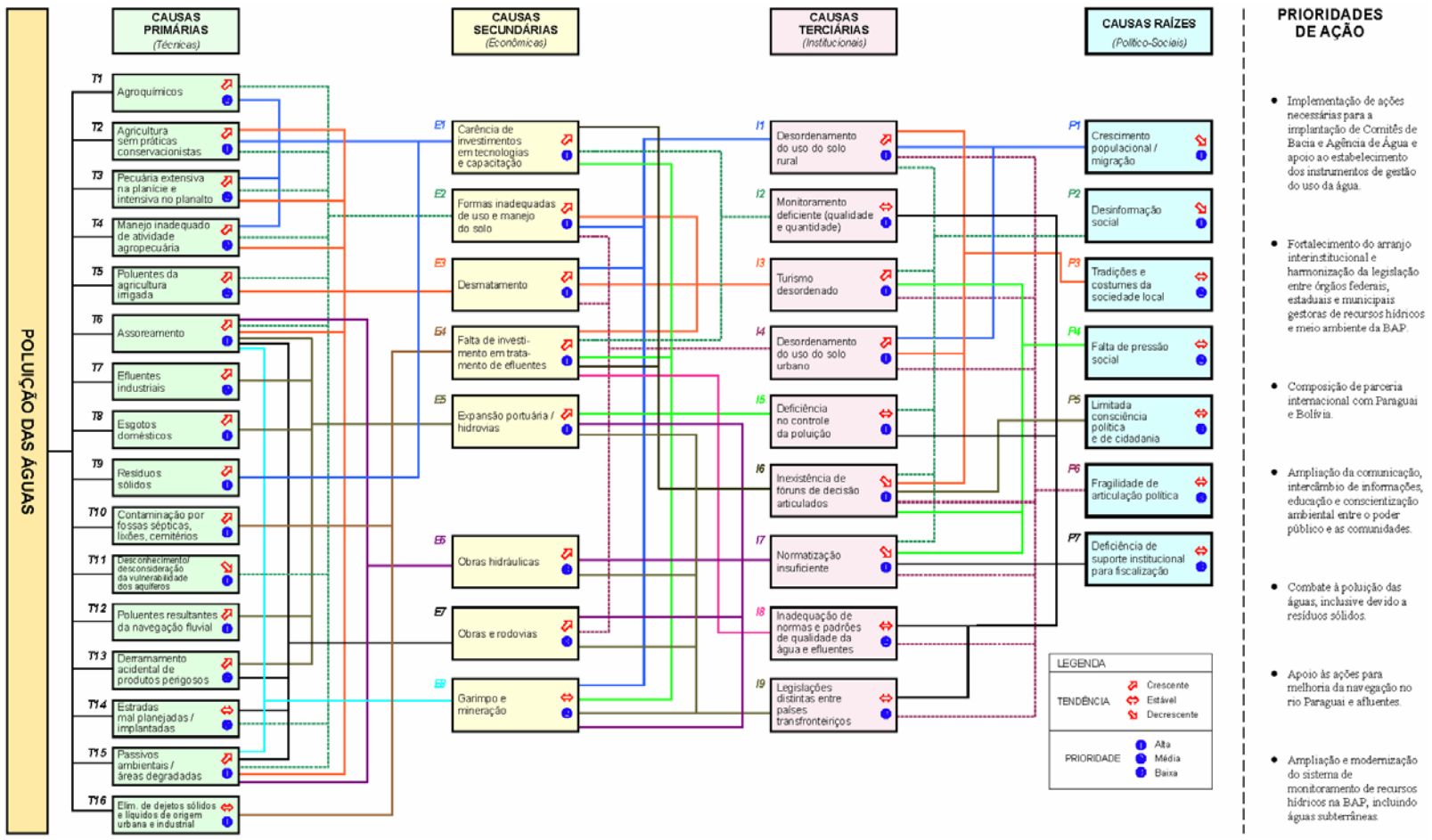


Figure 22 – GEF-Bermejo TDA: Causal chain of the top priority environmental problems



PRIORIDADES DE AÇÃO

- Implementação de ações necessárias para a implantação de Comitês de Bacia e Agência de Água e apoio ao estabelecimento dos instrumentos de gestão do uso da água.
- Fortalecimento do arranjo interinstitucional e harmonização da legislação entre órgãos federais, estaduais e municipais gestoras de recursos hídricos e meio ambiente da BAP.
- Composição de parceria internacional com Paraguai e Bolívia.
- Ampliação da comunicação, intercâmbio de informações, educação e conscientização ambiental entre o poder público e as comunidades.
- Combate à poluição das águas, inclusive devido a resíduos sólidos.
- Apoio às ações para melhoria da navegação no rio Paraguai e afluentes.
- Ampliação e modernização do sistema de monitoramento de recursos hídricos na BAP, incluindo águas subterrâneas.

Figure 23 – GEF- Pantanal/Upper Paraguay River TDA: Critical Issue of Water Pollution

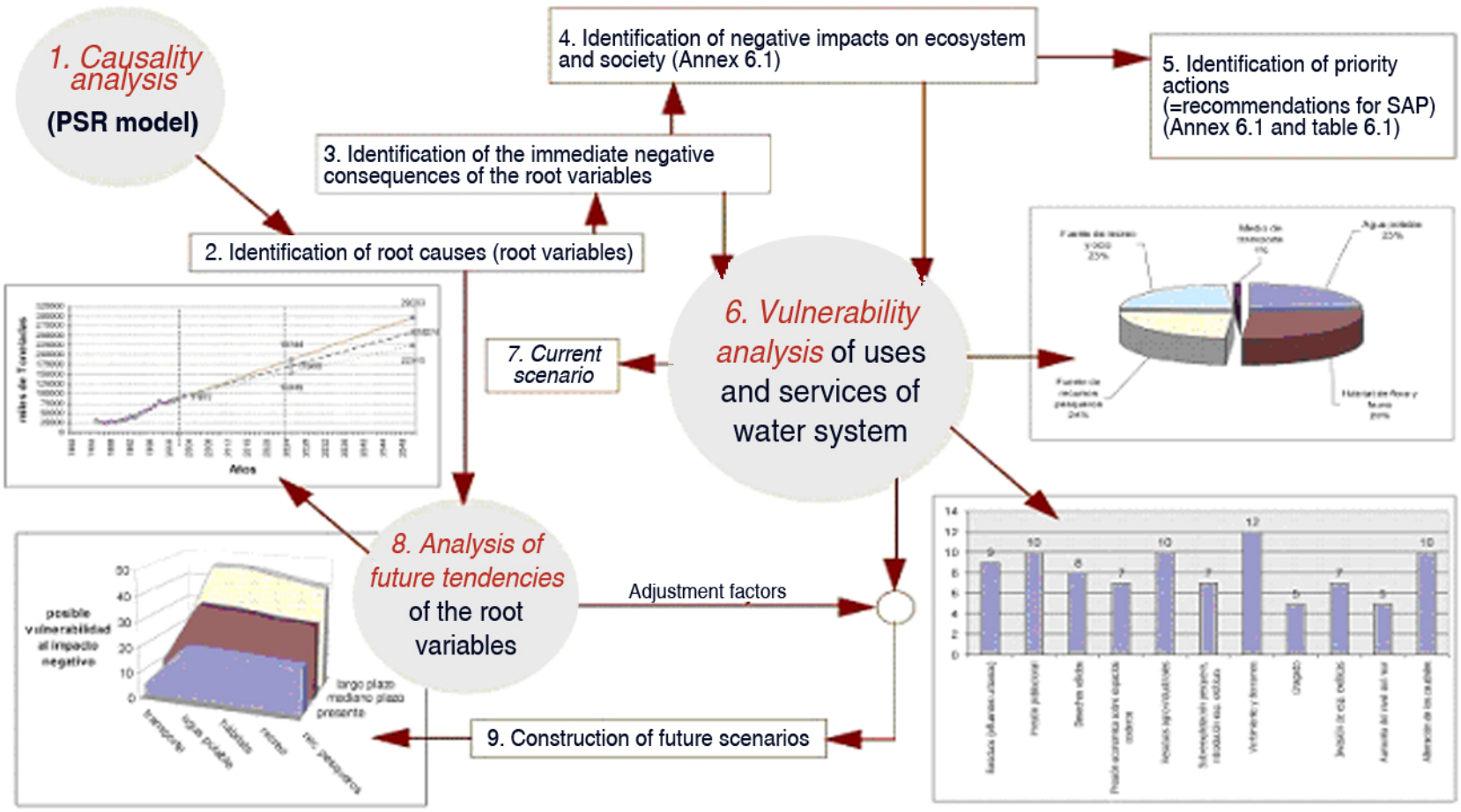


Figure 24 – Design methodology of the GEF-FREPLATA Project TDA based on the Pressure-State-Response model

Root variables	Immediate consequences	Negative impacts on the ecosystem	Negative impacts on society	Priority actions
AGROINDUSTRIAL ACTIVITY	Increase of volume (and changes in composition) of agroindustrial waste	Increase of localized or diffuse organic or inorganic pollutants in the water medium **(T, ZC)** Increase of mortality and/or disease in **sensitive species (RP, ZC)** Biomagnification of toxis substances in trophic chains **(RP, FM)** Modification of reproductive and/or migratory behaviour **(T, RP, FM)** Decline in the primary and/or secondary production of the ecosystem **(RP)** Increase in the frequency of undesirable algae reproduction **(T, RP, FM)**	Human health hazards Limited sustainable development Decline in quality of life Conflicts in the use of space Territorial reorganization, including urbanization processes in the coastal fringe and in key sectors of the basin Changes in mentality and conflicts of interest in society regarding the exploitation of resources and uses of the water medium Loss of ecological values	Coordinated legal frameworks between different jurisdictions and involved institutions Strategy for the environmental education and information of society Organized participation of civil society Integrated management plans for the coastal zone Integrated or coordinated management systems Training programs for public and private decision-makers Institutional strengthening programs Environmental monitoring and alert, and water quality programs Binational criteria of water-environment quality and sediments Early warning systems for undesired algae reproduction Strategies for environmental management and monitoring of urban and industrial waste Programs for information and dissemination of environmental monitoring results Updated and technically and economically viable standards for urban and industrial dumping and effluents Instruments to increase public-private cooperation Local and territorial participative management mechanisms in coastan zones and microbasins Air monitoring and quality programs Plans for promoting clean technologies and sustainable quality management systems

Figure 25 – One of the causal chains shown in the FrePlata TDA

GEF Framework Program

The Framework Program TDA applied a participative approach in two stages. During the first stage a Vision of the Plata Basin was drawn up, and the second stage involved the design of the Transboundary Diagnostic Analysis. National workshops were held in each of the five countries of the basin, followed by an international workshop. The national workshops worked on reaching a consensual national view of the basin's problems; the international workshops reached a consensual overall view of the problems.

The following definitions were adopted to classify the causes in the causal chain:

- **Primary or technical causes:** these are causes that refer to inadequate handling of scarce natural resources. One way to identify them is their direct relationship with environmental impacts;
- **Secondary or economic / management causes**: these causes arise from inadequate economic signs or management approaches. In this case there is a physical or technological link between the secondary causes and the consequent primary cause;
- **Tertiary or political / institutional causes**: they arise from the institutional sphere, that is, from the legal and organizational framework of a region or country;
- **Baseline or social / cultural causes:** these refer to the basic composition of society: its standards of conduct, ethics, customs, traditions, religion, etc.;
- **Root causes**: the root causes are those which are found at the root of the critical transboundary issue, by means of the basic or tertiary, secondary and primary causes.

Information gaps and proposed mitigation actions were identified as suggestions for SAP formulation, as well as the causes for each transboundary critical issue.

The causal chain for the Critical issue Non-sustainable use of transboundary aquifers is shown on Figure 26. The aquifers in this basin are: Guarani System (AR, BR, PY and UY); Upper cretaceous sandstones, on the coast of the lower Uruguay River (AR and UY); the Yrenda aquifer (PY) – Toba (AR) – Tarijeño (BO); Apa river aquifer (BR and PY), and aquifers of the Pantanal, Furnas, Caiuá, Parecis and Serra Geral (BR).

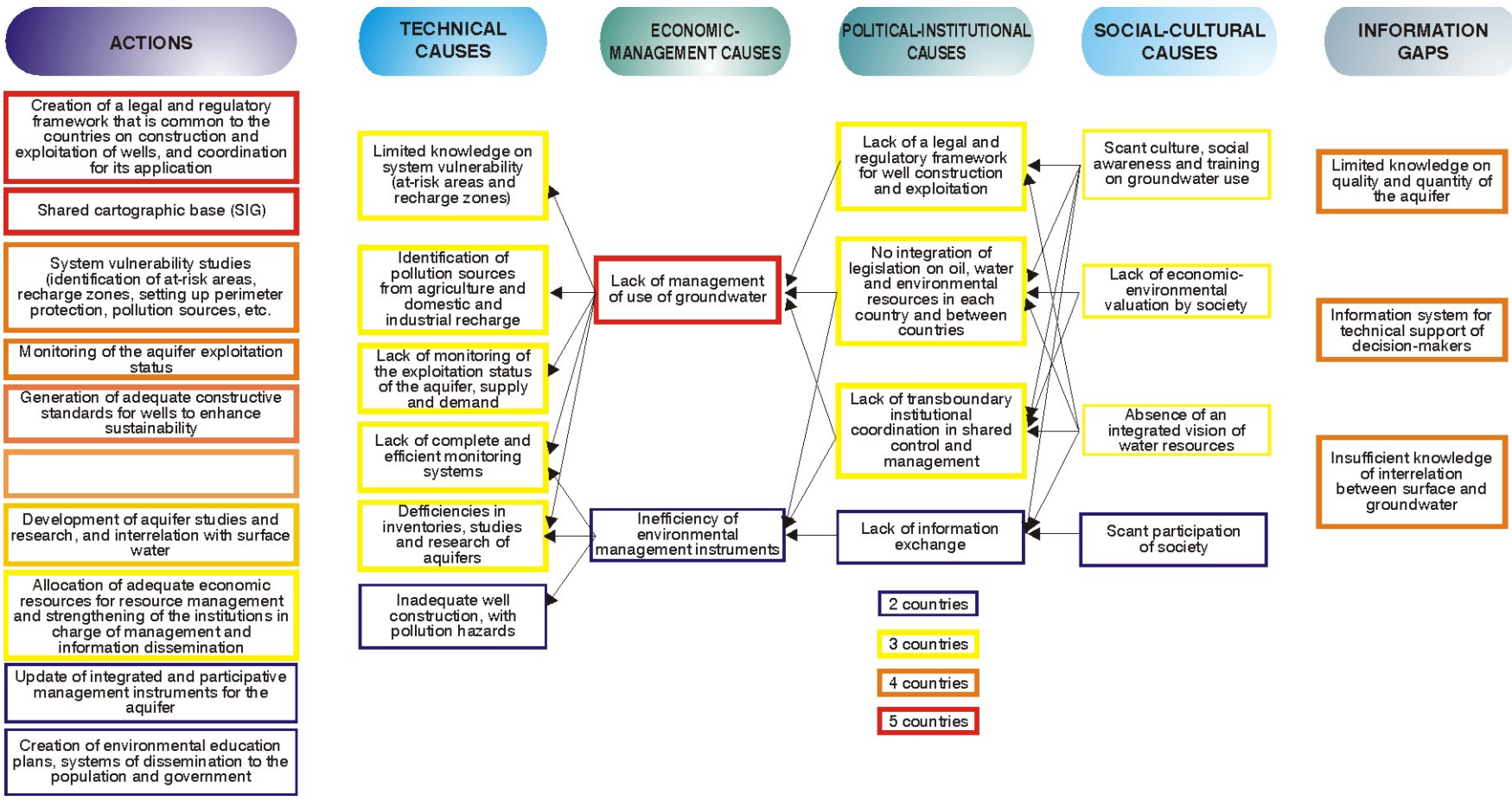


Figure 26 – GEF Framework program: causal chain of the critical issue Non-sustainable use of transboundary aquifers

GEF Projects in other regions

GEF-São Francisco

This project was designed for the São Francisco River Basin and its Coastal Zone in Brazil. There was a certain similarity with the methodology used for GEF-Pantanal in the implementation of 29 projects prior to TDA formulation, and also in the emphasis on stakeholder participation.

The causal chains, though they are similar to the GEF-Pantanal/Upper Paraguay River, are based on different definitions of primary, secondary and tertiary causes. They were conceived in terms of (1) Critical Problems/Issues; (2) Primary causes (technical), (3) Secondary causes (management), (4) Tertiary causes (political / social) and (5) Basic Causes (socio-economic / cultural), which would be the causes. These lead to the proposals for action. Figure 27 shows the causal chain of the critical issue “Uncontrolled exploitation of groundwater, dissociated from surface water”.

The classification of the causes is very similar to the GEF Framework Program, and is obviously the source of the methodology that was used. La clasificación de las causas, muy similar a las del GEF-Programa Marco, es explicada pues esto se inspiró en aquello para definición de las causas.

GEF-San Juan

This project was developed for the San Juan River Basin and its Coastal Zone, on the border between Costa Rica and Nicaragua. Figure 28 displays the cause-effect-root chain, the top, secondary and tertiary priority causes, and the root causes for these problems. The numbers which appear in brackets next to each top priority or immediate cause indicate the relationship between the cause and the main problems. The roman numbers which appear between brackets next to the tertiary causes indicate, in order or priority, the existing relationship between these and the causes of the problems.

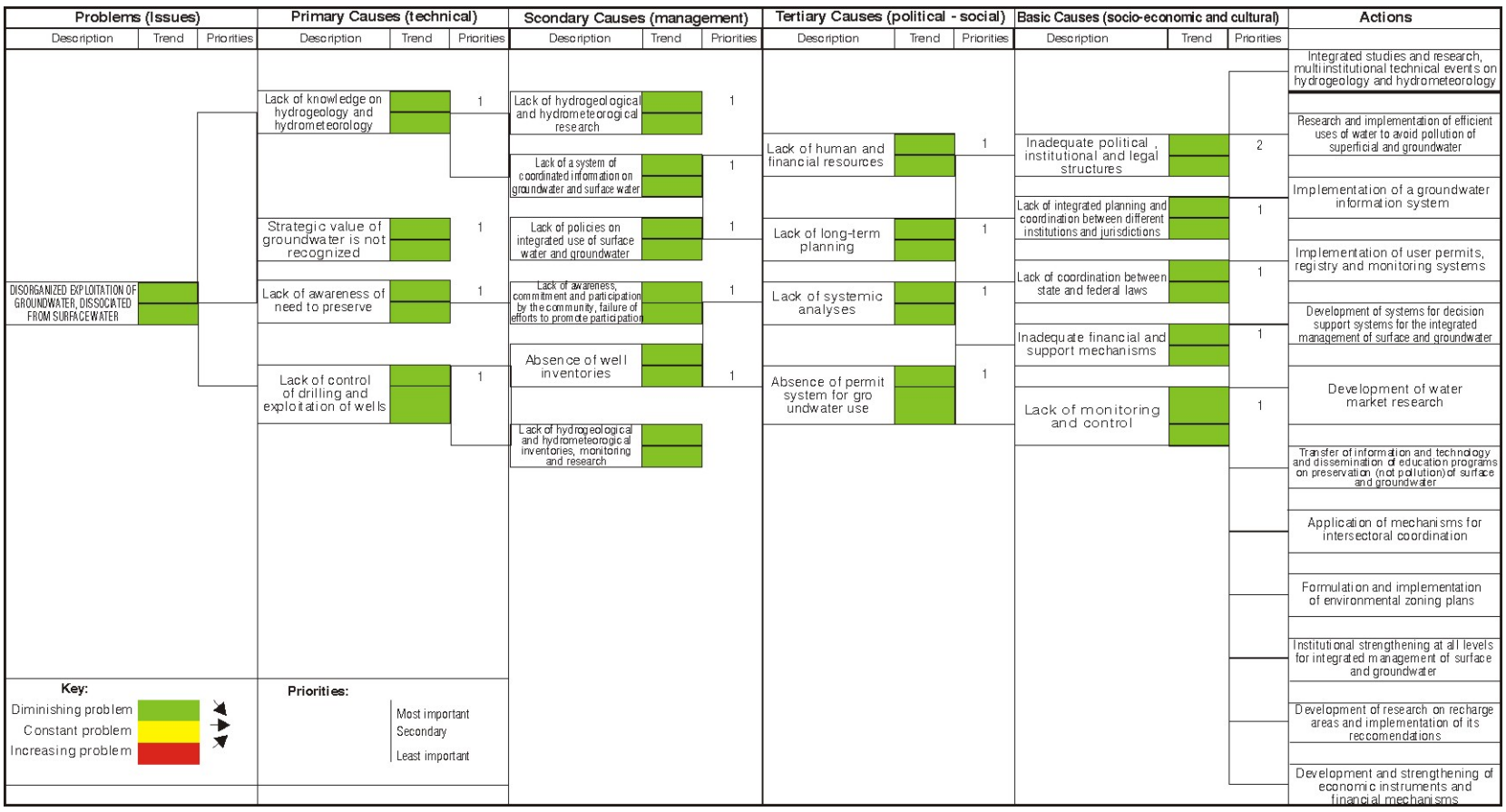


Figure 27 – GEF São Francisco: Causal Chain of the Critical issue Uncontrolled Exploitation of groundwater, dissociated from Surface water

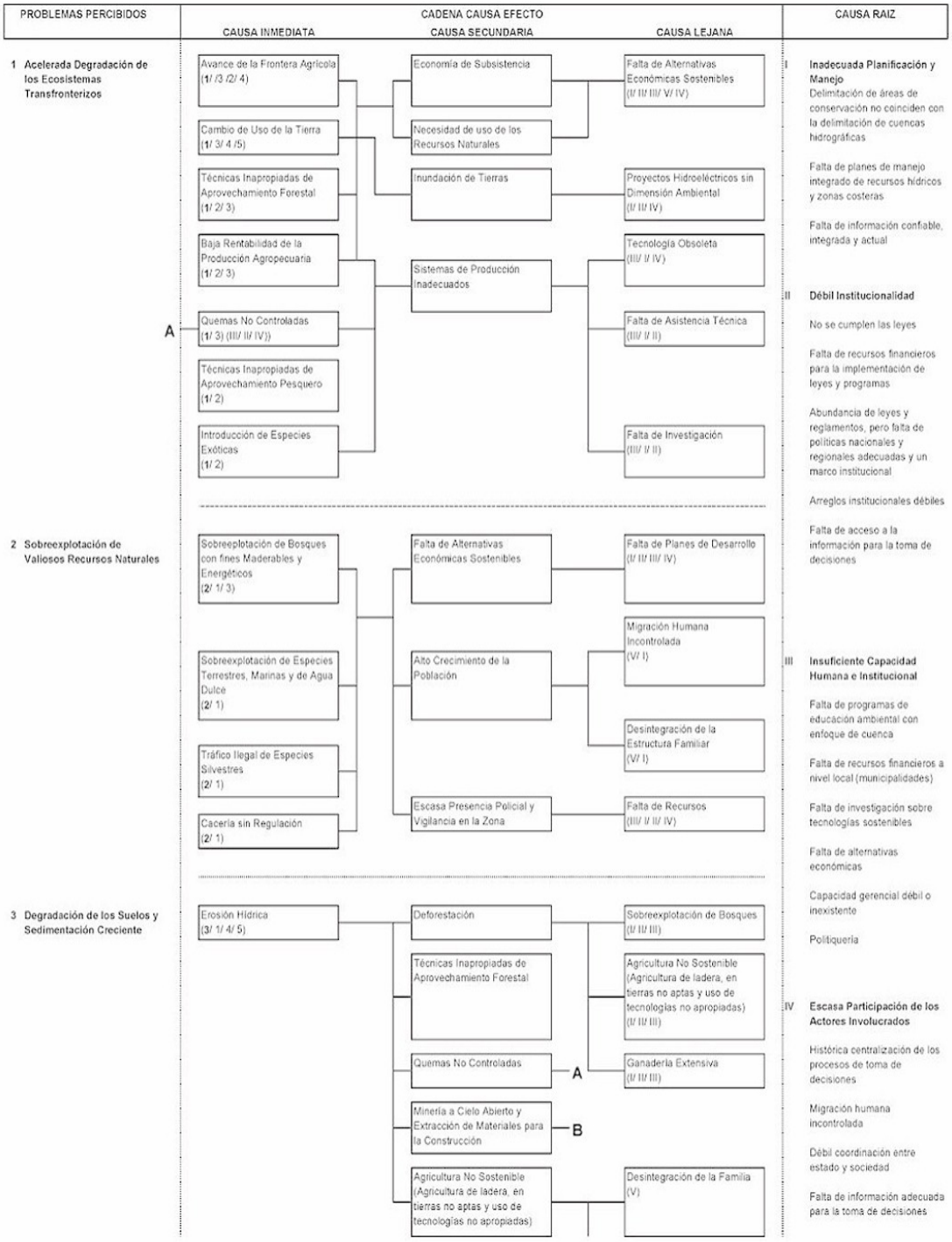


Figure 28 – GEF-San Juan: Causal Chain-Root Effect of the main problems

ANNEX 3 - EXISTING INFORMATION ON THE GAS

This annex summarizes the current information that is available on the GAS, mainly research work, much of which was produced with the support of the GASP. It should be mentioned that this is a personal contribution by the consultant on the basis of a report especially produced by geologist Roberto Kirchheim, and it should not be regarded as the official position of the GAS countries.

As mentioned in the preceding chapter, when a **Transboundary Diagnostic Analysis** is applied to a water body it becomes an exercise to assist in the identification of critical issues and gaps for its shared transboundary management. In addition to identifying and describing them, it attempts to analyze the cause and effect relationships between the gaps, proposing actions that have the purpose of enabling and guiding the intended management process. When the water body is an underground resource, which is difficult to perceive, more specifically water that saturates pores and fractures of rocks in a wide geographical and transboundary distribution, and it is also related to political borders and surface hydrographic basis, this analysis becomes a complex challenge.

The hydrographical body which is the object of the present analysis is the Guaraní Aquifer System (widely recognized throughout the region as the *SAG*). Its environmental preservation and sustainable development are being addresses via the execution of a complex GEF Transboundary Project which involves the governments of Argentina, Brazil, Paraguay and Uruguay (henceforth the GASP). The Guaraní Aquifer System is considered as a transboundary water body which is threatened by environmental degradation due to over-exploitation and pollution, as defined by GEF Operational Program Number 8 (see Annex 1). The long-term objective of the process which began with the Environmental Protection and Sustainable Development of the Guarani Aquifer System Project is to attain the sustainable management and use of that waterbody. Its purpose is to support the four countries in the design and implementation of a joint institutional, legal and technical framework to manage and preserve the GAS. The countries chose the Department of Sustainable Development of the Organization of American States (henceforth DSD-OAS) as the agency responsible for fund management and process direction, with the support of the IRBD as the executing agency.

Therefore it is a challenge that deserves, first and foremost, to be considered in the light of certain technical and scientific conceptual definitions, as well as legal and institutional ones.

Discussions should include the particular characteristics of the border areas and the survey of a series of factors which affect the resource, as well as emerging factors that may eventually lead to loss of quality and quantity. Additionally, when the Project was designed and implemented it included strategies and results that should be included in the above analyses.

Before presenting information on the GAS it is worthwhile to review certain myths regarding aquifers in general, which prevent a proper perception of the problems involved. Table 8 contains a brief presentation of these myths.

¿FINALLY, WHAT IS THE GUARANÍ AQUIFER SYSTEM - GAS?

The GAS is a groundwater reservoir with a strategic role in the MERCOSUR region due to its qualitative and quantitative potential, and also due to the potential exploitation of thermal waters in certain areas.

From a geological point of view the GAS is formed by a sequence of rocks, predominantly sandstone, whose fluvial and lacustrine sedimentation (analogous to the present-day transition areas between rivers and lakes) and eolian sedimentation occurred in the Triassic and Jurassic periods in a topographically depressed area of the south of the old South American continent, called the Sedimentary Parana and Chaco-Parana Basin (Araújo et al (1995).

These water-saturated rocks were extensively covered with basalt flows during the Upper Cretaceous period, which may reach 1.000 m at certain points. This Basin, formed during the long geological periods, is also described as cratonic, as it developed in the middle of the continent and is distant from the tectonic plates (where mountain ranges, earthquakes and volcanos are generated). Some of these rocks have shown high groundwater storativity and transmissivity ratios, and their water can be extracted in appreciable quantities; this is why they were called aquifers, and their hydrogeological significance introduced (Noyes et. al, 1972, Lohman et al, 1972 and Machado, 2005).

Table 8 – Common myths surrounding aquifers

Myth	Reality
The average recharge rate of an aquifer may be taken as a factor for sustainable extraction	This false paradigm does not take into account the need to preserve the natural discharges of the aquifer, or changes that may occur in terms of phreatic / potentiometric levels for other uses of groundwater such as preservation of aquatic ecosystems, containing the enroachment of the saline wedge.
Falling levels of aquifer groundwater always indicate over-exploitation - detected by the formation of large depression cones, a substantial increase of interference between wells and loss of water levels, among other effects.	Any exploitation of groundwater results in decreasing levels, and it may take many years to recover large aquifers - which in some cases may be interpreted as constantly declining groundwater levels.
Groundwater usually flows in the shape of underground rivers	This occurs exceptionally in areas of fractured calcareous rocks
By drilling deeper wells new groundwater resources can be tapped	Deeper aquifer formations may be found, but abstracting their groundwater usually results in induced leakage from overlying layers of the aquifer.
The recharge rates of an aquifer are constant	This commonly-accepted paradigm may lead to serious conflicts - recharge rates vary with the degree of anthropization of the natural drainage (rivers), changes in irrigation patterns, in the type of natural vegetation or agricultural cover, reduction of infiltration rates in urban areas, etc.

Source: Foster; Tuinhof; Kemper; Garduño; Nanni (2003)

In the uppermost layer of this sequence, in a desert climate environment, eolic and fluvial sandstone deposits occurred, creating thick layers of greatly porous and permeable sandstone in large geographic areas. This is what is known today as the main aquifer of the GAS, though it is not the only one, as there are others in the layers of the Jurassic period called Tacuarembó (Argentina, Uruguay), Botucatu (Brazil) and Misiones (Paraguay). Due to the fact that it is a multilayered group of rocks, and therefore a series of aquifers with different hydrdynamic properties (porousness and permeability) and general characteristics (geometry and chemistry), with confined and non-confined portions, the entire structure has been characterized as an aquifer system. The connotation of aquifer system in the case of GAS is used in an integrating manner, also to overcome the lack of a better definition and specific information on the different aquifers that compose it and their inter-relationships (personal opinion based on Machado, 2005).

The GAS, or rather the aquifers that form the GAS, are located in the sedimentary Parana Basin located in the subsoil of the east and center-south of South America, underlying parts of Argentina, Brazil, Paraguay and Uruguay, as displayed on Figure 29. In other words, its limits do not conform to political and administrative territorial borders, and therefore it can be defined as a transboundary water body.

Chart 1 and Figure 30 show a summary of the geographical distribution of the GAS in the countries. In general terms, notwithstanding a certain degree of fragmentation, the GAS has an average thickness of 250 m. In almost 90% of its total area it is confined by the overlying basalt rocks, and in the central areas of the sedimentary basin its depth may reach over 1.000 m (information obtained by several researchers, among them ROCHA, 1997). The total freshwater volume is estimated at approximately 46.000 km^3, with 166km^3 representing the sum of the natural and indirect annual recharge. (BORGHETTI; BORGHETTI; ROSA FILHO, 2004). It is generally believed that the stored water is drinkable, though in certain deep zones there may be an excess of fluorides or salinization.

Table 9 shows certain outstanding aspects of the GAS.

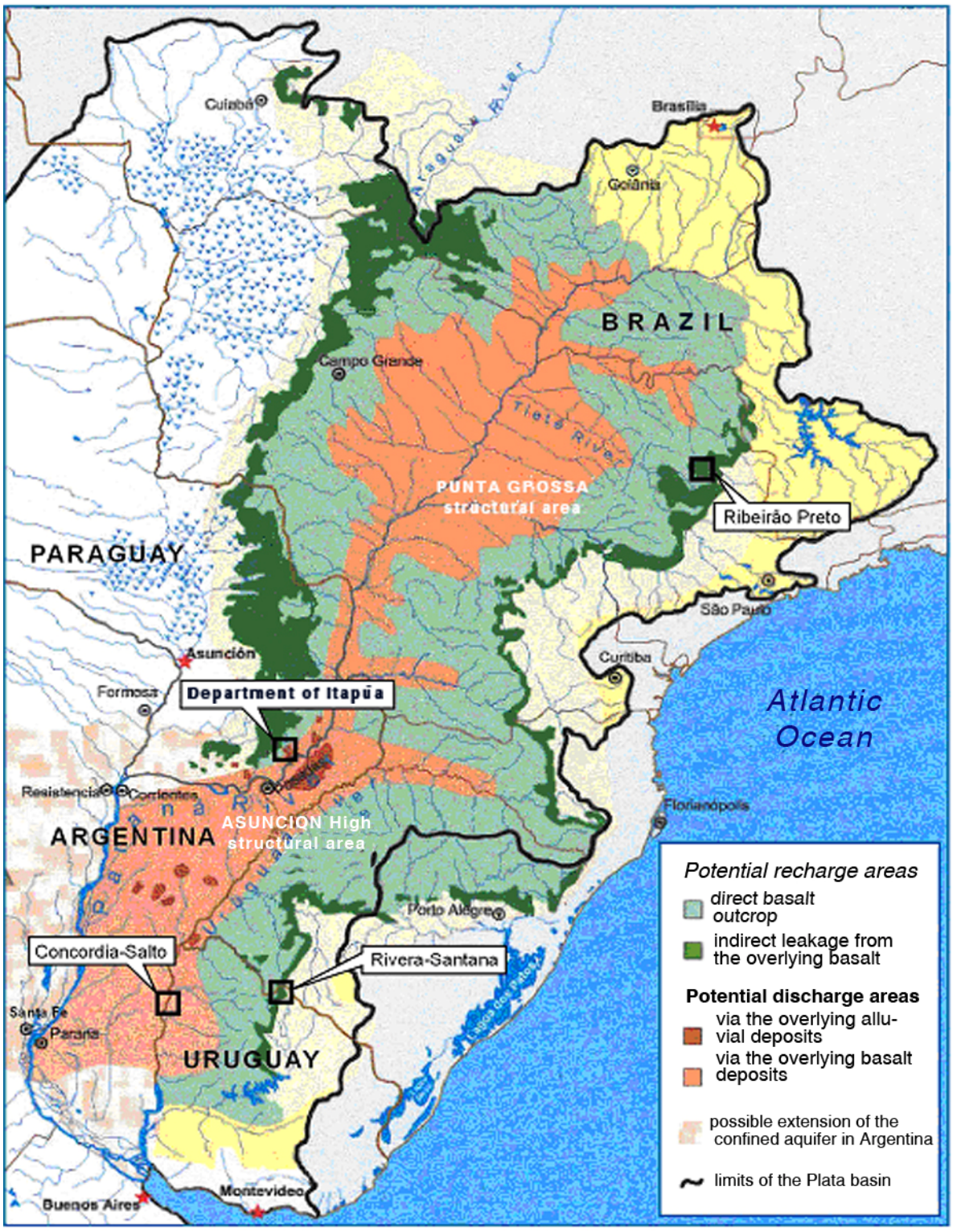


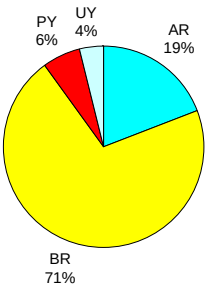
Figure 29 – Location of the Guarani Aquifer

Source: Brazil. Secretaria de Recursos Hídricos do Ministério do Meio Ambiente (2001) y AMORE, VARGAS, OLIVEIRA (2001).

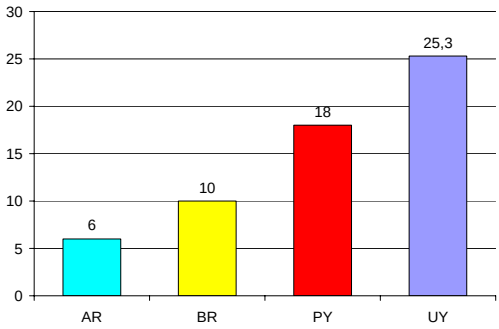
Chart 1 - Geographic distribution of the GAS in the countries

Characteristic		AR	BR	PY	UY	Total
Area of the aquifer	1.000 km^2	225,5	839,8	71,7	45	1.182
	%	19,1	71,0	6,1	3,8	100
Percentage of country area		6	10	18	25,3	10,3
Outcrop area in each country	%	0	67,8	30,1	2,1	100
Estimated population in the GAS area	Million inhabitants	2,6	24,9	1,9	0,6	30
Population in the outcrop area		0	2,6	1,0	0,1	3,7
Estimated volume of water	1.000 Km^3	8,7	32,5	2,8	2,3	46,3

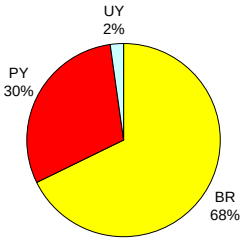
Source: BORGHETTI; BORGHETTI; ROSA FILHO, 2004



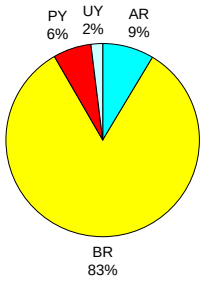
a) Distribution of the total GAS area per country



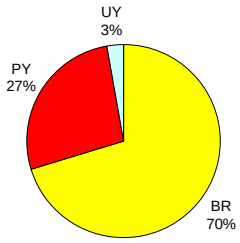
b) Area covered by the GAS as a percentage of the total country area



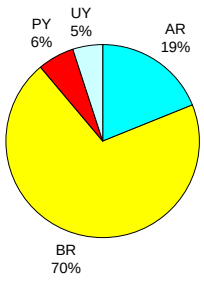
c) Distribution of the outcrop area of the GAS per country



d) Distribution of the population over the GAS area per country



e) Distribution of the population in the outcrop area by country



f) Distribution of the estimated water volume of the GAS per country

Figure 30 – Distribution of the GAS in the four countries

Table 9 – Matters regarding information on the GAS which are crucial for the formulation of the TDA

- It is necessary to improve the description of the GAS geometry and the interaction between the aquifers that compose it; it is imperative to individualize them for a proper interpretation of their state. Most studies were at a regional scale, when the full understanding of the transboundary effects of the GAS depends on more localized research. - There is a huge lack of long-term data; historical series are almost non-existent. - The limits of the GAS do not match the surface hydrographic basins, which are the basic units used for the integrated management of water resources. This element contributed additional complexity. - Interactions between underground and surface flow systems are complex. Pumping of water from an aquifer that is hydraulically connected with a surface water body may lead to a significant decline in the discharge rate of the groundwater flow towards that body, or to the reverse situation, an induced recharge from the surface waterbody. - There are areas of the GAS which are not deemed productive from the quantitative point of view, and/or their quality is unsatisfactory; this means that GAS quality is not homogeneous, which is an important factor when defining management strategies. Further information is need on quality and potential pollutants. Information on water quality was obtained in preparatory consultancies for the Guarani Aquifer Project: CHANG (2001) and SANTOS (2001). As an example, salinization was detected in Villa Elisa and La Paz (Entre Rios, Argentina), Londrina (F), Cianorte (STD), Presidente Prudente (F, STD), Andradina (F), Auriflama (STD), Santa Rosa (STD), Piratuba (STD), Erechim (F), Venancio Aires (F). - There is insufficient information and research to evaluate the sustainability of current extractions in areas of high use and dependence on groundwater. - There is also insufficient information and research to evaluate sustainability of present extractions in areas of high extraction and dependence on groundwater - Discharge conditions are unknown.

HISTORICAL PROGRESS IN THE PERCEPTION OF THE GAS

The geological continuity of the GAS was recognized in the nineties, and originated in the review of data from oil exploration drilling. The GAS appeared as a large, homogeneous transboundary system, with high potential and excellent chemical water quality. However, thanks to initiatives by diverse groups of researchers and experts, arguments and conceptual models arose that challenged the alleged homogeneity and unrestricted connection. The efforts of groups of regional experts and the inertia generated by preparatory actions for the GEF Project and its widespread dissemination in scientific and communication media created an awakening of hydrogeological sciences and the need for groundwater management. Towards the end of the project preparation stage and the beginning of the implementation stage, the approach to the GAS changed with the input of fresh information that was being generated at a larger scale. It is now being viewed as an increasingly complex and less homogeneous waterbody. Large tectonic structures which were mentioned in the literature were studied in further depth from the hydrogeological point of view, leading to new

discussions on the regional / transboundary flows. It is still a debated issue, and the results of the GAS technical consultancies will provide crucial data. For instance, the hydraulic effects of the basic intrusive structures like the diabase dykes which cut through the aquifer in some regions, or the displacement of plates due to faults are not too well-known and they should be studied in depth. Whereas in certain situations these structures act as flow barriers, as shown in the results submitted by Machado (2005 for the State of Rio Grande do Sul, Brazil, to mention one among many studies), other initiatives, like geophysical research in the geological structure of the Chaco-Parana basin in an area that focuses on the cities of Salto (Uruguay) and Concordia (Argentina) within the framework of the Universities Fund, indicate that uncertainty is still prevalent regarding the hydrogeological compartmentalization of the GAS as a result of these structures (in the case of the main faults). Technical review of the information and/or adoption of conceptual models is not an objective of this annex, nor is it a part of the formulation and validation process of the TDA document.

Setting this discussion aside, the use of the GAS was and still is on the increase, with escalating drilling and economic exploitation.

Certain issues that are considered crucial for the formulation of the TDA are shown on Table 10.

Table 10 – Issues on the continuity of the GAS that are crucial for the formulation of the TDA

- New and multiple information on the GAS is being generated since the nineties, leading to a substantial improvement of the understanding of the GAS as a groundwater body. - There are indications of strong tectonic control with possible implications for hydraulic operation and discontinuity. This fragmentation leads to significant changes in the understanding of reserves and possible extraction volumes, and therefore in the local sustainability of the GAS.

ASPECTS CONCERNING THE GAS REGIME

However, it is imperative to analyze the GAS flow regimes for the TDA. There is groundwater flow from the direct and indirect recharge zones, which contribute to the preservation of the permanent and/or active (regulating) reserves, and also to areas where there is natural discharge. These areas exhibit the following characteristics at the regional level: (MENTE, 2001; ARAÚJO ET AL., 1995, FUNPAR, 2001 and BORGHETTI, BORGHETTI, and ROSA FILHO, 2004):

Direct recharge zones: They occur in areas where erosion resulted in the exposure of part of the GAS aquifer rocks. Recharge occurs by leakage of excess rainfall, and also by the flow over the recharge zone, which is composed of the area of sandstone outcrops (approximately 150.000 km^2) and another much larger adjacent area, where a relatively thin layer of fractured basalt covers the sandstone.
Indirect recharge zones: These are areas where surface water leakage (vertical filtration) occurs through the basalt fractures, and also indirect flow along the overlying sedimentary rock formations, where potentiometric levels favor leakage.
Discharge Zones: The GAS natural discharge regime is still largely unknown. It is considered to occur regionally in areas with topographic heights below 300m, near the base level of rivers like the Parana, Uruguay, Pelotas and Tietê, or in their areas of influence further downriver in their basins (Argentine Mesopotamia), and in the form of seepage in the wetlands (Esteros de Ibera in the northeast tip of Argentina).

Associated to this view in terms of transfer characteristics is the notion of the GAS regime regarding potentiometric levels (water pressure rates). The outcrop areas match the zones known as free or unconfined areas, where the water is under the influence of atmospheric pressure. In confined zones the water pressure is much greater than atmospheric pressure, which causes water to surge in wells above the ceiling of the aquifer layer, or as springs and artesian wells. The difference in pressure between the waters of contiguous aquifers and their hydraulic characteristics determines the upwards or downwards vertical drainage.

Figure 31 shows an example of different areas of the GAS (recharge and discharge) induced by tectonic effects, and their probable relationship with the alluvial strata of the main rivers of the region (this specific example applies to the Parana River).

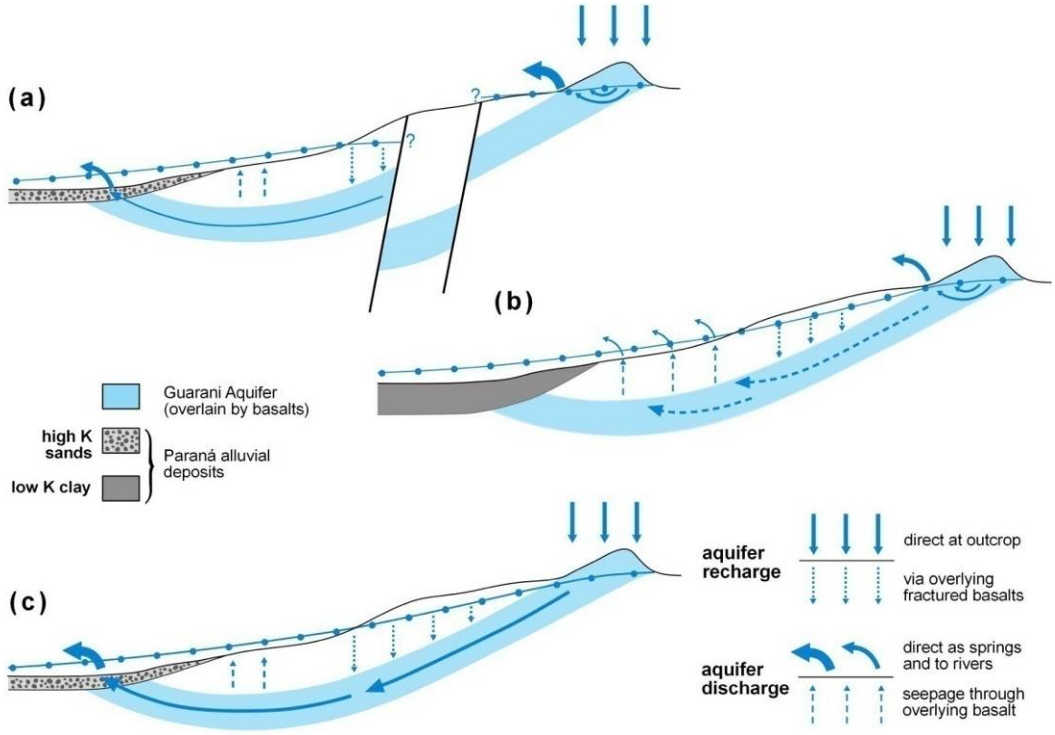


Figure 31 – Hypothetical cross section of the GAS, showing the potential impact of disturbances in the tectonic plate and characteristics of the alluvial deposits of the Parana river in the control of the flow regime.

SOURCE: FOSTER; KEMPER; GARDUÑO (2004).

An area can be more or less vulnerable to surface pollution according to whether it is confined or unconfined, a recharge or a discharge zone. It is an intrinsic vulnerability which results in a potential pollution risk when there is contact with the source of pollution. In the direct recharge areas in unconfined regimes, aquifers are formed mainly by permeable sandstones, therefore the outcrop areas have a higher intrinsic vulnerability to pollution. Vulnerability decreases as the degree of confinement of the aquifer increases.

Regarding flow transit, the temporal aspect is crucial. By definition an aquifer system shows different flow levels, from relatively shorter local flows up to large deep flows with long transit times. Figure 32 shows different situations with varying effects and magnitudes that respond to system characteristics.

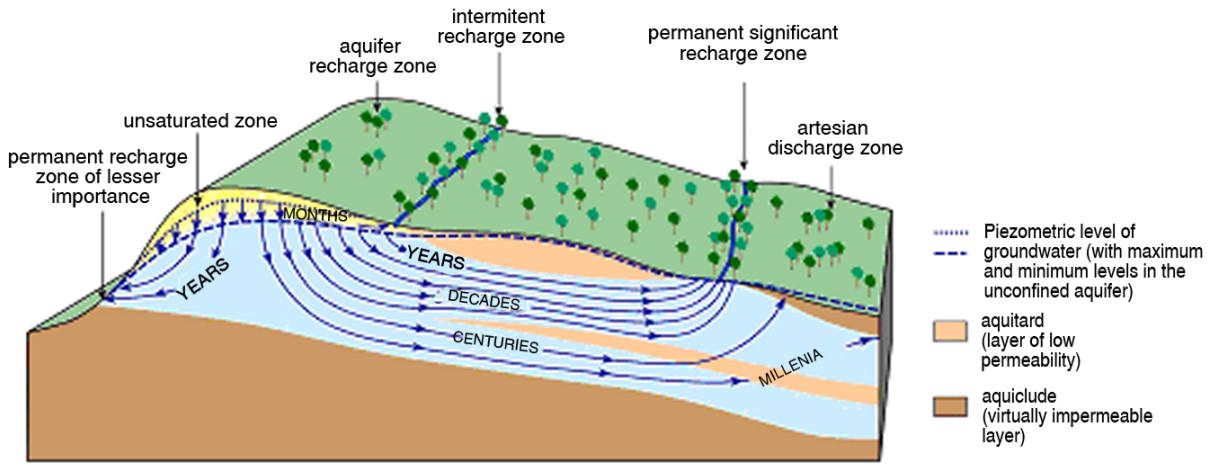


Figure 32 – Temporal aspects of groundwater flow

The temporal aspect is basic for an analysis of cause and effect relationships, which are usually misunderstood in aquifer systems. Non-sustainable exploitation of an aquifer occurring today will only be detected in a few years' time, depending on the distance between the observation points and the abstraction area. Studies of scenarios which evaluate the potential impacts of any intervention policy on the GAS, and therefore on surface aquatic systems is one of the possible by-products of the project. Another goal is fact-finding on the transference of impacts from one country or region to another. The project design includes development of a monitoring and control network and result dissemination via an open information system as one of the management tools.

Table 11 displays certain issues which are relevant to the GAS regime.

Table 11 - Matters which are relevant to the GAS regime and key for the formulation of the TDA

- Definition of the characteristics and direction of the flow system of a regional aquifer like the GAS is essential, and a starting point for shared management. More detailed studies that are compatible with the scale of management actions are required, whether these are regional or more local in impact. - All water management policies should take into account the differences between the different areas and the temporal aspect of cause and effect relationships. Different GAS areas will respond in different ways to short, medium and long-term interventions. The effects of abstraction development may take years to become evident. Therefore there is a tendency to underestimate the collection of field data and its subsequent analysis to support decision-making, until the impacts have already materialized. - Additional knowledge of the outcrop areas, recharge zones and confined areas is required. Strategies should be devised both for outcrop and confined areas.

PRESENT EXPLOITATION LEVEL

Current exploitation may be regarded as quite modest when it is evaluated in terms of the GAS as a regional aquifer system, but there are significant variations on intensity and end purpose of use. The hydraulic compartmentalization of the GAS may change the scenario for use evaluation and the status of certain regions regarding already existing abstraction. As all hypotheses, it needs further evaluation.

There are no updated and comprehensive well inventories in any of the countries. At the time of Project preparation (CHANG, 2001) the available data was of approximately 1.000 wells in Brazil, 347 in Uruguay (7 infrabasalt wells and 340 in outcrop areas), 7 deep wells in Argentina and 200 wells in Paraguay. In Brazil, mainly in the southern region, a project for a well inventory in the GAS area was implemented, which raised the amount of duly inventoried wells to 1.700 (see SIAGAS, CPRM). Also, projects developed by universities via the Universities Fund have significantly improved the level of information for the regions in which they act, particularly the transboundary recharge areas. Nine academic subprojects were funded via the Universities Fund. Four of these conducted their research in the pilot areas. However, mainly in Brazil and Paraguay the number of known wells is a small percentage of the existing ones. For evaluation of drilling in confined GAS areas (which, depending of the pressure relationships may have hydraulic connections to the GAS) the absolute figure and uncertainty increases considerably. Chart 2 summarizes the existing information.

Well output varies in accordance with construction characteristics (diameter and depth) and the specific capacity of the aquifer area. Most of the deep wells in operation produce an average of 300 m^3/h.

The estimate is that total groundwater production is some 1.000 to 3.000 Mm^3/year, concentrated mainly in Brazil. 80% of this is used for public urban supply (500 Brazilian towns are totally or partially supplied by the GAS), 15% is used for industrial purposes and 5% is for tourist use in resorts (*'SPAs'*).

A study that was carried out in Brazil (CHANG, 2001) detected a low level of water consumption when compared to the regional recharge rate. The state of São Paulo in Brazil shows the highest consumption levels in comparison with active recharge. However, when the same analysis is applied to sub-regions / cities a much more critical scenario appears, i.e., there are signs of over-exploitation. During the next 25 years, if use is limited to the cities which are reliant on the GAS today, the exploited quantities may still be replaced by direct

recharge. This will not be the case if all the cities become GAS-reliant. In this last case, the states of PR, MG and SP will be abstracting more water than is recharged.

Chart 2 – Basic information on the GAS

Country	Information on wells	Main uses	Present requirements	Estimates for 2025	Potential conflicts
AR	Known wells: 7 deep wells	Mainly for recreational use	Abstractions around 3.600m^3/h, plus infrabasaltic and shallow wells. In terms of potentiality, use is minimal.	Improved knowledge of reserves as use expands.	Risk of salinization of deep waters; potential use conflicts in thermal areas.
BR	Inventoried wells: 3000; absolute number of wells is still unknown. Most of the wells are located in outcrop or shallow areas; someras; western region of the state of Sao Paulo with countless municipalities supplied by the GAS	Prevalent use is drinking water supply to towns (70%), followed by industrial use (25%), and irrigation and recreational use (5%),	Estimated abstractions at 111.000 m^3/h (30 m^3/s);	Increasing pressure from use in the next few years.	Risk of pollution in the outcrop areas and franjas someras due to inadequate sanitation, diffuse pollution from agriculture, localized industrial pollution. Decline in levels and interference between wells. Errors in construction of new wells.
PY	Approximately 200 known wells and countless unregistered wells; 25% are private wells.	Concentrated use in 9 eastern departments; supply to towns (75%).	Installed abstraction capacity of 8.000 m^3/h (2.2 m^3/s) between infrabasaltic and outcrop wells.	Pressure from use will increase in the next few years.	Problems arising from the constructive characteristics of wells; expansion of agricultural activity and resulting diffuse pollution
UY	Registered: 12 infrabasaltic wells and 340 in outcrop areas	Recreational uses in the departaments of Salto and Paysandú; remaining 340 wells are	Total use estimated at 2.415 m^3/h (0,67 m^3/s)	Pressure from use will grow constantly in the next 25 years; tourism will use more water in	Conflicts refer mainly to the use of termal water, particularly in the outskirts of the city of Salto. Regarding quality, the main

Country	Information on wells	Main uses	Present requirements	Estimates for 2025	Potential conflicts
		used for drinking water and irrigation.		relative terms than other activities.	problem may occur in the outcrop areas (agrotoxics – rice cultivation and activities and forestation). Lack of sanitation becomes a risk. Forestation represents a risk, to be confirmed by research.

Fuente: CHANG (2001), SANTOS (2001).

In the larger municipalities, where demand will encourage drilling of new wells, the effects of over-exploitation will be significant. Decline in static and dynamic levels will be inevitable unless systems of permits and control of abstracted volumes are implemented. Loss of volume from interference with nearby wells is a likely situation. Economic factors, like the loss of subsidies for electric energy or the possible implementation of charges for the use of groundwater, may set limits to the use of GAS, partly discouraging the craze for new drilling.

It may be noted that in general in the regional context the search for exploitation and use of groundwater resources as an alternative is growing significantly. Among others, the reasons are the following:

- The perception that it is a use with no environmental impact;
- Progressive degradation of the quality of surface water resources and increasing costs of collection and treatment;
- Vulnerability of surface reserves in times of drought;
- Technological progress of pumping equipment that enable the safe abstraction of large volumes from great depths;
- Technological improvements in rotary and pneumatic drilling, reducing drilling costs and labor times;
- Expansion of the supply of electric energy in rural areas, and often subsidies to energy for certain productive activities;
- Progressive reduction in costs, reduction of timeframes and economic risks in construction and construction times of deep wells;
- Improved knowledge of hydrogeology and reserves;
- Promotion of irrigation;
- Promotion of thermal tourism.

These tendencies can easily be verified in national/institutional databases (as for example national census, new drilling licenses and permits for new wells, among others), where an increase in the use of groundwater is patent both in urban and rural areas. There is also a consensus between public decision-makers and technical and scientific actors; this is maerialized in the amount of new wells that enter the systems for licenses and permits, and the great coverage of goundwater in the media in the past few months.

Figure 33 shows the location of wells in the GAS area in Brazilian territory. Please note the density of wells in the GAS outcrop areas, or in areas where the aquifer has little depth, resulting from the cost of deep drilling and the risk of not finding quality water. The distribution of wells in the other countries shows the same tendency.

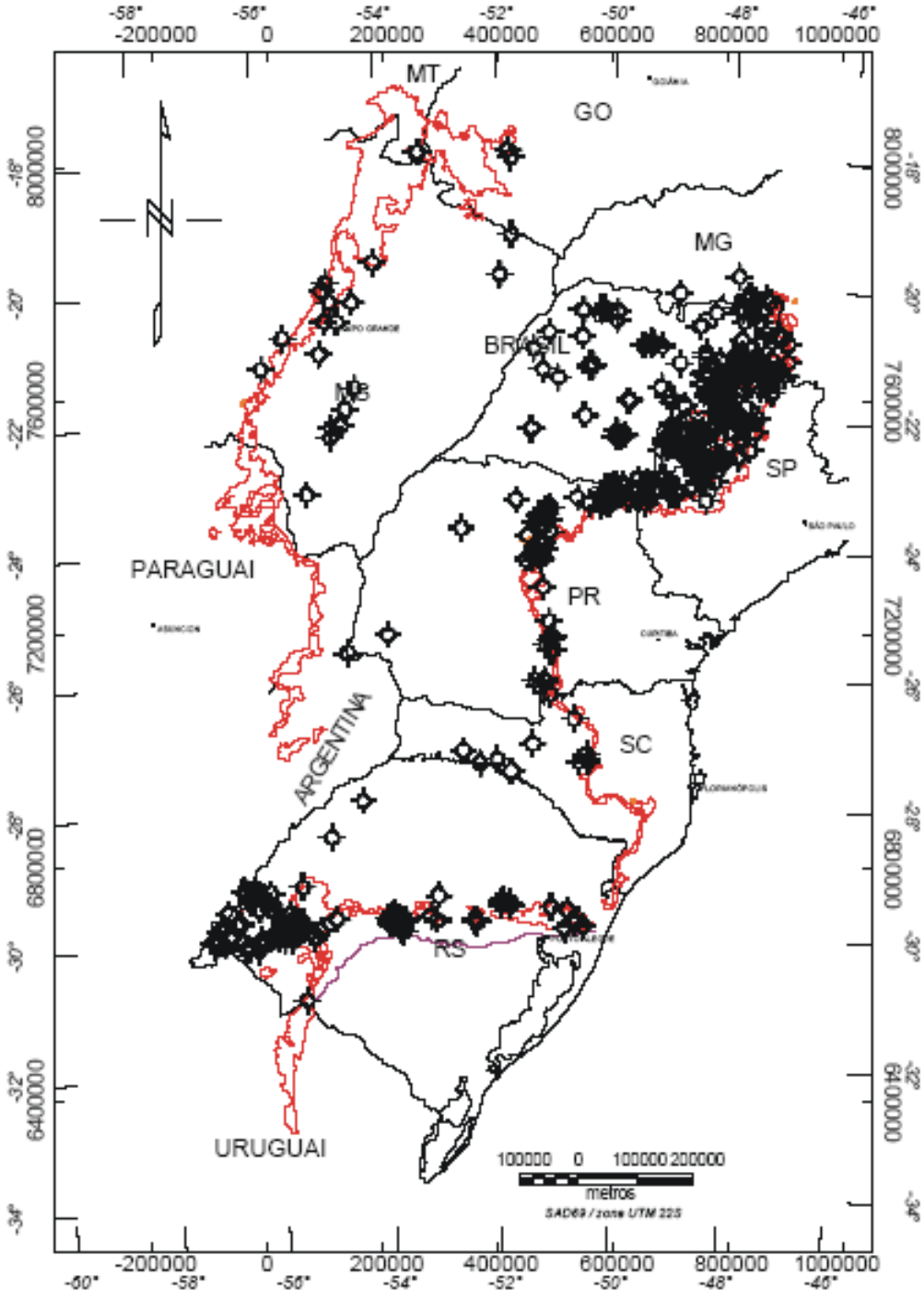


Figure 33 - Location of well drilling in the Brazilian GAS area

Source: CHANG (2001)

Table 12 mentions certain sigues that are relevant to the above.

Table 12 – Aspects on the exploitation level of the GAS which are considered crucial for the preparation of the TDA

- The notion that the volumes that are abstracted from the system must necessarily bcome out of somewhere and inevitably will result in some type of change must be re-examined. The abstracted water may originate in: (i) more water in the system (increase in the recharge); (ii) less water leaving the system (decline in discharge); (iii) removal of water from system storage; - There are serious deficiencies in the well inventories in the countries / states / cities. The speed of well construction surpasses the registration rate in the current registries. As a consequence there are uncertainties on the real abstracted volumes and their spatial distribution. - The consequences of continued abstraction of groundwater from an aquifer system must be taken into account by the actors involved and by society, and tolerance limits must be evaluated and determined. Certain variables have to be assessed from an economic point of view.

POLITICAL AND ADMINISTRATIVE BORDERS AND GROUNDWATER

The main aspect of a transboundary condition is the intersection of the natural flows of groundwater within an aquifer with an international border, in such a way that water moves from one side of the border to another, as shown on Figure 34. In a very simplified way, this system may have its entire recharge zone on one side of the border, and the discharge zone on the other. Another situation that arises from the same Figure in respect of the different types of flows is that local flows are controlled by physical and geographical aspects like topography, whereas regional flows are more influenced by aquifer geometry.

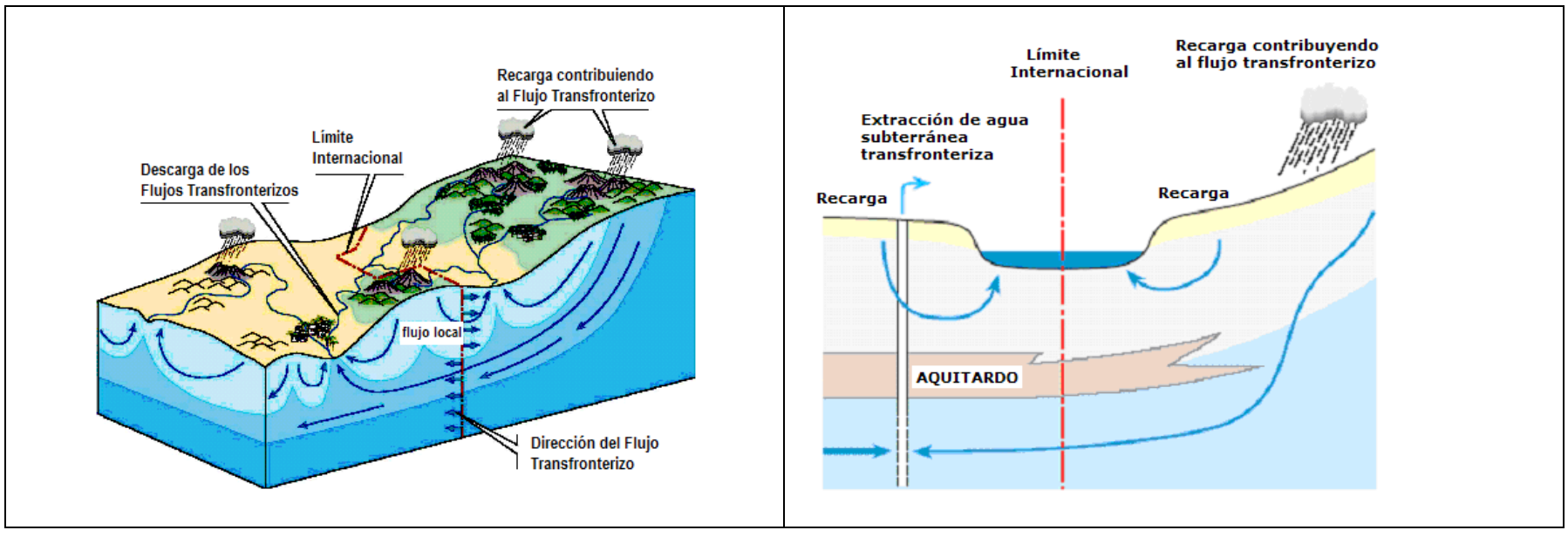


Figure 34 – Examples of transboundary transfers of groundwater

Source: Modified from IHP-VI (2001)

In fact, situations are much more complex and from the hydrogeological point of view the flows which cross international borders can only be determined by means of observation and analysis of consistent registers (in this case hydraulic parameters). Even in the case when internacional borders lie on surface waterbodies (as rivers, for example), underlying aquifers do not necessarily reflect a balanced transfer of groundwater from one side to the other. Obviously the transboundary question does not contribute to aquifer geometry and regime, but rather to institutional, legal, economic and social issues. It is necessary to recognize the existence of socio-economic pressures that potentially induce the extraction of groundwater, and whether these extractions in the present and emerging scenarios involve some kind of non-sustainable impact or development situation in the broadest sense. Table 13 presents certain relevant issues.

Table 13 – Border issues that are considered crucial for the preparation of the TDA

What are the possible transboundary problems that may emerge or become intensified by the use of GAS water?
Contrariwise, what opportunities does the sustainable use of the GAS offer for solving present or emerging transboundary problems?
Which are the possible problems for the sustainable exploitation of GAS water that may emerge or become intensified by the problems or type of transboundary occupation?
¿Al contrario, de qué manera las instituciones creadas para tratar las cuestiones transfronterizas podrán ofrecer una oportunidad para el uso sostenible del GAS?

HYDROGEOLOGICAL CHARACTERIZATION OF CERTAIN GAS AREAS AND THE RELEVANT GASP PROJECTS

Table 14 shows a theoretical conceptualization of the possible critical hydrogeological aspects of the GAS. Annex 4 details the pilot projects. Finally, Table 15 characterizes the hydrogeology of the border areas of GAS and identifies the relevant GASP projects in those areas.

Table 14 – Typology of possible flow situations in transboundary areas

Borders and underground flows	Hydro-geological zones	Main aspects	Necessary information
Borders with hydraulic GAS connection	Recharge zone	> vulnerability, tendency to greater amount of wells, phreatic decline	Evaluation of the water balance, modeling of abstractions and phreatic decline in space and time
	Transit zone	< vulnerability; possible flow inversion	Intermediate situation
	Discharge zone	Vulnerability arising from maintenance of surface waterbodies or recharges of more superficial aquifers	Evaluation of size of discharges, degree of connection with surface bodies
Borders with no hydraulic GAS connection	Areas on the edge of the hydrogeological basin, with no transboundary flow	Situation that depends on the degree of compartmentalization of the GAS. It may be a recharge or discharge zone, or an area with varied vulnerability. Relevance at national level. No relevance for transboundary level.	

Source: drawn up by Kirchheim especially for this report.

CHALLENGES TO MANAGEMENT IN PRACTICE - TOWARDS THE TDA

The preparation of the GASP was a preliminary version of the Transboundary Diagnostic Analysis (TDA), and its main conclusions, which have been corroborated so far, are shown on Table 16. Their analysis resulted in Table 17, which summarizes the management needs of the GAS and their appropriate levels of resolution.

Table 15 – General table of hydrogeological characterization of the border areas and the relevant GASP projects

Hydrogeology	Countries and provinces / Departments	Project Activities
Transit and discharge area, undefined interrelation with Uruguay River, hydrothermal potential in full development, mainly in the departments of Salto and Paysandú (UY), and the province of Entre Ríos (AR)	AR: Province of Entre Rios; UY: Departments of Paysandú and Salto	Project: Geophysical investigation of the geological structure of the Chaco-Paranaense basin, in an area centered in the cities of Salto (UY) and Concordia (AR) (17) UR (UY); UTN (AR); UNAM (MX); Project: Methodological development for evaluation of the recharge and vulnerability of the Guaraní Aquifer System in Argentina and Uruguay (12) - UNL (AR); DINAMA. (UY); INA. (AR); IHLLA (AR) Project: Why Project the GAS; Project: Workshops for social stakeholders. Coastal thermal area; Project: Movete por el ambiente (Move around the environment) Project: Communication, dissemination and awareness-raising of civil society in the GAS area; Project: Teacher education and training: Guaraní Aquifer.
Confined aquifer zone; connections with fractured basalt aquifers; undefined interrelation with Uruguay River; hidrothermal potential; compartmentalization of the GAS	AR: Province of Corrientes and Province of Misiones; BR: States of Rio Grande do Sul, Santa Catarina, Paraná	Project: Estudo do movimento das águas subterrâneas do sistema Aqüífero Guarani (GAS) através de isótopos, no Paraná, São Paulo e no Uruguai (16) – UFPR (BR). UR (UY); USP (BR) Project: The power of communication through water; Project: The Guaraní Aquifer goes to school: strategy for citizen participation and environmental education; Project: Potencial sustainable industrial uses of the Guaraní Aquifer in the province of Misiones. Analysis and dissemination.
Large outcrop and recharge area of the GAS; important agricultural center with intensive use of agrochemicals	AR: Provinces of Misiones, Corrientes, Chaco and Formosa; PY: Departments of Neembucú, Misiones, Itapuá and Alto Paraná	Itapuá Pilot Project Environmental Education Campaign – GAS; Project: Dissemination and awareness-raising of the environmental implications of the irracional management of the GAS in the eastern region of Paraguay; Project: Environmental education of leaders for the racional use of GAS water in the departments of Itapúa and Caazapá in Paraguay; Pilot Project on Environmental Promotion and Education on the GAS

Hydrogeology	Countries and provinces / Departments	Project Activities
		in the districts of Itakyry and Minga Porâ; Project: The power of communication through water; the Guaraní Aquifer goes to school: strategy for citizen participation and environment education; Project: Potencial sustainable industrial uses of the Guaraní Aquifer in the province of Misiones. Analysis and dissemination.
Outcrop area in the region of Rivera-Santana do Livramento with GAS recharge. Transit zone and confined aquifer to the west near Artigas-Quaraí; lack of sanitation and use of agrochemicals	BR: State of Rio Grande do Sul; UY: Departments of Rivera and Artigas.	Project Piloto Rivera-Santana Project: Vulnerability and hydrogeological risk of the Guaraní Aquifer System in the outcrop area of Rivera, Uruguay (28) UR (UY); UBA (AR); Project: Characterization of recharge and discharge areas of the GAS in Rivera - Livramento and Quaraí - Artigas. Vulnerability study in the area of influence of Artigas – Quaraí(10 - UFSM (BR) UR (UY) Project: Communication, dissemination and awareness-raising of civil society in the GAS area; Project: Minuto agua (a minute for water); Teacher education and training: Guaraní Aquifer
Outcrop and recharge area of the GAS, agricultural center with intensive use of agrochemicals	BR: States of Paraná and Mato Grosso do Sul PY: Departments of Itapuá, Alto Paraná and Canindeyu	Project: Dissemination and awareness-raising on the environmental implications of the irrational use of the GAS in the eastern region of Paraguay; Project: Mbaracayú: a drop of life, a drop of hope for the Guarani Aquifer

Table 16 – Aspects of the GAS which are relevant to the TDA

- The GASP is 'preventive' in nature, since there are no conflicts to be solved, but rather great potential benefits may be foreseen for cooperation between the countries, mainly regarding a future sustainable use; - In general, problems are mainly local and involve two countries, and can be solved by means of agreements and actions at a level that is consistent with their significance; - Potential transboundary effects might grow from the local scale to a basin scope only in the measure that extensive changes occur in the use of soil for agriculture and under a certain combination of hydrogeological conditions; - The importance of GAS groundwater for socio-economic development determines the need to strengthen the public bodies that are responsible for management, and train staff from the technical and administrative points of view; - In this sense, the following must be addressed: (a) the efficiency of the present institutional arrangements in the field, (b) the ability of environment and water regulatory agencies to take preventive measures instead of merely reacting to conflicts and demands, and (c) the levels of participation of the diverse sectoral organizations of users on the use and risks of groundwater. - Equally, it is necessary to evauate the existing legal standards for management and protection of groundwater in the countries/provinces/states of the Guarani aquifer, as well as their implementation strengths and weaknesses, in view of the present and future protection of the aquifer.

Table 17 – Framework of the GAS management requirements

Typology	Situations with transboundary local effects in pilot areas	Potential situations with regional transboundary effects
I – Protection of the GAS from pollution and quantity-related aspects II – Use of groundwater and geothermal resources III – Sustainable management of the GAS	1 - Pollution of drinking water wells due to inadequate sanitation and unplanned use of land *(R-P PP and R-S PP)* 2 - Impacts on the wetlands (mainly the Esteros de Ibera (AR) and Niembucú (PY), as well as the Uruguay river, respectively) and reduction of the rivers' baseflow and a possible consequence of potentially intensive exploitation of groundwater for agricultural irrigation *(GASP Component 1)* 3 - Impacts on the quality and recharge rate of the aquifer as a result of extensive changes in the use of agricultural soil as in cultivation types and systems *(IT PP)* 4 - Impacts on the water balance of water consumption caused by afforestation and its effect on recharge *(GASP Comp. 1)* 5 - Salinization caused by unsealed deep wells; it is unknown whether these last are in the GAS area *(C-S PP)* 6 - Reduction of aquifer artesianism and geothermalism due to uncontrolled exploitation of geothermal wells *(C-S PP)*	7 - Growth of the impacts to a greater scale if intensive use of soil and/or the water resource are encouraged, considering a) the present ecologic role of aquifer discharge and b) the hydraulic continuity of the aquifer system in the relevant areas (GASP Comp. 1)

Source: Based on FOSTER; KEMPER; GARDUÑO (2004)

10. ANNEX 4 - MANAGEMENT IN PRACTICE: THE ROLE OF THE PILOT PROJECTS

Four pilot projects on groundwater management were designed within the GASP, with a view to identifying and promoting local agreements and actions for 'typical problems' which are specific to the management and protection of GAS groundwater. Two projects are transboundary, while the other two are within one country and state. Information on these projects is presented below, summarized from FOSTER; KEMPER; GARDUÑO (2004).

Concordia (AR) / Salto(UY) pilot project

This pilot Project is transboundary and focuses of the analysis of the management of the Guarani aquifer in an area that exploits geothermalism. Table 18 shows some of its characteristics.

Table 18 – Concordia (AR) / Salto(UY) Pilot Project

Issue	Information
General diagnosis for the area	Covers an area of 500km^2 on both sides of the Uruguay River, which is the international border between Argentina and Uruguay; it is the most populated part of the border region, with some 200.000 inhabitantes, distributed almost equally on each side of the border. The GAS lies under basalt flows at 800 a 1.000m, and its groundwater exhibits artesianism and a strong geothermal potential (temperatures from 36 to 48^{o}C). The yield of geothermal wells is from 100 to 300m^3/h, for well depths up to 1.500m. The main source of income in the area is tourism and citrus and horticultural production.
Status of Use	Salto (Uruguay) is the most developed thermal resort area in the MERCOSUR; Concordia recently began construction of its first thermal resort; the GAS is not a significant source of drinking water, as the supply is covered by processing plants that draw water from the Uruguay river and some shallow wells from other aquifers. Current institutional arrangements for water management are harmonious on both sides of the border.
Real and potential impacts	Hydraulic Interference between neighbouring wells (to date there are eight geothermal wells in a relatively restricted area) which may reduce artesianism and also the temperature of the groundwater. It is necessary to evaluate whether there is any risk of salinization in the completed works or in the works under way. It is also necessary to assess if there is any risk of salinization from the south-southeast of the GAS where there are aquifers (it is uncertain whether they are GAS aquifers) which contain high salinity thermal water of natural origin. Many thermal resorts still lack adequate management of water demand and use.
Management Actions	To develop and disseminate in the community effective practices for the use of geothermal water, including efficient use, reuse and safe deposit of effluents. To develop management capacities regarding water and geothermal resources, - applying standardized criteria for the design, construction and operation of

Issue	Information
	thermal wells. Strengthen the Transboundary Committee of the Concordia-Salto pilot project.

The expected results and relevant management tools for the scope of this pilot project are presented in Table 19. Figure 35 shows a schematic interpretatation of the regional hydrogeology.

Table 19 – Expected results of the Concordia-Salto Pilot Project

Expected Results	Management tools to be developed
Coordinated Management of the Groundwater Resource: - conflict solving - preserve artesian flows - preserve water temperature - prevent salinization by sealing wells with high salinization; - Optimization of the socio-economic and environmental benefits of the use of hydrogeothermal resources; - to evaluate the development of a binational tourist area based on the use of thermal waters.	- Detailed databases with local hydrogeological data, as well as maps that are accessible via the local node of the aquifer geographic information system (SIGAS); - Conceptual and numeric models of the aquifer, adequate for evaluating resource management scenarios; - Diagnosis of the transboundary geothermal potential; - Coordinated aquifer management system, with agreed ruled for distribution, design, construction and operation of wells and use of water; - Institutional mechanism for consultation and agreement on proposals for the future development of the resource and protective measures; - Coordinated network for monitoring and exchanging information on level, temperature, quality and use of groundwater.

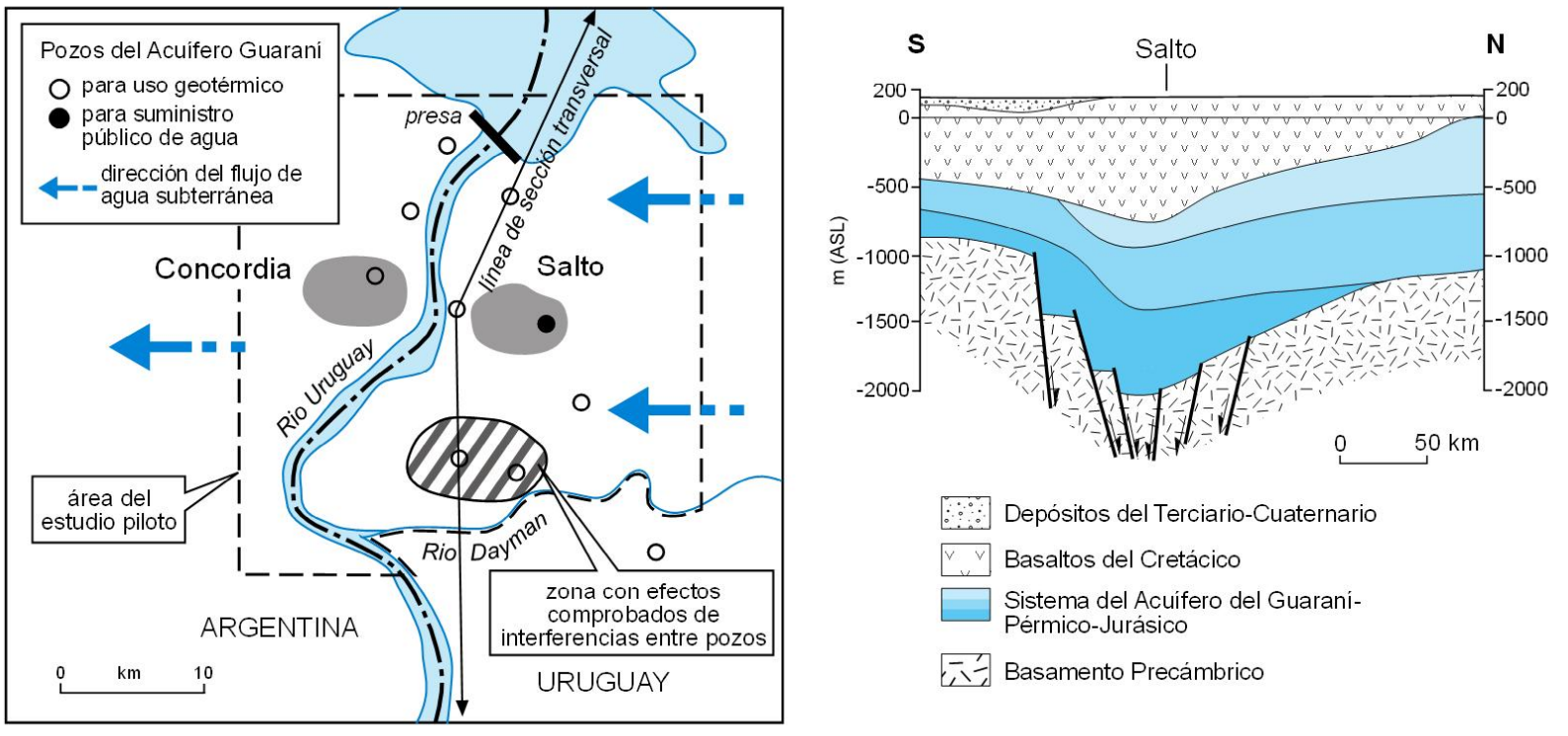


Figure 35 - Schematic hydrogeological map and cross-section of the Concordia-Salto Pilot Project

Rivera (UY) – Santana do Livramento (BR) Pilot Project

This is another transboundary pilot project, and its characteristics are shown on Table 20.

Table 20 – Rivera (UY) / Santana do Livramento (BR) Pilot Project

Issue	Information
General diagnosis for the area	Covers an area of 750 km^2 on the border between Uruguay (Department of Rivera) and Brazil (State of RS). The cities of Rivera and Santana do Livramento have a total population of 200.000 inhabitants; fast growth, and they live and interact practically as single city; main economic activity is agriculture-based (cattle and sheep raising, production of meat and hides, grapes, rice, maize and increasingly, soy); on the Uruguayan side there is forestry production and timber.
Status of Use	The GAS is the main source of water supply with close to 170 wells (OSE) in Rivera and (DAE) in Santana do Livramento. These wells yield up to 5,1 and 8,7 Mm^3/annum approximately, which represents around 70% and 100% of the total public supply, respectively.
Real and potential impacts	Cover by the water supply network is over 95%; limited sewage network - 30% in Rivera and 40% in Santana do Livramento; substantial offload of wastewater to an aquifer of relatively high vulnerability to pollution, either directly from septic tanks or indirectly via polluted flows, uncontrolled dumps for municipal solid waste; infiltration in the soil of a variety of industrial effluents and presence of several gas stations with deficient maintenance represent additional threats to the quality of groundwater.
Manage-ment Actions	Strengthen the Guaraní Aquifer Transboundary Committee (COTRAGUA), with local user representatives from each country (local government offices, water companies, drilling companies, several NGOs and bodies related to agriculture, hydrology and public health). Establish protection zones or perimeters for the main sources of public water supply by means of adequate land use planning (both urban and rural), to ensure sustainability and to protect the investments and the associated infrastructure at the source.

To achieve the objects of this project, several specific management tools should be developed as shown on Table 21. Figure 36 displays a schematic interpretation of the regional hydrogeology.

Table 21 – Expected results of the Rivera – Santana do Livramento Project

Expected results	Management tools to be developed
Coordinated Management of the groundwater resource to: -- solve conflicts -- prevent groundwater pollution -- protect the sources of public water supply -- control hydraulic interference -- Mobilize investments to implement a joint action plan to improve urban sanitation and territorial planning -- Production of groundwater for public supply, concentrated in fields with wells that are protected from indiscriminate urban expansion and intensive agricultural practices. -- Optimization of socio-economic and environmental benefits arising from the sustainable use of groundwater	- Detailed databases with local hydrogeological data, as well as maps that are accessible via the local node of the aquifer geographic information system (SIGAS); - Conceptual and numeric models of the aquifer, adequate for evaluating resource management scenarios and define protection areas; - Study for the diagnosis of the transboundary issues of groundwater, for instance the effects of hydraulic interference and origin and transport of pollution - Coordinated aquifer management system, with agreed ruled for land management, areas of protection of wells and distribution, design, construction and operation of wells - Institucional mechanism for consultation and agreement of proposals for future development of the resource and protective measures l - Joint action plan with top priority improvements of the sewage network and final deposit of wastewater - Coordinated network to monitor levels, temperature quality and use of groundwater, as well as the implementation of a joint information system

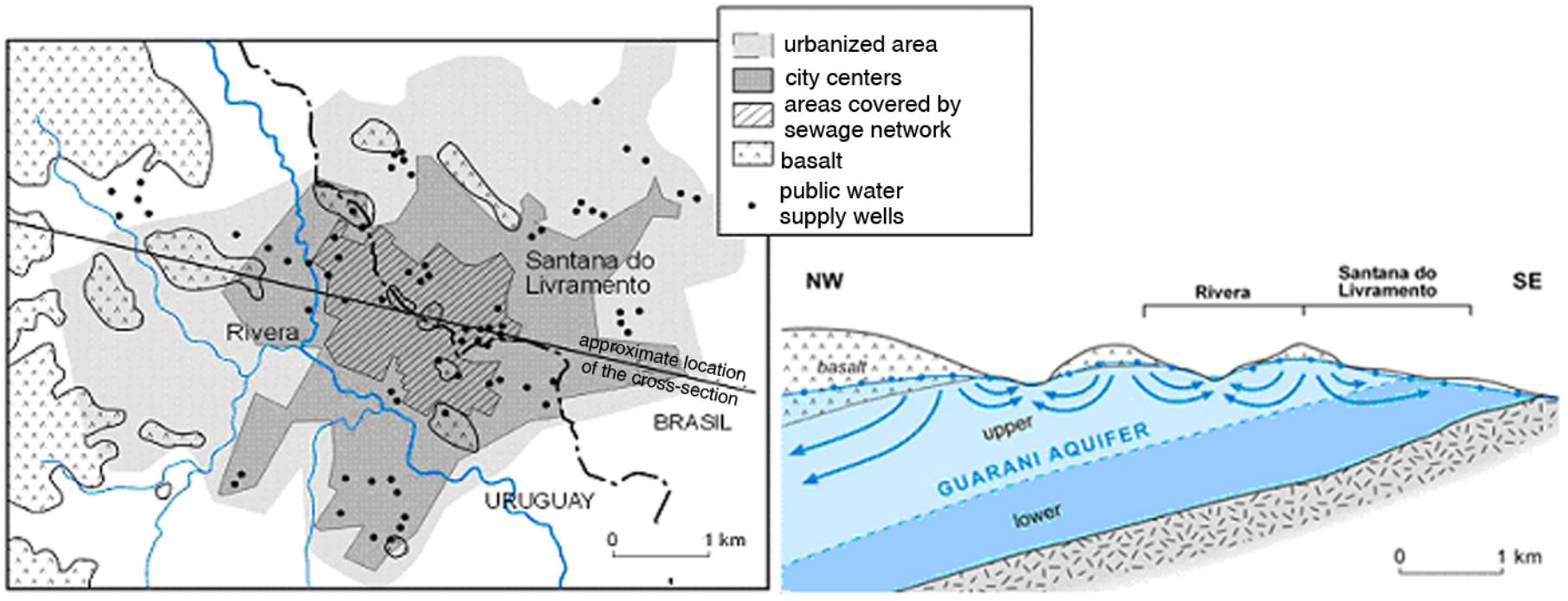


Figure 36 - Schematic map of water infrastructure and hydrogeological section of the Rivera – Santana do Livramento pilot project area, showing probable regime of the underground flow before infrastructure was developed

Itapúa Pilot Project (PY)

This pilot project was developed only for Paraguay and it studies the impacts of intensified irrigation on the GAS. Table 22 summarizes its characteristics.

Table 22 – Itapúa Pilot Project

Issue	Information
General Diagnosis for the area	The pilot project of the Itapuá Department (DI) involves predominantly agricultural and cattle-raising areas that cover 800 km^2 on the southeast corner of Paraguay, in the districts of Bella Vista, Jesus, Trinidad, Hohenau and Obligado.
Status of Use	Nearly 50 wells are registered by SENASA, and inspected by the current technical assistance project by Germany, together with the Secretariat for the Environment (SEAM). Their depth ranges from 70 to 120 m, though a few reach 300 m. Quite a few of the shallower wells exhibit signs of incipient nitrate contamination.
Real and potential impacts	Potential impact depends on the socio-economic and agricultural/irrigation evolution of the area; Inadequate use of the soil and lack of planning; Inadequate use of agricultural inputs.
Management Actions	To predict future trends and identify the need for management actions to ensure the sustainable development of the groundwater resource and Project the environment; to establish the potential of GAS to sustain agricultural irrigation; to evaluate the effect of deforestation on GAS recharge and its transformation into a grazing area where large amounts of fertilizers and pesticides are used. The relative importance of these 'development processes' in areas with different types of soils, with contrasting effects between the areas of basalt and sandstone outcrops. The relative vulnerability of the GAS to pollution in the layers beneath the outcrops, with sandstone layers of variable thickness. To develop an integral model for sustainable development of groundwater and use of land for provincial governments and the many municipalities that compose the area.

Ribeirão Preto Pilot Project

This project, as the previous one, is executed in only one country, in this case Brazil. It studies the impacts of the use of GAS water in an urban region with a high rate of exploitation. Table 23 displays its characteristics, and Figure 37 shows a sketch of the regional hydrogeology.

Table 23 - Ribeirão Preto Pilot Project

Subject	Information
General Diagnosis of the area	Population of 505.000 inhabitants; comprises an area of 651 km^2, which includes 137 km^2 of the outcrop of the Guarani Aquifer; substantial agricultural productivity; highly industrial area, and wide variety of very active manufacturing enterprises.
Status of use	The GAS is exploited through over 1.000 wells. The DAERP (Departament of Water and Sanitation) has 97 very active wells which produce some 3.700 l/s and an annual production set at 65 Mm^3/annum. Uncertainty on the real amount of abstracted groundwater - estimated growth from 45 Mm^3/year in 1976 to 96 Mm^3/year in 1996.
Real and potential impacts	Reduction in the phreatic level (from 15 to 25m) has decreased and in fact almost eliminated natural discharge to surface water currents (almost entirely replaced by waste water discharge). Some waterways which were formerly effluents have become tributaries, increasing the risk of groundwater pollution; abstraction exceeds the present recharge rate of the aquifer; increase of the operative costs of drinking water supply; reduction of well productivity; loss of groundwater confinement in some wells.
Management Actions	- To promote planning of the use of land in the recharge zone of the Guarani Aquifer, in a manner that is consistent with its main function of supplying high-quality municipal drinking water at low cost (vulnerability maps of the aquifer, demarcation of protection areas at the source of groundwater supply); - evaluate the risks entailed by sanitation, industrial and agricultural activities, and promote actions to handle well-proven and significant risks; - it is necessary to find a way to reduce demand by 20-30% and ease the pressure on the groundwater resource, and to define a sensible minimal value for the tract of land that must be protected for the benefit of the supply of municipal drinking water; to consider the strengthening of municipal capacities to produce groundwater from confined areas, which are most protected ones, on one hand to replace the sources with a high risk of pollution and, on the other, to cover the increasing demand for water; - development of a numeric model as a tool to integrate all the existing data, identify key research and monitoring needs, evaluate possible scenarios for exploitation and management, and to facilitate the dialogue between interested groups and the authorities.

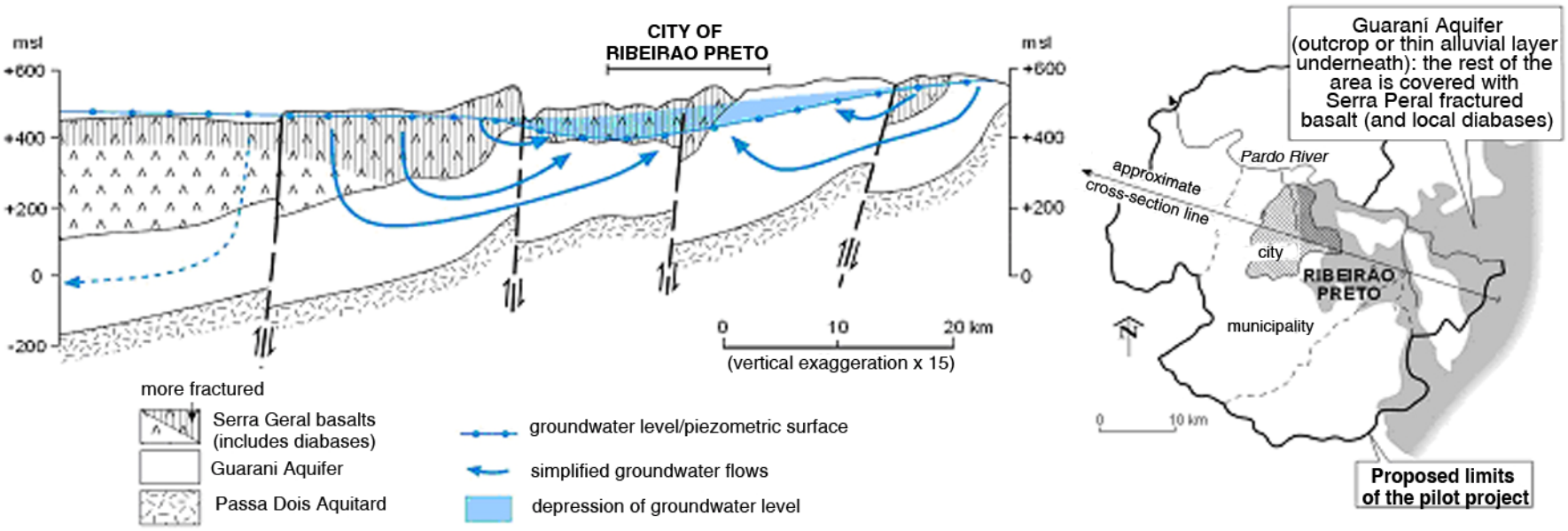


Figure 37 - Hydrogeological sketch and cross-section of the area of the Riberão Preto Pilot Project

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