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Governance of Groundwater Resources in Transboundary Aquifers (GGRETA)

PHASE 1 – 2013-2015

Main **Achievements** and Key **Findings**

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Governance of Groundwater Resources in Transboundary Aquifers (GGRETA)

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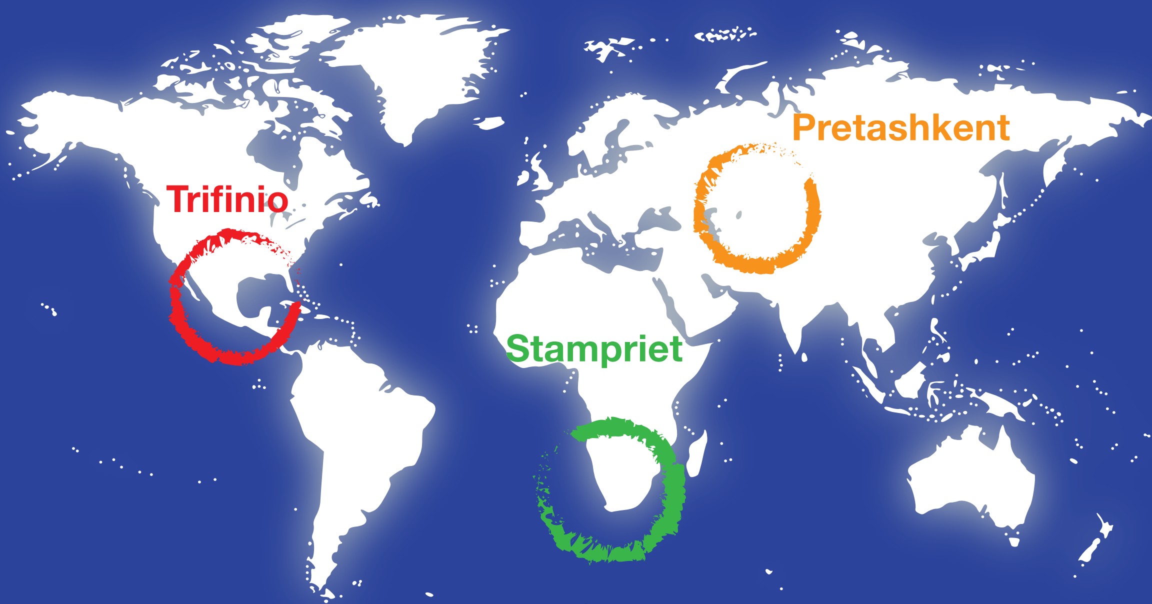
List of Acronyms

BOD	Biochemical Oxygen Demand
CTPT	Tri-national Commission of the Plan Trifinio
DPSIR	Drivers, Pressures, State, Impacts, Responses
DWA	Department of Water Affairs
GEF	Global Environment Facility
GGRETA	Governance of Groundwater Resources in Transboundary Aquifers (Project)
GIS	Geographical Information System
IGRAC	International Groundwater Resources Assessment Centre (UNESCO Centre)
ICWC	Interstate Commission for Water Coordination in Central Asia
IHP	International Hydrological Programme (UNESCO)
IMS	Information Management System
IUCN	International Union of the Conservation of the Nature
IWRM	Integrated Water Resources Management
ISARM	International Shared Aquifer Resources Management (Programme)
KTP	Kgalagadi Transfrontier Park
MCCM	Multi-Country Cooperation Mechanism
MFA	Ministry of Foreign Affairs
NAU	Namibia Agriculture Union
NNFU	Namibia National Farmers' Union
OC-C	Ocotepeque-Citalá Aquifer
ORASECOM	Orange-Senqu River Commision
PCCP	From Potential Conflict to Cooperation Potential (UNESCO Programme)
PMU	Project Management Unit (GGRETA Project)
PT	Plan Trifinio
PTBA	Pretashkent Transboundary Aquifer
SADC	Southern Africa Development Community
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goal
STAS	Stampriet Transboundary Aquifer System
TBA	Transboundary Aquifer
TDS	Total Dissolved Solids
TWAP	Transboundary Aquifers Assessment Programme (GEF/UNESCO)
UNECE	United Nations Economic Commission for Europe
UNESCO-IHE	Centre for Water Education (UNESCO Centre)
WUC	Water Utilities Corporation (Botswana)
WWAP	World Water Assessment Programme

GGRETA
Project



1. Introduction

1.1. The GGRETA Project

1.1.1 Context

The need for groundwater resource assessment and management, and for governance structures of comparable scope, has come to the forefront of the global agenda on sustainable development. Modern, comprehensive assessments of the groundwater resources available in a given territory are indispensable tools for monitoring, protecting and managing sustainably, and to their full extent, these strategic yet invisible resources.

Many groundwater systems around the world (or 'aquifers', as exploitable groundwater reservoirs are called) are transboundary, which means that they either extend over two or more administrative units inside a country or are crossed by international boundaries. Evidently, the latter condition adds special challenges to groundwater governance and management: governance of such transboundary aquifers requires harmonization and cooperation across the national borders among the various authorities in charge of groundwater, based on mutual trust and on transparency.

The GGRETA project ("Governance of Groundwater Resources in Transboundary Aquifers") is part of the *Water Diplomacy and Governance in Key Transboundary Hot Spots Programme* financed by the Swiss Agency for Development and Cooperation (SDC) and draws from the unique experience gained by UNESCO on transboundary aquifers (ISARM)[1], and from the results of recent efforts promoted by the Global Environment Facility (GEF) and led by UNESCO, aimed at bringing to the global attention the importance of transboundary groundwater resources, and the need to substantially improve their governance (the "Transboundary Waters Assessment Programme - TWAP"[2], and the "Groundwater Governance" Project[3]).

1.1.2 Objectives

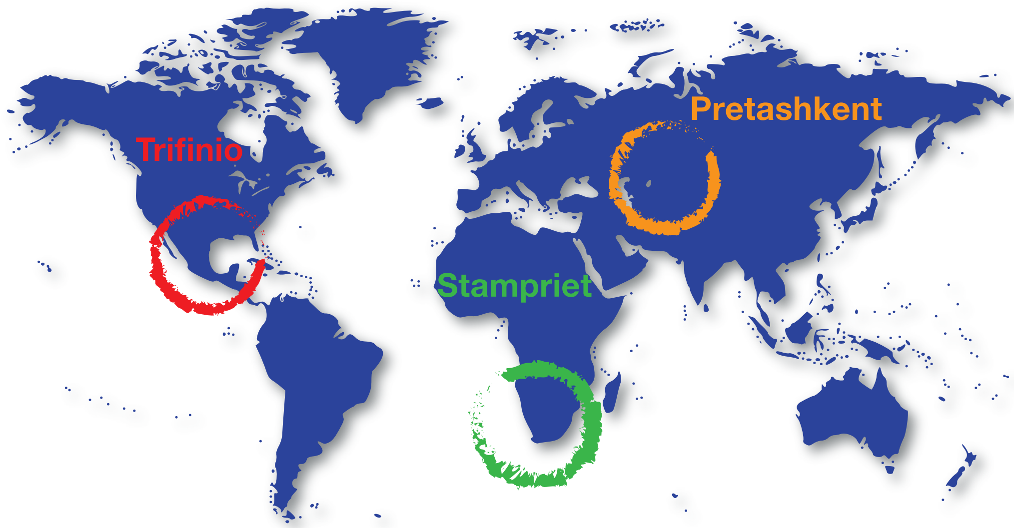
The GGRETA project is a technical assistance effort that strives to achieve a better integration of groundwater resources into the water budget of basins, countries and regions, as part of a step-by-step approach to enable and foster transboundary cooperation. GGRETA focused on the two first steps of this process towards transboundary cooperation over groundwater: establishing a shared science based understanding of the resource, and strengthening the technical capacity in the countries sharing the aquifer.

Three transboundary aquifers were selected as pilot cases, based on their level of representativeness of major aquifer types, and on their different transboundary contexts (see Figure 1.1):

1. UNESCO launched in 2002 the International Shared Aquifer Resources Management (ISARM) Programme. Its objectives are to identify transboundary aquifers on each continent and to address their hydrogeological, socio-economic, environmental, legal and institutional aspects; to support countries in the recognition of these "invisible" shared resources, and assist countries in their assessment and management. In 2012, at the 20th Session of the IHP Intergovernmental Council, the respective ISARM Resolution (XX-3) was adopted. It encourages Member States to cooperate on the study of their transboundary aquifers.
2. TWAP-Groundwater component: www.twap.isarm.org
3. Groundwater Governance Project: www.groundwatergovernance.org

1. The Esquipulas-Ocotepeque-Citalá (Trifinio) Aquifer in Central America (Guatemala, El Salvador and Honduras)
2. The Stampriet Transboundary Aquifer System (STAS) in Southern Africa (Botswana, Namibia, South Africa)
3. The Pretashkent Transboundary Aquifer (PTBA) in Central Asia (Uzbekistan, Kazakhstan)

Figure 1.1 | Approximate location of the three pilot study areas



GGRETA is implemented by the UNESCO-International Hydrological Programme (IHP), in close cooperation with the UNESCO- International Groundwater Resources Assessment Centre (IGRAC) and project teams composed of professionals from the respective regions. The International Union for the Conservation of Nature (IUCN) was UNESCO's local implementing partner in the Trifinio pilot study.

GGRETA is a two-phased demonstration project in which the first phase (2013-2015) was designed as an assessment phase, with three major objectives:

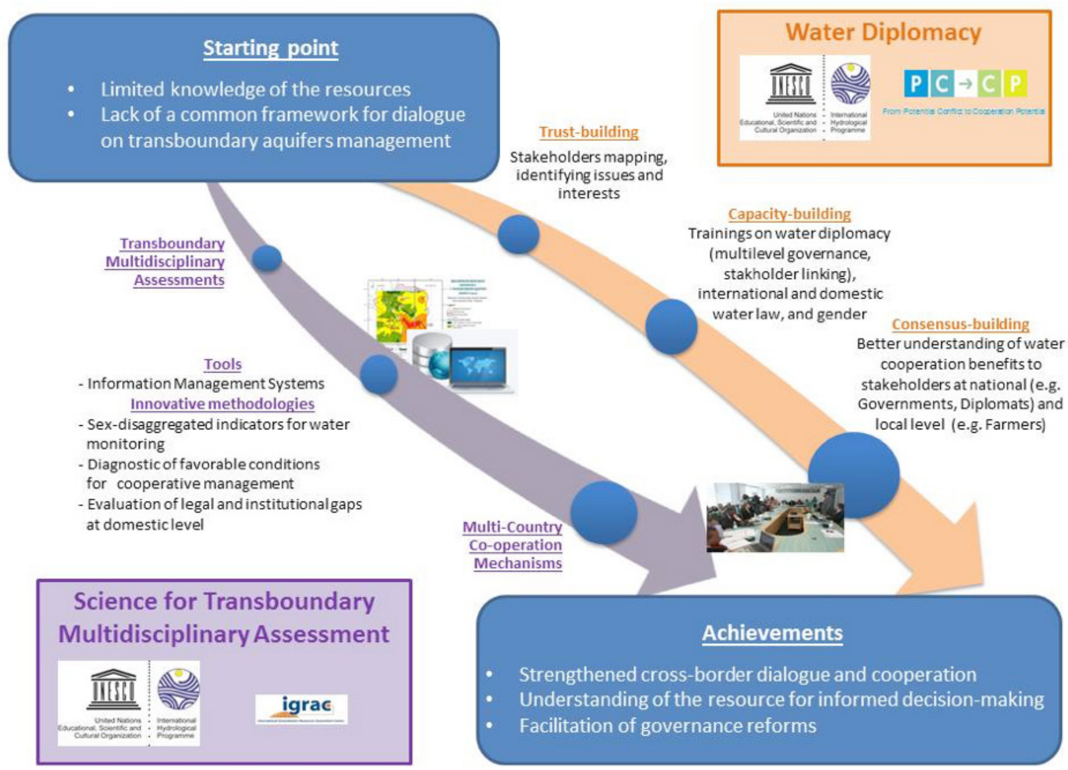
- Focusing the attention of the international community on transboundary aquifers, and providing examples of their assessment and diagnostics;
- Assessment of the transboundary aquifers and their context for the three pilot cases (Trifinio, Stampriet and Pretashkent);
- Fostering recognition of the shared nature of the groundwater resource and facilitating cross-border dialogue and technical exchanges.

The project document specifies two scientific outputs to be produced during phase 1:

- Reports on indicator-based assessments for each of the three pilot areas, describing the current conditions of the aquifers, including a diagnostic of transboundary concerns, conducted with full participation of national experts;
- A database and Information Management System (IMS) for field data storage and elaboration, established for each aquifer system.

Building on the generated scientific knowledge, a strong focus was given to a *water diplomacy track* as a means to promote gender equality and enhance the much-needed capacity-building for improved transboundary and correlated domestic water resources governance (see Figure 1.2).

Figure 1.2 | **GGRETA project's general approach**



Within the framework of the 2030 Agenda for Sustainable Development, the results obtained in the GGRETA project will contribute to the monitoring of the Sustainable Development Goals (SDG) indicator 6.5.2 on water cooperation; for which UNESCO-IHP and the United Nations Economic Commission for Europe (UNECE) have been entrusted by UN-Water as the legitimate organisations in charge of the further development and monitoring of this indicator.

1.2. Purpose of this report

This report summarizes the outcomes of the first phase of GGRETA, and in particular the tangible outputs as specified above. Consequently, it intends in the first place to present in broad lines the pictures emerging from the assessment studies of the three transboundary aquifer systems and it provides a brief description of the IMS that has been developed. More detailed descriptions can be found in the corresponding technical reports prepared for each of the pilot studies. These aquifer-specific reports also present full reference to the sources of data and information, which has not been done in the present final report, in order not to overload it.

Furthermore, the report evaluates the assessment methodology adopted in the project, and identifies critical data, information and knowledge gaps. Finally, some tentative conclusions are drawn on the contribution of this project phase to better recognition of the shared nature of the groundwater resources and on how it has facilitated cross-border dialogue and technical exchanges significantly.

1.3. Acknowledgements

Numerous entities and persons have contributed in different ways to this project phase (GGRETA-1) and its achievements. The Swiss Agency for Development and Cooperation (SDC) as the initiator of the *Water Diplomacy and Governance in Key Transboundary Hot Spots Programme* and as financier of its groundwater component GGRETA; Mr Jac van der Gun, Senior Advisor to UNESCO-IHP, who is the main author of this report which was prepared based on data collected, analysed, and harmonised by local experts; IUCN; UNESCO IGRAC; water-related ministries, groundwater agencies, universities and other entities in the countries sharing the three transboundary aquifer systems by making available local data and knowledge as an input to the assessment; and a large number of professionals, belonging to or invited by the aforementioned entities, by co-operating in the project teams and jointly producing the outputs. All these actors and their contributions are gratefully acknowledged.

2. General approach and methodology

2.1. Scope of activities

2.1.1 Pilot studies: Science for transboundary multidisciplinary assessment

In principle, GGRETA's assessments had been designed mainly as desk studies, to be based on existing data and information, without substantial acquisition of new data by field work. Hence, an essential initial step in the general approach was the identification of sources of information on the target aquifers and their context, accompanied by finding out how to access the data and information. Obviously, knowledgeable national professionals were indispensable to carry out this step successfully and efficiently. Next came data processing and the harmonization and aggregation of data and information – to the extent needed. Tables, maps and other graphical presentations were prepared to facilitate analysis, interpretation and communication. The interpretation of all collected information in an integrated view should culminate primarily in a proper understanding of the hydrogeological regime (conceptual model) and in conceptual building stones for transboundary aquifer management (diagnostics).

In order to compensate for the lack of data on some aspects of the assessment, a few field studies were undertaken to collect new data. This was done in the first place by a geophysical and hydrogeological field survey in the Trifinio area, meant to obtain a reliable basis for the delineation of the transboundary aquifer. In addition, surveys on gender aspects were carried out in each of the three areas.

2.1.2 Information Management System (IMS)

Development of the dedicated software for the IMS has been carried out by UNESCO-IGRAC. In parallel, the national teams have been collecting data and developing databases of selected types of data. The information management system, although useful during the assessment phase, is primarily designed as a permanent groundwater governance tool. It is accessible, for each of the pilot areas separately, at a special GGRETA platform in UNESCO-IGRAC's Global Groundwater Information System (GGIS). It has a public viewer –allowing to view a basic set of data– and a private viewer with access to much more information. The latter is password-protected and only available to those permitted to view all data.

2.1.3 Water diplomacy

While there are more than 450 agreements on international waters, which are generally dealing with surface water, there are only 6, directly addressing shared groundwater resources[4]. The establishment of joint mechanisms of transboundary water resource management, requires formal interstate agreements which "function" under the governing principles of international water law. Yet, those remain a formality, unless riparian states have a capacity to implement them. The real cooperation will

4. Northern Western Saharan Aquifer System (NWSAS) Aquifer; Iullemeden Aquifer; Nubian Sandstone Aquifer; Guaraní Aquifer; Genevese Aquifer; Disi Aquifer.

be then efficient only if the positive aspects of benefit-sharing are recognized at all levels, and sufficient institutional capacity is developed.

UNESCO-IHP has applied the From Potential Conflict to Cooperation Potential (PCCP) programme[5] approach as a platform to facilitate multi-level and interdisciplinary dialogues in order to foster cooperation in GGRETA countries. The programme follows the rationale that although transboundary water resources can be a source of conflict, their joint management can be strengthened and even used as a mean for further cooperation. PCCP demonstrates that a situation with undeniable potential for conflict can be transformed into a situation where cooperation potential can emerge.

GGRETA project has taken the lead in offering capacity-building programmes in water diplomacy and law to introduce practical advances to stakeholders, decision-makers and law practitioners, in order to strengthen their understanding of the ultimate benefits of joint management of (ground) water resources. The purpose of such an approach is to transform different visions both on national and international level into a common agreed framework, that equitably allocates not only the water resource, but the benefits derived from it.

Considering that new trends and possibilities for a more efficient use and management of the aquifers' resources require collaboration and dialogue between decision makers, scientific experts and other stakeholders, GGRETA water diplomacy track was a means to promote transboundary aquifer management by tackling three main components described as follows:

- Trust-building: Stakeholders mapping, identifying issues and interests;
- Capacity-building: Trainings on water diplomacy (multi-level governance, stakeholder linking), international and domestic water law and gender);
- Consensus-building: Exercises aimed at providing a better understanding of water cooperation benefits at national (e.g. Governments, Diplomats) and local level (e.g. Farmers). In Stampriet case study, for instance, other activities included an inventory and analysis of models for the setting up of Multi-Country Cooperation Mechanisms (MCCM).

In addition, UNESCO has concentrated on building skills to bring competing interests and institutions together to craft workable solutions by the means of preventive diplomacy and alternative dispute resolution. Hence, through carefully crafted simulation exercises and interactive lectures, stakeholders in all GGRETA countries gained skill and knowledge on:

- The understanding of needs;
- Negotiation, mediation, and facilitation techniques;
- The necessity of multi-level and interdisciplinary dialogues at domestic and international level.

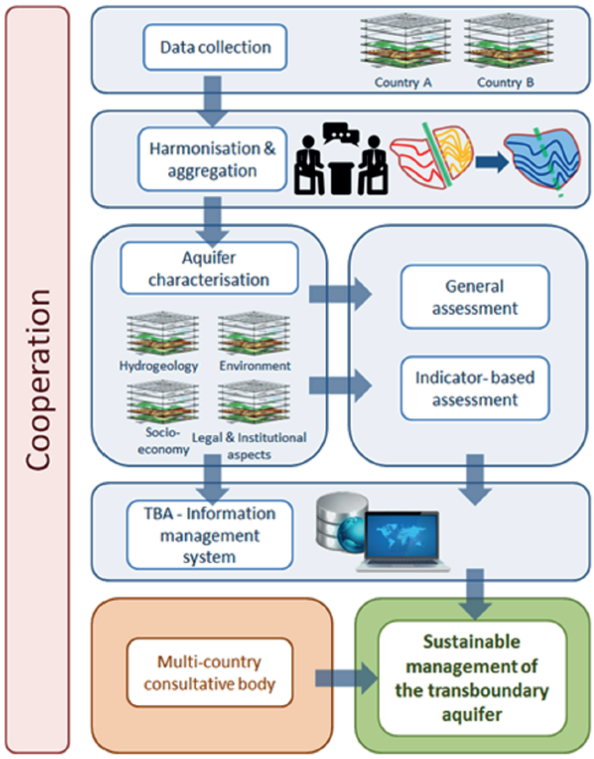
2.2. GGRETA's transboundary multidisciplinary assessment guidelines

Right from the start of GGRETA, attempts were made to elaborate an assessment methodology for the three case studies and to present it in the form of guidelines. UNESCO-IGRAC took the lead in this endeavour. Important building blocks for this methodology were the views and approach developed since 2001 within the *ISARM programme (International Shared Aquifer Resources Management),* lead

5. http://www.unesco.org/new/en/natural-sciences/environment/water/ihp/ihp-programmes/pccp/

by UNESCO-IHP and the International Association of Hydrogeologists (IAH), and –of more recent date – the indicator-focused methodology developed in the Groundwater Component of the Transboundary Waters Assessment Programme (TWAP), executed by UNESCO-IHP and funded by the Global Environmental Facility (GEF). Figure 2.1 defines the main steps in the assessment and it shows how the role of assessment and information management is perceived in the overall context of sustainable management of transboundary aquifers.

Figure 2.1 | Assessment and information management in the context of transboundary aquifer management (Source: IGRAC and UNESCO-IHP, 2015)



During the project's activities, steady interactions with the different stakeholders involved in the project gave rise to some improvements in the methodology and the corresponding guidelines. Their status at the time of finalizing the assessment studies in the three pilot areas is laid down in the publication *Draft Guidelines for Multidisciplinary Assessment of Transboundary Aquifers* (IGRAC and UNESCO-IHP, September 2015). It distinguishes four main steps in assessment (data collection; harmonisation/ aggregation, aquifer assessment and data management) and provides in appendices detailed instructions on the data to be collected and on the indicators to be used.

2.3. Indicators

In the TWAP project, indicators have been defined and applied with the purpose to make objective comparisons between large numbers of transboundary aquifers, which would enable to classify them according to groundwater management issues and rank them according to the relative priority of addressing these issues. Consequently, it was attempted to define indicators that are meaningful and cover the most relevant aspects of aquifers and their management, but at the same time should be simple enough to allow them to be assessed and properly understood for the majority of the aquifers.

Obviously, indicators used in GGRETA will have a different purpose. Rather than facilitating the comparison between different aquifers, the indicators should act here as a supporting tool in the diagnostic analysis of a single aquifer system. It was postulated that the TWAP indicators might also be suitable for that purpose, subject to testing this in GGRETA's pilot studies. The simplicity and relatively modest data requirements are an advantage, but the fact that the TWAP indicators are aggregated over the entire aquifer (lumped) certainly limits their usefulness for aquifer-level analysis. In the end, GGRETA decided to adopt eighteen of the twenty TWAP indicators and to replace the last two TWAP indicators (on the implementation of groundwater resources management measures) by fourteen more specific indicators on the enabling environment at the domestic level. Table 2.1 shows the complete set of GGRETA indicators.

Table 2.1 | The set of GGRETA indicators

1		**Defining or constraining the value of aquifers and their potential functions**
	1.1	Mean annual groundwater recharge depth
	1.2	Annual amount of renewable groundwater resources per capita
	1.3	Natural background groundwater quality
	1.4	Aquifer buffering capacity
	1.5	Aquifer vulnerability to climate change
	1.6	Aquifer vulnerability to pollution
2		**Role and importance of groundwater for humans and the environment**
	2.1	Human dependency on groundwater
	2.2	Human dependency on groundwater for domestic water supply
	2.3	Human dependency on groundwater for agricultural water supply
	2.4	Human dependency on groundwater for industrial water supply
	2.5	Ecosystem dependency on groundwater
	2.6	Prevalence of springs
3		**Changes in groundwater state**
	3.1	Groundwater depletion
	3.2	Groundwater pollution
4		**Drivers of change and pressures**
	4.1	Population density
	4.2	Groundwater development stress
5		**Enabling environment for transboundary aquifer resources management at bi-/multinational level**
	5.1	Transboundary legal framework
	5.2	Transboundary institutional framework
6		**Enabling environment for transboundary aquifer resources management at domestic level**
	6.1	Policy framework
	6.2	Legislative/regulatory framework
	6.3	Legal status of groundwater
	6.4	Groundwater planning framework
	6.5	Regulatory framework of groundwater abstraction and use
	6.6	Regulatory framework for the protection of groundwater from point source pollution
	6.7	Regulatory framework for the protection of groundwater from diffuse pollution
	6.8	Regulatory framework for the protection of groundwater recharge from man-made interferences
	6.9	Legislative/regulatory framework implemented
	6.10	Legislative/regulatory framework enforced
	6.11	Customary water rights
	6.12	Formal institutional framework (government)
	6.13	Formal institutional framework (users)
	6.14	Informal institutional framework

Note: For definitions of the indicators, see: Guidelines for Multi-disciplinary Assessment of Transboundary Aquifers (IGRAC & UNESCO-IHP, 2015)

2.4. GGRETA: a gender-sensitive assessment

Access, use, management and authority over water resources are all highly gendered. For these reasons, women constitute distinctive key stakeholders in water policy and programmes – and are treated as such, at least in declarations of interest and in most major policy platforms in development[6]. Over the past two decades, the connected issues of gender and water have received considerable international policy attention and triggered a call for gender-disaggregated data as about half of countries do not produce any gender statistics related to water[7].One of the most important factors and tools to support bringing to light existing gender inequality is sex-disaggregated data collection and analysis. The relative novelty of the subject, lack of specially trained experts to conduct scientific research as well as the limited scope and details of national gender statistics often allow only for a partial vision and understanding of the situation.

GGRETA is the first ever multi-country and multi-regional water-monitoring project with comparable sex-disaggregated data. It has done so by integrating the United Nations World Water Assessment Programme (UN WWAP) / UNESCO toolkit on sex-disaggregated water indicators and methodology. The toolkit captures quantitative and qualitative data on water and gender issues, providing the baseline for gender sensitive decision making in the water sector, with a view to promoting gender equality; a UNESCO priority[8]. It includes:

- a list of high-priority gender–sensitive water indicators covering water governance, safe drinking water, sanitation and hygiene, decision making and knowledge production, international water resources management, and income generation for agricultural uses,
- a proposed methodology for collecting sex-disaggregated data from transboundary, national, local, household, and intra-household level,
- a compilation of guidelines for data gathering in the field,
- a tailor-made questionnaire for practitioners to collect sex-disaggregated data.

The project has been an important catalyst in promoting and raising gender issues in all GGRETA countries. GGRETA's approach in conducting a thorough data collection and analysis of existing national statistics at the aquifers' level served as an impetus to raise experts' awareness of the importance of gender in the water sector. The mere fact of integrating gender into the activities of the project largely contributed to attracting the attention of national parties (authorities and experts) to the subject.

Obtained results (summarized in Appendix 4) will be useful for the formulation of informed decisions on water resource management, use and access in the areas of interest of GGRETA. The sex-disaggregated data overview will also prove the importance to get such data on a global scale, in view of the 2030 Agenda for Sustainable Development the monitoring of the Sustainable Development Goals (SDG) strategy. Additionally, the gathered empirical data and professional analysis could further strengthen the case for gender equality in presentations to regional, national and local stakeholders.

6. The 1992 Dublin Statement on Water and Sustainable Development, 1992 United Nations Conference on Environment and Development, The 1995 Beijing Declaration and Platform for Action, Millennium Development Goal 3
7. UN Statistical Commission (2013) available at http://unstats.un.org/unsd/statcom/doc13/2013-10-GenderStats-E.pdf
8. UNESCO 2014-2021 Priority Gender Equality Action Plan

Part 1.
Trifinio

3. The Trifinio Aquifer pilot project

3.1. Organization and implementation of the pilot project

The technical activities of this pilot study were executed by a local tri-national team coordinated by the IUCN (International Union for Conservation of Nature), the local implementing partner of UNESCO. A close cooperation was set with the *Plan Trifinio*[9]. Apart from compiling and analysing existing information (mainly limited to climate, geology and hydrogeology), the focal components of the pilot study were a geophysical survey (subcontracted to the company Geofísica Aplicada), a study of gender issues (in cooperation with municipalities) and the development of a geo-referenced database (supported by UNESCO-IGRAC). In addition, initial advocacies for a multi-actor consultation platform for sustainable groundwater management were made at the occasion of meetings with local authorities and personnel of the Plan Trifinio.

3.2. Location and delineation of the transboundary aquifer system

Figure 3.1 and Figure 3.2 show the location and the topography, respectively, of the catchment area of the Upper Lempa river (Río Lempa). At the onset of the project, this catchment area was assumed to include a *"Trifinio Transboundary Aquifer"* – named after the zone where the three countries Guatemala, Honduras and El Salvador meet –, but in that stage the boundaries of this aquifer were still insufficiently known, except for being linked to the valley of the Lempa river. As will be shown in section 3.4, GGRETA's geological and geophysical surveys have enabled to delineate the Trifinio Aquifer, but they have revealed also that this aquifer is in fact composed of two laterally disjunct aquifer zones located in the valley floor of the sub-basin of the Upper Lempa river: one in the Valle de Esquipulas and another one in the Valle de Ocotepeque-Citalá. Their delineation is shown in Figure 3.7. Only the aquifer zone in the Valle de Ocotepeque-Citalá (OC-C) is transboundary, shared between Honduras and El Salvador.

3.3. General features of the Upper Lempa area

3.3.1 Topography

The Upper Lempa area, as shown in Figure 3.2, is 996 km^2 in extent and has a marked relief. Surface elevations vary between 720 m and 2418 m above mean sea level. The Lempa river (Figure 3.3) passes through the area from North to South; its relatively flat and wide river valleys are called Valle de Esquipulas (in Guatemala), Valle de Ocotepeque (in Honduras) and Valle de Citalá (in El Salvador). Their mean elevation is around 800 m above mean sea level. The surrounding mountains are dissected by tributaries of the Lempa river.

9. *Plan Trifinio* refers to the tri-national development plan for the area and the institution ensuring its execution

Figure 3.1 | Location of the upper Lempa catchment area

Figure 3.2 | Topography of the upper Lempa catchment area

3.3.2 Climate

In conformity with its geographic position (facing the Pacific Ocean, between 14° and 15°N), the area has a tropical wet-and-dry climate (Aw-climate, according to Köppen), with a marked rainy season from May through October. With increasing elevation, the climate becomes more humid.

Mean annual temperature varies from 24°C at the lowest to 16°C at the highest elevations. The mean monthly temperature is highest in April and lowest in December/January, but its annual range is only around 4°C, which is substantially lower than the mean daily range of the temperature.

Rainfall varied during the previous twenty years between 909 and 2,369 mm/year, averaged over the entire Trifinio region; between 1,300 and 2,100 mm/year in the Valles de Ocotepeque and Esquipulas. Compared to potential evapotranspiration (1,300 to 1,850 mm/year, depending on elevation), there is a rainfall deficit during the dry season November–April and a rainfall surplus during May–October.

3.3.3 Demography

The total population of the area includes 138,487 inhabitants, of which 58% lives in Guatemala, 21% in Honduras and 20% in El Salvador. The female population –52% of the total – is slightly larger than the male population in each of the three national segments. Migration to other parts of the country or to other countries has an impact on family structure and economy in northern Central America; in the municipalities of the Trifinio aquifer the annual migration rate varies from 0.1 to 2.0 per thousand inhabitants.

3.3.4 Water supply and sanitation

Although the Trifinio region is richly endowed with water, only 83.6% of the population is connected to domestic water supply system. Domestic water supplies are mainly drawing from groundwater (17.4% from wells and 47.7% from springs). Unconnected households get their water from public taps, wells and other sources, which is usually a time-consuming task of women and children. Sanitary provisions are available in 84.8% of the households. Solid waste is disposed in open air, both on municipal waste dumps and on illegal ones.

Figure 3.3 | Upper Lempa river

3.3.5 Economic activity

Agriculture, traditional products and tourism are the main economic activities in the Trifinio Region. Agriculture is widespread and focuses on coffee (24,000 ha), grains and horticulture. Tourism attracts annually 1.7 million visitors to the region. In spite of the region's development potential, a significant number of people, especially in the El Salvador segment, have emigrated to escape from poverty.

3.4. Aquifers and groundwater in the Trifinio area

3.4.1 Geological setting

Geological formations ranging from Jurassic to Quaternary age are outcropping in the area. Among these, formations belonging to the Tertiary Padre Miguel Group cover by far the largest part of the area. They are predominantly of volcanic origin, with andesitic and basaltic rocks as main components, but they include also sandstones. In the valleys of the Lempa river, volcanic rocks of the Padre Miguel Group are concordantly overlain by Quaternary alluvial deposits. The latter contain unconsolidated material ranging in size from blocks and gravel to sand and silts. Faults and fractures are abundant. Table 3.1 shows a simplified stratigraphic table.

Table 3.1 | Stratigraphic table

Era	Period	Unit	Lithology
Cenozoic	Quaternary	Alluvial	Volcanic blocks in a tuff matrix
	Tertiary	Padre Miguel Group	Andesites and basalts with lahars, tuffs, sandstones and volcanic ashes (silt and clay)
		Subinal Formation and/or Valle de Angeles Formation	Conglomerates with sandstone and shale, rich in hematite
Mesozoic	Cretaceous	Yojoa Group, Atima Formation	Massive limestone with calcite crystals
Palaeozoic	Carboniferous to Permian	San Diego Phyllites	Phyllites with quartz, talc, micas, graphite and staurolite

3.4.2 Aquifers and aquitards

The porous and unconsolidated Quaternary alluvial deposits in the river valleys have a mean thickness of approximately 30 m only and form a shallow phreatic aquifer, overlain by an unsaturated zone of some 10 m, on average. From a hydraulic point of view, it is a very poor aquifer (very low transmissivity) and it is highly vulnerable to pollution. It is underlain by a massive tuff layer that forms an approximately 60 m thick aquitard. Below this aquitard lies a confined deep aquifer, consisting of poorly sorted red-coloured sediments, ranging from clays and sands to conglomerates, and underlain by impermeable Padre Miguel rocks. This is a fractured aquifer and also poorly productive (reported transmissivities of 6 to 10 m^2/day), but it is better protected against pollution than the shallow aquifer. The confined aquifer is extending laterally beyond the flat valley floor, but groundwater there usually can be found only at great depth. The cross-section shown in Figure 3.4 gives an impression of the geological setting of the described aquifer–aquitard system. The figures 3.5 and 3.6 give an impression of the alluvial deposits and massive tuff, respectively.

Figure 3.4 | SW-NE geological cross-section across the Valle de Esquipulas

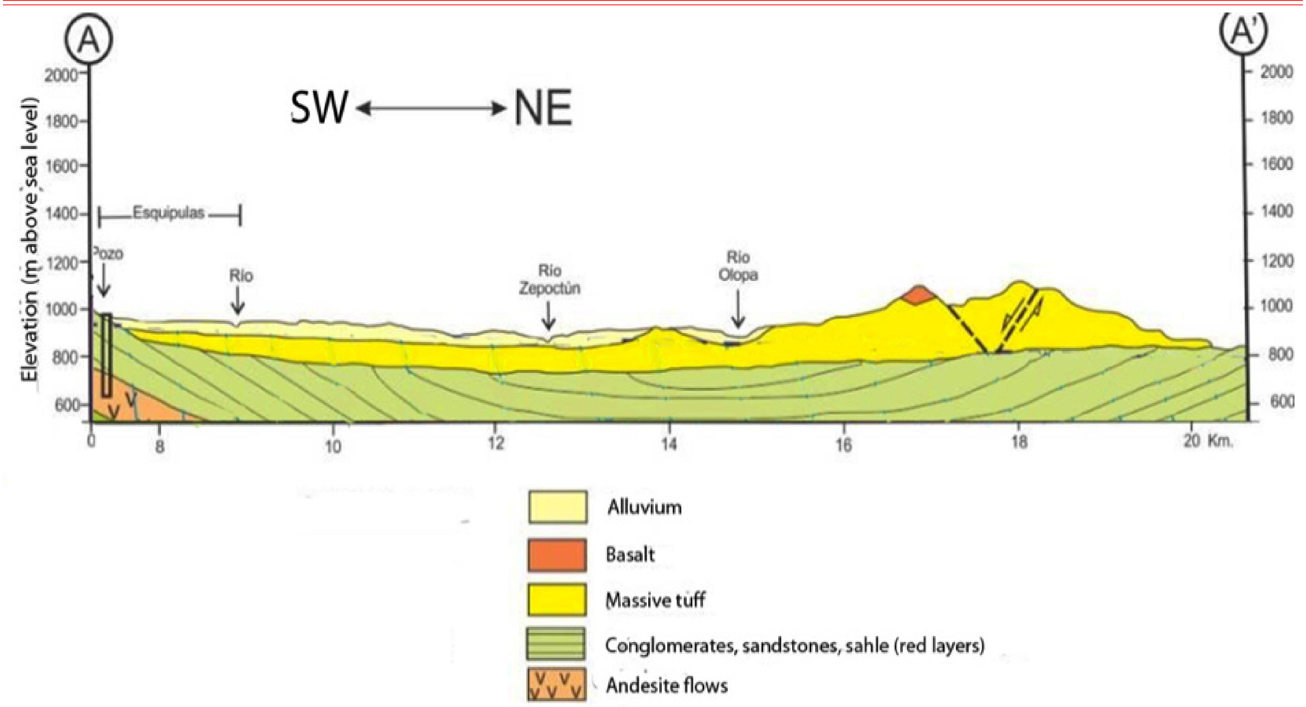


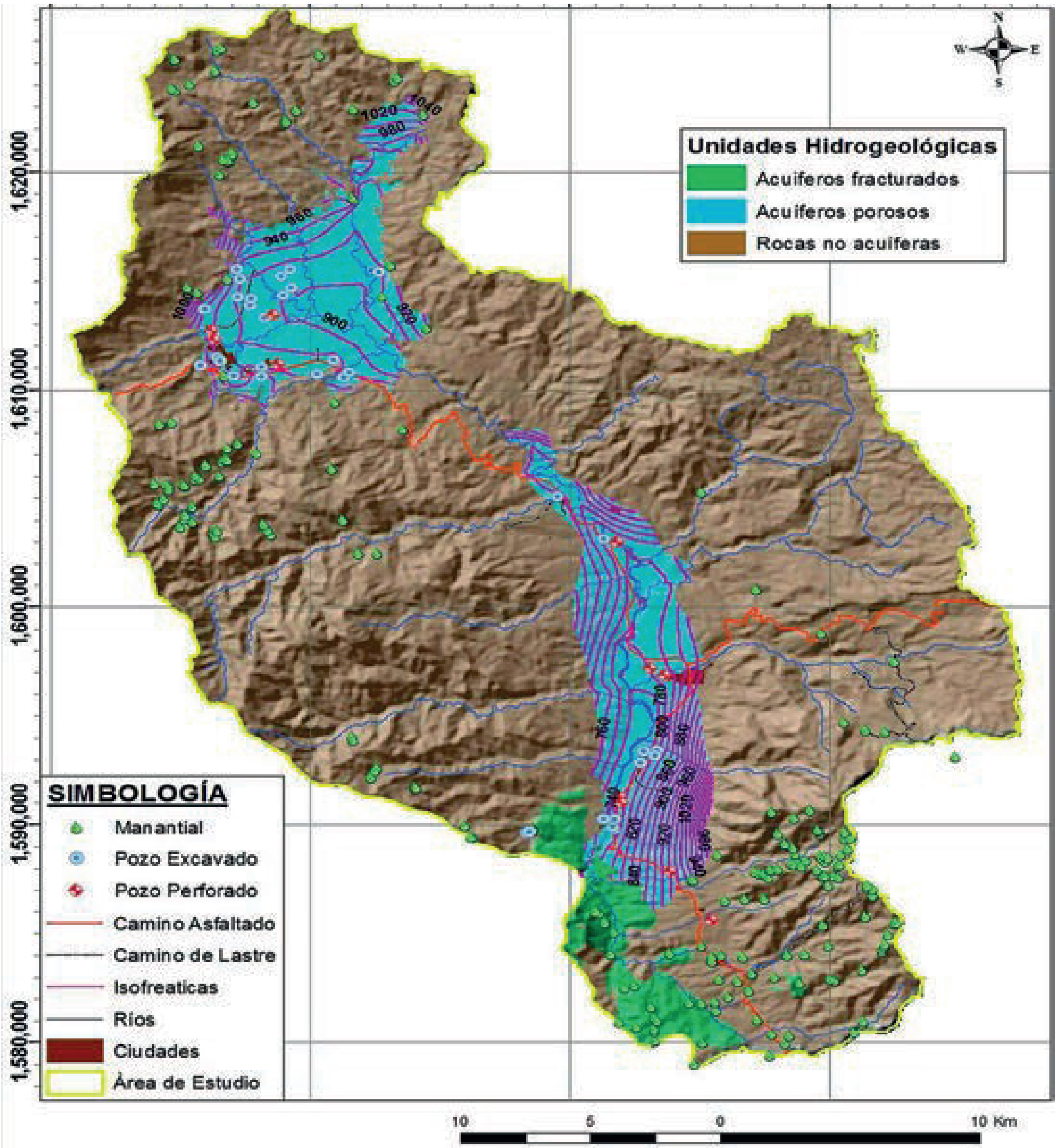
Figure 3.5 | Alluvial deposits as found in the Esquipulas and Ocotepeque–Citalá valleys

Figure 3.6 | Outcrop of massive tuff (which forms aquitard between shallow and deep aquifer)

3.4.3 Geo-structural divide between the Valle de Esquipulas and the Valle de Ocotepeque-Citalá

The geological and geophysical field surveys carried out by GGRETA in 2015 have revealed the existence of recent faults that determine a clear morphological high, separating the Esquipulas basin in the North-West from the Río Lempa valley to the South East. The tectonically uplifted block of massive volcanics forms a hydraulic barrier, which implies that the described double-layer aquifer system is laterally not continuous along the Upper Lempa river, but consists of two distinct units: the Valle de Esquipulas aquifer and the Valle de Ocotepeque-Citalá (OC-C) aquifer (see Figure 3.7). Only the latter is transboundary: it is shared by Honduras and El Salvador.

Figure 3.7 | **Hydrogeological map showing the alluvial aquifer units (in blue) of the Valle de Esquipulas and the Valle de Ocotepeque–Citalá**



3.4.4 Conceptual model

Surface water and groundwater in the area are strongly interlinked and their dynamics is governed by the rainfall surplus during the wet season at the one hand, and by the Upper Lempa river at the other. During abundant rains, water will run off quickly from the mountain and hill flanks towards the lower parts of the area –the river valley floor of Lempa river–, from where it either infiltrates and recharges the phreatic aquifer or contributes to the direct flow of the river. The shallow phreatic and the deep confined aquifer are probably interconnected by vertical seepage across the aquitard that separates them, but zones of upward and those of downward seepage have not yet been identified and mapped. It is not impossible that a significant part of the recharge of the 'deep' aquifer[10] takes place outside the zones where the alluvial aquifer is present.

Groundwater in the phreatic alluvial aquifer generally flows towards the Lempa river, in downstream direction, but close to the river the flow direction may be temporally reversed during high flood peaks in the river. Since the river and the shallow aquifer are hydraulically connected, it follows that the rivers links the aquifer unit of the Valle de Esquipulas with that of the Valle de Ocotepeque-Citalá. Discharge of the 'deep' aquifer may occur either by springs in zones bordering the river valley floor, or by seepage through the aquitard towards the phreatic alluvial aquifer.

3.4.5 Natural groundwater quality

Groundwater from wells and springs has been sampled (in 2012 and 2014) and analysed for major chemical constituents. Among the seven samples taken from the Esquipulas Valley (all of them fresh), three main chemical water types can be distinguished: calcium-bicarbonate, sodium bicarbonate and a mixed type with predominance of bicarbonate and admixtures of sulphate and/or chloride. The 23 samples taken from wells and springs in the Valle de Ocotepeque show more chemical variability. Apart from the three main chemical types mentioned above, there are also a few wells with predominance of chlorides and nitrates among the anions (which may be the result of agricultural activitites, e.g. coffee). The samples from the wells here show that recharge is taking place in the valley, while the low mineralisation of the water of some springs suggests that they are part of local flow systems. The analysed groundwater samples taken from wells and springs during 2012 are all classified as fresh: the average TDS is around 250 mg/l, with a maximum of 575 mg/l and a minimum of 12 mg/l (in one of the springs).

3.5. Role and use of groundwater in the area

3.5.1 Groundwater abstraction and use

According to latest information, there are 114 wells in the area: 85 dug wells and 29 drilled wells. Almost all wells are located within the limits of the Trifinio aquifer. Reported well yields range from 4.4 m^3/h (dug wells) to 57 m^3/h (the most productive drilled well in the confined aquifer). In addition there are 460 springs in the area, the majority of which are found outside the Trifinio aquifer zone. A breakdown of wells and springs is presented in Table 3.2. Groundwater abstraction from these wells and from springs is estimated to be 5.1 million cubic metres per year. Of this total, 4.93 million is for domestic use (i.e. around 100 litres/capita per day), and 0.18 for agro-industrial use. As mentioned in section 3.3.4, groundwater (from wells and springs combined) covers around two-thirds of the domestic water demands. Irrigation during the dry season is making use of surface water, but some farmers are contemplating using groundwater since surface water becomes increasingly scarce in tributaries with intermittent flow.

10. For reasons of identification, we continue calling it 'deep' aquifer, although in some zones it may be located close to the surface.

Table 3.2 | Springs and wells and in the Upper-Lempa area

	Springs	Dug wells	Drilled wells	Total
Honduras	24	54	15	93
El Salvador	278	6	5	289
Guatemala	158	25	9	192
Total area	**460**	**85**	**29**	**574**

3.5.2 Groundwater pollution

A diversity of pollution sources is observed in the area, such as domestic solid waste and untreated domestic waste water, chemicals used in agriculture (fertilizers, herbicides and pesticides), wastewater and solid waste from agro-industrial processing, gas stations, and buried storage tanks of hydrocarbon products. Adequate sanitation is absent in many communities; wastewater and solid waste tend to be dumped untreated and uncontrolled to the environment, in absence of treatment facilities and controlled waste dumps; and many storage tanks are probably leaking. Surface water in the Lempa river and most of its tributaries is directly exposed to various sources of pollution and hence suffers from coliform pollution, low content of dissolved oxygen, high Biochemical Oxygen Demand (BOD) and heavy metals, which significantly reduce the suitability of this water for different uses, unless it is treated. The area's groundwater resources are exposed to similar pollution sources, but they are less vulnerable than surface water, especially at greater depth and if protected by an overlying aquitard. As mentioned before, the vulnerability of the shallow alluvial is high, but no aquifer-wide information is available on the current state of pollution of this aquifer. The confined aquifer has low vulnerability to pollution.

3.5.3 Other threats to sustainable groundwater use

So far, no indications of groundwater depletion have been observed in the area, but if uncontrolled abstraction continues, it might become a problem in the median term. Climate change may in principle result in longer dry seasons and more intensive rainfalls. The former may increase the demands for groundwater, the latter may result in less recharge and reduction of spring flow rates.

3.6. Legal, institutional and policy framework

3.6.1 The international level

In their *Plan Trifinio Treaty (1987),* Guatemala, Honduras and El Salvador declare the Trifinio Region as an “undividable ecological unit” and establish the coordination for the joint sustainable management of the natural resources of this region. Groundwater is not specifically addressed in this treaty, but it is implicitly included. The Comisión Trinacional del Plan Trifinio has developed a transboundary water strategy (“*Estrategia agua sin fronteras*”) as a political instrument for regional development, including shared water resources. Another tri-national actor is the autonomous Mancomunidad Trinacional Fronteriza del Río Lempa (created in 2007).

3.6.2 The national level

At the national level, each of the countries has its legal framework to support regulation and management of water resources. In El Salvador this framework consists of more than twenty laws, including the Constitution and laws on specific aspects of water (aqueducts and sewerage systems;

irrigation; groundwater use; hydroelectricity; IWRM; groundwater protection; etc...). The country has a National Environmental Policy (*Política Nacional de Medio Ambiente; 2012),* that includes a National Water Resources Strategy.

Guatemala has no specific legislation dedicated to water, but a diversity of laws (including the Constitution and Civil Code) that are applicable to various aspects of water management. It has adopted a National Water Policy (2011), a policy on International Waters (2012) and a national Water Agenda (2013). National sovereignty is emphasized in the policy on International Waters.

The General Water Law of 2009 made an end to a dispersed and often contradictory set of laws in Honduras. The law is quite comprehensive, and its implementation requires strengthening institutions and dedicated technical and financial resources.

3.6.3 The local level

Management at the local level is the task of the municipalities, but these do not have enough capacity and instruments for this task. Some municipalities appeal to the *Mancomunidad Trinacional Fronteriza del Río Lempa* (created in 2007) for technical and political support, which may give them some guidance, although not specifically related to groundwater and without legal tools.

Apart from the municipalities, responsible for the local water supplies, there are at the local level also the '*juntas de agua*', a kind of water boards at community level, taking care of all operational tasks on water, with support of the municipalities, the Mancomunidad, and/or international assistance.

3.7. Stakeholder involvement in water governance, including gender issues

3.7.1 The agricultural sector

Coffee cultivation and livestock farming are the main agricultural activities in the Trifinio Region and there are several farmers' associations in the area. Although farmers currently only use surface water for their productive activities, it has been reported that because of climate instability, they are foreseeing to start using groundwater. Additionally, given that their productive activities can potentially lead to pollution of the shallow alluvial aquifers, farmers should be considered as a key stakeholder for the sound management of groundwater resources.

3.7.2 Domestic water sector of settlements and communities

Due to the lack of infrastructure for water supply in rural areas, communities resort to the use of groundwater through traditional sources such as springs. As these springs are increasingly yielding less water (and can run out of water in the dry season), communities are increasingly building dug wells to meet their basic needs. Most of the work to fetch water rely on women (80%) and usually takes about 40 minutes per day.

Water management both surface and groundwater is being done through user associations, water boards or water committees in all municipalities of the study area. It has been accounted that about 1,120 people (27% women and 73% men) are running local water governance.

3.7.3 Gender issues

Guatemala, Honduras and El Salvador have adequate national legislation and a good institutional framework at local level for gender issues. All municipalities in the Trifinio Region have a dedicated office with a mandate to empower women and promote their participation in productive activities. By law, each office has a minimum percentage of the municipality's budget (around 0.05%). These offices have a different level of capacity but have been instrumental in providing training in the region. As a result, the presence or participation of women in cooperatives has increased in recent years; nowadays accounting about 20%.

3.8. Diagnostics

3.8.1 The overall picture emerging from the assessment

The assessment has produced valuable information, but it is clear that the available data, information and knowledge are still limited and subject to considerable uncertainty, both in relation to the groundwater systems in the area and to the only sparsely addressed environmental and socio-economic context. In addition, no information has been presented on the trends in time of the groundwater state variables (groundwater levels, groundwater quality/pollution) and the drivers and pressures behind such changes (population growth, economic development, water demands, groundwater abstraction rates, improvements in sanitation, pollution loads, etc.). The most important physical features identified by the assessment are: (a) the main aquifer beds are present in the valley floor; (b) in a horizontal sense, they occupy two separate aquifer zones (Esquipulas and Ocotepeque–Citalá); (c) these two zones are hydraulically interconnected by the Lempa river (the alluvial aquifers and the river are inseparably linked).

3.8.2 Importance of groundwater and challenges to its sustainable use

Groundwater is of vital importance to the area, in particular as it is virtually the only source of domestic water. It is expected that the demand for domestic water will increase, and the resulting pressure on the groundwater systems will probably be intensified by irrigation water demands that cannot be met any more by surface water. It is therefore important to govern and manage the groundwater resources of the area carefully.

Pollution forms a major water resources management challenge in the area. As mentioned before a diversity of pollution sources is observed. The alluvial aquifers – including the transboundary Ocotepeque–Citalá transboundary aquifer – are directly exposed to these sources and very vulnerable to pollution. Without effective pollution control, their groundwater is bound to become more and more polluted over time.

At first sight, the alluvial aquifer systems do not seem to be threatened by groundwater quantity problems (such as declining water levels and exhaustion), but careful monitoring over a longer period is needed to validate this impression and to anticipate potential groundwater quantity problems in the future.

Other major challenges may become apparent after improving groundwater governance in the area. Their early identification may prevent problems from escalating beyond the levels where they still can be controlled.

3.8.3 State of groundwater governance

The assessment has shown that information and knowledge on the groundwater systems and its context are still limited. Hence, monitoring the change of state and pressures over time, and continued upgrading of information systems and knowledge are essential. Beyond assessment and monitoring, many other aspects need to be addressed to enhance groundwater governance in general and to enable sustainable management of the transboundary aquifer in the Trifinio area. This entails in particular empowerment of women and institutional aspects, the main theme programmed for the second phase of GGRETA. Some preparatory activities have been carried out already during the first phase, notably the discussions on establishing a multi-actor groundwater management platform.

3.9. Building stones for improving groundwater governance

3.9.1 Towards multi-actor cooperation for transboundary groundwater management

Management of surface water and groundwater is not yet well developed in the Trifinio Region. Cooperation between actors need to be established at different levels: local, municipal, sub-national, national and tri-national. As a preliminary step, meetings were organised with representatives of these different levels: mayors, local platforms such as the *Mancomunidad Trinacional del Río Lempa,* executive and technical personnel of the Comisión Trinacional del Plan Trifinio (CTPT), academics and investigators and the water boards. An enquiry among those actors captured their views on priorities related to establishing groundwater management:

- Focal points for integrated and sustainable management: standards, policies and laws; investigations
- Themes: Promotion and awareness raising
- Stakeholder involvement: education
- Support to mayors and their corporations: education on groundwater and its management.

3.9.2 Promotion of gender equality

Given the key role of women in society, the three countries and the *Comisión Trinacional del Plan Trifinio* have a policy of gender equality and empowerment of women, accompanied by programs and projects intending to reduce the gaps between women and men at all levels. The current GGRETA case study contributed by organising several workshops intended to building capacity among the personnel of the women's offices and environmental offices of the municipalities.

3.9.3 Information Management System

As mentioned in section 2.1.2, an Information Management System (IMS) has been developed and implemented during this project phase for each of the three pilot areas: Trifinio, Stampriet and Pretashkent. The content of the IMS for the Trifinio case study is summarized in Table 3.3. It is the intention that this content will continuously be updated and expanded, in order to offer optimal information services to decision-makers and other stakeholders involved in governing the transboundary and other aquifer systems in the region. Among others, use will be made of linking the IMS to the GIS database of *Plan Trifinio* that is expected to become accessible through a web portal in the course of 2016.

Table 3.3 | Data in GGRETA's IMS for Trifinio, as per December 2015

	Data in IMS	Coverage
1	Physiography and climate	
1.1	Temperature (mean annual temperature, 1970-2015)	Plan Trifinio
1.2	Precipitation (mean annual, 1990-2010)	Plan Trifinio
1.3	Evapotranspiration (mean annual)	Plan Trifinio
1.4	Topographic elevation (100 m and 500 m intervals)	Plan Trifinio
2	Aquifer geometry	
2.1	Hydrogeological map	Plan Trifinio
2.2	Geo-referenced boundary of the Transboundary Aquifer	Two aquifers: Esquipulas and Ocotepeque-Citalá
2.3	Geo-referenced boundary of the Plan Trifinio	Plan Trifinio
3	Soil characteristics	
3.1	Soil types (11 classes)	Upper Lempa basin
4	Other data sets	
4.1	Sub-basins Plan Trifinio	Plan Trifinio
4.2	Network of roads (differentiation paved and non-paved roads)	Plan Trifinio
4.3	Upper Lempa Basin (subdivision)	Plan Trifinio
4.4	Municipalities	Plan Trifinio
4.6	Population (towns and villages in six population size classes)	Plan Trifinio
4.7	River basins Central America	Region
4.8	Upper Lempa (subdivision by country)	Plan Trifinio

Part 2.
Stampriet

4. The Stampriet Transboundary Aquifer System (STAS) pilot project

4.1. Organization and implementation of the pilot project

For this pilot study, a project team was established consisting of three multidisciplinary national teams (Namibia, Botswana and South Africa), each with its own national co-ordinator, supervised by a regional project coordinator and the project management unit (UNESCO-IHP/UNESCO-IGRAC). Apart from collecting and studying relevant reports and other literature for assessment and diagnostics, the team has spent much attention to compiling basic data and to GIS mapping. First drafts of separate report chapters were prepared in the region, in a decentralised way, after which homogenization and final report drafting and editing was done.

4.2. Location and delineation of the transboundary aquifer system

The Stampriet Transboundary Aquifer System (STAS) covers a large arid region stretching from Central Namibia into Western Botswana and South Africa's Northern Cape Province, approximately between 17 and 21° East and 22 and 26° South (Figure 4.1). It contains two confined sandstone aquifers, overlain by unconfined Kalahari aquifer units. It is not easy to define clear and unambiguous criteria for delineating the STAS. For the time being, it has been decided that the delineation of the STAS area follows the outer boundary of the so-called Ecca Group of geological formations within the catchments of the Auob and Nossob rivers. Around 73% of the very large STAS area is located within Namibia, 19% in Botswana and 8% in South Africa.

4.3. General features of the STAS area

4.3.1 Topography and hydrographic network

The STAS area, shown in Figure 4.1, is very large: 86 647 km^2 in extent. The area is rather flat and gently sloping from NW to SE, with elevation approximately between 1450 and 900 m above mean sea level (Figure 4.2). The area is largely dune-covered in its centre and south-east, while calcrete-underlain plains with shrubs and bushes are found in the western and eastern part of the area. There are no permanent rivers in the area; only two ephemeral rivers run from NW to SE: the Auob and Nossob rivers. Apart from these ephemeral rivers that provide some water during the rainy season, there are surface water pans scattered over the area that collect and store water for livestock watering; these reserves can last a few months after the rains. Figure 4.3 gives some impressions of the landscape, including a view of the encroachment of the alien Prosopis species along the Auob and Nossob rivers.

Figure 4.1 | Location and delineation of the Stampriet Transboundary Aquifer System

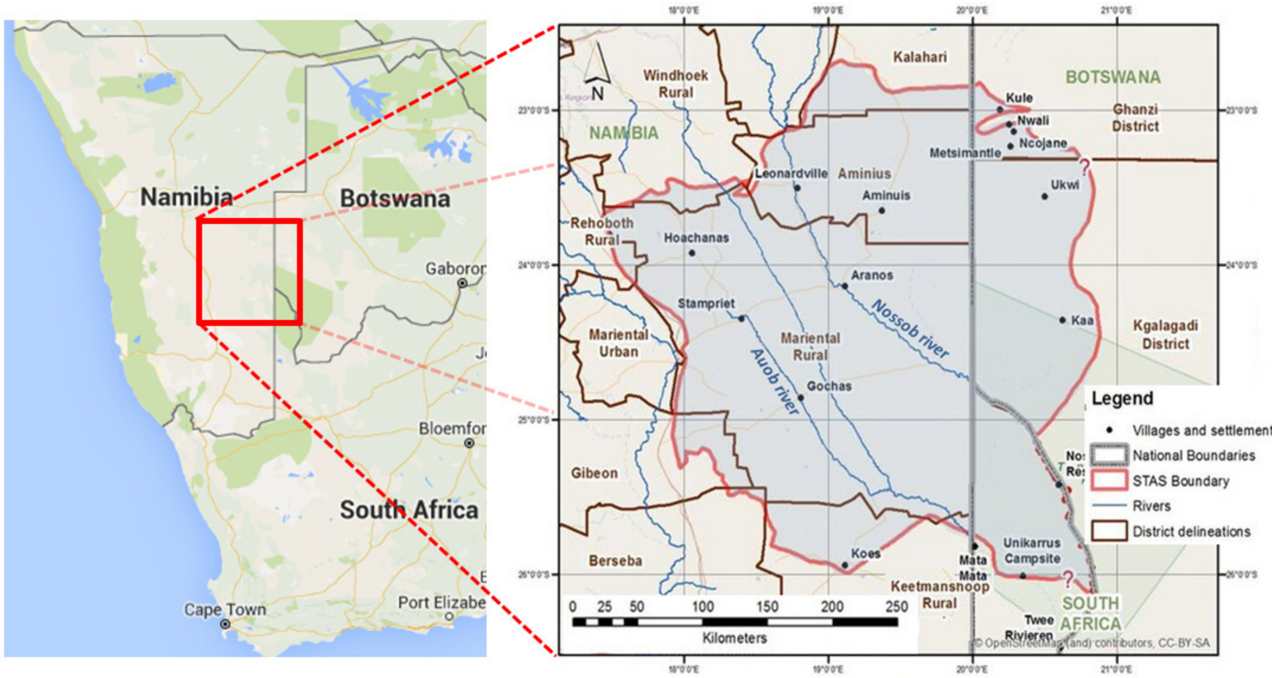


Figure 4.2 | Topography of the STAS area

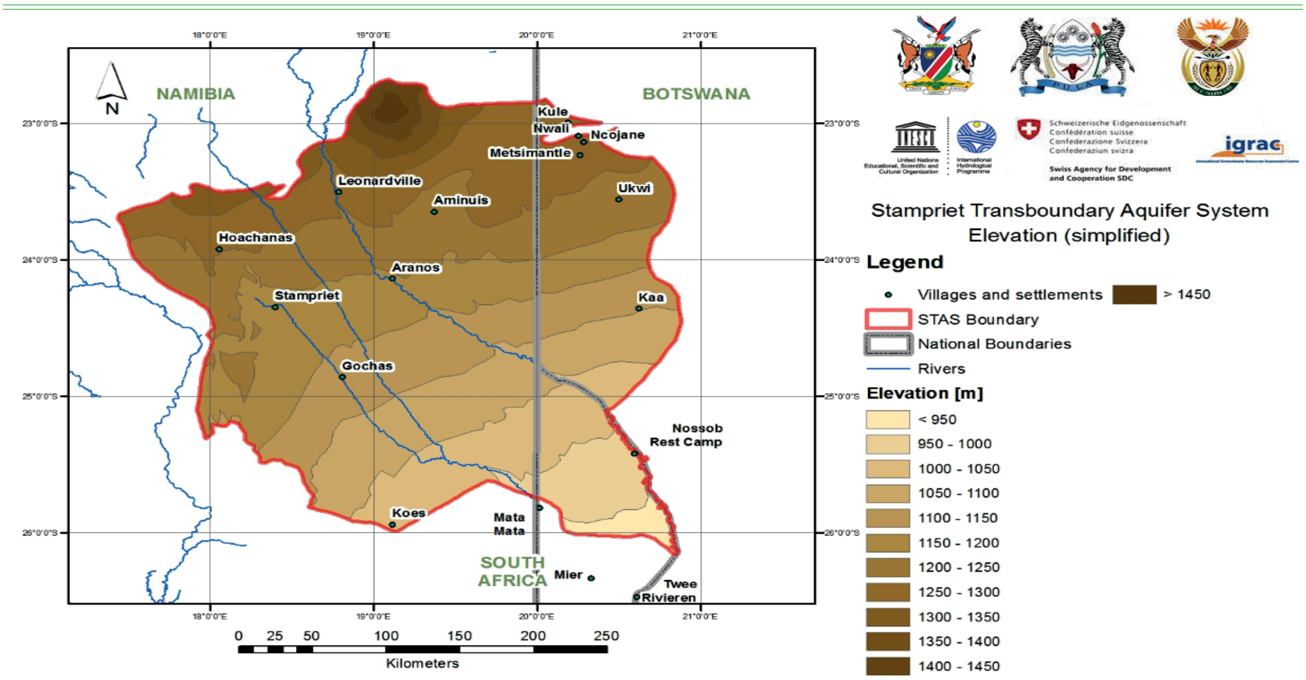
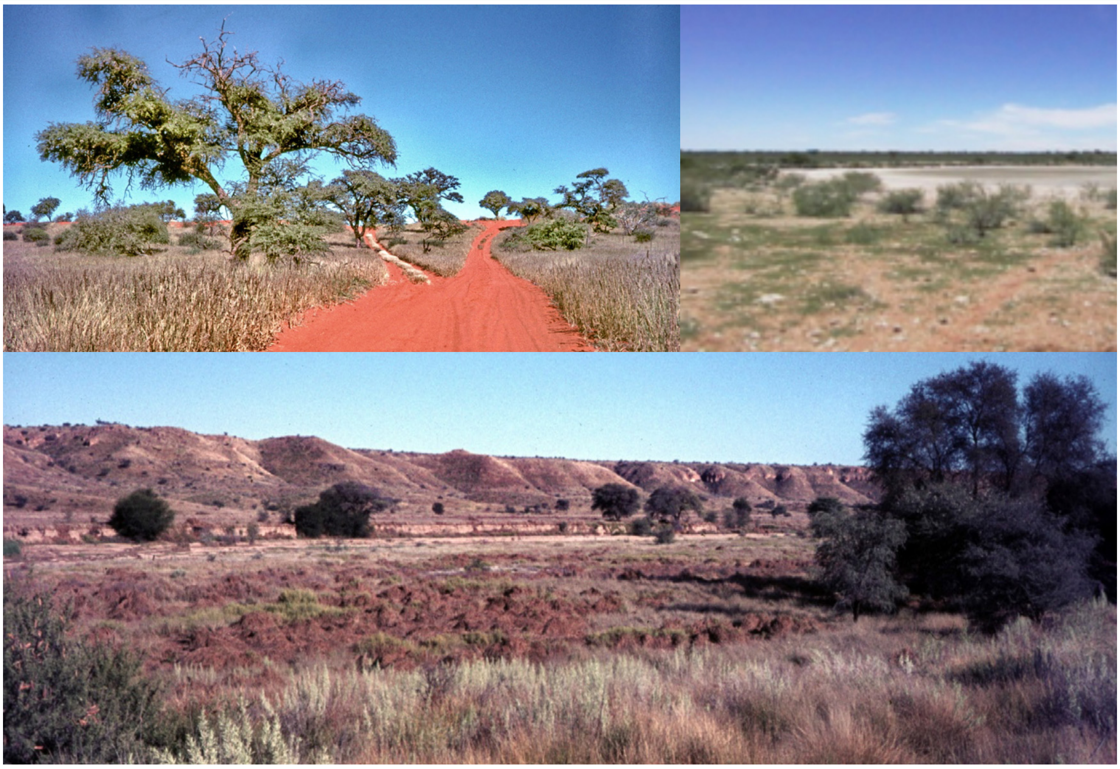


Figure 4.3 | Some impressions of the landscape: (a) dune area (top left); (b) calcrete/sandy surface where pans are common (top right); (c) Prosopis covered Nossob river upstream of Leonardville (bottom)



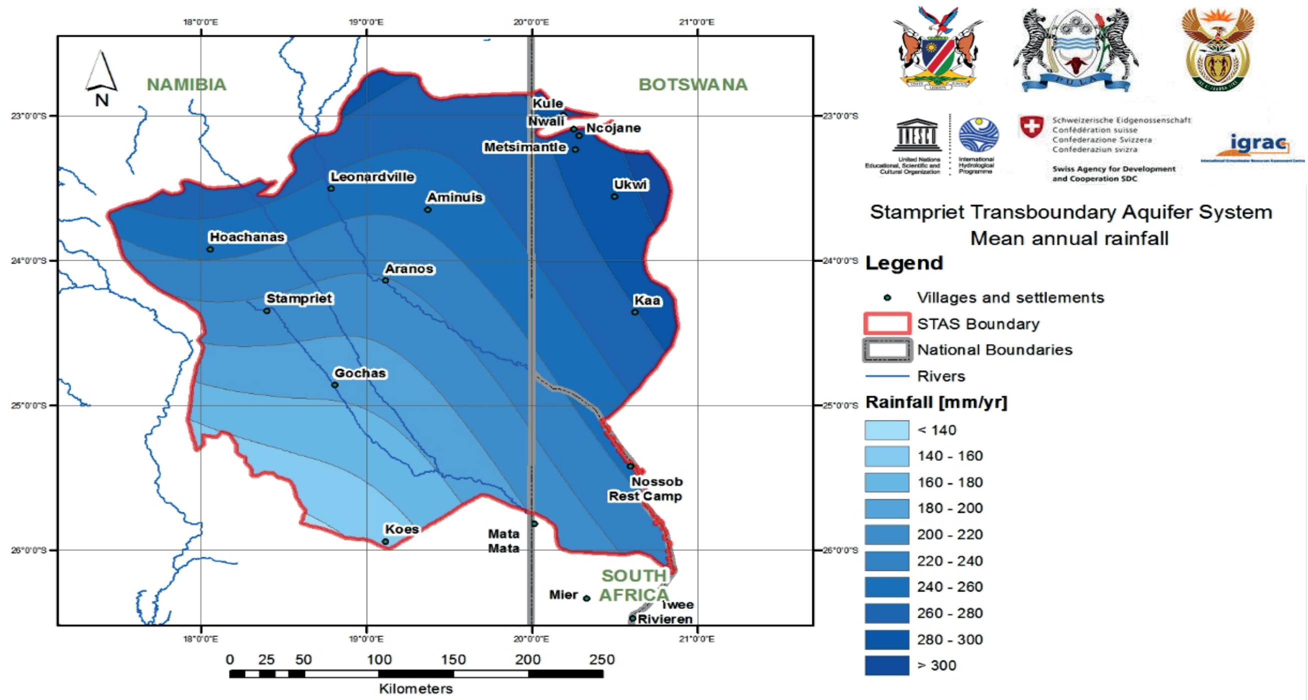
4.3.2 Climate

The STAS area has a hot and dry climate, with an annual mean temperature of 19-22 °C and mean annual rainfall ranging from 140 mm/year in the SW to 310 mm/year along the northern and north-eastern border (Figure 4.4).

Rainfall normally occurs between December and April, predominantly in the form of thunderstorms (high intensity and short duration). The months of highest rainfall are from January to March, while during the period May through September there is hardly any rainfall. Interannual variability is high and occasional cloud bursts (e.g. in 1960, when 489 mm was recorded in only 24 hours) can produce heavy flooding. The mean annual rates of potential evaporation and potential evaporation are not accurately known, but they are much larger than the annual amounts of precipitation, hence the climate is characterized by a rainfall deficit, even during the relatively wet months.

Climate variability is inherent to the region, for instance with marked influence of the El Niño Southern Oscillation (ENSO) on the rainfall regime. Global climate change is expected to cause warming and to increase spatial and temporal variation in precipitation, but there are no observations yet to get evidence of trends or underpin projections.

Figure 4.4 | Mean annual rainfall in the STAS area



4.3.3 Population and administrative units

With an estimated population of approximately 50 000, the STAS area is sparsely populated, in spite of an increase by some 20 000 inhabitants since 1990. Around 91% lives in Namibia, 8% in Botswana and 1% in South Africa. There are twelve settlements in the STAS area or close to its boundaries, all of them with less than 5000 inhabitants. Major settlements are Aranos and Koes in Namibia; all other settlements have less than 2000 inhabitants.

As Figure 4.1 shows, the STAS area comes administratively under eight constituencies in Namibia (Kalahari, Aminuis, Mariental Rural, Gibeon, Rehoboth Rural, Keetmanshoop Rural, Berseba, and Windhoek Rural), two districts in Botswana (Kgalagadi and Ghanzi) and one in South Africa (Kgalagadi Transfrontier Park). Mariental Rural and Aminuis constituencies in Namibia cover at least 80% of the area, and hold the largest population.

4.3.4 Land use and economic activities

The Namibian sector of the STAS area – as mentioned before, covering approximately 73% of the land – is almost completely in use as agricultural land. The Botswana sector (19%) includes from North to South three distinct land use zones: agricultural land (mainly in Ghanzi district), wildlife management area and national park. The South African sector (8%) is entirely used as national park.

Agriculture is the most important economic sector. There are approximately 1200 farms in the area (mostly in Namibia), among which a relatively small number (80) of commercial farms has a mixed system of livestock (mainly sheep, but also cattle and other animals) and irrigated crop production. Fodder (lucerne) is the dominant crops, although some farmers have started switching to horticulture (e.g. melons, tomatoes, grapes, beans). Ownership of farm lands is predominately private, while some land is referred to as communal land are under traditional authority, or is owned by the government. In Botswana there is a combination of pastoral, arable and residential land uses. The Kgalagadi Transfrontier Park is solely used for nature preservation and for non-consumptive uses such as recreation, with limited tourism camping facilities.

There are no commercial industrial and mining activities in the STAS area.

4.4. Aquifers and groundwater in the STAS area

4.4.1 Geological setting and main hydrogeological units

From a geological point of view, the STAS area is part of a huge sedimentary basin (Kalahari basin) in which a thick sequence of layers has been deposited. The layers of Carboniferous through Jurassic age are together known as Karoo Supergroup and contain mainly sandstones, shales, mudstones, siltstones and limestone. They are covered by a blanket of sediments of the *Kalahari Group,* of Tertiary-Quaternary age and consisting predominantly of sand, calcrete (duricrust), gravel, clayey gravel, sandstone and marl. Table 4.1 presents a stratigraphic table.

Three main aquifer units have been identified in the area. In the first place the predominantly phreatic local Kalahari aquifers, consisting of discontinuous permeable zones in the Kalahari sediments. Below these Kalahari aquifers and separated from them by an aquitard, can the confined Auob aquifer be found, in turn separated by an aquitard from the deeper confined Nossob Aquifer. Both confined aquifers belong to the Ecca Group and they form together the so-called 'Stampriet Artesian Basin' (see Table 4.1). They are continuous across the international boundaries between Namibia, Botswana and South Africa and form together, overlain by discontinuous phreatic Kalahari aquifers, the Stampriet Transboundary Aquifer System.

The cross-section of Figure 4.5 illustrates the geological setting of the aquifers and aquitards.

Figure 4.5 | SW-NE cross-section through Stampriet, Aminius (Namibia) and Ncojane (Botswana). Aquifers are shown in blue colours and question marks indicate the absence of stratigraphic information

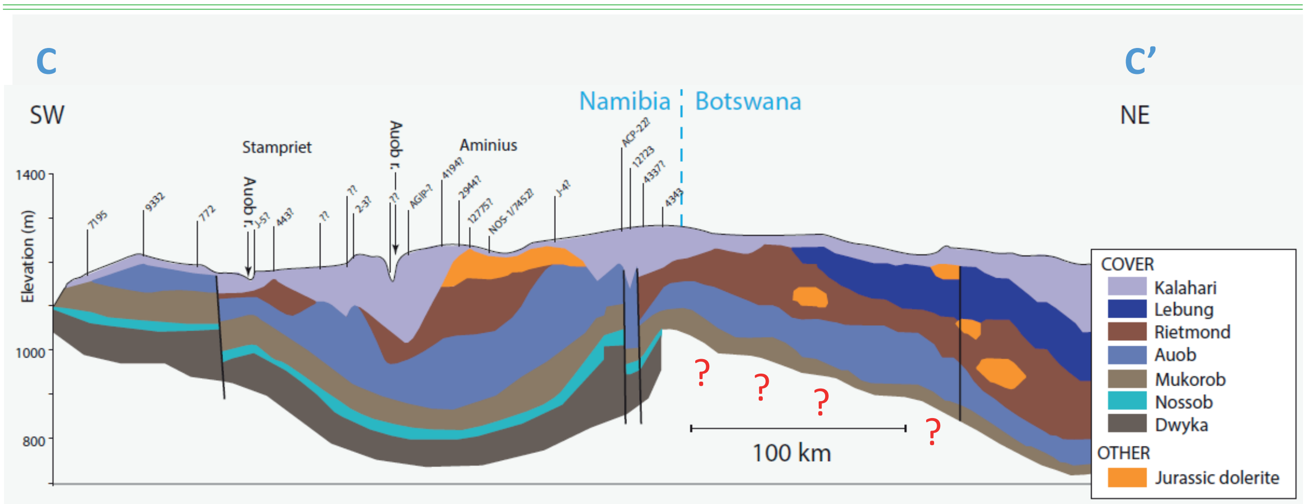


Table 4.1 | Stratigraphy of the Stampriet Transboundary Aquifer System (STAS) and corresponding hydrogeological classification

<table>
<tr><th colspan="8">GEOLOGY</th><th colspan="2">HYDRO-GEOLOGY</th></tr>
<tr><th>Age</th><th>Super group</th><th>Group</th><th colspan="4">Formation/Member</th><th>Lithology</th><th colspan="2"></th></tr>
<tr><td></td><td></td><td></td><td>Botswana (Smith, 1984)</td><td>Namibia (Miller, 2008)</td><td>S. Africa (SACS, 1980)</td><td>This report</td><td>(simplified)</td><td colspan="2">STAS</td></tr>
<tr><td>Tertiary to Quaternary</td><td>Kalahari</td><td>Kalahari</td><td></td><td></td><td></td><td>Kalahari beds</td><td>Sand, silcrete, calcrete (duricrust), gravel, sandstone, marls, clayey gravels</td><td colspan="2">Unsaturated zone
Kalahari aquifers</td></tr>
<tr><td>Jurassic</td><td rowspan="7">Karoo</td><td>Stormberg-lava (B)
Kalkrand (N)
Drakensberg (SA)</td><td></td><td>Neu Loore</td><td></td><td>Kalkrand</td><td>Basalt and dolerite</td><td colspan="2" rowspan="3">Kalahari aquifers</td></tr>
<tr><td>Triassic</td><td>Lebung (B)
Etjo (N)
Clarens (SA)</td><td>Ntane
Mosolotsane</td><td></td><td></td><td>Ntane</td><td>Sandstone</td></tr>
<tr><td rowspan="5">Permian</td><td rowspan="5">Ecca</td><td>Kule</td><td>Whitehill</td><td>Whitehill</td><td>Whitehill</td><td>Shale and limestone</td></tr>
<tr><td>Rietmond</td><td>Rietmond</td><td rowspan="4">Prince Albert</td><td>Rietmond</td><td>Shale and sandstone</td><td colspan="2">Aquitard/ aquiclude</td></tr>
<tr><td>Otshe</td><td>Auob</td><td>Auob</td><td>Sandstone, interbedded with shale and coal horizons</td><td>Auob aquifer</td><td rowspan="3">Stampriet Artesian Basin</td></tr>
<tr><td>Kobe</td><td>Mukorob</td><td>Mukorob</td><td>Shale, mudstone, siltstone</td><td>Aquitard/ aquiclude</td></tr>
<tr><td>Ncojane</td><td>Nossob</td><td>Nossob</td><td>Sandstone</td><td>Nossob aquifer</td></tr>
<tr><td>Carboniferous</td><td>Dwyka</td><td></td><td></td><td></td><td></td><td>Glacial sediments</td><td colspan="2">Aquitard/ aquiclude</td></tr>
<tr><td>Cambrian</td><td>Pre-Karoo</td><td>Nama</td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
</table>

4.4.2 Kalahari aquifers

The Kalahari sediments consist mainly of fine sand, calcrete, silt and clay. They contain phreatic aquifers (free water table), that are easily within reach of the local inhabitants and well-exposed to recharge from rainfall excess, which explains that the Kalahari aquifers are the most intensively used aquifers of the STAS area. Their lateral extent is limited, hence they form discontinuous local aquifers and do not constitute a transboundary aquifer system.

4.4.3 Auob aquifer

The Auob aquifer (in Botswana called 'Otshe aquifer') is a confined aquifer, consisting of up to three sandstone layers separated by shale. It has isolated outcrops in the extreme western part of the STAS area in Namibia, but elsewhere it tends to be deeply buried, locally more than 300 m. The Auob is often called an artesian aquifer because in some zones (of limited size) it has the capacity to feed flowing wells. The thickness of the Auob aquifer varies from 0 to 150 m.

4.4.4 Nossob aquifer

Like the Auob aquifer, the Nossob aquifer is also a confined aquifer with isolated outcrops in the extreme western part of the STAS area in Namibia. It consists of two sandstone units, interbedded with thin mudrock layers and siltstones and underlain by impermeable shales and glacial tillites of the Dwyka Formation. Its thickness is estimated to vary between 0 and 60 m in Namibia and between 0 and 30 m in South Africa, but a large margin of uncertainty characterizes all information on the Nossob aquifer. Due to its greater depth (it is found locally at more than 400 m of depth), the Nossob aquifer has been explored less intensively than the Kalahari and Auob aquifers.

4.4.5 Hydrogeological regime: conceptual model

Rational exploitation and management of aquifers require knowledge of their properties and proper understanding of their behaviour. Conceptually, the physical processes taking place in the STAS are reasonably understood, but quantification is still limited and subject to uncertainty – in spite of many efforts made over a long period of time.

Figure 4.6 | Conceptual model of the STAS – Auob and Nossob transboundary aquifers

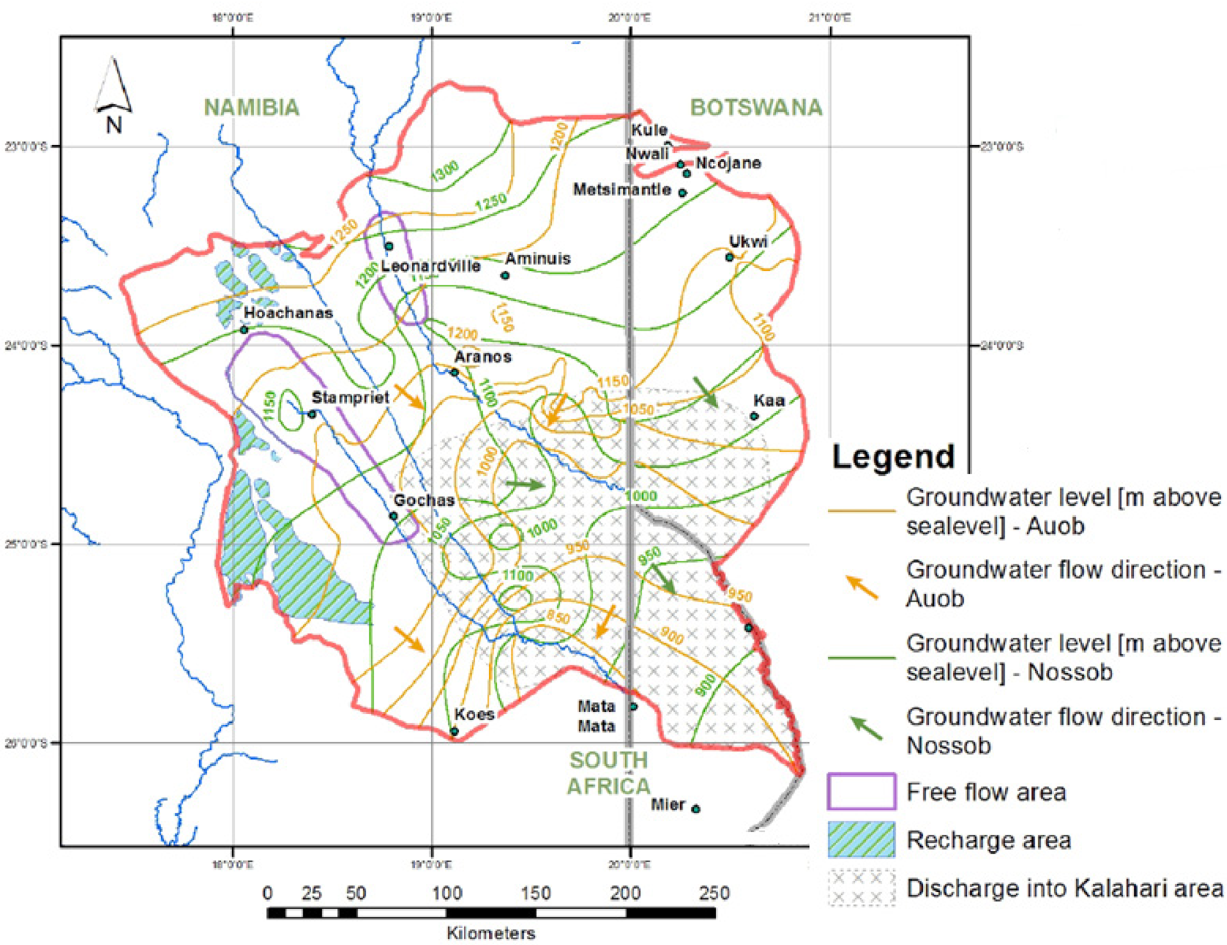


Figure 4.6 presents a conceptual model of the STAS, summarizing how the hydrogeological regime of the Auob and Nossob aquifers currently is understood. Before looking in detail at this figure, it is important to realize that the volume of groundwater stored in the STAS aquifers (Auob and Nossob aquifers) is huge (of the order of one or a few thousands of km^3), while the mean annual recharge, although not yet assessed, is certainly much less than one-thousandth of that volume. The STAS therefore is very close to a non-renewable aquifer system. Nevertheless, the dynamics of the aquifer system is very strongly conditioned by recharge, either contemporaneous or produced long ago. The depicted piezometric surface (based on field observations) shows that the regional groundwater flow direction is from North-West and North to South-East, which suggests recharge zones to be located predominantly in the North-Western and Northern part of the area, and discharge zones in the South-Western part. Indeed, assumed diffuse recharge by downward seepage from the Kalahari aquifers is likely to be strongest in the Northern rainfall-endowed area, and there are some recharge zones in the Western part of the STAS area in Namibia where sinkholes facilitate concentrated recharge during rare wet years. In the South-Eastern quadrant of the area, groundwater is presumed to sweep upward from the confined aquifers and discharges into the Kalahari formations, from where it evaporates. Groundwater salinity in this zone – known under the name Salt Block – therefore is rather high. Man-made discharge from the confined aquifers is by wells; most of them pumped, but free-flowing in a few zones in the Auob and Nossob river valleys due to artesian conditions. Based on hydraulic gradient, it is estimated that it takes groundwater in the Auob aquifer some 30 000 years to travel from North-West to South-East. Outcomes of isotope analysis of groundwater samples is largely confirming the picture described above.

The regionalized piezometric surface for the Kalahari aquifers slopes in NW-SE similar direction. To what extent this is due to lateral hydraulic contact between the local aquifer zones or vertical hydraulic contact with the deeper confined aquifers is not yet known. Provisional estimates of the mean annual recharge of these aquifers range from 0.5% of the rainfall during average years to 3% during very wet years.

Available groundwater time series are not yet sufficient (too short, too few observational sites) to characterize and explain the multiannual variations of the hydrogeological regime.

4.4.6 Regional groundwater quality patterns

Groundwater quality samples of around 1000 boreholes in the area have been analysed in order to define regional groundwater quality patterns. Maps of such patterns have been prepared for the following parameters: total dissolved solids (TDS), nitrate, sulphate and fluoride. Together they show a general regional decline of groundwater quality towards the South African segment and the Southern part of the Botswana segment (i.e. the Salt Block zone) for all three aquifers, but water quality in the Auob aquifer is generally better than in the Kalahari and Nossob aquifers.

Figure 4.7 integrates these maps in terms of suitability for human consumption. This figure highlights that in large parts of the Kalahari and Nossob aquifers groundwater is not fully suitable for drinking water supply, which is in contrast with the Auob aquifer, most water meets the standards. Except for a rather small zone in the salt block, groundwater in the Kalahari aquifers does meet the less strict standards for livestock watering.

4.5. Role and use of groundwater in the STAS area

4.5.1 Groundwater: the area's only permanent and dependable source of water

Given the climatic and other geographic features, there are no permanent rivers in the STAS area. Surface water resources are therefore very limited: the ephemeral Auob and Nossob rivers provide some water during the rainy season, and the surface water pans scattered over the area that collect runoff can supply water for livestock only during a few months after the rains. The only permanent and dependable water resource in the area is groundwater.

4.5.2 Groundwater abstraction and use

Groundwater is withdrawn from the Kalahari, Auob and Nossob aquifers, by means of dug wells and boreholes (Figure 4.8). In total, 6167 boreholes have been inventoried, of which 95% in Namibia, 3% in Botswana and 2% in South Africa. Borehole yields vary considerably in each of the aquifers, from 0.1 to 50 m^3/hr in the Kalahari and Auob aquifers and from 0.1 to 20 m^3/hr in the Nossob aquifer, but it is unknown whether the variation is caused mainly by formation properties or by borehole characteristics.

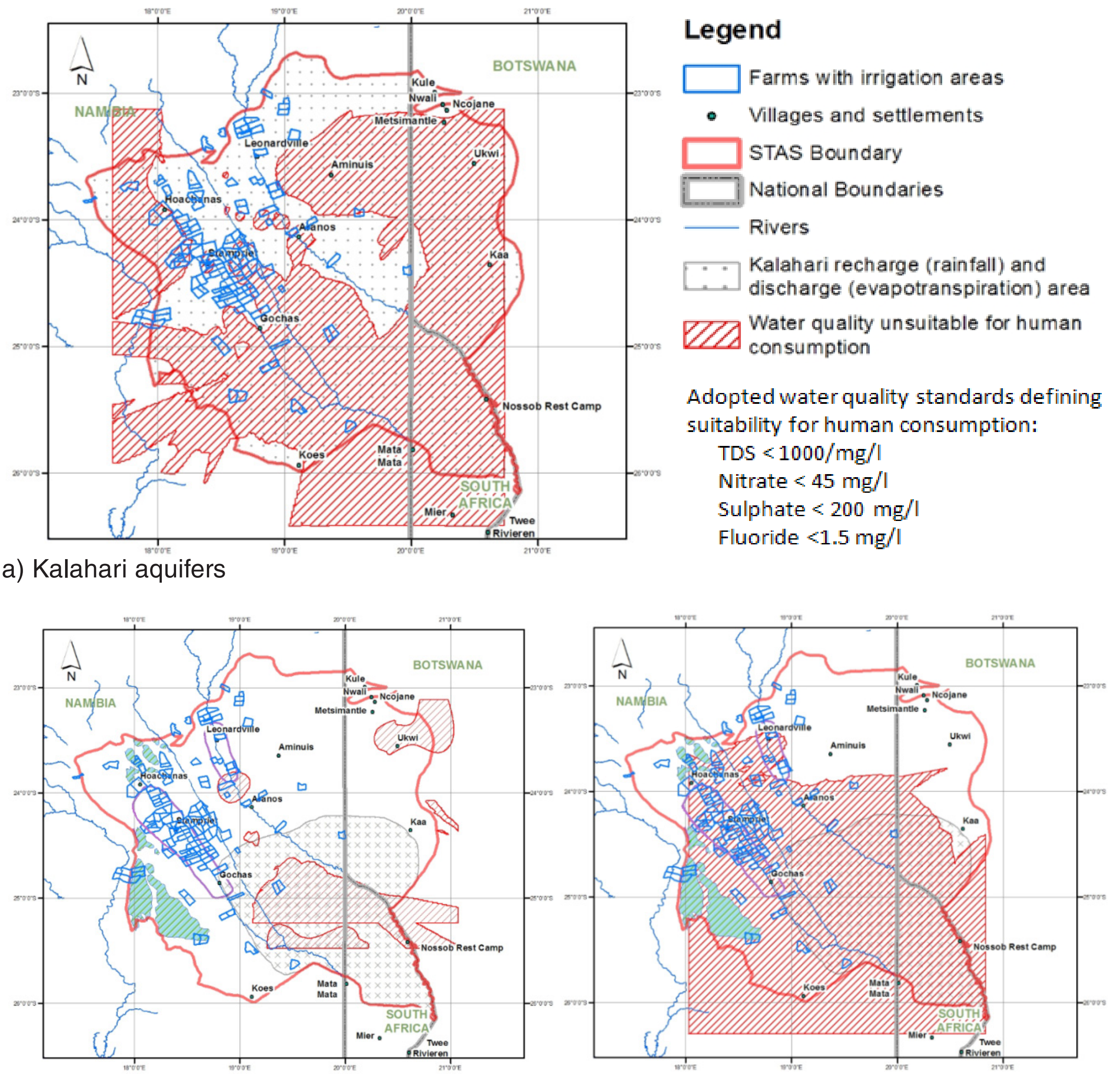
The estimated annual groundwater abstraction in the area was some 14.9 million cubic metres in 2002. It is estimated that in 2015 it was around 20.4 million cubic metres, of which 66% came from Kalahari aquifers, 33% from the Auob Aquifer and 1% from the Nossob aquifer. Groundwater for domestic purposes in the larger settlements in the area is mainly abstracted from the Auob aquifer; Koes is using water from the Nossob aquifer. The breakdown of total groundwater abstraction, according to country and to type of water is, is presented in Table 4.2.

Groundwater abstraction from the Auob aquifer in Botswana is expected to increase by around 30% in the coming years as a result of a water transfer scheme aimed at supplying water to four primary demand centres collectively known as Matsheng Villages and also to other secondary demand centres located in the northern Kgalagadi District and central and southern Ghanzi District.

Table 4.2 | Breakdown of the estimated groundwater abstraction in 2015 in the STAS area (m^3/yr)

	Namibia	South Africa	Botswana	Total area
Domestic water use:	3 000 000	1 600	116 450	3 118 050
Public water supply	770 000	N/A	116 450	886 450
Private (Commercial)	2 000 000	N/A	N/A	2 000 000
Communal	130 000	1 600	N/A	131 600
Irrigation	9 545 000	N/A	N/A	9 545 000
Livestock:	6 022 500	22 700	1 642 500	7 687 700
a) Small	4 380 000	N/A	985 500	5 037 000
b) Large	2 642 500	N/A	657 000	2 628 000
Tourism	4 445	11 200	N/A	15645
Total abstraction	**18 571 945**	**35 800**	**1 758 950**	**20 366 695**

Figure 4.7 | **Regional patterns of zones where groundwater quality does not meet drinking water standards**

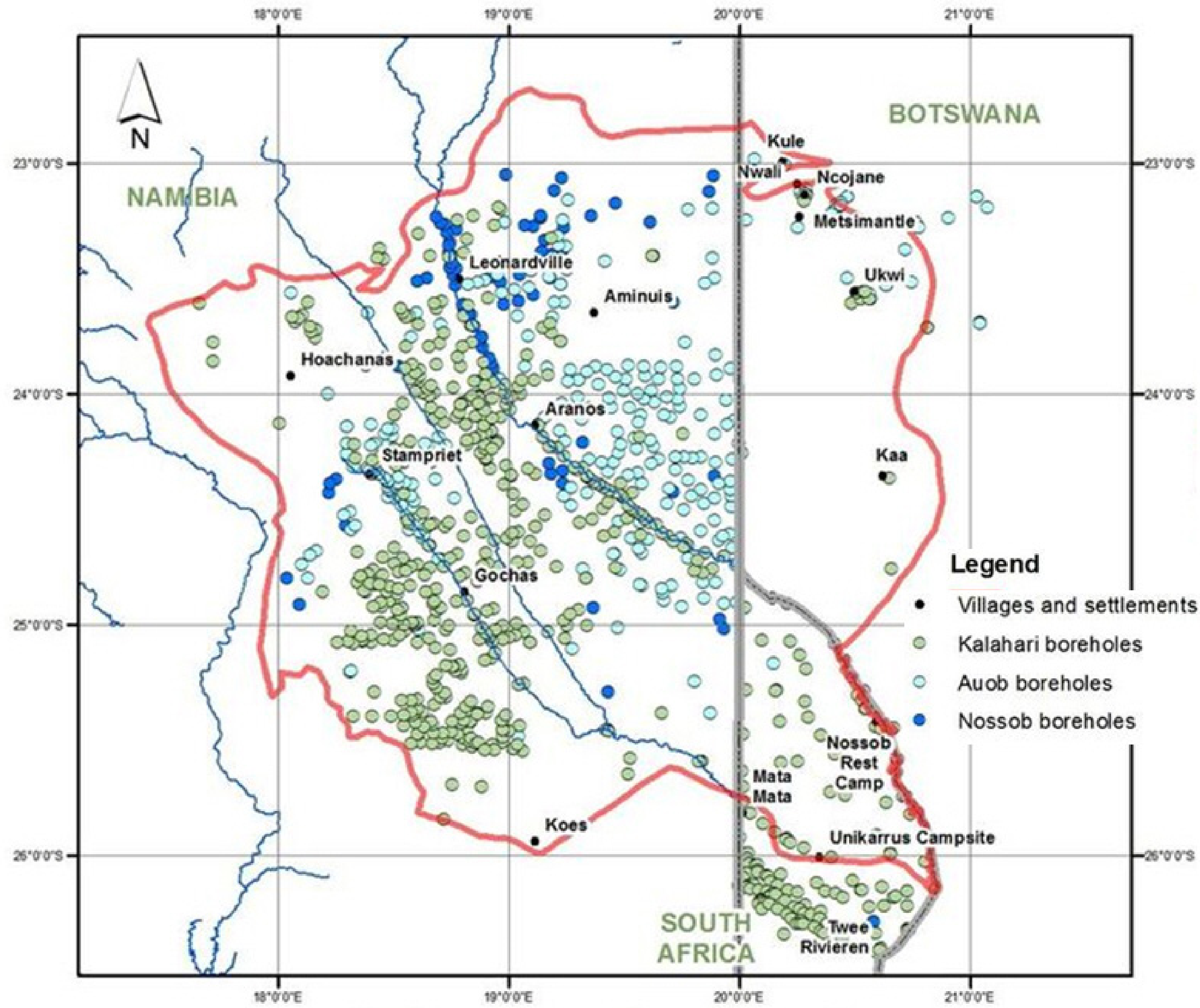


a) Kalahari aquifers

b) Auob aquifer

c) Nossob aquifer

Figure 4.8 | **Patterns of boreholes according to the aquifer tapped (showing only the subset of boreholes for which such information is available)**



4.5.3 Groundwater use for domestic purposes

Groundwater covers virtually all domestic water demands of the area's population (around 50 000 inhabitants). In general, the urban centres and villages receive water for domestic purposes from governmental schemes, parastatals (NamWater in Namibia) and water utilities corporations (WUC in Botswana). Around 90% of the population of the settlements has access to safe drinking water. Households without direct household water connections take water from communal standpipes, generally using a prepaid token system. While most households in the area have access to potable water, the distances travelled by households vary and as such also the burden of collecting water for domestic use. Communal farmers and private land owners get water from the state and from private boreholes, respectively.

Approximately 49% of all municipal water is lost or unaccounted for.

4.5.4 Groundwater use for economic purposes

Livestock and agricultural production are the main economic uses of groundwater in the STAS area. The corresponding activities are almost entirely concentrated in a relatively small number of commercial farms in Namibia that combine livestock (mainly sheep, but also cattle and other animals) and irrigated crop production. Other commercial and communal farms mainly rely on livestock farming in grazing areas in Namibia and Botswana.

Groundwater abstraction for livestock watering is estimated to be some 7.7 million cubic metres per annum: 5.04 million for small stock (1.15 million heads, mainly sheep (80%) and goats (15%)) and 2.63 million for large stock (180 thousand heads, mainly cattle). The annual gross income from sheep, goats and cattle is 197 million, 22 million and 267 million N$, respectively.

For climatic reasons, rain-fed arable farming is marginal and regionally concentrated in the northern communal areas in the Namibian and Botswana segments of the area. Consequently, irrigation prevails on commercial arable farm land. Around 9.5 million cubic metres of groundwater is abstracted annually to irrigate 619 ha of irrigated land in the Namibian segment, where lucerne, vegetables, maize and oats are the main crops and a gross annual income of around 107 million N$ is earned.

Tourism (eco-tourism and business tourism) is concentrated in the Kgalagadi Transfrontier Park (KTP) in Botswana and South Africa, with its territory of 46 000km^2 (10 000km^2 in South Africa and 36 000 km^2 in Botswana) one of the largest conservation areas in the world. It enjoys approximately 40 000 visits a year (more than 30 000 nights). The annual volume of groundwater abstracted to sustain tourism is relatively modest (15.6 thousand cubic metres). Tourism in Namibia is restricted to a few lodges with 10-15 rooms each.

4.6. Threats to sustainable groundwater use in the STAS area

4.6.1 Groundwater quality degradation

Aquifer zones originally containing water of good quality may degrade as a result of human influences. One of the mechanisms consists of man-induced local changes in groundwater flow direction and intensity, which may lead to replacement of good-quality groundwater by poor-quality groundwater, or vice versa. In the STAS area this undoubtedly has happened and may continue to happen by poor borehole construction creating unintended shortcuts between superimposed aquifers.

A more ubiquitous mechanism is pollution by contaminants produced by humans or their activities. The pollution risk for groundwater in each aquifer zone depends on the local aquifer vulnerability to pollution (an intrinsic property of the aquifer and its setting) and the presence of potential pollutants. With regard to vulnerability, it may be concluded that the phreatic Kalahari aquifers are much more vulnerable than the Auob and Nossob aquifers, but considerable variations may be present, for instance due to variations in thickness and lithological composition of the unsaturated zone. The Auob and Nossob aquifers are generally well-protected by confining layers, but these are missing in their outcropping or sub-cropping recharge zones.

Table 4.3 gives an overview of the main pollution sources present in the STAS area. There is evidence that the most critical pollution sources (by volume and by potential impact) are located in Namibia, and that these are in particular related to irrigation, oxidation ponds, septic tanks and the storage/ disposal of oil and fuels. Pollution in the area accumulates over time, thus the water quality in the shallow Kalahari aquifers is likely to degrade progressively near settlements and in the zone where irrigation is concentrated, unless the sources of pollution are removed.

Table 4.3 | Groundwater pollution sources and the estimated intensity of aggregated impacts

	Pollution Source	Rationale for Potential Pollution Source Impact (by STAS area segment)		
		Botswana	South Africa	Namibia
Settlements	Pit Latrines	**Very low:** Although pit latrines are the common form of sanitation, there are only three settlements (population of 3229), with combined population and the water table is generally more than 100 m deep	**Very low:** Given the low population density	**Very low:** Given the low percentage of pit latrines (only 3% of households).
Settlements	Septic Tanks & Effluent Soakaways	**Very low:** Because out of 1254 households, only 13.2% use septic tank flush toilets; there are probably a few septic tanks used in campsites in the park (KTP)	**Very low:** Given the low population density of the area	**Medium:** As there is high use of septic tanks in centres like Aranos Aminuis, Kries, Hoachanas and Leonardville.
Settlements	Sewage Works & Oxidation Ponds	**No Impact:** Because they are non-existent	**No Impact:** Because they are non-existent	**Medium-High:** Because oxidation ponds for effluent are used in all urban centres. Most of them were constructed before new standards were adopted (hence not sealed with the necessary impermeable structures to avoid leakage.
Settlements	Burial Sites	**Very low:** Given the low population density	**Very low:** Given the low population density	**Very low:** Given the low population density
Settlements	Oil/Fuel Storage & Disposal	**Very low:** The intensity of the source relates to storage and disposal of borehole machinery related oils.	**Very low:** There could be some oil or fuel storage & disposal activities in the lodges in KTP.	**Medium:** Storage and disposal of oils or fuels used in service stations, and irrigation/borehole related machinery.
Rural areas	Irrigation (including the use of fertilisers & pesticides)	**No Impact:** Because this type of land use is non-existent.	**No Impact:** Because this type of land use is non-existent.	**Medium-High:** Irrigated agriculture poses the most significant pollution threat to groundwater. However, only 619 ha is under irrigation.
Rural areas	Livestock excreta	**Very low:** Because only a small part of the area is exposed: the northern edge of the STAS area (Ncojane-Ukwi area). The tendency to kraal and water livestock at boreholes and pans enhances the risks.	**No Impact:** Because this type of land use is non-existent	**Very low:** Because only a small part of the area is exposed.

4.6.2 Groundwater depletion

Although available information on groundwater replenishment is limited and based on assumptions rather than on observations, it may be concluded that the Kalahari aquifers are only weakly recharged, while the Auob and Nossob aquifers receive so little recharge that provisionally they can be ranked in the category of aquifers with non-renewable groundwater resources. This means that progressive groundwater depletion (accompanied by steadily declining groundwater levels) is a realistic threat to the STAS area. Infrequent wet years may produce some recovery of the water levels –as observed several times in the area during the last decades–, but on the longer term this might not be sufficient to prevent long-term depletion, in particular when groundwater abstraction intensities in the area increase. The latter is very likely to occur, as the 30% increase of annual groundwater abstraction rate between 2002 and 2015 demonstrates.

Although the expected progressive increase of the water demands in the area is probably the largest factor behind the risk of groundwater depletion, there are other factors that may aggravate the situation. The first one is the loss of water due to leaking boreholes; to be reduced by introducing better well construction techniques and implementing more effective protocols. The second one is the encroachment of water-fed invasive Prosopis tree species along the rivers and gravel plains; stopping the currently 18% increase per annum will save significant quantities of water (50 litres per day is used per tree). The third one is climate change, still a largely unexplored factor. It is expected that climate change will result in an increased climate variability in the area: higher rainfall variability, more frequent droughts and longer duration of dry spells. Indirectly, it may also aggravate water scarcity by increased overall unit water demands.

Although no significant declines of groundwater levels have been reported yet, this does not mean that they are not occurring or are unlikely to occur in the near future. On the contrary, the Stampriet Transboundary Aquifer System is very fragile form the point of view of depletion, thus needs to be carefully protected.

4.7. Stakeholder involvement in water governance, including gender issues

4.7.1 The agricultural sector

Major activities in the STAS area are livestock and agricultural production, depending critically on water and providing an income to farmers and farm labourers of approximately 1200 farms. Three categories of farmers can be distinguished:

- *Established commercial farmers in Namibia:*
  They form the highest-income group, consisting of around 800 farmers, who control approximately 49 900 km^2, which is over 80% of the agriculturally usable land in the STAS area.

- *Emerging commercial farmers in Namibia:*
  Middle-income group, around 140 small-scale farmers (mainly livestock farming), primarily from disadvantaged communities, who acquired control of farms by land reform or the Affirmative Action Loan Scheme[11]; together they control less than 1% of the agriculturally usable land.

- *Communal farmers in Namibia and Botswana:*
  Lowest-income group, consisting of subsistence farmers on communal land, which implies that traditional authorities grant usufruct rights to households for crop production, grazing and access to common pastures; this group uses approximately 15% of all agricultural land.

Around 80% of the established farmers and 35% of the emerging farmers are affiliated with *farmer associations*, under the Namibia Agriculture Union (NAU). Only 25% of the communal farmers is affiliated

11. "The Affirmative Action is a land reform programme launched by the Government of Namibia after independence aimed at assisting communal farmers to acquire commercial farms through subsidised interest rates and loan guarantees".

with farmer associations; their national organization in Namibia is the Namibia National Farmers' Union (NNFU).

4.7.2 Domestic water sector of settlements and communities

Several local entities deal with domestic water supply affairs.

In Namibia there are the *Water Point Committees* that manage and control water provided by the Department of Water Affairs and Forestry (DWAF). Furthermore, Village Councils in some villages – and Regional Councils elsewhere – are responsible for operation and maintenance of the water supply network and public standpipes. In addition, there are elected councillors to advise towns and villages on water and sanitation services; and public hearings are organised to accommodate discussions with the general public on local development, including water. Users of settlements are represented through the Settlement Development Committee.

In Botswana, the *Ghanzi and Kgalagadi Districts Councils* oversee and approve activities of authorities such as the Department of Water Affairs (DWA), Water Utilities Corporation (WUC), Land Board, Department of Environment and Department of Agriculture. In addition, operational tasks related to water supply are carried out by borehole syndicates in the towns (domestic water) and farmers associations (livestock water).

4.7.3 The Kgalagadi Transfrontier Park (KTP)

Groundwater management within the Kgalagadi Transfrontier Park is under the auspices of the Departments of Environment of Botswana and South Africa. Boreholes on the Botswanan side of the park are only for the purpose of attracting animals - tourists must bring their own water supplies. While in South Africa, boreholes are both for animals and tourist facilities. In Botswana, maintenance and monitoring is conducted by park staff and there is little interaction with the Botswana DWA in this regard. On the South African side, the staff conducts weekly water level monitoring and facilities checks, albeit using rudimentary yet affordable equipment. There is a *Joint Management Board* composed of the Departments of Environment of both countries, the Khomani San indigenous community and the Mier municipal authority from South Africa. The committee makes decisions about park operations including issues of water management, although water regulators are not included in the committee.

4.7.4 Gender issues

Some 50.5% of the population in settlements and 40% of that on farms is female. These percentages are not replicated in the role of women in different aspects of daily life. First, while in the settlements 40-50% of the household heads is female, this percentage is only 10-20% on established commercial farms, 25-30% on emerging commercial farms and 20% on communal farms. Land ownership and livestock show similar low percentages related to women. The same tends to be true for decision-making at household level, except for decision-making on water use and monitors –that is where women dominate. In terms of representation in farmers' associations, women only account for less than 20% of affiliates.

There are positive messages with regard to achieving gender equality. First of all, there is evidence that political reforms and legislation have increased women's access to land and livestock in many Namibian communities. The fact that 59% of the elected local councilors for water, sanitation and hygiene consists of women is also encouraging.

4.8. Legal and institutional framework

4.8.1 At the international level

At the global level, there is Resolution 63/124 on the Law of Transboundary Aquifers, adopted by consensus in the 63rd session of the UN General Assembly in 2008. The articles of the Law describe the basic norms of inter-State behaviour in relation to transboundary aquifers.

At the level of the Southern African region, there are two important legal instruments:

- *The revised SADC Protocol on Shared Watercourses*
  Signed by the Governments of Botswana, Namibia and South Africa on 7 August 2000 in Windhoek, this protocol aims at fostering closer cooperation regarding 'shared water courses' (including surface water and groundwater)
- *The ORASECOM Agreement*
  Signed on 3 November 2000 in Windhoek by Botswana, Lesotho, Namibia and South Africa, for establishing the Orange-Senqu River Commission (ORASECOM).

Both at the SADC or STAS level, there are no legal instruments specific to the management of transboundary aquifers.

Relevant institutions at the same regional level are the SADC Water Division and ORASECOM. Their mandates include activities relevant to the STAS: (a) data collection, exchange and monitoring; (b) utilization and allocation of transboundary waters; (c) protection of transboundary waters from pollution; (d) resolution of disputes. Whether these mandates include groundwater without hydraulic connection to any surface watercourse remains an open issue.

From the above, it follows that there is a clear need for a Multi-Country Cooperation Mechanism (MCCM) for the STAS, paving the way for developing STAS-specific rules of inter-State behaviour.

4.8.2 At the level of the individual countries (domestic level)

A domestic policy, legal and institutional framework for groundwater is in place in all three STAS countries. The laws of the three countries regulate abstraction and potential point-source pollution through a permit system. When it comes to non-point source pollution control, other laws step in, typically environmental protection and mining Acts.

The contemporary Namibian (2013) and South African (1998) water laws have dedicated sections on groundwater. So does the Botswana Water Act, which dates back to 1968. Although Namibia has a promising legal and institutional framework, implementing regulations are not yet in place since the promulgation of the Water Resources Management Act in 2013.

From the domestic legal and institutional perspective, it is fair to conclude that the laws in place in the STAS countries are adequate to deal with the challenges ahead of the aquifer. Strengthening domestic capacities in implementation and enforcement is necessary to support cooperation for the management of the STAS.

4.9. Diagnostics

4.9.1 Purpose and approach

The purpose of the diagnostic is to draw conclusions from the information and knowledge collected during the assessment, in order to define focus and priorities for the next steps towards improving groundwater management and governance. This is done by answering three main questions:

- How valuable is the STAS and its groundwater resources?
- Which area-specific issues should be addressed by groundwater resources management plans in order to secure or improve sustainable benefits from this aquifer system?
- To what extent do the current groundwater governance setting and provisions favour adequate management of the groundwater resources?

In addition to conventional methods of analysis, use has been made of indicators (most of them adopted from TWAP), the DPSIR methodology (Drivers, Pressures, State, Impacts, Responses) and the Groundwater Governance project's approach for assessing groundwater governance. The GGRETA indicator scores for the STAS are shown in Appendix 1.

4.9.2 Value of the Stampriet Transboundary Aquifer System

In spite of a relatively modest abstraction in the area (only around 20 million cubic metres annually), groundwater is of vital importance for the area's population and its activities, because it is the only dependable permanent source of water in the area. Ensuring sustainable groundwater use is therefore a priority to keep the area suitable for human life.

Groundwater is abstracted from both the (non-transboundary) Kalahari aquifers and the two transboundary aquifers (Auob and Nossob aquifers). Since the Auob aquifer is the only one of these three aquifers that contains almost everywhere water that meets drinking water quality standards, this aquifer seems to be the most valuable of the three.

4.9.3 Identified groundwater management issues

Identified groundwater management issues are in the first place related to observed threats, as discussed already in section 4.6:

- *Groundwater depletion*
  Basically caused by abstraction rates in excess of the aquifer's coping capacity, so these rates should be controlled (by regulation and demand management) and/or recharge should be protected. The depletion risks are enhanced by leaking wells (inadequate well construction), by encroachment of water-fed vegetation such as Prosopis and by climate change; all of these need management responses.

- *Groundwater quality degradation (pollution, salinization)*
  Degradation can be stopped or delayed by reduction of pollution sources, or by avoiding shortcuts between aquifers or between aquifers and polluting zones at the surface (dug wells, water pans, etc.).

An additional issue is not related to threats to the groundwater resources, but rather to the opportunities offered by groundwater:

- *Making better use of groundwater for improving domestic water supply and sanitation*
  Implementing safe drinking water facilities (based on groundwater) and improved sanitation would serve both public health and sustainability of groundwater resources, provided that adequate provisions are implemented for handling the associated waste and wastewater.

Addressing these issues is mainly a domestic activity, since physical transboundary effects are minimal. A transboundary dimension of addressing these issues could be created by exchanging data, information and technologies among the three countries and by carrying out joint programmes on selected interventions. This certainly has the potential to create synergy.

4.9.4 Groundwater governance and governance provisions

A limited number of components and aspects of governance have been assessed during this project phase:

- *Legal and institutional frameworks*
  At the international level, some useful elements are there (SADC Water Protocol, ORASECOM Agreement and related institutions), but there are no dedicated instruments; therefore, a Multi-Country Cooperation Mechanism (MCCM) should be considered. At the national levels, the legal and institutional frameworks are in place in all three countries, but with some scope for improvement. Implementation has not been assessed but is probably the most challenging component.

- *Data and information management*
  Very significant data and information is available, and the project is substantially contributing to harmonizing the data and bringing them together for the entire STAS in databases and Information Management System (IMS). Nevertheless, there is still considerable uncertainty (e.g. on recharge) and aquifer-wide monitoring of important time-dependent variables (groundwater abstraction, groundwater levels, water quality, pollution sources, etc.) is missing.

- *Gender and other stakeholder issues*
  Gender inequality is still high in the area (low gender sensitivity in government agencies; women's heavy burden in carrying water and exposed to risks of missing toilet facilities; women mainly involved in back-yard gardening; planning and management in agriculture are male dominated, etc.). Promising steps towards gender equality are awareness raising programmes and improvement of water supply and sanitation.

4.10. Building stones for improving groundwater governance

4.10.1 Multi-Country Cooperation Mechanism (MCCM) for transboundary groundwater management

A Multi-Country Cooperation Mechanism (MCCM) would fill a governance gap, as was argued in section 3.7. In addition to what the three STAS countries could do by themselves, the MCCM could produce (a) a STAS vision; (b) consistency of direction and purpose of domestic STAS-relevant action; (c) joint control of the flow of data and information into the IMS.

Provisionally, two alternative models have been developed for the MCCM:

- *Model 1 – Coordinating STAS Committee*

It would consist of a Steering Committee of senior groundwater officials, plus a research institution in each STAS country, providing scientific input to the Steering Committee.

- *Model 2 – Nesting a MCCM for STAS in the ORASECOM structure*

This would entail upgrading the Hydrogeology committee of the Technical Task Team for technical matters to a new dedicated Hydrogeology Task Team, with a priority focus on the STAS.

The first model is more easy to establish, but has the disadvantage of relative impermanence of the committee and dependence on priorities and agendas of the government entity hosting it. The second model offers –among others– economies of scale, but will face competition for resources and subordination to priorities and agendas of third parties.

4.10.2 Information Management System

As mentioned in section 2.1.2, an Information Management System (IMS) has been developed and implemented during this project phase for each of the three pilot areas: Trifinio, Stampriet and Pretashkent. The content of the IMS for the STAS case study is summarized in Table 4.4, and it is the intention that it will continuously be updated and expanded, in order to offer optimal information services to decision-makers and other stakeholders involved in governing the groundwater in the region.

Table 4.4 | Data in GGRETA's IMS for the STAS, as per January 2016

	Data in IMS		Coverage			
			STAS area	Kalahari aquifers	Auob aquifer	Nossob aquifer
1	**General area-wide data**					
	1.1	STAS Boundary	X			
	1.2	District boundaries	X			
	1.3	Villages and settlements	X			
	1.4	Population [Number of inhabitants]	X			
	1.5	Location of all the boreholes	X			
	1.6	Completion date of boreholes	X			
	1.7	Land use	X			
	1.8	Land use - Farms	X			
	1.9	Land use - Irrigated farms	X			
	1.10	Surface elevation [m. above sea level]	X			
	1.11	Rivers	X			
	1.12	Rainfall - mean annual [mm/yr]	X			
	1.13	Temperature - mean annual [°C]	X			
	1.14	Temperature - mean annual minimum [°C]	X			
	1.15	Temperature - mean annual maximum[°C]	X			
2	**Data on aquifers and groundwater**					
	2.1	Location of boreholes		X	X	X
	2.2	Free flowing wells area			X	X
	2.3	Recharge and discharge areas		X		
	2.4	Recharge area			X	X
	2.5	Discharge area			X	X
	2.6	Groundwater level [m above sea level]		X	X	X
	2.7	Borehole yield [m3/h]		X	X	X
	2.8	Water strike [m above sea level]		X	X	
	2.9	Total dissolved solid [mg/l] - boreholes		X	X	X
	2.10	Total dissolved solids [mg/l]		X	X	X
	2.11	Nitrate [mg/l] - boreholes		X	X	X
	2.12	Nitrate [mg/l]		X	X	X
	2.13	Fluoride [mg/l] - boreholes		X	X	X
	2.14	Fluoride [mg/l]		X	X	X
	2.15	Sulphate [mg/l] - boreholes		X	X	X
	2.16	Sulphate [mg/l]		X	X	X
	2.17	Water quality unsuitable for human consumption		X	X	X
	2.18	Water quality unsuitable for stock watering		X		X

Part 3.
Pretashkent

5. The Pretashkent Transboundary Aquifer (PTBA) pilot project

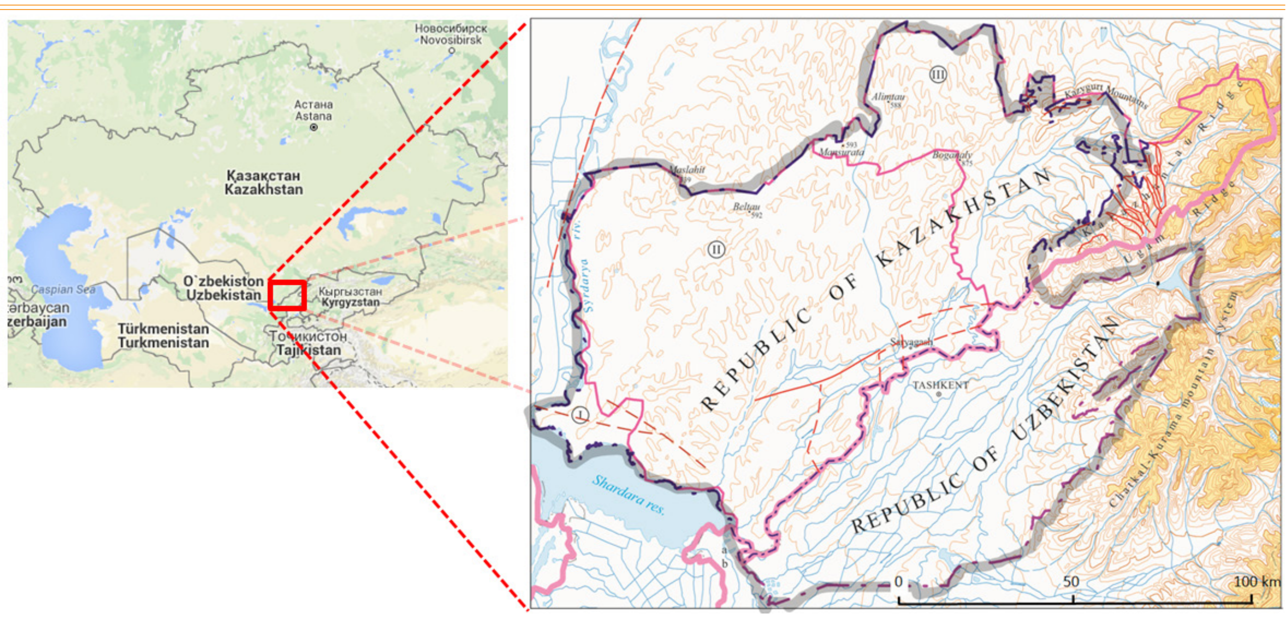
5.1. Organization and implementation of the pilot project

Although the Pretashkent Transboundary Aquifer (abbreviated as PTBA) covers parts of both Kazakhstan and Uzbekistan, in this stage a multidisciplinary assessment has been conducted only for the Kazakhstani segment. Therefore, this pilot study –a synthesis and interpretation of existing information – was carried out by a team of Kazahkstani scientists and technical specialists only and, apart from a few contextual features, it does not describe the Uzbekistani part of the Pretashkent Aquifer, but merely addresses the Kazakhstani part.

5.2. Location and delineation of the transboundary aquifer

The Pretashkent Transboundary Aquifer is located at considerable depth under a relatively flat area of piedmont and alluvial plains bordered by the Shardara reservoir and Syrdarya river in the south and West, and by spurs of the Tian Shian and Chatkal-Kurama mountain systems to the North-East and East. This area includes three administrative districts of southern Kazakhstan and thirteen districts in the adjoining part of Uzbekistan (including the capital Tashkent). The aquifer delineation, shown in Figure 5.1, is based on geological formation boundaries and the location of the aquifer's main discharge zone.

Figure 5.1 | Location and delineation of the Pretashkent Transboundary Aquifer



5.3. General features of the PTBA area

5.3.1 Topography and landscapes

The area underlain by the Pretashkent Transboundary Aquifer (PTBA area), shown in Figure 5.1, measures approximately 17 000 km^2, of which 10 840 km^2 is located in Kazakhstan. The elevation of the area ranges from 214 m above mean sea level at its Western border to slightly over 1000 m in the East. The Eastward bordering mountain ridges, outside the PTBA area, rise to more than 3600 m. Figure 5.2 shows the topography of the area (Kazakhstan segment only).

Correspondingly, there is a diversity of landscapes inside or bordering the area, including – from East to West – mountain ranges, gently sloping piedmont plains, sand dune areas and alluvial plains along the Syrdarya river (Figure 5.3).

Figure 5.2 | **Elevation map of the PTBA area (500-m intervals)**

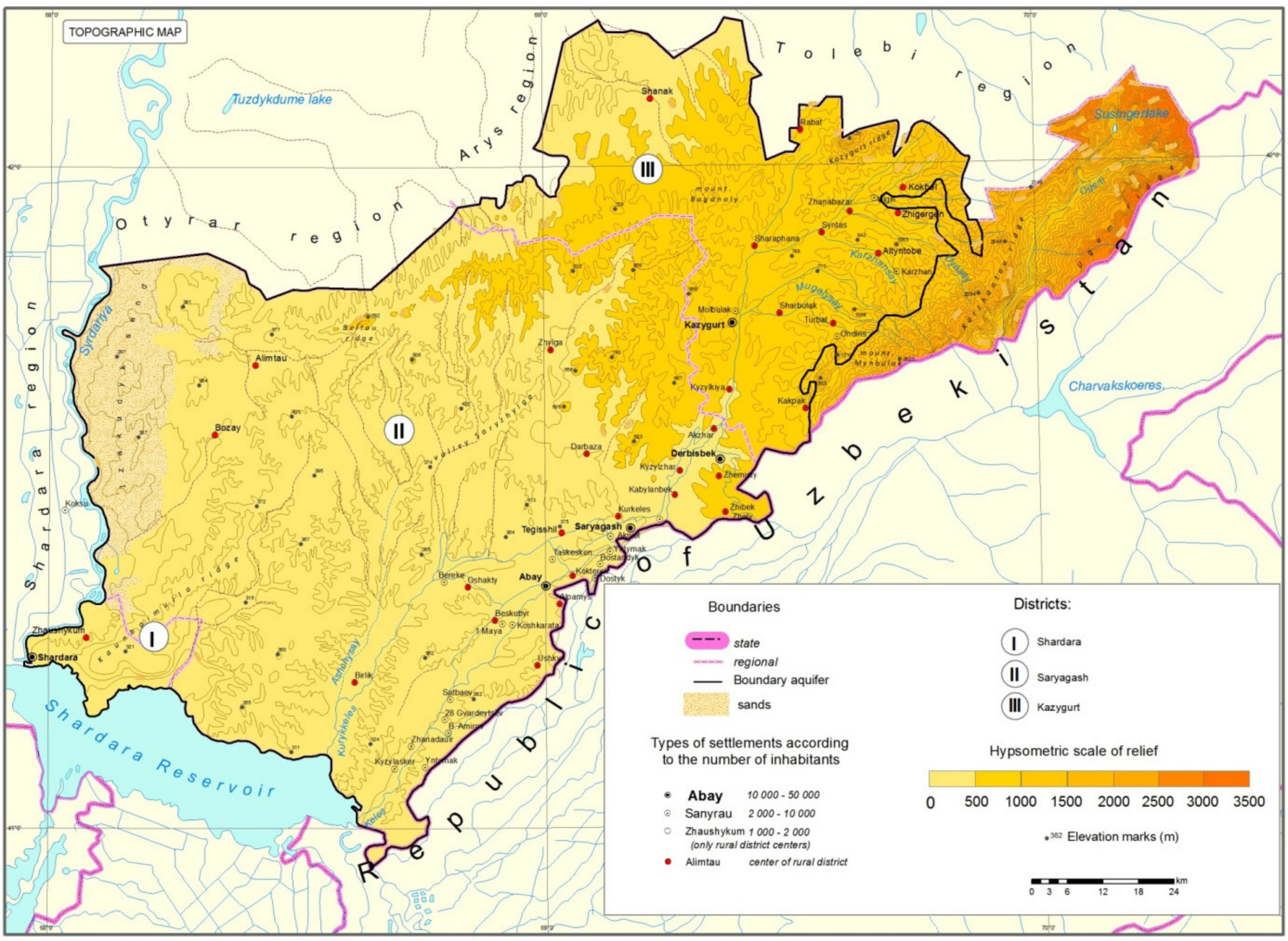
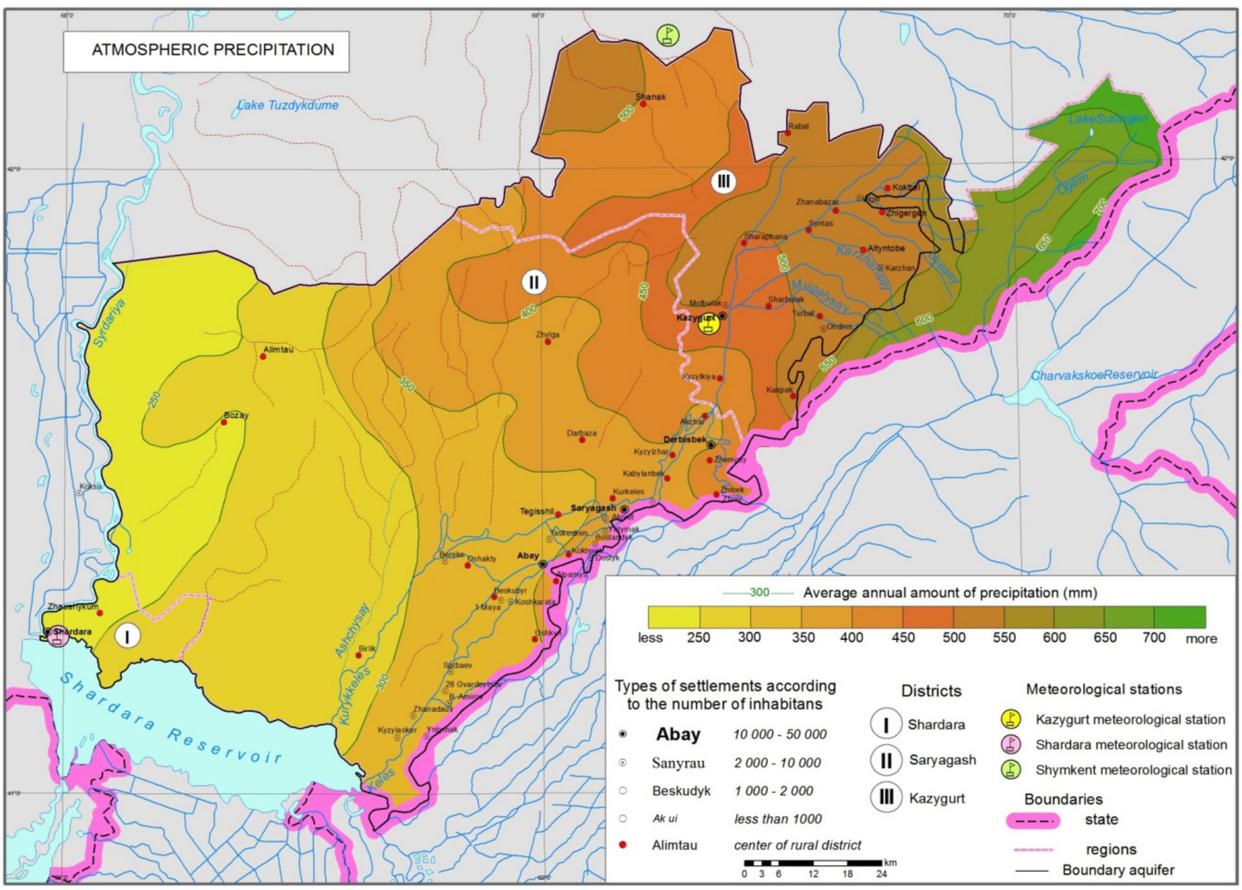


Figure 5.3 | Landscapes in the area of the Pretashkent Transboundary Aquifer

Figure 5.4 | Long-term mean annual precipitaion in the PTBA area (100-mm intervals)



5.3.2 Climate

The area has a continental dry climate, with hot summers (mean July temperature 25 to 30°C) and a relatively warm winter (mean January temperature -4 to 0°C). Precipitation falls mainly during the period November-May – during winter mostly in solid form, during other seasons in the form of rains. Precipitation varies from year to year: between 200 and 350 mm/year in the South-Western plain zone (Shardara) and between 350 and 650 mm/year on the piedmont plain (Kazygurt), but reaches substantially higher values at the Eastern border. Long-term mean annual precipitation is shown in Figure 5.4. The area's climate is characterised by a precipitation deficit during summer.

5.3.3 Hydrography and wetlands

The hydrographic network in the Kazakhstani segment of the PTBA area includes:

- **Syrdarya river:** longest river in Central Asia, fed mainly by snowmelt; flows along Western border of the PTBA area; long-term mean runoff at the outlet of Shardara reservoir is 37 km^3/year; salinity range: 0.7–2.5 g/l
- **Keles river and tributaries:** fed mainly by snowmelt; flows close to the boundary with Uzbekistan; long-term mean runoff is 0.96 km^3/year; salinity range: 0.3–0.5 g/l
- **Aschyssay and Kurykkeles ephemeral streams:** running more or less parallel to Keles river
- **Shardara reservoir:** wet area of 900 km^2 and average width of 20 km; recharged from September to April; water level decreases during summer by 6 to 10 m due to water withdrawal for irrigation
- **Keles irrigation canal:** transboundary canal (constructed in 1986), tapping Chirchik river in Uzbekistan; flow rate decreases from 35 m^3/s in upper part (Uzbekistan) to 8 m^3/s in Saryagash district (Kazakhstan)

The river water resources are used for irrigation and watering pastures.

Shallow water tables (< 3 m deep) are widespread along the rivers and the shores of Shardara reservoir. The Shardara reservoir in the territory of the PTBA is included in the list of wetlands of national significance. The zone hosts the largest population of wintering swimming birds in Kazakhstan, consisting of many species, among which endangered species.

5.3.4 Demography and administrative units

Around 92% of the population of 5.5 million in the PTBA area lives in Uzbekistan, thus the population density in the Uzbekistani sector (which includes the Tashkent capital territory) is more than one order of magnitude higher than in the Kazakhstani sector. This difference in population density is reflected in the dominant categories of economic activities at both sides of the international boundary: mainly agriculture and food industries in the Kazakhstani sector, versus engineering, chemical industries, metallurgy and agriculture in the Uzbekistani sector.

Population in the Kazakhstani segment of the PTBA area has increased between 1990 and 2014 from 303 500 to 463 400 (mean annual growth rate of 1.8%) and the highest population densities are found in a broad belt along the rivers in the boundary zone with Uzbekistan. The Kazakhstan segment includes three administrative districts: the Saryagash district (N and NE), the Kazygurt district and a small part of Shardara district (W); these are, in turn, subdivided into 41 rural districts with 234 rural settlements. There are three towns of more than 10 000 inhabitants: Shardara, Kazygurt and Saryagash.

5.3.5 Land use

Agriculture is the predominant form of land use in the Kazakhstani segment of the PTBA area. There are 1 002 700 ha of agricultural land within the area (92.5% of the area). The break-down is as follows: pastures 76.9%, irrigated and non-irrigated arable land 19.0%, hayfields 3.1%, perennial crops 0.6% and fallow land 0.4%. In 1960, there was still substantially less agricultural land: only 655 900 ha. During the period 1960-1985 there was a marked increase in pasture and arable land, afterwards the area of pastures has increased slightly, while the area of arable land and of hayfields decreased by approximately the same number of hectares. Soil degradation and lack of irrigation water were the reason of the decrease of arable land.

The main agricultural crops of the area are wheat (47%), potato, feed crops, vegetables and gourds. There are also productive vineyards, but their area is drastically decreasing.

5.4. The Pretashkent Aquifer

5.4.1 Geological setting

The Pretashkent Aquifer forms part of a depressed geological structure – the Mesozoic-Cainozoic Pretashkent depression – where a more than 2000 m thick sequence of sediments has accumulated during the last 140 million years. The Mesozoic-Cainozoic sediments in this depression – sandstones, sands, conglomerates, gritstones, gravels, boulders, silts, clays, argillites and limestones – are arranged in sub-horizontal layers (slightly tilted and folded) that produce an alternation of permeable layers (aquifer beds) and layers that offer resistance to groundwater flow (aquitards). The stratigraphic sequence is shown in Table 5.1 and the Figures 5.5 and 5.6 illustrate the geometry of the formations.

5.4.2 Aquifers and aquitards

Table 5.1 shows the main hydrogeological units in the area. The upper aquifer beds (of which the uppermost one has a free water-table) tend to be fragmented and several of them contain brackish water. The Upper-Cretaceous Cenomanian Aquifer Complex, in the lower part of the sedimentary sequence, however, is continuous over the region and transboundary, and is called the *Pretashkent Transboundary Aquifer (PTBA)*. It is the most important aquifer in the area, contains fresh water and it is in artesian conditions, characterised by flowing wells. Although the PTBA is located at great depth (mean depth 1064 m), there is substantial information available on its hydrogeological and hydraulic properties.

5.4.3 The Pretashkent Transboundary Aquifer

The northern boundary of the PTBA runs along the Palaeozoic high that runs from Kazygurt mountain to Syrdarya river; at the South, Southeast and East it is rimmed by the Chatkal-Kurama mountain system (Uzbekistan) and the Karzhantou ridge (Kazakhstan); while the Western boundary is defined by the Ordabasskiy tectonic fault that runs along the modern riverbed of the Syrdarya.

Table 5.1 | Main hydrogeological units in the PTBA area

Age			Name	Symbol	Lithology and Thickness	Comments and hydrogeological characterization
Cainozoic	Quaternary		Upper-Quaternary-Modern alluvial aquifer	aQ_{III-IV}	Boulders, pebble gravel, sand interbedded with loam. Thickness 1.5-20 to 40-60 m.	Widespread in the Pretashkent TBA territory. Non-artesian. Its fresh and brackish groundwater used for drinking and agricultural water supply and watering pastures.
Cainozoic	Quaternary		Middle-Quaternary alluvial-proluvial aquifer	apQ_{II}	Pebble gravel, sands, loam. Thickness: 5-42 m	Non-artesian. Ground water mineralisation is 0.6-13.7 g/l. Fresh and brackish waters are used for agricultural water supply and watering pastures
Cainozoic	Tertiary		Miocene local aquifer	N_1	Sands, sandstone, gritstone and conglomerates in clay mass. Thickness: 10-45 m	Locally present. Weakly artesian. Groundwater mineralisation is 0.6-59.7 g/l. Fresh and brackish waters are used for agricultural water supply and for watering pastures. It is a local aquitard in most of the area.
Cainozoic	Tertiary		Middle-Eocene aquifer	$P_2 2$	Fine and medium sands and poorly consolidated sandstones. Thickness: 13.5-75 m	Weakly artesian. Groundwater mineralisation is 0.6-2.8 g/l. Used for utility and drinking water supply for a group of villages, for agricultural water supply and for watering pastures.
Cainozoic	Tertiary		Paleocene local aquifer	P_1	Fractured limestone bedded as interlayers in clay	Locally present. Groundwater mineralisation is 2.3-11.0 g/l. Brackish waters, used for watering of pastures.
Mesozoic	Cretaceous	Upper	Turonian-Senonian aquifer complex	K_2t_2+sn	Sands and sandstone interbedded with clay and silts, 135-561 m thick	Artesian. Groundwater mineralisation is 5.2-7.5 g/l. Low water productivity. Brackish groundwater, used for watering pastures.
Mesozoic	Cretaceous	Upper	Lower-Turonian aquitard	K_2t_1	Clays with thin local sandstone layers and lenses, up to 140 m thick	Regional aquitard
Mesozoic	Cretaceous	Upper	Cenomanian aquifer complex	K_2s	Sandstone, sand, gritstone, conglo¬me-rates, clays, argillite, limestone	Pretashkent Transboundary Tquifer (PTBA). Artesian, except in and near its outcrops.
Mesozoic	Cretaceous	Lower	Lower-Cretaceous Albian aquifer complex	K_1al	Badly graded sand, poorly consoli¬dated sandstones and gritstones	Highly artesian. Lies at the depth of 548-2,000 m. Groundwater mineralisation is from 0.5-2.2 g/l.
Mesozoic	Cretaceous	Lower	Neocomian-Aptian aquifer complex	K_1ne+a	Sandstone, sand, rarely conglomera¬tes and gritstone in clay/silt mass	Highly artesian. Widespread in the part of the territory at the depth of 627-1516 m. Groundwater mineralisation: 5.0-14.6 g/l.
Palaeozoic			Fractured Palaeozoic aquifer	PZ	Fractured sedimentary and magmatic rocks	Studied on the basis of some wells in Uzbekistan.

The average depth to the top of the aquifer is 1064 m, but the depth varies considerably in the area: from zero in the outcrop zones to 1900 m in synclinal troughs. The gross thickness of the Cenomanian aquifer complex is on average 179 m, which corresponds with a mean effective aquifer thickness of 90 m. The aquifer's transmissivity is rather low: between 5 and 35 m^2/day, with highest values in the central zone. The aquifer is confined in almost its entire area and hydraulically well isolated from overlying aquifers. A map of the piezometric surface dating from 1987, with piezometric levels from almost 1000 m to a little below 250 m above sea level, shows an East-West groundwater flow, from Kazygurt mountain foothill area towards the Syrdarya river valley.

Mineralisation of groundwater observed in the PTBA varies from 0.4 to 1.7 mg/l; the predominant water type is sodium bicarbonate water. Both the TDS and the mineral composition are stable over time, which is to be expected in this type of aquifer. The Western one-third of the area and a smaller Northern zone contain water with TDS exceeding 1.0 g/l, which is locally the limit for drinking water. The 37 operational wells in the Kazakhstani segment of the PTBA abstracted during 2013 a total of 4.18 million cubic metres (equivalent to 132.4 l/s), most of it for utility and drinking water supply for settlements.

Figure 5.5 | **Hydrogeological map (outcropping formations)**

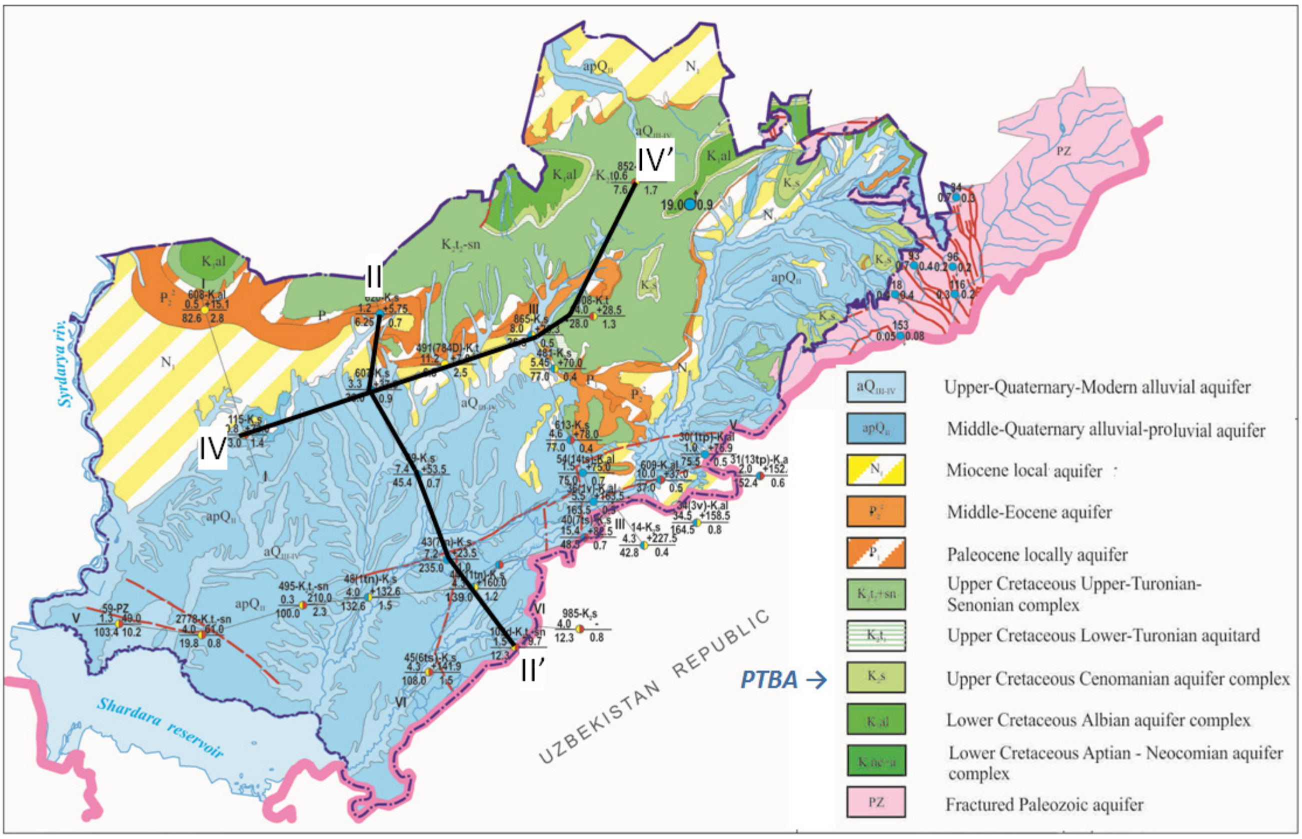


Figure 5.6 | **Cross-sections**

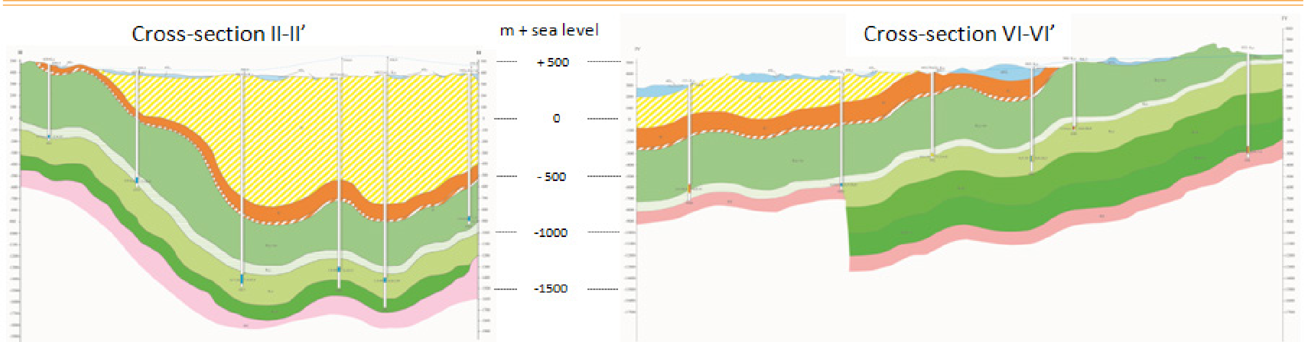
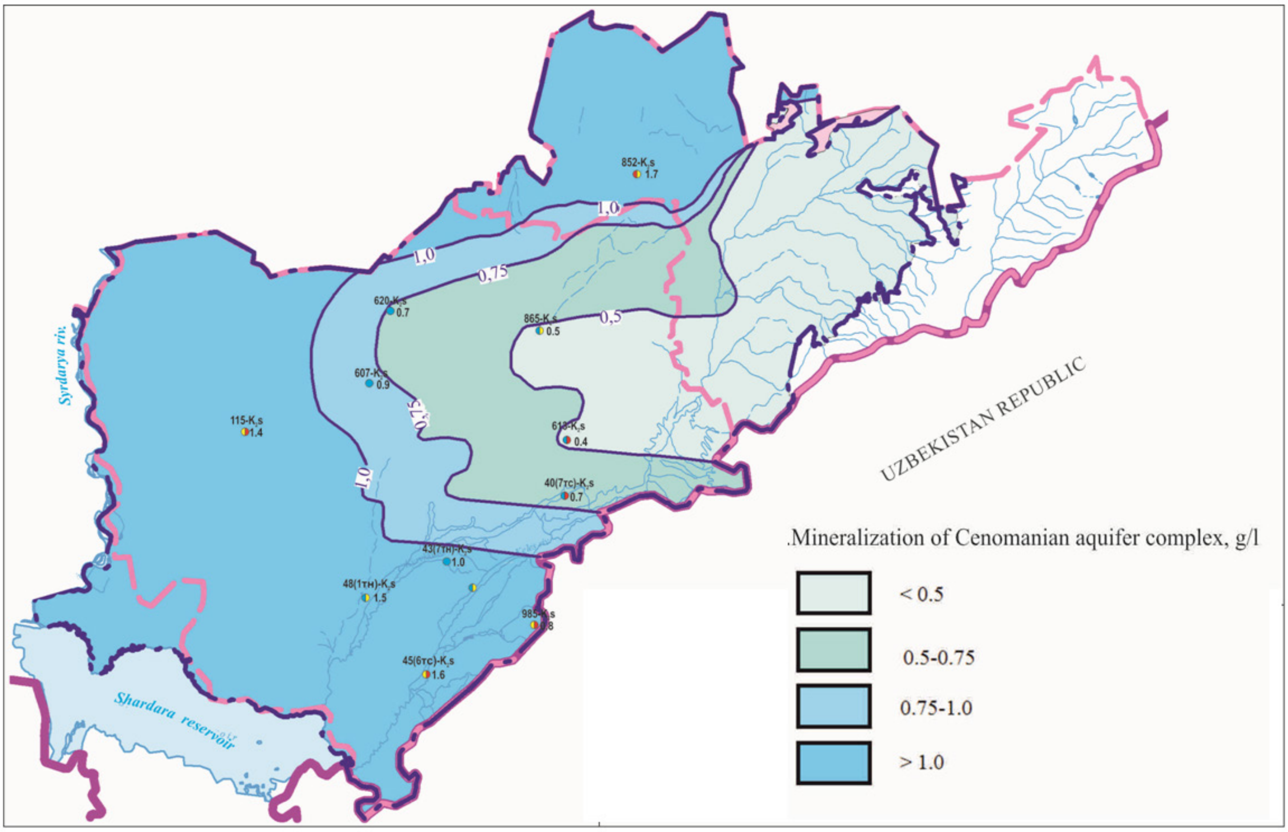


Figure 5.7 | **Total dissolved solids (TDS) of groundwater in the Pretashkent Transboundary Aquifer**



5.4.4 Hydrogeological regime: conceptual model

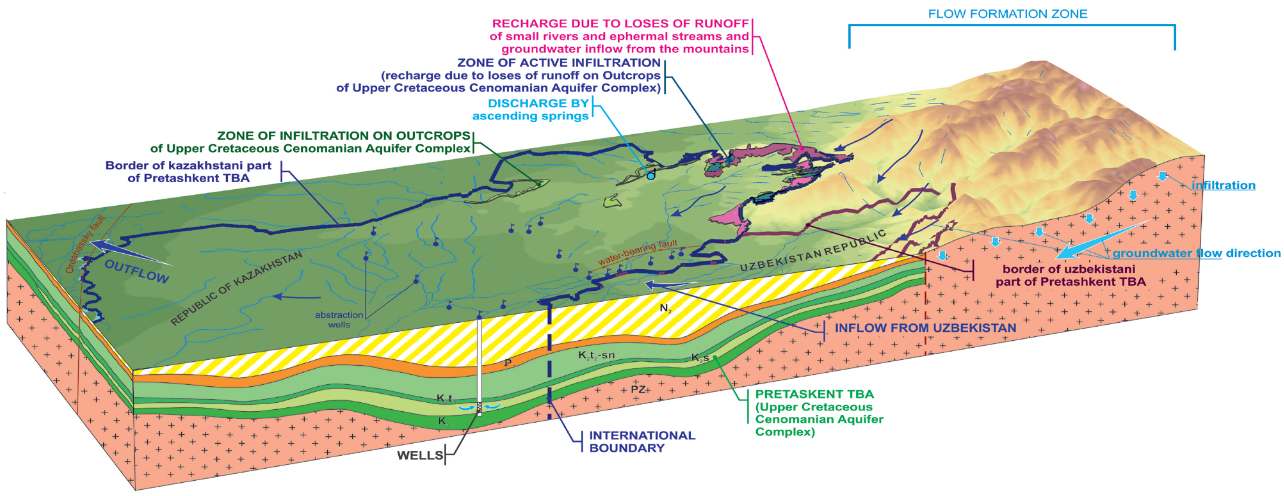
The hydrogeological regime of the Pretashkent Transboundary Aquifer is conceptually illustrated in the three-dimensional diagram shown in Figure 5.8. The information presented below is limited to the Kazakhstani segment of the PTBA only.

On the basis of field studies conducted during 1981-1982 the following types of recharge zones can be distinguished:

- Outcrops of the Upper-Cretaceous Cenomanian aquifer complex mainly recharged by infiltrating rainfall.
- Outcrops of the Upper-Cretaceous Cenomanian aquifer complex mainly recharged by losses of runoff from small rivers and ephemeral streams.
- Zones where losses of runoff from small rivers and ephemeral streams infiltrate into overlying sediments and/or where groundwater inflow from the mountains reaches these sediments, from where water seeps downward and recharges the underlying Upper-Cretaceous Cenomanian aquifer complex indirectly.
- Zones where recharge is produced by water moving along a tectonic fault.

Most the recharge takes place in outcrops bordering the mountain zone of Palaeozoic rocks, which is the main zone of flow generation. The long-term average recharge is estimated to be 1.59 million cubic metres per year (equivalent to 50.4 l/s).

Figure 5.8 | Conceptual model of the Pretashkent Transboundary Aquifer



The mean regional hydraulic gradient is less than 0.001, on the basis of which the mean velocity of water particles in the aquifer is in the order of a few metres per year. Consequently, the travel time of groundwater from the recharge zones to the Western boundary of the area is in the order of tens of thousands of years. The age of groundwater pumped by Saryagash Spa wells – 6000 years, according to isotope analysis – confirms such low flow velocities.

Discharge from the PTBA is by subsurface outflow at the Western boundary of the area into an adjacent sedimentary basin (at a rate approximately equal to that of mean recharge) and by anthropogenic discharge, i.e. groundwater abstraction. Observations during the period 1981–2010 have shown that pumping from the 37 production wells (at an average annual rate of 3.94 million cubic metres) is accompanied by a significant progressive decline of the groundwater levels: on average 0.83 m per year. Obviously, the poorly recharged aquifer behaves as an aquifer with non-renewable groundwater. The total volume of groundwater stored in the PTBA (Kazakhstan segment) is 97.6 km^3, which seems at first glance large enough to sustain the current groundwater abstraction for thousands of year. However, not the stored volume of groundwater will define the aquifer's exploitable resources, but rather the rapidly increasing exploitation cost and technical problems as a result of groundwater level declines, including the risk of inducing hydraulic contact with overlying aquifers that contain water of poor quality.

5.5. Role and uses of water in the area (Kazakhstani segment)

5.5.1 Water use and the share groundwater

As outlined in section 5.3.3, there are very significant surface water sources in the area, in terms of fluxes dwarfing the groundwater resources of the area. The most prominent surface water system components are the Syrdarya river, the Shardara reservoir, the Keles river and the Keles irrigation canal. In spite of their very large total discharge, their resources tend to become scarce in the dry season, during periods of highest water demands.

Groundwater, on the contrary, remains available throughout the year and fresh groundwater is in many cases also preferred because of better quality. Therefore, the relative importance can not only be judged on the basis of fluxes and quantities abstracted. Groundwater is not only abstracted from the PTBA, but also from other aquifers, most of which superimposed above it. Groundwater is fresh in some of these formations, but in others it is brackish. Shallow groundwater tables (less than 3 m deep) are found mainly near the rivers and along the Shardara reservoir.

Table 5.2 summarizes water use during the year 2013, subdivided according to category of water use and to sources of water (surface water or groundwater).

Table 5.2 | Water withdrawal in 2013 in the Kazakhstani segment of the PTBA area (in million m^3/year)

Category of use	Surface water	Groundwater	Total
Utility and drinking water	0.360	4.629	4.989
Bottling	–	0.265	0.265
Industrial water	0.032	–	0.032
Agriculture	488.692	21.345	510.037
TOTAL	**489.084**	**26.239**	**515.323**

Almost 99% of all water withdrawn is for agriculture (mainly for irrigation) and most of the remaining 1% is for domestic and public water supply. Bottling and other industrial uses account for less than 0.06%. Representing only 5.1% of all water withdrawn, groundwater seems at first glance an insignificant source of water, but this is not the case, since only groundwater meets drinking water quality standards. Therefore, the population depends for drinking water almost entirely on groundwater. Most groundwater used for domestic purposes (90%) and all water used for bottling comes from the PTBA, while groundwater used for agricultural purposes is withdrawn from overlying non-transboundary aquifers. Abstraction from the PTBA represents 16% of all groundwater abstracted.

Water demands and water use are likely to increase in the future, in response to population growth (mean annual growth rate was 2.6% over the period 2005–2014), to economic development (although the area of arable lands tends to decrease) and perhaps also to climate change.

5.5.2 Benefits of the PTBA's groundwater for the area

Since 90% of the population depends on it, groundwater of the PTBA is of paramount importance for the drinking water supply of the area. Furthermore, it offers special opportunities for enhancing the region's economy and welfare by:

- Expanding the health resort treatment network (sanatoria and new facilities, traffic network and other infrastructure), leading to increased employment of the population;
- Development of the food and beverage industry, resulting in increased production of Saryagash bottled mineral water;
- Higher attractiveness of the region for investments in construction and for development of travel and hotel business.

5.5.3 Stakeholders: perceptions and aspirations

Stakeholders in the harmonized development of the PTBA are the administrative and management entities of Saryagash, Kazygurt and Shardara administrative districts, including the heads of industrial enterprises engaged in food production, small and medium business, hydrogeological enterprises, and public environmental organisations. They should be concerned about threats to sustainable use of the PTBA's groundwater resources and implement measures such as expanding the monitoring networks, elaborating programmes for the region's sustainable development and designing methods for managing the aquifer's resources (in a joint program of Kazakhstan and Uzbekistan).

5.5.4 Gender issues (entire PTBA area)

Selected indicators on gender aspects for both the Kazakhstani and Uzbekistani segments of the PTBA area are shown in Table 5.3.

The share of females in the total population is slightly more than 50% in both national PTBA area segments. This share is still a little less than 50% at birth, but the share of women increases at more advanced ages, with the result that women are predominant in the population above the age of 60 years (62% and 60% in Kazakhstani and Uzbekistani segments, respectively). The substantially better life expectance of women is to them not only advantageous.

For a number of aspects, gender equality clearly has not yet been achieved. For instance, women's share in economic activities is only around 44% in both segments, female unemployment rate is substantially higher than male unemployment rate, and there is still a big gap in both countries between the average women's salary and that of men. With regard to women's representation in water governing bodies, the percentage is lower and accounts approximately 20%.

Achieving gender equity is government policy in both Kazakhstan and Uzbekistan. Comparison of statistics for 2005, 2010 and 2014 reveals positive trends for both life expectancy and for the indicators of women's share in economic activities and remuneration.

Table 5.3 | Some indicators on gender aspects in the PTBA area, as per 2014

Indicator	Kazakhstani segment			Uzbekistani segment		
	Total	Female	Male	Total	Female	Male
Population (x 1000)	**463. 4**	50.1%	49.9%	**5078.8**	50.7%	49.3%
Annual natural population growth	**2.56%**	—	—	**1.94%**	—	—
Shares in population growth	—	49.8%	50.2%	—	49.6%	50.4%
Life expectance at birth (years)	**67.5**	72.0	63.0	**73.5**	75.8	71.1
Population over 60 years of age	**6.8%**	—	—	**7.0%**	—	—
Shares in population over 60 years	—	62.1%	37.9%	—	60.1%	39.9%
Economic activity level (workforce)	**45.2%**	—	—	**49.3%**	—	—
Shares in economic activity	—	43.8%	56.2%	—	44.6%	55.4%
Unemployment rate	**6.4%**	7.9%	5.3%	**6.8%**	8.2%	5.7%
Women's salary to men's salary	**63.8%**	—	—	**63.4%**	—	—

5.6. Environmental aspects

5.6.1 The PTBA's vulnerability to pollution

Due to its predominantly great depth, the absence of hydraulic contact with surface water bodies, the very limited recharge and the hydraulic protection by an overlying regional aquitard, the PTBA is in general not vulnerable to pollution. Nevertheless, the outcrops of the aquifer formation are locally vulnerable zones. In addition, if long-time intensive exploitation of the PTBA would reverse the vertical hydraulic gradients, then the aquifer may become vulnerable to downward intrusion of poor- quality groundwater from overlying formations.

5.6.2 Point pollution sources

Main potential sources of point pollution in the area are:

- Cattle-breeding complexes,
- Poultry farms',
- Enterprises for processing agricultural products,
- Animal burial grounds (47 in the PTBA area).

The first three are obliged to have waste disposal plants and sanitary protection zones, in order to prevent pollution. The last one is subject to sanitary, epidemiological and veterinary supervision.

5.6.3 Water supply, sanitation and control of wastewater and solid waste

Groundwater is the main source of drinking water supply. Around 44.4% of the population is served by a centralised water supply system, 53.1% makes use of a decentralized system (standpipes, dug or drilled wells, springs) and 2.5% uses imported water. In general, the centralised systems provide better-quality water than the decentralized systems.

Sewerage networks are present only in the towns of Saryagash and Shardara, but more than half of them need replacement. It is also only these towns that are provided with facilities for water treatment and wastewater disposal. Treated wastewater is collected in ponds from where it is allowed to seep downwards to the upper aquifer, thus polluting shallow groundwater.

In 2013, a volume of 837 000 m^3 of wastewater and drainage water was dumped, respectively into natural water bodies (45.8%), to ponds and filtration fields (52.5%), and onto the land surface (1.7%).

There are 53 landfills for solid domestic waste in the area (receiving 280 000 tons in 2013) and another 194 spontaneous dump sites in distant rural settlements.

5.6.4 Other sources of potential diffuse pollution

Modern farming systems utilizes pesticides and other chemical substances that contribute to optimal crop yields. They form potential threats to the water quality of shallow groundwater.

5.6.5 Observed pollution of surface water and groundwater

Based on monitoring the chemical state of surface water of the Syrdarya and the Keles rivers and the Shardara reservoir, all three are classified as moderately polluted. The most polluted one is the Keles River, highly polluted with sulphates, copper, phenols and magnesium due to intake of polluted collector and drainage water from the territory of Uzbekistan.

Out of three monitored groundwater wellfields, only the Abay wellfield shows some pollution (by nitrates). Groundwater pollution is absent at the Upper Keles and Saryagash wellfields.

5.7. Legal and institutional aspects

5.7.1 At the international level

No bilateral agreement exists between Kazakhstan and Uzbekistan on the PTBA, nor is there a Kazakh-Uzbek institution in place for the coordinated management of the PTBA.

Nevertheless, the two countries are a party to several water-related legal instruments, both of regional and of global scope. The most important ones are:

- The *Almaty Agreement (between* Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan) on 'Joint Management of the Use and Conservation of Water Resources of Interstate Sources' (groundwater is implicitly included). This agreement was signed in 1992;
- The *UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes* (Helsinki, adopted in 1992 and in force since 1996).

In addition, Uzbekistan is a party to:

- The *UN Convention on the Law of the Non-Navigational Uses of International Watercourses* (New York, adopted in 1997 and in force since 2014).

The *Interstate Commission for Water Coordination in Central Asia* (ICWC), comprised of the heads of the national water authorities of the five Central Asian countries, was established in 1992 by the Almaty Agreement (see above). Although by implication of the Almaty Agreement the Commission's mandate can be taken to include groundwater, in practice ICWC deals only with surface waters.

5.7.2 At the domestic level

Legislation on groundwater at the domestic level seems to be quite comprehensive and adequate in both countries. To what extent implementation and enforcement are satisfactory is not known. Regarding institutional arrangements on groundwater, both countries seem to follow a pattern of consolidation of principal responsibilities under one roof, and of centralization of the same at the hands of central government. However, there is competition between the specialized agencies involved in water resources management, which may be an obstacle to smooth cooperation among them.

5.8. Diagnostics

5.8.1 Purpose and approach

The purpose of the diagnostic is to draw conclusions from the information and knowledge collected during the assessment, in order to define focus and priorities for the next steps towards improving groundwater management and governance. This is done by answering three main questions:

- How valuable is the Pretashkent Transboundary Aquifer (PTBA) and its groundwater resources?
- Which area-specific issues should be addressed by groundwater resources management plans in order to secure or improve sustainable benefits from this aquifer? (and are the dynamics behind them well understood?)
- To what extent do the current groundwater governance setting and provisions favour adequate management of the groundwater resources?

In addition to conventional methods of analysis, use has been made of TWAP indicators and the DPSIR methodology. The TWAP indicator scores for the PTBA are shown in Appendix 2.

5.8.2 Current role and relevance of the PTBA

The PTBA is a unique source of deep lying fresh groundwater in Central Asia, located within the territories of Kazakhstan and Uzbekistan. The population of 463 400 in the Kazakhstani segment of the area underlain by this aquifer depends greatly on the PTBA groundwater, which in the most part of its distribution is the only source for drinking water supply. Groundwater of the PTBA is mineral by its quality and is widely used for Spa and bottling in Kazakhstan and in Uzbekistan.

5.8.3 Issues to be addressed by groundwater resources management plans for the PTBA

The key issues as derived from the assessment (and assisted by inspection of the TWAP indicator scores) are listed in Table 5.4. Brief clarifications and comments follow below.

Table 5.4 | Key issues to be addressed by groundwater management plans in the PTBA area

Key issues	Impact on the environment and socio-economic development	Economy sector	Urgency of interventions	
			In the short term	During the next 15-20 years
Depletion of groundwater storage	Lack of drinking water and interconnected problems of population's health deterioration, decrease in life expectancy, disease spreading, gender issues	- Households - Utilities - Health care - Balneology - Bottling	Moderate	High
Groundwater quality degradation	Decrease in available resources for utility and drinking water supply. Threat to population's health due to increasing disease levels	- Households - Utilities - Health care - Bottling	None for the PTBA; High for shallow aquifers	Moderate (?) for the PTBA; High for shallow aquifers

Groundwater storage depletion is unavoidable under the present groundwater abstraction regime, since the rate of abstraction is too high to be compensated by an increase in recharge and/or a decrease of natural discharge. In effect, none of both natural groundwater budget components is likely to change significantly on the short and medium term, thus the PTBA behaves virtually as a non-renewable aquifer, which means that abstracted groundwater is taken mainly from groundwater storage. At present, groundwater abstraction is predominantly by free-flowing wells (artesian wells), but the groundwater levels are declining quickly (around 1 m per annum) since water is released by elastic decompression. After losing artesian hydraulic head, the well will need to be pumped, year after year lifting groundwater from greater depths, which leads to progressively higher cost of water and on the longer run also to technical problems. The mandated government authorities and the local stakeholders together should define which pathway towards depletion would be most optimal, taking into account the rising water demands triggered by demographic and economic development at the one hand, and the desirability of a long useful life of the PTBA at the other. It will be indispensable to consider the Kazakhstani and Uzbekistani segments together and to use a simulation model to explore alternative development options.

Demographic and economic development most likely remain important drivers that lead to progressively increasing water demands in the area. Nevertheless, several types of mitigating measures may reduce the demands for water from the TBA, for instance:

- Abstracting brackish and saline groundwater from overlying aquifers and using it – after desalination and other forms of treatment (if needed) – for drinking water supply;
- Implementing demand management measures (e.g. control of leaks and other losses in distribution networks);

- Reconstructing inadequate water supply networks;
- Creating motivation and incentives for the adoption of water-saving techniques by the general public;
- Implementing regulations with financial incentives (taxes, credits, grants) for enterprises that adopt water-saving techniques.

Groundwater quality degradation inside the PTBA is unlikely to happen in the short run (except locally in the recharge zones), but it might become a problem in the longer run, only after the hydraulic heads in the aquifer will have declined enough to induce flows of poor-quality groundwater from overlying aquifers. Nevertheless, the pollution risks of the shallow aquifers in the PTBA area are considerable and should not be overlooked, because if groundwater of these aquifers becomes unsuitable for satisfying the current uses, then the PTBA comes under the pressure of substituting the corresponding volumes of water.

It is clear that both key issues have a transboundary dimension. Changes in pressure in the confined PTBA rapidly propagate in lateral direction, potentially resulting in modified groundwater fluxes across the international boundary. The bulk of transboundary water quality degradation moves through surface water bodies (like Keles irrigation canal), but groundwater may be indirectly affected by infiltration of these surface waters.

5.8.4 Groundwater governance and governance provisions for the entire PTBA

Only a few groundwater governance aspects have been touched upon during this project phase.

This refers in the first place to *information and knowledge*. Apart from the fact that Uzbekistani information is largely missing in this assessment, it may be concluded that also the information on the Kazakhstani segment is still subject to many uncertainties, in particular by lack of time series of relevant variables (groundwater abstraction data, water levels, groundwater quality data both for the PTBA and overlying aquifers) and by insufficient data sharing between the different Kazakhstani state organisations. Upgrading of monitoring networks and monitoring practices is therefore recommended, as well as improving cooperation between the state organizations.

Overall progress in the development of groundwater resources management of the PTBA at the domestic level is slow in both countries. Not only because of insufficient monitoring data (see above), but also by deficiencies in national planning and coordination between various authorities and other entities that have a stake in the area's water resources. Insufficient budgeting of the corresponding government authorities may be one of the underlying reasons.

Other identified specific needs for improving groundwater governance include:

- Developing legislation and regulations to enhance conjunctive use and protection of water resources at both the domestic and transboundary level,
- Raising public awareness on consequences of irrational groundwater abstraction and pollution,
- Strengthening capacity of all relevant agencies on improved groundwater resources management in line with requirements of multilateral environmental agreements,
- Finally, transboundary cooperation between Kazakhstan and Uzbekistan on the PTBA is still missing. Establishing this cooperation would be a major step forward in groundwater governance.

5.9. Building stone for improving groundwater governance: the Information Management System

As mentioned in section 2.1.2, an Information Management System (IMS) has been developed and implemented during this project phase for each of the three pilot areas: Trifinio, Stampriet and Pretashkent. The content of the IMS for the PTBA case study is summarized in Table 5.5. It is the intention that the content of the IMS will continuously be updated and expanded, in order to offer optimal information services to decision-makers and other stakeholders involved in governing the groundwater in the region.

Table 5.5 | Data in GGRETA's IMS for the PTBA, as per February 2016 (Kazakhstani segment only)

	Data in IMS		Comments
1	**Physiography and climate**		
	1.1	Elevation	500 m intervals
	1.2	Relief	
	1.3	Soil type	
	1.4	Rivers	
	1.5	Average air temperature in July	0.5 °C intervals
	1.6	Average air temperature in January	0.5 °C intervals
	1.7	Mean annual precipitation	50 mm intervals
2	**Administrative units and population**		
	2.1	KAZ-Boundary_Pretashkent_POL	PTBA area + Eastern part of Kazygurt region
	2.2	Territorial boundaries and subdivisions	(lines)
	2.3	Administrative regional division of the districts	3 regions (poligons)
	2.4	Administrative territorial division of the districts	43 districts (poligons)
	2.5	Population density	By district, habitants/km^2
	2.6	Type of settlements	According to number of inhabitants
3	**Land and water use, sanitation and pollution**		
	3.1	Land use	
	3.2	Lakes and water reservoirs	
	3.3	Irrigation canals	
	3.4	Sources of water supply	By settlement (5 types of sources)
	3.5	Population using public water supply	Percentage by district
	3.6	Population using sewage systems	Percentage by region
	3.7	Sources of pollution	
4	**Geology and hydrogeology**		
	4.1	Fractures	lines
	4.2	Hydrogeological map	
	4.3	PTBA boundary (Kazhkstani segment)	
	4.4	Outcrop Cenomanian aquifer	
	4.5	Top Cenomanian aquifer (isolines)	0; 200; 500; 1000 and 1500 m
	4.6	Thickness Cenomanian aquifer	
	4.7	Recharge zones	
	4.8	Piezometric level	PTBA; 50 m intervals
	4.9	Mineralization	PTBA; TDS: 0.5 mg/l intervals
	4.10	Saline region	empty

6. Conclusions and comments

6.1 On the outcomes of the assessment

As can be concluded from the preceding chapters (and more convincingly from the detailed technical reports on each of the three pilot projects), the assessments have produced a clear picture of the transboundary aquifers systems concerned. None of these pictures is perfect, however: there are limitations in the scope of elements assessed, and for those aspects assessed there remains in many cases considerable uncertainty. The assessment activities, however, have effectively contributed to identifying these uncertainties and their analysis has helped defining which ones are crucial and how to address them. The assessments leave no doubts about the shared nature of the groundwater resources of the three selected aquifer systems and the assessment results facilitate cross-border dialogue and technical exchanges.

Among the three assessments, it appears that the Stampriet and Trifinio pilot projects are broadest in scope, while the Pretashkent pilot project is the most advanced one in assessing its aquifer and it also includes more information on time-dependent variables than any of the other two studies. A significant limitation of the latter assessment, however, is that it covers the territory of only one of the two countries sharing the transboundary aquifer.

All three assessments have been able to present a diagnostic analysis. These outcomes are of crucial importance for defining the main focus and direction of local groundwater resources management and governance, in spite of all uncertainties. Continued study, observation and interaction with stakeholders will allow the diagnostics to be amended and improved over time.

This is also a characteristic of the Information Management System for each of the areas: it is a dynamic system, meant to be continuously updated as new information and new knowledge become available.

The key and overarching conclusion from the assessments is that, unless it is underpinned and facilitated by a solid legal and institutional foundation domestically, groundwater governance frameworks at the transboundary level will not be forthcoming in terms of negotiating new frameworks. The outcomes of the assessment studies demonstrate that good governance is highly desirable. They also suggest that managing and governing a transboundary aquifer has to start at the domestic level, i.e. at the level of the individual countries. The transboundary issues are only a limited part of all issues to be addressed. More benefit is to be achieved already by a better protection and control at the local and national levels, while solving transboundary problems will be arguably much easier, if groundwater governance at the national level is already satisfactory. Moreover, it was evaluated that domestic groundwater governance frameworks need either review and upgrading of Water Laws or complementing Water Law with Regulations. Strengthening domestic capacities in implementation and enforcement is necessary to support cooperation in the three pilot cases.

The gender assessment has evidenced the scarcity of relevant data not just for groundwater, but also for water in general in all GGRETA countries. Although there are marked differences among the three pilot cases in gender policy settings, political reforms and improving legislation have increased women's empowerment, including access to land and trainings, especially in the Trifinio countries. It has been noted that training programmes and stakeholder consultations are crucial to establish sex-disaggregated data collection protocols, and to serve as a basis for advocating change towards gender equality and women's empowerment. Common characteristics in the three pilot cases highlight that gender inequality tends to be higher in rural areas, especially when it comes to decision-making processes for irrigation as more than 80% of decisions are taken by men. Women representation in cooperatives and farmers' association is also low and generally does not exceed 20%. A similar trend for decision-making seems to be true at household level, except for decision-making on water use and monitoring –that is where women dominate. At national and international level, although there isn't any policy on equal representation, there seems to be no discrimination of women's opinions in water-policy decision boards for highly skilled and educated women. Systematic application and collection of sex-disaggregated data will facilitate a more comprehensive, methodological quantitative gender analysis for policy making.

The project has also allowed a general positive shift towards transboundary groundwater cooperation. Yet, GGRETA countries need to increase their capacity to internalize benefits of cooperation. The conventional approaches of moving from positions to counter positions proved to be less efficient, whereas, the identification of the interests or needs as a base for the development of solutions has been identified as one of the essentials. Parties actually have to educate each other in their interests, and thus become re-educated in their own interests in the process. In this connection, in order to foster chances of cooperation it is desirable that the stakeholders in all GGRETA countries gain skills on:

- Identification and understanding of needs and interests,
- Negotiation, mediation, and facilitation techniques,
- Conducting and initiating multi-level and interdisciplinary dialogues on domestic and international level

6.2 On the usefulness and replicability of the assessment methodology and tools

From a methodological point of view, the assessment studies have been supported by GGRETA's Draft *Guidelines for Multidisciplinary Assessment of Transboundary Aquifers* (UNESCO-IGRAC and UNESCO-IHP, 2015). These guidelines have been very useful and that they have contributed to a consistent assessment approach among the three studies and the methodology presented is certainly suitable for replication to a wide range of transboundary aquifer systems.

The indicators presented in the methodology acted as a supporting tool in the diagnostic analysis of each aquifer system. The application of measurable and monitorable indicators proved to be a springboard to advance to the policy level. Apart from providing a better understanding of the complexity of the different factors playing a role in building countries' cooperation over transboundary aquifers governance and to identify and prioritize gaps to be filled, indicators have become an advocacy tool to communicate to higher political levels in order to gain support for both domestic and transboundary efforts. The latter is particularly relevant for the legal and institutional indicators, prepared especially for GGRETA.

Table 6.1 illustrates that the indicators also have the merit to provide the ground for comparison of the transboundary aquifer systems and their setting. Some salient features between the Ocotepeque-Citalá (OC-C), the Stampriet confined aquifers (STAS) and the Pretashkent Transboundary Aquifer (PTBA; only Kazakhstani segment) can immediately be detected:

- Very low recharge of STAS and PTBA versus medium to very high recharge of OC-C,
- Natural background groundwater quality tends to be more favourable for smaller-sized aquifers,
- High buffering capacity of STAS and PTBA versus low to medium one of OC-C,
- Vulnerabilities to climate change and to pollution are high for OC-C and low for STAS and PTBA,
- Groundwater is very important for domestic water supply in all three areas,
- Agriculture highly depends on groundwater only in the STAS,
- For none of the transboundary aquifers has significant pollution or depletion been reported,
- Population density is high in the Trifinio area (OC-C) and very low in the STAS area,
- Groundwater development stress is very high for PTBA, and probably low to medium for OC-C and the STAS, but data are missing),
- A transboundary legal framework for the TBAs is missing in all three areas,
- The same holds true for a transboundary institutional framework for the TBAs, but in OC-C and STAS there are international bodies that could be entrusted with a mandate for TBA management.

Table 6.1 | Comparison between indicator scores of the three transboundary aquifer systems: Ocotepeque-Citalá (OC-C), Stampriet confined aquifers (STAS) and Pretashkent Transboundary Aquifer (PTBA; only Kazakhstani segment)

1	Defining or constraining the value of aquifers and their potential functions*	OC-C	STAS	PTBA
1.1	Mean annual groundwater recharge depth	3-5	1	1
1.2	Annual amount of renewable groundwater resources per capita	1-2	1-2	1
1.3	Natural background groundwater quality	4-5	4	3
1.4	Aquifer buffering capacity	1-2	3	3
1.5	Aquifer vulnerability to climate change	1/3	1	1
1.6	Aquifer vulnerability to pollution	1/5	1	1
2	Role and importance of groundwater for humans and the environment**			
2.1	Human dependency on groundwater	2-3	4-5	1
2.2	Human dependency on groundwater for domestic water supply	4	5	5
2.3	Human dependency on groundwater for agricultural water supply	1	4	1
2.4	Human dependency on groundwater for industrial water supply	1	1	1
2.5	Ecosystem dependency on groundwater	2-3	1	1
2.6	Prevalence of springs	3	1	4
3	Changes in groundwater state*			
3.1	Groundwater depletion	1-2	1	1
3.2	Groundwater pollution	1-2	1	1
4	Drivers of change and pressures			
4.1	Population density**	4	1	3
4.2	Groundwater development stress*	2-3	2-3	5
5	Enabling environment for transboundary aquifer resources management at bi-/multinational level**			
5.1	Transboundary legal framework	1	1	1
5.2	Transboundary institutional framework	2	2	1

Notes:

1: Very low -: relates to an interval
2: Low /: relates to several aquifers (e.g. shallow and deep aquifers)
3: Medium
4: High
5: Very high

* Related specifically to the transboundary aquifers considered
** Related to the total pilot study area

The Information Management Systems (IMS) for each of the pilot studies have become operational and provide easy access to key information collected. The IMS will certainly be very valuable during the next stages, when groundwater management alternatives have to be explored and plans have to be prepared.

6.3 On next steps towards adequate management and governance of the transboundary aquifers

The outcomes of the assessment studies may be used to focus the attention of the international community on transboundary aquifers. They may demonstrate which challenges are present, what type of action would be required to address the challenges, and what benefits could be expected to accrue from interventions.

The studies may also highlight the uniqueness of each transboundary aquifer system and the diversity of groundwater systems observed across the globe. This was the reason to select pilots in very different settings: (a) Trifinio as an example of aquifers in small alluvial valleys in mountainous areas characterised by strong links between groundwater and surface water; (b) Stampriet as an example of a very large weakly renewed confined aquifer system in a semi-arid area without any significant surface water; (b) Pretashkent as a medium-sized nearly non-renewable artesian aquifer in an area with abundant surface water during part of the year.

The assessment studies, however, are primarily to be used for the benefit of the local inhabitants of the three areas. Therefore, the results should be disseminated among the local authorities in charge of groundwater resources management and stakeholders of the zone. This should create awareness and motivation to co-operate and comply with new rules and regulations.

Next steps should take the diagnostics as point of departure and intend to develop a shared vision on how to manage and govern the aquifer systems. This will require a gradually improving interaction and cooperation between government authorities and key stakeholders of the area, first at the national levels only, later also on the international level between the countries that share the transboundary aquifer. This needs to be supported by new platforms for interaction, improvement of the legal and institutional frameworks, information management systems, model simulations, stakeholder involvement, planning, etc.

As far as information and knowledge are concerned: analysis and model predictions of possible futures are in all three areas seriously hampered by the lack of relevant time series. Therefore, establishing and operating adequate monitoring networks is a first priority.

Regarding the development of a vision: in all three assessment pilot studies an Integrated Water Resources Management approach (IWRM) needs to be adopted. In Trifinio this is evident, because surface water of Río Lempa links all alluvial aquifers physically, even if they are discontinuous in the subsurface. But in the Stampriet area and the Pretashkent area, where the transboundary aquifers seem physically unconnected to other aquifers and to surface water, there is a strong link with overlying aquifers via the water demands. This implies that transboundary aquifer management goes beyond the physical limits of the aquifer concerned, and needs to address its entire context.

In view of the findings of Phase 1, the basic general methodological approach for a follow up phase, valid for all three pilot cases, is that introducing/improving groundwater governance at the domestic level represents a necessary step and a prerequisite for the establishment of any multi-country cooperative arrangement. This implies building the capacity of policymakers, experts and institutions, engaging more relevant stakeholders, filling key data gaps emerged from the assessments, promoting awareness at the domestic level on groundwater issues.

Recommendations emerging from the Phase 1 work are:

1. To focus on improving domestic groundwater governance (especially on implementing water laws and fostering interagency cooperation) with a strong priority on water diplomacy, legal and institutional and gender components as a means to provide a solid domestic legal and institutional foundation for negotiating governance frameworks at transboundary level in the future.
2. To build on and strengthen the favorable conditions that have been created for initiating multi-country dialogues and cooperation mechanisms in two pilot transboundary aquifers (Trifinio and Stampriet). This should be the key focus of the actions proposed for these two pilot cases. The approach proposed for the Stampriet case could also involve launching a dialogue at the regional level among aquifer countries and major regional players in water management issues in Southern Africa. The dialogue, while helping identifying the most feasible multi-country management arrangements for the Stampriet, would have a much broader impact on the management and utilization of the predominantly transboundary surface and groundwater water resources of Southern Africa and beyond.
3. To pursue efforts on capacity building component on water and gender at domestic level focused on the pilot cases, but applicable to all water resources in the GGRETA countries. The work undertaken as part of Phase 1 evidenced the novelty for the project regions of gender consideration in water management and use, as well as the scarcity of relevant data not just for groundwater, but also for water in general.

7. References

Trifinio Aquifer

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Stampriet Transboundary Aquifer System

UNESCO-IHP, 2016. *Stampriet. Transboundary Aquifer System Assessment. Governance of Transboundary Aquifers Systems (GGRETA) – Phase 1. Technical Report*. UNESCO, Paris.

Pretashkent Transboundary Aquifer

UNESCO-IHP, 2016. Pretashkent Aquifer Assessment Report. *Governance of Transboundary Aquifers Systems (GGRETA) – Phase 1. Technical Report*. UNESCO, Paris.

Miscellaneous

UNESCO-IGRAC and UNESCO-IHP, 2015. Guidelines for Multidisciplinary Assessment of Transboundary Aquifers. Draft version, September 2015, 91 p.

GGRETA Information Management System: https//ggis.un-igrac.org/ggis-viewer/ggreta/regions

12. Although this report carries the same date as its draft version ('borrador'), both reports vary significantly. As far as presented data are different, those of this latest report have been adopted.

8. Appendices

8.1 Appendix 1 - Indicators evaluated for the Trifinio Aquifers: Esquipulas (Guatemala) and Ocotepeque-Citalá (Honduras and El Salvador). Assigned scores and classes are in bold font.

No	Categories and indicator names	Indicator definitions	Classification	Comments
1 - Defining or constraining the value of aquifers and their potential functions				
1.1	Mean annual groundwater recharge depth (mean annual recharge volume per unit of area)	Long-term mean groundwater recharge, including man-made components (return-flows, induced recharge, artificial recharge), divided by area	1. Very low: < 2 mm/yr 2. Low: 2 -20 mm/yr **3. Medium: 20-100 mm/yr** **4. High: 100-300 mm/yr** **5. Very high: > 300 mm/yr**	No recharge data. Expected value in one of the classes 3 – 5
1.2	Annual amount of renewable groundwater resources per capita	Long-term mean groundwater recharge, including man-made components, divided by the number of inhabitants of the area occupied by the aquifer	**1. Low: < 1000** **2. Medium: 1000 - 5000** 3. High: > 5000	Population in the study area is around 140 000 inhabitants
1.3	Natural background groundwater quality	Percentage of the area occupied by the aquifer where groundwater is found of which natural quality satisfies local drinking water standards	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% **4. High: 60-80%** **5. Very high: > 80%**	
1.4	Aquifer buffering capacity	Ratio between volume stored and long-term mean groundwater recharge (equivalent to mean residence time)	**1. Low: < 10 years** **2. Medium: 10 – 100 years** 3. High: > 100 years	
1.5	Aquifer vulnerability to climate change	Extent of expected groundwater budget regime change in response to change in climatic conditions	**1. Low: confined aquifers containing only fossil water or receiving negligible recent recharge (deep aquifer only)** 2. Medium: weakly recharged aquifers with limited interaction with other components of the hydrological cycle, due to location at considerable depth and/or hydraulic confinement. **3. High: aquifers actively interacting with streams, atmosphere and/or sea (shallow alluvial aquifer only)**	There are two aquifers: a shallow alluvial aquifer and a deep confined aquifer)
1.6	Aquifer vulnerability to pollution	Percentage of its horizontal area where the aquifer is considered moderately to highly vulnerable to pollution	**1. Very low: < 20% (deep confined aquifer only)** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% **5. Very high: > 80% (shallow alluvial aquifer only)**	There are two aquifers: a shallow alluvial aquifer and a deep confined aquifer)
2 - Role and importance of groundwater for humans and the environment				
2.1	Human dependency on groundwater	Percentage of groundwater in total water abstraction for all human water uses.	1. Very low: < 20% **2. Low: 20 -40%** **3. Medium: 40-60%** 4. High: 60-80% 5. Very high: > 80%	

No	Categories and indicator names	Indicator definitions	Classification	Comments
2.2	Human dependency on groundwater for domestic water supply	Percentage of groundwater in water abstraction for domestic water use.	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% **4. High: 60-80%** 5. Very high: > 80%	
2.3	Human dependency on groundwater for agricultural water supply	Percentage of groundwater in water abstraction for agricultural water use (mainly irrigation).	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	
2.4	Human dependency on groundwater for industrial water supply	Percentage of groundwater in total water abstraction for domestic water use.	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	
2.5	Ecosystem dependency on groundwater	Percentage of the aquifer's area where the aquifer has a phreatic water level shallower than 5 m below surface	1. Very low: < 5% **2. Low: 5 – 10%** **3. Medium: 10-25%** 4. High: 25-50% 5. Very high: > 50%	
2.6	Prevalence of springs	Total annual groundwater discharge by springs, divided by mean annual groundwater recharge	1. Very low: < 5% 2. Low: 5 – 10% **3. Medium: 10-25%** 4. High: 25-50% 5. Very high: > 50%	
3 – Changes in groundwater state				
3.1	Groundwater depletion	Observed current rate of long-term progressive decrease of groundwater storage (accompanied by steadily declining groundwater levels), expressed as an equivalent depth of water averaged over the aquifer.	**1. Absent to very low: < 2 mm/yr** **2. Low: 2 -20 mm/yr** 3. Medium: 20-50 mm/yr 4. High: 50-100 mm/yr 5. Very high: > 100 mm/yr	
3.2	Groundwater pollution	Observed polluted zones as a percentage of total aquifer area (due to pollution caused water quality to exceed drinking water quality standards)	**1. Very low: < 5%** **2. Low: 5 – 10%** 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	
4 - Drivers of change and pressures				
4.1	Population density	Number of people per unit of area on top of the aquifer	1. Very low: < 1 p/km^2 2. Low: 1-10 p/km^2 3. Medium: 10-100 p/km^2 **4. High: 100-1000 p/km^2** 5. Very high: > 1000 p/km^2	
4.2	Groundwater development stress	Total annual groundwater abstraction divided by long-term mean annual groundwater recharge	1. Very low: < 2% **2. Low: 2-20%** **3. Medium: 20-50%** 4. High: 50-100% 5. Very high: > 100%	
5 – Enabling environment for transboundary aquifer resources management				
5.1	Transboundary groundwater management legal framework	Existence, status and comprehensiveness of a binding agreement on the transboundary aquifer under consideration	**1. No agreement in existence, nor under preparation** 2. Agreement under preparation or available as an unsigned draft 3. Agreement with limited scope signed by all parties (e.g. agreement to co-operate or exchange information) 4. Agreement with full scope for TBA management signed by all parties.	

No	Categories and indicator names	Indicator definitions	Classification	Comments
5.2	Transboundary groundwater management institutional framework	Existence, mandate and capabilities of institutions or institutional arrangements for managing the transboundary aquifer under consideration (all types of interventions)	1. No institutions in existence that have the mandate and capability for TBA management **2. Such institutions do exist, but with limitations in mandate and/or capability for TBA management** 3. Domestic agencies do exist that have full mandate and adequate capabilities for TBA management 4. A special bi- or multi-national transboundary institution has been established with full mandate and adequate capabilities for joint management of the specific TBA.	

8.2 Appendix 2 - Indicators evaluated for the Stampriet Transboundary Aquifer System.
Assigned scores and classes are in bold font.

A. Auob & Nossob confined aquifers (transboundary)

No	Categories and indicator names	Indicator definitions	Classification	Comments
1 - Defining or constraining the value of aquifers and their potential functions				
1.1	Mean annual groundwater recharge depth (mean annual recharge volume per unit of area)	Long-term mean groundwater recharge, including man-made components (return-flows, induced recharge, artificial recharge), divided by area	**1. Very low: < 2 mm/yr** 2. Low: 2 -20 mm/yr 3. Medium: 20-100 mm/yr 4. High: 100-300 mm/yr 5. Very high: > 300 mm/yr	No thorough recharge estimate
1.2	Annual amount of renewable groundwater resources per capita	Long-term mean groundwater recharge, including man-made components, divided by the number of inhabitants of the area occupied by the aquifer	**1. Low: < 1000** **2. Medium: 1000 - 5000** 3. High: > 5000	Very low recharge in combination with very low population density
1.3	Natural background groundwater quality	Percentage of the area occupied by the aquifer where groundwater is found of which natural quality satisfies local drinking water standards	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% **4. High: 60-80%** 5. Very high: > 80%	WHO drinking water quality standards as a criterion.
1.4	Aquifer buffering capacity	Ratio between volume stored and long-term mean ground-water recharge (equivalent to mean residence time)	1. Low: < 10 years 2. Medium: 10 – 100 years **3. High: > 100 years**	
1.5	Aquifer vulnerability to climate change	Extent of expected groundwater budget regime change in response to change in climatic conditions	**1. *Low:* confined aquifers containing only fossil water or receiving negligible recent recharge.** 2. Medium: weakly recharged aquifers with limited interaction with other components of the hydrological cycle, due to location at considerable depth and/or hydraulic confinement. 3. High: aquifers actively interacting with streams, atmosphere and/or sea .	

No	Categories and indicator names	Indicator definitions	Classification	Comments
1.6	Aquifer vulnerability to pollution	Percentage of its horizontal area where the aquifer is considered moderately to highly vulnerable to pollution	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Pollution risk localized at few settlements and irrigation farms scattered through the study area. The most vulnerable area is around Stampriet given its high density of irrigation farms.
3 – Changes in groundwater state				
3.1	Groundwater depletion	Observed current rate of long-term progressive decrease of groundwater storage (accompanied by steadily declining groundwater levels), expressed as an equivalent depth of water averaged over the aquifer.	**1. Absent to very low: < 2 mm/yr** 2. Low: 2 -20 mm/yr 3. Medium: 20-50 mm/yr 4. High: 50-100 mm/yr 5. Very high: > 100 mm/yr	No thorough recharge estimate
3.2	Groundwater pollution	Observed polluted zones as a percentage of total aquifer area (due to pollution caused water quality to exceed drinking water quality standards)	**1. Very low: < 5%** 2. Low: 5 – 10% 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	Local drinking water quality standards as a criterion.
4 - Drivers of change and pressures				
4.2	Groundwater development stress	Total annual groundwater abstraction divided by long-term mean annual groundwater recharge	1. Very low: < 2% **2. Low: 2-20%** **3. Medium: 20-50%** 4. High: 50-100% 5. Very high: > 100%	

B. Kalahari Aquifers (non-transboundary)

No	Categories and indicator names	Indicator definitions	Classification	Comments
1 - Defining or constraining the value of aquifers and their potential functions				
1.1	Mean annual groundwater recharge depth (mean annual recharge volume per unit of area)	Long-term mean groundwater recharge, including man-made components (return-flows, induced recharge, artificial recharge), divided by area	**1. Very low: < 2 mm/yr** 2. Low: 2 -20 mm/yr 3. Medium: 20-100 mm/yr 4. High: 100-300 mm/yr 5. Very high: > 300 mm/yr	No reliable recharge estimate
1.2	Annual amount of renewable groundwater resources per capita	Long-term mean groundwater recharge, including man-made components, divided by the number of inhabitants of the area occupied by the aquifer	**1. Low: < 1000** **2. Medium: 1000 - 5000** 3. High: > 5000	Very low recharge in combination with very low population density
1.3	Natural background groundwater quality	Percentage of the area occupied by the aquifer where groundwater is found of which natural quality satisfies local drinking water standards	1. Very low: < 20% **2. Low: 20 -40%** 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	WHO drinking water quality standards as a criterion.

No	Categories and indicator names	Indicator definitions	Classification	Comments
1.4	Aquifer buffering capacity	Ratio between volume stored and long-term mean groundwater recharge (equivalent to mean residence time)	1. Low: < 10 years 2. Medium: 10 – 100 years **3. High: > 100 years**	
1.5	Aquifer vulnerability to climate change	Extent of expected groundwater budget regime change in response to change in climatic conditions	1. Low: confined aquifers containing only fossil water or receiving negligible recent recharge. 2. Medium: weakly recharged aquifers with limited interaction with other components of the hydrological cycle, due to location at considerable depth and/or hydraulic confinement. **3. *High:* aquifers actively interacting with streams, atmosphere**	
1.6	Aquifer vulnerability to pollution	Percentage of its horizontal area where the aquifer is considered moderately to highly vulnerable to pollution	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Pollution risk localized at few settlements and irrigation farms scattered through the study area. The most vulnerable area is around Stampriet given its high density of irrigation farms.
3 – Changes in groundwater state				
3.1	Groundwater depletion	Observed current rate of long-term progressive decrease of groundwater storage (accompanied by steadily declining groundwater levels), expressed as an equivalent depth of water averaged over the aquifer.	**1. Absent to very low: < 2 mm/yr** 2. Low: 2 -20 mm/yr 3. Medium: 20-50 mm/yr 4. High: 50-100 mm/yr 5. Very high: > 100 mm/yr	
3.2	Groundwater pollution	Observed polluted zones as a percent¬age of total aquifer area (due to pollution caused water quality to exceed drinking water quality standards)	**1. Very low: < 5%** **2. Low: 5 – 10%** 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	
4 - Drivers of change and pressures				
4.2	Groundwater development stress	Total annual groundwater abstraction divided by long-term mean annual groundwater recharge	1. Very low: < 2% **2. Low: 2-20%** **3. Medium: 20-50%** 4. High: 50-100% 5. Very high: > 100%	

8.3 Appendix 3 - Indicators evaluated for the Pretashkent Transboundary Aquifer (Kazakhstani segment only)

No	Categories and indicator names	Indicator definitions	Classification	Comments
1 - Defining or constraining the value of aquifers and their potential functions				
1.1	Mean annual groundwater recharge depth (mean annual recharge volume per unit of area)	Long-term mean groundwater recharge, including man-made components (return-flows, induced recharge, artificial recharge), divided by area	**1. Very low: < 2 mm/yr** 2. Low: 2 -20 mm/yr 3. Medium: 20-100 mm/yr 4. High: 100-300 mm/yr 5. Very high: > 300 mm/yr	Assumed that TBA extends over 10 840 km2; TBA contains non-renewable groundwater (see also 1.4)
1.2	Annual amount of renewable groundwater resources per capita	Long-term mean groundwater recharge, including man-made components, divided by the number of inhabitants of the area occupied by the aquifer	**1. Low: < 1000** 2. Medium: 1000 - 5000 3. High: > 5000	Extremely low, consistent with the classification of non-renewability
1.3	Natural background groundwater quality	Percentage of the area occupied by the aquifer where groundwater is found of which natural quality satisfies local drinking water standards	1. Very low: < 20% 2. Low: 20 -40% **3. Medium: 40 – 60%** 4. High: 60-80% 5. Very high: > 80%	Suitability for drinking water used as criterion. It is accepted that local drinking water standards may vary.
1.4	Aquifer buffering capacity	Ratio between volume stored and long-term mean groundwater recharge (equivalent to mean residence time)	1. Low: < 10 years 2. Medium: 10 – 100 years **3. High: > 100 years**	Proxy for the aquifer's resilience to climatic variability
1.5	Aquifer vulnerability to climate change	Extent of expected groundwater budget regime change in response to change in climatic conditions	**1. Low: confined aquifers containing only fossil water or receiving negligible recent recharge.** 2. Medium: weakly recharged aquifers with limited interaction with other components of the hydrological cycle, due to location at considerable depth and/or hydraulic confinement. 3. High: aquifers actively interacting with streams, atmosphere and/or sea	Class 1 refers to 'non-renewable groundwater'.
1.6	Aquifer vulnerability to pollution	Percentage of its horizontal area where the aquifer is considered moderately to highly vulnerable to pollution	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Except in recharge zone, TBA is buried under thick overburden (including aquitards) in most of the area
2 - Role and importance of groundwater for humans and the environment				
2.1	Human dependency on groundwater	Percentage of groundwater in total water abstraction for all human water uses.	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Abstraction of water includes the quantity used and all losses.
2.2	Human dependency on groundwater for domestic water supply	Percentage of groundwater in water abstraction for domestic water use.	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% **5. Very high: > 80%**	Abstraction of water includes the quantity used and all losses.

No	Categories and indicator names	Indicator definitions	Classification	Comments
2.3	Human dependency on groundwater for agricultural water supply	Percentage of groundwater in water abstraction for agricultural water use	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Abstraction of water includes the quantity used and all losses.
2.4	Human dependency on groundwater for industrial water supply	Percentage of groundwater in total water abstraction for industrial water use.	**1. Very low: < 20%** 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Abstraction of water includes the quantity used and all losses.
2.5	Ecosystem dependency on groundwater	Percentage of the aquifer's area where the aquifer has a phreatic water level shallower than 5 m below surface	**1. Very low: < 5%** 2. Low: 5 – 10% 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	No shallow phreatic water level outside recharge zones
2.6	Prevalence of springs	Total annual groundwater discharge by springs, divided by mean annual groundwater recharge	1. Very low: < 5% 2. Low: 5 – 10% 3. Medium: 10-25% **4. High: 25-50%** 5. Very high: > 50%	Springs are very sensitive for changes in groundwater budget. Therefore a meaningful indicator of change.
3 – Changes in groundwater state				
3.1	Groundwater depletion[4]	Observed current rate of long-term progressive decrease of groundwater storage (accompanied by steadily declining groundwater levels), expressed as an equivalent depth of water averaged over the aquifer.	**1. Absent to very low: < 2 mm/yr** 2. Low: 2 -20 mm/yr 3. Medium: 20-50 mm/yr 4. High: 50-100 mm/yr 5. Very high: > 100 mm/yr	Depletion estimate refers to long-year trend. Because the TBA is confined, small changes in storage cause large changes in piezometric level.
3.2	Groundwater pollution	Observed polluted zones as a percentage of total aquifer area (due to pollution caused water quality to exceed drinking water quality standards)	**1. Very low: < 5%** 2. Low: 5 – 10% 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	Local drinking water quality standards as a criterion. Some currently polluted zones may have remained unobserved.
4 - Drivers of change and pressures				
4.1	Population density	Number of people per unit of area on top of the aquifer	1. Very low: < 1 p/km2 2. Low: 1-10 p/km2 **3. Medium: 10-100 p/km²** 4. High: 100-1000 p/km2 5. Very high: > 1000 p/km2	
4.2	Groundwater development stress	Total annual groundwater abstraction divided by long-term mean annual groundwater recharge	1. Very low: < 2% 2. Low: 2-20% 3. Medium: 20-50% 4. High: 50-100% **5. Very high: > 100%**	Measure for the degree of modification of the groundwater budget (repercussions for outflow and storage)
5 – Enabling environment for transboundary aquifer resources management				
5.1	Transboundary legal framework	Existence, status and comprehensiveness of a binding agreement on the transboundary aquifer	**1. No agreement in existence, nor under preparation** 2. Agreement under preparation or available as an unsigned draft 3. Agreement with limited scope signed by all parties (e.g. agreement to co-operate or exchange information) 4. Agreement with full scope for TBA management signed by all parties.	

No	Categories and indicator names	Indicator definitions	Classification	Comments
5.2	Transboundary institutional framework	Existence, mandate and capabilities of institutions or institutional arrangements for managing the transboundary aquifer	**1. No institutions in existence that have the mandate and capability for TBA management** 2. Such institutions do exist, but with limitations in mandate and/ or capability for TBA management 3. Domestic agencies do exist that have full mandate and adequate capabilities for TBA management 4. A special bi- or multi-national transboundary institution has been established with full mandate and adequate capabilities for joint management of the specific TBA.	The institutions are not only in charge of the implementation of legal measures, but also of other aspects of TBA management (plan development, economic measures and incentives, monitoring, etc.) Note: Capabilities here interpreted in terms of staffing and budget (compared to needs)

8.4 Appendix 4 - Gender indicators evaluated for the three pilot cases

INDICATOR GROUPING	INDICATOR	TRIFINIO	STAMPRIET	PRETASHKENT
GENERAL INFORMATION	Aquifer's area total population disaggregated by sex	**M:** 66,726 (48.2%) **F:** 71,761 (51.8%) **T:** 138,487	**M:** ≈26,500 (53%) **F:** ≈23,500 (47%) **T:** ≈50,000	**M:** 2,737,800 (49,4%) **F**: 2,804,400 (50,6%) **T:** 5,542,200
	Percentage of rural and urban population (%).	**Rural:** ≈65-75 **Urban:** ≈25-35	**Rural:** ≈60-70 **Urban:** ≈30-40	**Rural:** 31.3 **Urban:** 68.7
	Mortality rate for M/F population in the aquifer area (0/00).	**M:** N/A **F:** N/A **T:** 3.7	**M:** ≈15 **F:** ≈20	**M:** ≈ 4.4 **F:** ≈ 5.2
	Literacy rate (%) by M/F population in the aquifer area.	**M:** ≈75 **F:** ≈80	**M:** ≈85 **F:** ≈85	**M:** ≈100 **F:** ≈100

WATER GOVERNANCE	Number of M/F in paid and unpaid positions in local water governance formally-structured entities (water users associations, etc…) at town/village level.	**M:** 817 (73%) **F:** 303 (27%) **T:** 1120 Unpaid position in water users associations and local water boards	There are no basin water committees in the aquifer area. There are water point committees which generally exhibit an equal gender balance. 59% of the elected local councillors in Namibia for water, sanitation and hygiene consists of women	**M:** ≈80-85% **F:** ≈20-15% There is no precise data or statistics to the number of women in the governing bodies of water related entities on regional and municipal level. There are no basin water commissions. The water governance is dispersed among various entities on regional levels
	Presence and nature of gender sensitive training within responsible ministries/lead agencies.	**Plan Trifinio:** Staff is sensitized but there is a lack of training **Municipalities:** Every municipality has an office for gender mainstreaming with a minimum percentage of budget (≈0.05%). Levels of training differ across municipalities.	**Ministries:** Staff is sensitized but there is a lack of training **Municipalities:** No gender-specific trainings in the area	Nominally, there are responsible officers for gender within government [water] structures. State agencies for statistics have departments of gender which are represented at the studies on national, regional and municipal levels. Regional authorities conduct gender awareness trainings However, personnel at all levels require professional in depth capacity building on both gender sensitive and technical matters.
	Presence and nature of gender-specific objectives and commitments (or gender strategy) in national and sector-level water policies.	Good institutional framework at local and national legislation for each country.	Good national legislation for each country. Limited institutional capacity at local level.	Good legislation in both countries. Local and national institutional frameworks exist but are rather underdeveloped. A qualified and specially trained personnel (both in qualitative and quantitative analysis) is lacking especially at local level.
SAFE DRINKING WATER, SANITATION AND HYGIENE	M/F perceptions of the adequacy of current water supply/availability in both quality and quantity.	Both women and men consider that there is water scarcity in dry periods. Perception of women and men that water quality has declined in recent years is also widespread.	Women and men share same perception that water quality and quantity are good. However, there is a widespread dissatisfaction with the sanitation situation. 54% of households do not have access to any toilet facilities (in some settlements in Namibia, it can go up to 80%) and the bush system exposes women and children to sexual abuse, and snake bites.	In Kazakhstan 80% women and men believe in shortage of water (mainly for utility, drinking and household supply) In Uzbekistan only 20-30% feel the shortages, mainly in summer period due to increase in utilization of water by the population of cities especially for watering urban gardens.
DECISION MAKING AND KNOWLEDGE PRODUCTION	Intra-household-based decision-making process in water decisions %	**Urban:** Water decisions are generally taken both by women and men **Rural:** Water decisions are dominated by women	**Urban:** **M:** 15-20 **F:** 60-70 **Both:** 10-15 **Rural:** **M:** 10-20 **F:** 70-80	**Urban:** **M:** ≈ 20 **F:** ≈ 60 **Both:** ≈ 20 **Rural:** **M:** ≈ 20 **F:** ≈ 80

INTERNATIONAL WATER RESOURCES MANAGEMENT	Percentage of M/F staff in transboundary water commissions	There is no requirement for gender equality in the representation of Commissioners. That some of these Commissioners happen to be female is not due to any policy on equal representation, and is only indicative of the level of seniority of the individuals concerned		
	Presence and nature of gender-specific objectives and commitments (or gender strategy) in transboundary agreements.	**Plan Trifinio:** No gender strategy. However, the Plan Trifinio New Strategic Plan 2014-2018 includes an thematic axis “Sustainable social development with a gender and youth focus”; one of the lines of action is “supporting capacity-building with an gender equity approach”	**ORASECOM:** No gender strategy **SADC:** The SADC Gender Policy provide guidelines for institutionalising and operationalising gender as a key development strategy for achieving gender equality, equity and women’s empowerment within SADC Member States and the region as a whole. It covers 12 thematic areas and makes a direct reference to water access.	No gender strategy in transboundary agreements. Both countries have strategies for gender equality which serve as a basis for policy and law development,
INCOME GENERATION FOR AGRICULTURAL USE	Household-based decision-making process regarding irrigation (e.g. perceptions, decisions, reallocation of time and financial resources; crops to be irrigated).	Dominated by men	**M:** >80% **F:** <5% In communal areas, about 50% of women active in agriculture do not get paid for their work	**M:** ≈ 80% **F:** ≈ 20%
	Percentage of M/F in cooperatives or farmers associations %	**M:** ≈80 **F:** ≈20	**M:** ≈80 **F:** ≈20	**M:** ≈80-90 **F:** ≈10-20

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