A SAVOIR

03

December 2011

Toward a Joint Management of Transboundary Aquifer Systems

Methodological Guidebook

A Collective Work

AGENCE FRANÇAISE DE DÉVELOPPEMENT

Toward a Joint Management of Transboundary Aquifer Systems

Methodological Guidebook

Hubert MACHARD DE GRAMONT

Bureau de recherches géologiques and minières - BRGM

h.machard@brgm.fr

Coralie NOEL

International Office for Water

coralie.noel@hotmail.fr

Jean Louis OLIVER

Académie de l'eau

academie@academie-eau.org

Didier PENNEQUIN

Bureau de recherches géologiques and minières - BRGM

d.pennequin@brgm.fr

Martina RAMA

Académie de l'eau

academie@academie-eau.org

Raya Marina STEPHAN

UNESCO – IHP

r.stephan@unesco.org

CONTACT

Karine FROUIN

Water and Sanitation Division, AFD

frouink@afd.fr

eau_assainissement@afd.fr

À Savoir

The 'À Savoir' collection was created in 2010 by the AFD Research Department; it combines scientific papers and state-of-the-art reviews on subjects of operational interest.

Drawing upon research work and feedback from research scientists and field workers, from AFD and its partners, the books in this collection are conceived as working tools. They target a public of specialist professionals in the subjects covered and/or the regions described.

Earlier publications in the collection:

À Savoir No.1: The Regulation of Water and Sanitation Services in DCs

À Savoir No. 2: Managing Public Expenditures in Developing Countries (in French)

All our publications can be found on http://recherche.afd.fr

Acknowledgements

The Consortium members who prepared this Methodological Guidebook – the French Académie de l'eau, UNESCO, BRGM and the International Office for Water – express their gratitude to the Agence Française de Developpement (AFD) for its confidence in assigning them with the delicate task of proposing a general method for developing a joint management of transboundary aquifer systems, and for its constant support during this study. They also thank the many French and international organizations that helped in, and contributed to, creating this work.

Publications Director:
Dov ZERAH

Editorial Director:
Robert PECCOUD

FSC

Design and execution: Ferrari / Corporate – Tel.: 0033 (0)1 42 96 05 50 – J. Rouy / Coquelicot
Printed in France by STIN

Preface

"The future is not what will happen, but what we are going to do"

Gaston BACHELARD, French philosopher

Over half of the Earth's population and many socio-economic activities depend upon groundwater: 65% of such water is used for agriculture, 25% is for domestic use, and 10% is required by industry. However, this distribution is very different between regions: in many developed countries groundwater is the main drinking-water resource, as in Europe where it covers 70% of such needs. In arid and semi-arid countries, where surface water is rare, intermittent, or even completely absent, groundwater commonly covers most of the mobilized, or potentially mobilized, water resources.

The pressure exerted on groundwater is increasing because of changes in consumption modes, and the growth in world population and its corresponding needs, such as agriculture, drinking water, industry, energy generation, etc. The impact of such pressures can be very harmful (lowering of groundwater level, change in water quality, land subsidence, salt-water intrusion, pollution, loss of biodiversity, etc.), leading to a situation that is irreversible or will require major remediation costs. Experience has shown that certain aquifer systems are managed in an unsustainable manner, because of abstraction rates that are greater than the recharge threshold, compromising access to water by the concerned populations.

It is thus clear that the economic, social and environmental stakes of a joint management of aquifer systems are considerable, and that they are further increased in the case of transboundary aquifer systems, where crises may already be brewing between countries.

Today, over 270 transboundary aquifer systems have been identified worldwide,[1] but very few are the target of projects aiming at a better mutual management or, where this question is raised, only cover certain aspects. For instance, transboundary aquifer systems are still too rarely taken into account for Integrated Water Resource Management (IWRM).

[1] Source: Puri and Aureli, 2009.

One of the main challenges is to narrow the gap between the availability of – still poorly evaluated – water resources and an increasing demand that, in some places, already is no longer satisfied. This gap between supply and demand may become even larger under the influence of climate change.

The improved management of transboundary aquifer systems is, first of all, based on a better scientific understanding of such systems and their potential. Secondly, monitoring and rational management of the shared water resources must be set up, which is much more difficult in the case of transboundary resources. Some countries, in order to ensure their development and safeguard the needs of future generations, will effectively have no other choice than cooperation and joint implementation of suitable tools and mechanisms, to ensure the equitable and sustainable exploitation of their shared groundwater resources.

It is from this perspective that AFD, for whom IWRM is one of its priority activities, has supported the initiative by the Académie de l'eau, the Bureau de Recherches Géologiques et Minières (BRGM), the International Office for Water, and UNESCO, to create a Methodological Guidebook for the joint management of transboundary aquifer systems.

Dov ZERAH
Chief Executive Officer, AFD

Abstract

Aquifer systems constitute a substantial part of a country's available water resources, yet in some regions they are very incompletely known and understood.

Aquifer systems, much more commonly than transboundary rivers, can be shared between several countries that generally use them in an independent and often intensive manner, for drinking-water supply, industry and in particular for irrigated agriculture. The often poorly managed use of such resources leads in many cases to groundwater mining and pollution, which in turn creates local tensions, and the risk of crises and conflicts between countries.

The aim of the present Methodological Guidebook is to deepen our knowledge of such groundwater systems, fostering a collaborative, equitable and sustainable management of these resources. It first recalls the main issues at stake regarding transboundary aquifers and the need for a more comprehensive approach based on IWRM principles (Part I). It then describes some existing tools that can help in improving our knowledge and management of these precious resources; this includes technical, legal, organizational and economic tools, as well as training and cooperation tools (Part II). Finally, it proposes a progressive, multi-pronged approach for implementing the collaborative, equitable and sustainable management of transboundary aquifer systems. It also takes a look at the potential mechanisms for creating and sustainably operating an appropriate institutional structure to manage these shared groundwater resources (Part III).

Contents

Preface 3

Abstract 5

Introduction 9

1. Stakes, Specificities and Need for an Integrated Management of Transboundary Aquifer Systems 13

1.1. The stakes 13
- 1.1.1. The importance of groundwater 13
- 1.1.2. Threatened groundwater with harmful economic and health consequences 16
- 1.1.3. Significant economic stakes 23
- 1.1.4. Groundwater: an often little known water resource 25

1.2. The specificities of groundwater and transboundary aquifer systems 26
- 1.2.1. "Invisible" water resources that interact with the subsurface environment 26
- 1.2.2. Complex functioning in a three-dimensional space 27
- 1.2.3. The great inertia of aquifer systems 29
- 1.2.4. The fundamental distinction between aquifer systems containing rechargeable water and those with fossil water 30
- 1.2.5. Implications of the transboundary character of an aquifer system 32

1.3. The need for integrated management of transboundary aquifer systems 33

2. The Available Tools for Understanding and Managing Transboundary Aquifer Systems 39

2.1. Scientific and technical tools for investigations and studies 40
- 2.1.1. Inventory of transboundary aquifer systems 40
- 2.1.2. Inventory of the needs for obtaining a better understanding of aquifer systems and their functioning 42

2.2. Legal tools 49
- 2.2.1. International legal tools 49
- 2.2.2. National legal tools 50
- 2.2.3. The general legal principles of managing transboundary aquifer systems 51

2.3. Institutional, administrative and organizational tools 52

2.4. Economic, financial and fiscal tools 54

2.5. Training and professional improvement tools 55

2.6. Tools for participation and cooperation 56

3. Methodological Approach and Mechanisms Proposed for a Joint Management of Transboundary Aquifer Systems 61

3.1. At the national and local levels 61
3.1.1. Clarify the roles and responsibilities of local institutions 62
3.1.2. Improve the understanding of transboundary aquifer systems 62
3.1.3. Information, participation and dialogue between the different players and users 63
3.1.4. Involve the relevant local and regional authorities 64

3.2. On the transboundary level 66
3.2.1. Preliminary technical contacts 66
3.2.2. Holding official meetings 66
3.2.3. Collecting, organizing and sharing data in a harmonized framework 67
3.2.4. Creating common management tools 69
3.2.5. From simple dialogue to collaborative planning and joint management 71

3.3. Recommended actions at the level of the community international 73
3.3.1. Strengthen international law on transboundary groundwater 73
3.3.2. Encourage and provide diplomatic and technical support to the relevant countries 73

3.4. Nature and functions of an organization for managing transboundary groundwater (possibly including surface water) to be created or strengthened 74
3.4.1. Possible structure of an organization for managing transboundary groundwater (possibly including surface water) 75
3.4.2. Possible functions of an organization for managing transboundary groundwater (possibly including surface water) 75
3.4.3. Conceivable legal framework 78
3.4.4. Necessary funding for implementation and long-lasting operation 80
3.4.5. Networks for sharing experience 82

Conclusions 85

Appendix 87

Appendix 1 – Case histories having served to establish this Methodological Guidebook 87
Appendix 2 – Resolution 63/124 on the Law of Transboundary Aquifers 93

List of Acronyms and Abbreviations 103

Glossary 105

References 111

List of Authors 117

Introduction

Why a methodological guidebook for the joint management of transboundary aquifer systems?

Today, more than half of the Earth's population and a large number of socio-economic activities, especially agriculture, are dependent upon groundwater, which itself is under increasing pressure from pumping and pollution. For this reason, groundwater is increasingly considered as a heritage to be preserved for today's needs as well as for future generations. This is the guiding spirit of the European Water Framework Directive, whose main principles, first set at the scale of the European Union, now are disseminated worldwide.[2]

This strategic resource thus requires particular attention and the most rational possible sustainable management, in order to withstand unavoidable economic and societal evolutionary pressures, while maintaining or improving the living conditions of its users.

This is even more necessary if the aquifer systems are transboundary, *i.e.* crossed by political borders and thus shared between two or more sovereign States. If this stake is poorly or insufficiently appreciated, it can lead to a loss of opportunity in terms of human and economic development, as well as a degradation of living conditions in the concerned regions, thus causing tension and even open conflict.

Until now, most efforts concerned the management of *transboundary surface waters*. This is seen in the growing number of existing or future agreements and by initiatives that have led to the creation of transboundary catchment basin organizations, as well as to the setting up of suitable means for sharing thoughts and experience, such as is part and parcel of the International Network of Basin Organizations (INBO).

On the other hand, only few actions have concerned *transboundary groundwater* systems, except for a restricted number of projects concerning a few shared aquifer systems, and covering only some aspects of the question. The fact that groundwater is invisible and subject to complex working modes certainly does not help decision makers in fully assessing the vulnerability, real potential and true stakes represented by this resource.

[2] Text available on: http://ec.europa.eu/environment/water/water-framework/index_en.html

Nevertheless, today more than 270 transboundary aquifer systems have been recorded by the UNESCO Internationally Shared Aquifer Resources Management (ISARM) programme. Such systems are quantitatively and qualitatively strongly affected by the development of human activity, especially agriculture and growing urban development. Moreover, in many arid and semi-arid areas such underground water resources are not, or hardly, renewed. Their rational use then becomes all the more crucial, while climate change risks will even further aggravate this situation in the coming decades.

To avoid the irreversible degradation of such shared aquifer systems, not penalize future generations and prevent potential conflicts between countries on the use of these essential resources, it is crucial to establish dialogue and constructive collaboration between the concerned parties. This implies the definition of common objectives and suitable strategies, as well as the design and implementation of certain transboundary management mechanisms. A good understanding of the characteristics and functioning of the aquifer systems is an indispensable precondition without which no informed decision can be taken.

This is the objective of the Resolution on the Law of Transboundary Aquifers as adopted by the General Assembly of the United Nations on 11 December 2008 (A/Res/63/124),[3] which, in appendix, contains the draft articles on the Law of Transboundary Aquifers prepared by the International Law Commission. This is also a clear conclusion from several international events on water resources, especially the 5th World Water Forum, held in Istanbul in March 2009, or the World General Assembly of the INBO held in January 2010.

Generally speaking, the combined effects of increased demand, of lowering groundwater levels and menacing pollution, of the need for diversification and quantitative and qualitative safeguarding of water resources, and of climate change, have progressively underlined the importance of transboundary aquifer systems within the international community. Viewpoints – and sometimes practices – of certain countries are starting to evolve, international institutions are mobilizing, knowledge is progressing, and ideas and projects are maturing, in order to arrive at a rational and satisfactory solution of the particularly complex and sensitive problems posed by managing shared aquifer systems.

However, the road remains long and difficult before shared aquifer systems, like transboundary rivers and lakes, are better known and managed.

[3] The text of this Resolution is given in Appendix 2 of this Guidebook.

In order to help set up appropriate management systems for such shared groundwater, AFD has co-financed a study carried out by a consortium consisting of BRGM, UNESCO, the International Office for Water, and the French Académie de l'eau, which has led to establishing methodological guidelines for a joint management of transboundary aquifers. The objectives of this Guidebook are to assist the concerned political and administrative authorities in progressively setting up a collaborative, equitable and sustainable management of their groundwater and their shared aquifer systems.

This Guidebook starts by reminding the reader of the stakes, specificities and tensions inherent in transboundary aquifer systems, and for the need of integrating these points in a general IWRM approach (Part 1). It then describes the various available and complementary technical, legal, organizational and economic tools (Part 2). Finally, it presents several proposals for action aimed at the concerned players at local, national, transboundary and international levels. It sketches out the mechanisms to be set up or adapted, with the new functions, statutes, funding and networks to be planned for implementation and sustainable operation of a transboundary-groundwater-management organization (Part 3).

The writing of this Guidebook – the third part of a much more global study – was preceded by major preparatory work that is accessible on the Internet sites [4] of the consortium partners:

- The first part of this preparatory work included preliminary observations and general analyses, including identification of the on-going dynamics in the legislative, institutional and technical fields, identification of the main stakes involved, and an analysis of several management experiences of transboundary aquifers (Northern Sahara, Lullemeden, Guarani, Nubian Sandstone, Upper Rhine aquifer, Carboniferous aquifer, Genevois and Stampriet aquifers).
- The second part consisted of detailed case studies of seven transboundary aquifer systems that represent major stakes (Mekong, Ghana-Togo-Benin coastal aquifer, Lake Chad Basin, Senegal-Mauritania, Taoudeni-Tanezrouft, Lullemeden, and the Mountain and Coastal aquifers of the Gaza Strip).

A table summarizing the examples dealt with in this preparatory work is presented as Appendix 1.

[4] The relevant Internet sites are given at the end of the References, at the end of this Guidebook.

1. Stakes, Specificities and Need for an Integrated Management of Transboundary Aquifer Systems

Almost everywhere on Earth, the subsurface contains groundwater resources. These are found at variable depths and in different quantities, they can be renewable or little- to non-renewable, but they are generally of better quality than surface waters as they are better protected against the impact of human activities.

Groundwater in aquifer horizons can be superposed at different depths, which may or may not communicate among each other or with overlying surface waters. The latter can be permanent or intermittent, according to the seasons, years or periods. It is thus generally preferable to speak of **'aquifer systems'**, sets of aquifers that are variably connected in a hydraulic sense, either internally or with the associated surface waters.

Such systems can extend over areas of highly variable size, ranging from a few dozen square kilometres to enormous expanses such as the northern Sahara aquifer system (SASS) that covers well over 1 million km^2 of Algeria, Tunisia and Libya, and is estimated to contain around 60 billion m^3 of water. Obviously, such systems completely ignore administrative or political boundaries and many are of a transboundary nature.

1.1. The stakes

Groundwater, like surface water, is fundamental for life in all its aspects, as well as for socio-economic activities everywhere in the world. Nevertheless, such resources today are subjected to numerous threats.

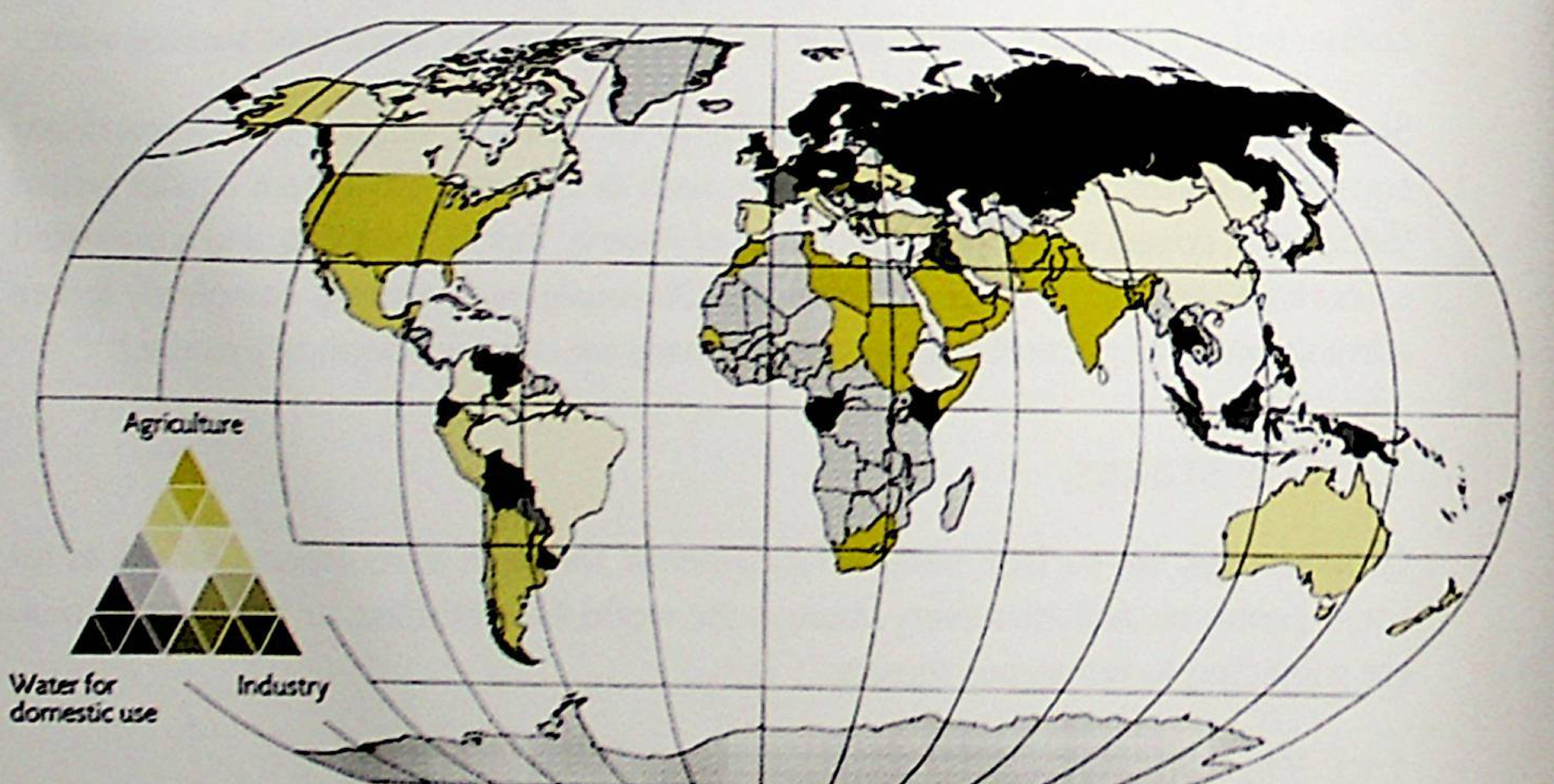
1.1.1. *The importance of groundwater*

Importance of groundwater for human activities

All human activities use water (domestic and urban uses, agriculture and animal breeding, industry and crafts, energy production, river navigation, etc.). More than surface water, groundwater plays a major role in the socio-economic development of our societies, as over half of the Earth's population depends upon it. Generally speaking, groundwater, because of its relatively extensive three-dimensional presence in the sub-surface, allows for a better distribution of human activities in space, compared to surface water that generally requires a linear or circular concentration of activities, near rivers and lakes.

Worldwide, 65% of abstracted groundwater satisfies agricultural requirements, 25% is for domestic use, and 10% goes to industry, including mining and energy activities (Margat, 2008). However, this distribution strongly varies between regions: in many developed countries groundwater is a major drinking-water resource, as in Europe where it covers 70% of needs. In arid or semi-arid countries, where surface water is rare, intermittent or completely absent, groundwater commonly constitutes most of the resources that are, or can be, mobilized. This is especially the case in the Middle East; the Maghreb and sub-Saharan Africa. For instance, groundwater is the main conventional drinking-water resource in Saudi Arabia or Libya (almost 100%), in Yemen, Pakistan and Chad (75 to 100%), India (about 64%), or Algeria and Niger (over 60%).

Map 1 *Groundwater use by type*



Source: Map modified from Margat, 2008.

It is thus clear that, almost everywhere, groundwater is a major, if not total, component of the water resources that can be mobilized, especially in some interfluves between major rivers and streams, and in many arid or semi-arid regions where no perennial surface water exists.

Because of its subsurface location, groundwater is better protected against human pollution than surface water and is often of better quality, even if it remains globally vulnerable.

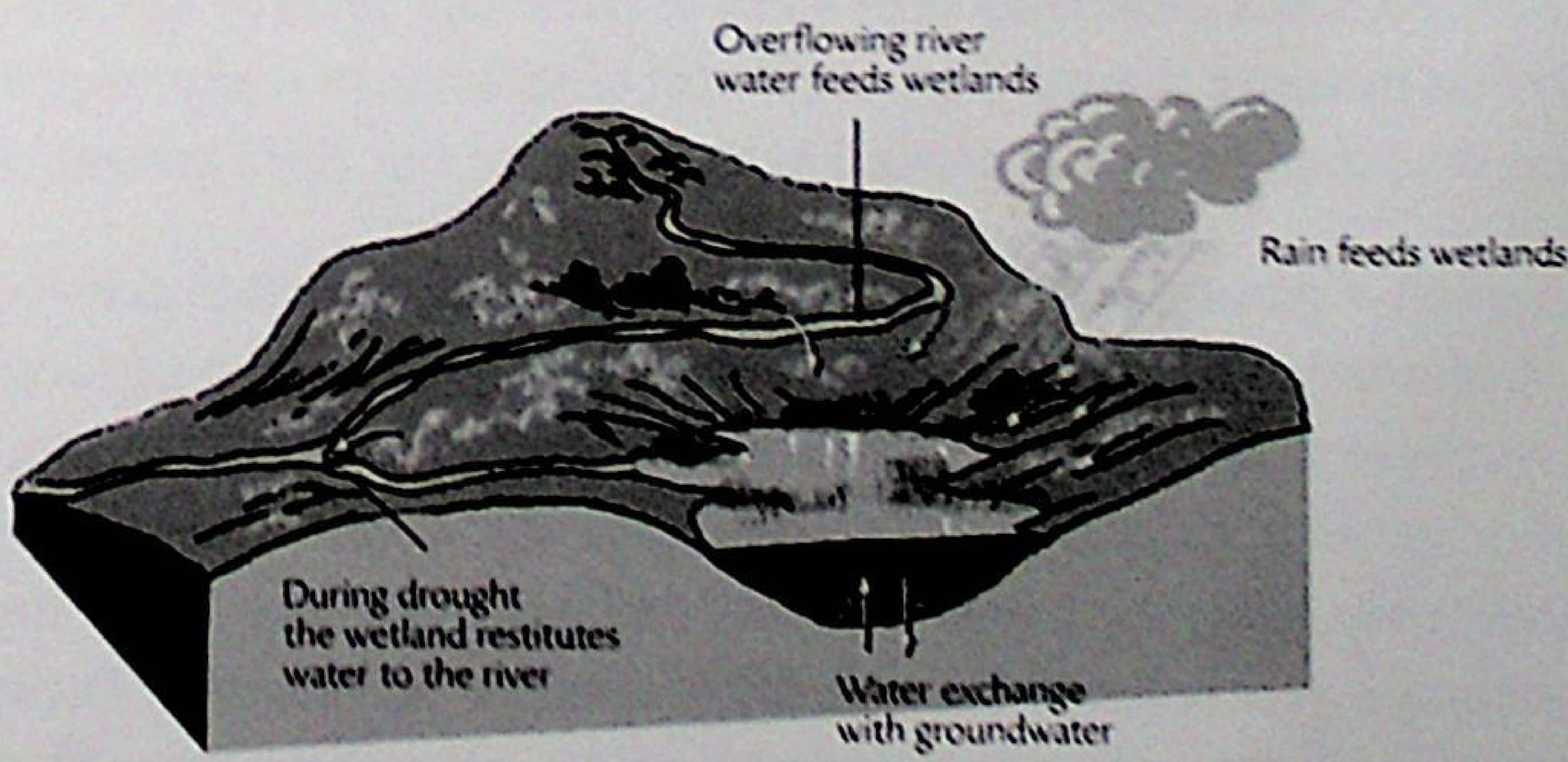
Finally, faced with climatic hazards the great inertia of aquifer systems gives them a better stability and resilience than surface waters. Provided the underground resource is well used, such relative stability might be particularly valuable in the face of climate change, which already causes extreme hydro-meteorological phenomena, in particular droughts, that risk becoming even more frequent and intense in the near future.

The importance of groundwater for surface water, ecosystems and biodiversity

Groundwater commonly interacts with surface water and may be an important source of river, lake and wetland waters, especially during dry periods when it sustains their flow and bottom water level.

Groundwater also plays an essential role in aquatic environments, where it contributes to preserving and maintaining the lacustrine and riparian fauna and flora, as well as feeding numerous wetlands. The latter host a great biodiversity, create carbon sinks, and allow a natural cleaning of pollution in sediments and plant-root systems, as well as their associated fungi and bacteria.

Diagram 1 *The functioning of wetlands*



Source: Web site of the Rhone-Mediterranean and Corsica Water Agency, 2010.

Terrestrial ecosystems very often also depend upon groundwater, which provides the necessary humidity for many plant species, whether directly or indirectly through underlying humid soil. In arid environments, for instance, oases can only exist near shallow or resurgent groundwater.

Box 1 *Example of interaction between surface- and ground-waters in the Balkans*

Lake Dojran is shared between the Republic of Macedonia and Greece. The major drought affecting the region during the past decade, which reduced precipitation, and the intensive pumping of groundwater for irrigation on the Greek side, have led to a substantial lowering of the lake level. This lowering has had a negative impact on the lacustrine ecosystem and on the fishing industry on the Macedonian side.

Source: Aureli and Ganoulis, 2005.

1.1.2. *Threatened groundwater with harmful economic and health consequences*

Today, there is increasing pressure on the underground water resources of many regions. These are affected by increased water abstraction related to population growth, growing urbanization, socio-economic development and improved living conditions, and by increased pollution due to human activity.

Thanks to technical progress over the past decades, groundwater has become more easily accessible. Not counting deep aquifers, whose resources can only be mobilized by players having access to heavy drilling means (public authorities or major industry), shallow groundwater, such as phreatic aquifers, today is within reach of a large number of users. The result is a proliferation of wells, in particular serving agricultural industry that, today, has become the main groundwater consumer. In many countries, aquifer systems are thus increasingly exploited in an intensive but disorganized way.

In addition, even if groundwater is better protected against human activity than rivers and lakes, it remains vulnerable to infiltration of pollutants with a surface origin. The latter commonly end up in groundwater, even where it is covered by semi-permeable layers (soil or geological layers with a predominantly marly or clayey composition) that generally only delay the contamination process. Rapid economic development without adequate protective measures often leads to increased pollution of water. Once contaminated, groundwater can remain so for a long time even after corrective measures have been taken.

Climate change in certain regions can cause accelerated desertification and fresh outbreaks of extreme hydro-meteorological phenomena. This further risks aggravating the situation, particularly in arid or semi-arid regions such as North Africa, where aquifer systems are the main, or even only, water resource.

The main consequences of these multiple pressures are:

- Overpumping of renewable aquifers, with a catastrophic lowering of the water table and, possibly, a change in water quality;
- Drying up of springs, wells, foggaras/qanats and boreholes, the latter having to be constantly deepened;
- Exhaustion or progressive drying up of fossil-water aquifers;
- Compaction and subsidence of the ground, causing damage to buildings and infrastructure and increasing the risk of flooding by sea or river waters;
- Salinization of soil and/or aquifer systems;
- Salt-water intrusion in coastal aquifers that become irreversibly unfit for use (salt-water wedge); and
- Pollution that is irreversible – or difficult to reverse – of groundwater, degrading its natural quality and rendering it unsuitable for human consumption

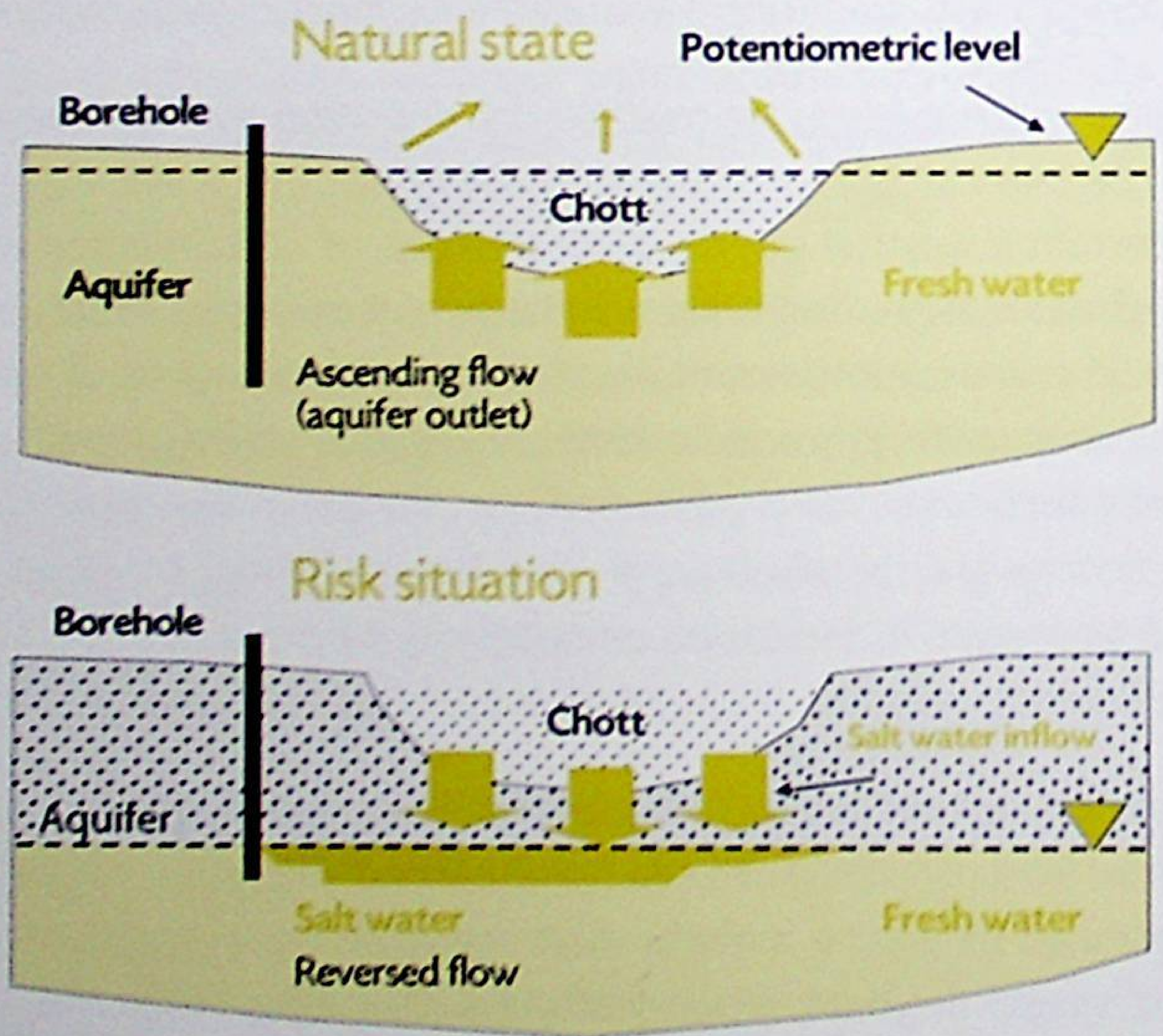
The implications of these points are multiple: drinking water shortages, restricted access to water for certain categories of users, increased cost of water, increased cost of producing certain industrial goods, delocalization of certain activities, increased waterborne diseases, degraded living standards, and even population displacement. This happens in many countries and on all continents, regardless of their degree of development, and not only in arid or semi-arid regions where groundwater is under particular pressure.

Box 2 Example of overpumping accompanied by an aquifer salinization mechanism: the case of the chotts

In arid zones, where evaporation is very strong, groundwater may flow toward closed (endorheic) basins, either through simple gravity or because of capillary rise along faults. Evaporation over a long period then creates vast expanses of salt crust, called a 'chott' in North Africa. Some springs may persist on the edge of such chotts, drawing upon the same aquifer, creating oases and allowing agriculture. Locally, wells are drilled to capture the fresh water before it enters the chott. However, too many wells can cause lowering of the watertable and drying up of the springs. At the same time, chotts can be filled with surface water, becoming true temporary salt lakes. Lowering the watertable causes the migration of brines to the aquifer, which then becomes increasingly salty and unfit for consumption.

This is especially the case of some parts of the SASS aquifer (northern Africa aquifer system) in Algeria and Tunisia.

Diagram 2 Salinization mechanism of an aquifer in the chotts area



Source: Adapted from OSS, 2004.

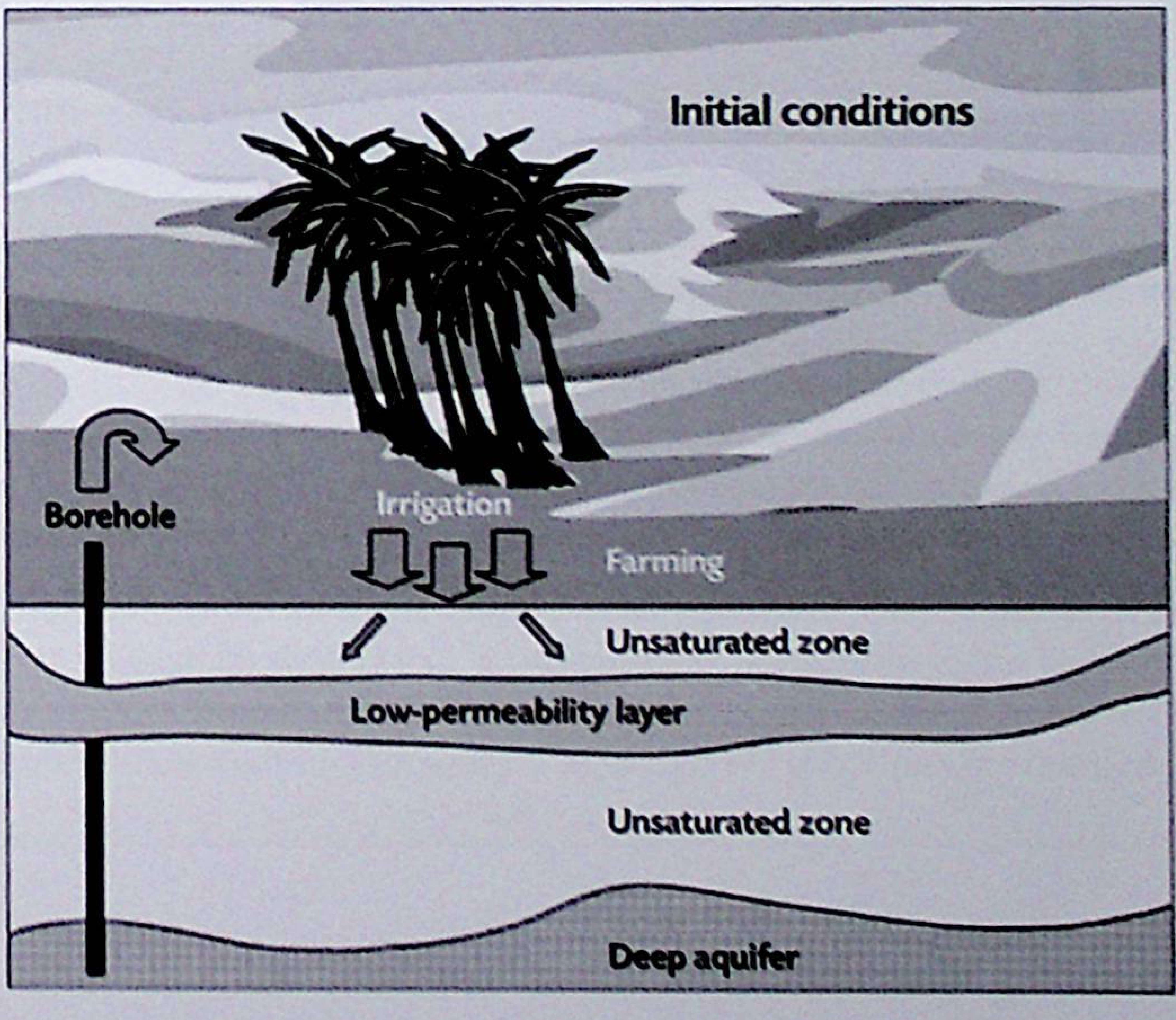
Box 3 *Example of soil salinization in arid zones of the great sedimentary basins.*

In arid or desert areas, where the existence of an aquifer at medium depth allows irrigation and agriculture, the returning irrigation water is often not properly drained away. In this case, such water infiltrates into the subsurface where it can form a temporary so-called perched aquifer

Strong evaporation can affect this perched aquifer, causing the water to rise through capillarity and evaporation. The result is an accumulation of salt crusts that end up sterilizing the soil, rendering it unfit for agriculture (*cf.* diagrams 3 and 4).

Once this has happened, it is very difficult to rehabilitate such soil, whose structure has been profoundly modified. In fact, the leaching of such soil with fresh water – a very costly process in this type of environment – generally no longer suffices.

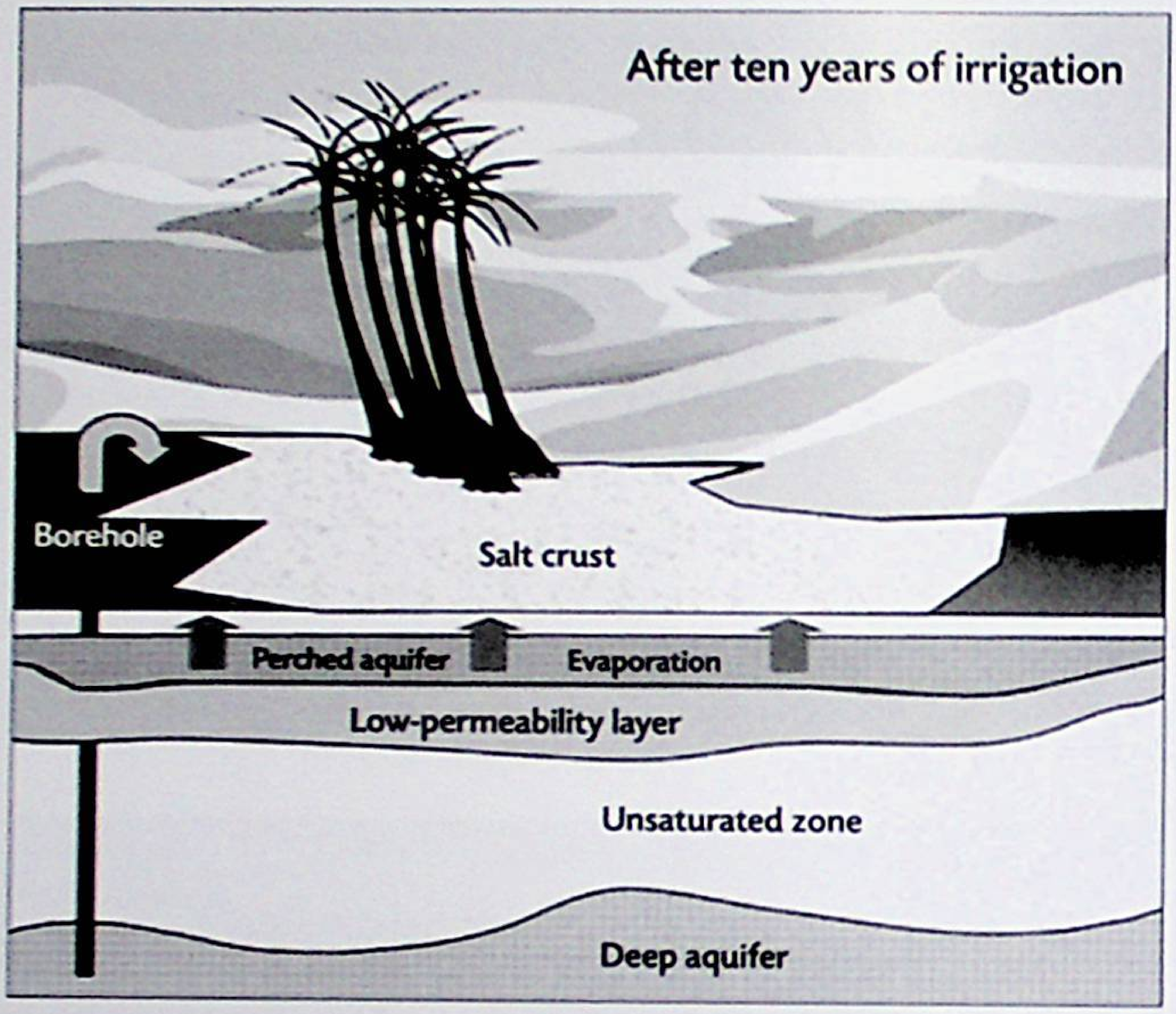
Diagram 3 *Initial conditions, start of irrigation*



Source: BRGM, 2010.

...

Diagram 4 *Salt-crust formation*



Source: BRGM, 2010.

Such quantitative phenomena are not the only ones at stake. In other cases, the uncontrolled evacuation of wastewater can create an extremely polluted shallow aquifer, contaminating the environment and locally provoking a disappearance of the vegetation. This has happened in certain Algerian oases fed by the SASS aquifer.

The management of water in a desert or arid environment therefore requires a rational and controlled use of water, limiting supply to the strict needs, eliminating as much as possible all return flow from irrigation (by using drip irrigation, membranes, etc.), and, in a more general sense, restricting the discharge of effluents into the natural environment.

Box 4 *Example of a strongly threatened and degraded resource: the coastal aquifer system in the Gaza Strip*

The only supply of fresh water in the Gaza Strip is the coastal aquifer along the Mediterranean Sea, which also extends into Israel.

This aquifer is subject to excessive pumping – well over its capacity for renewal – for agricultural and domestic use, the population density of the Gaza Strip being one of the highest in the world at about 5800 inhabitants/km².

This results in a continuous decline of the aquifer level and, connected with this, a major intrusion of sea water. Over 70% of the aquifer system today is brackish, and only about 5 to 10% of the aquifer remain fit for human consumption.

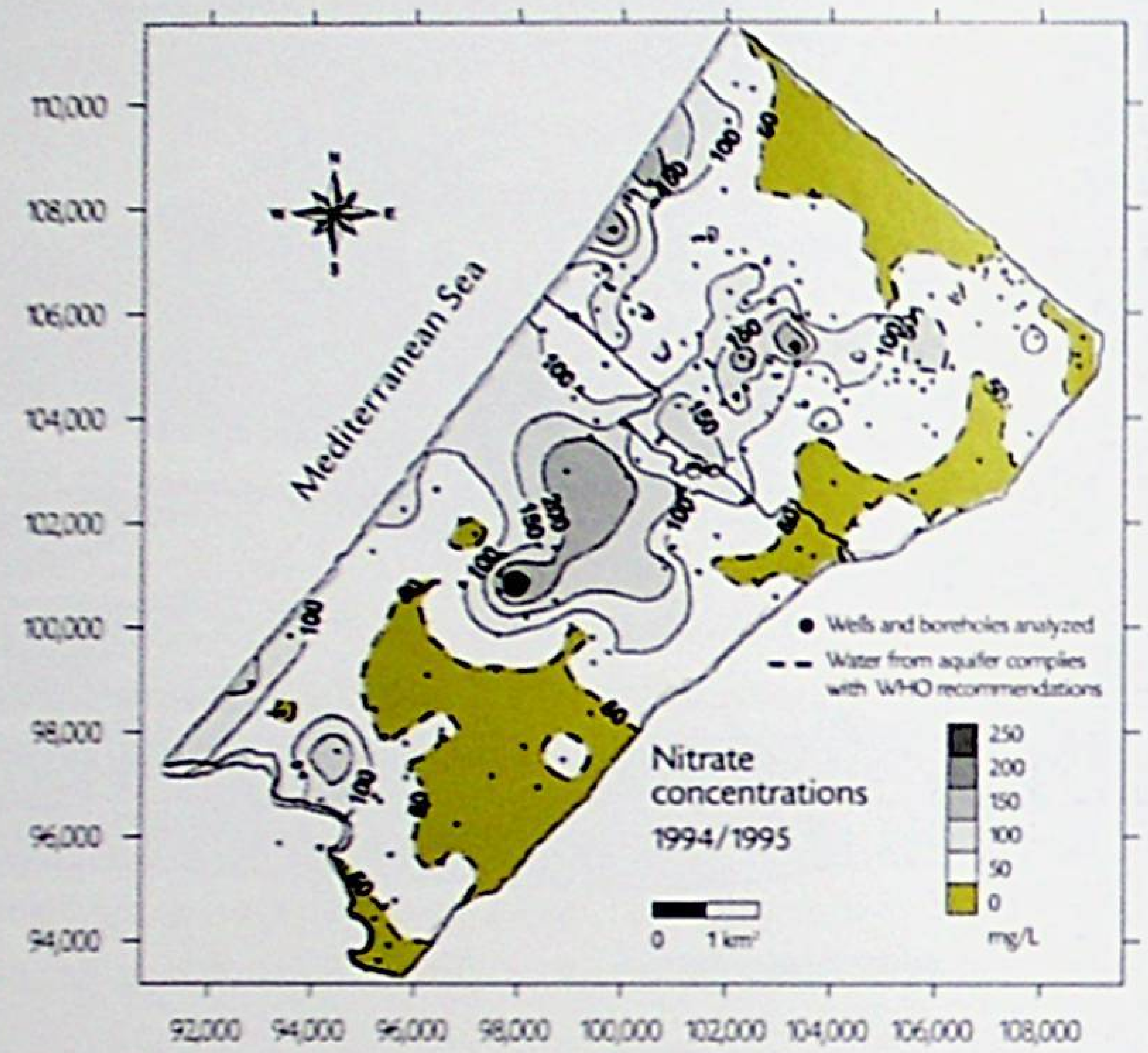
In addition to its salinization through seawater intrusion, the aquifer is also polluted by infiltrated wastewater, and fertilizers and pesticides used for agriculture, but also by domestic effluents and industrial discharge. Because of this, Gaza water has nitrate, chloride and pesticide contents that are very much over the World Health Organization (WHO) recommendations, rendering the water unfit for human consumption and creating a serious public-health problem, such as kidney and liver diseases, cancers, etc.

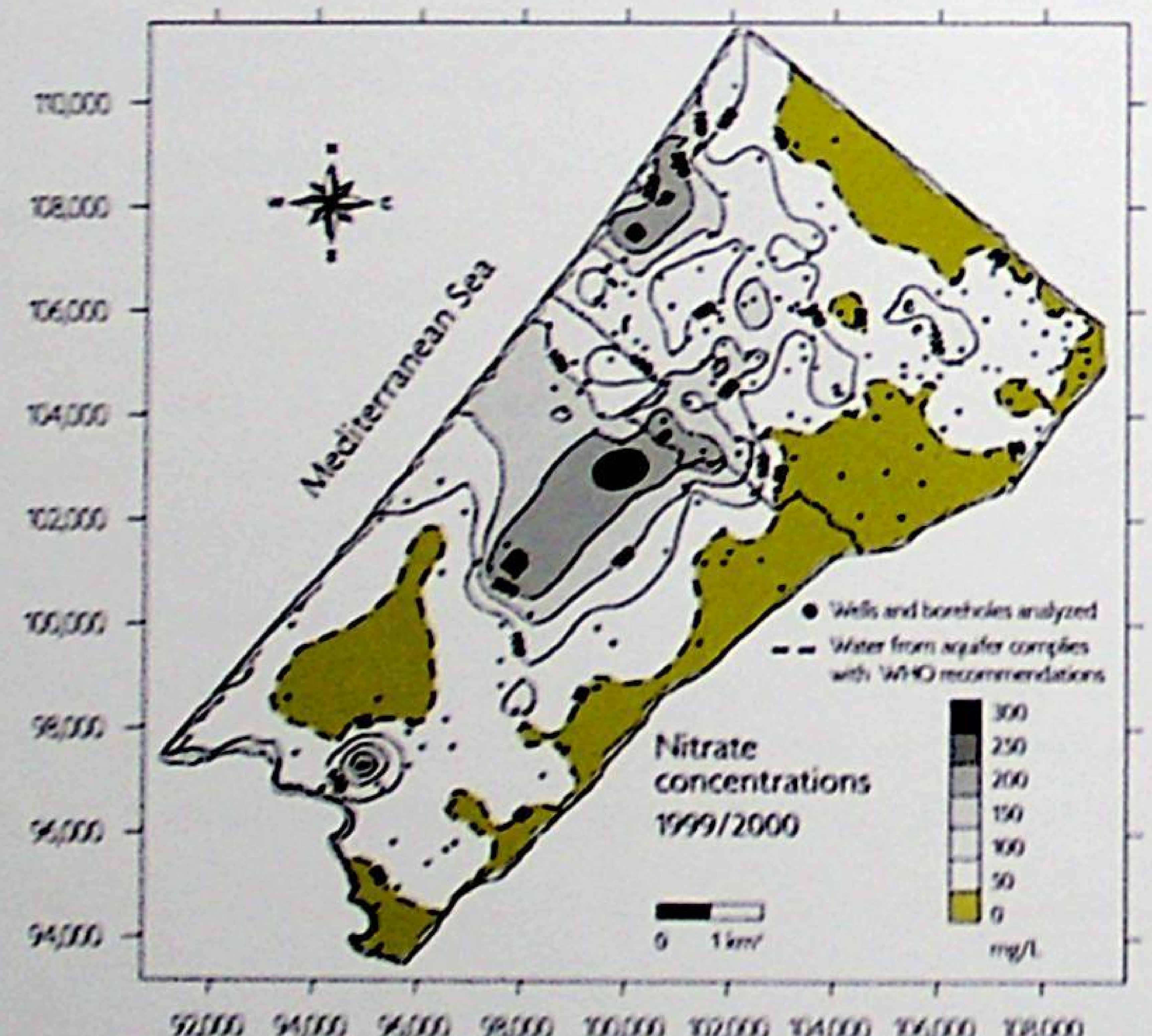
Map 2, hereafter, bounded to the south by Wadi Gaza, only covers the North Gaza and Gaza City administrative areas, and not those of Deir El Balah, Khan Younis and Rafah, which lie south of Wadi Gaza.

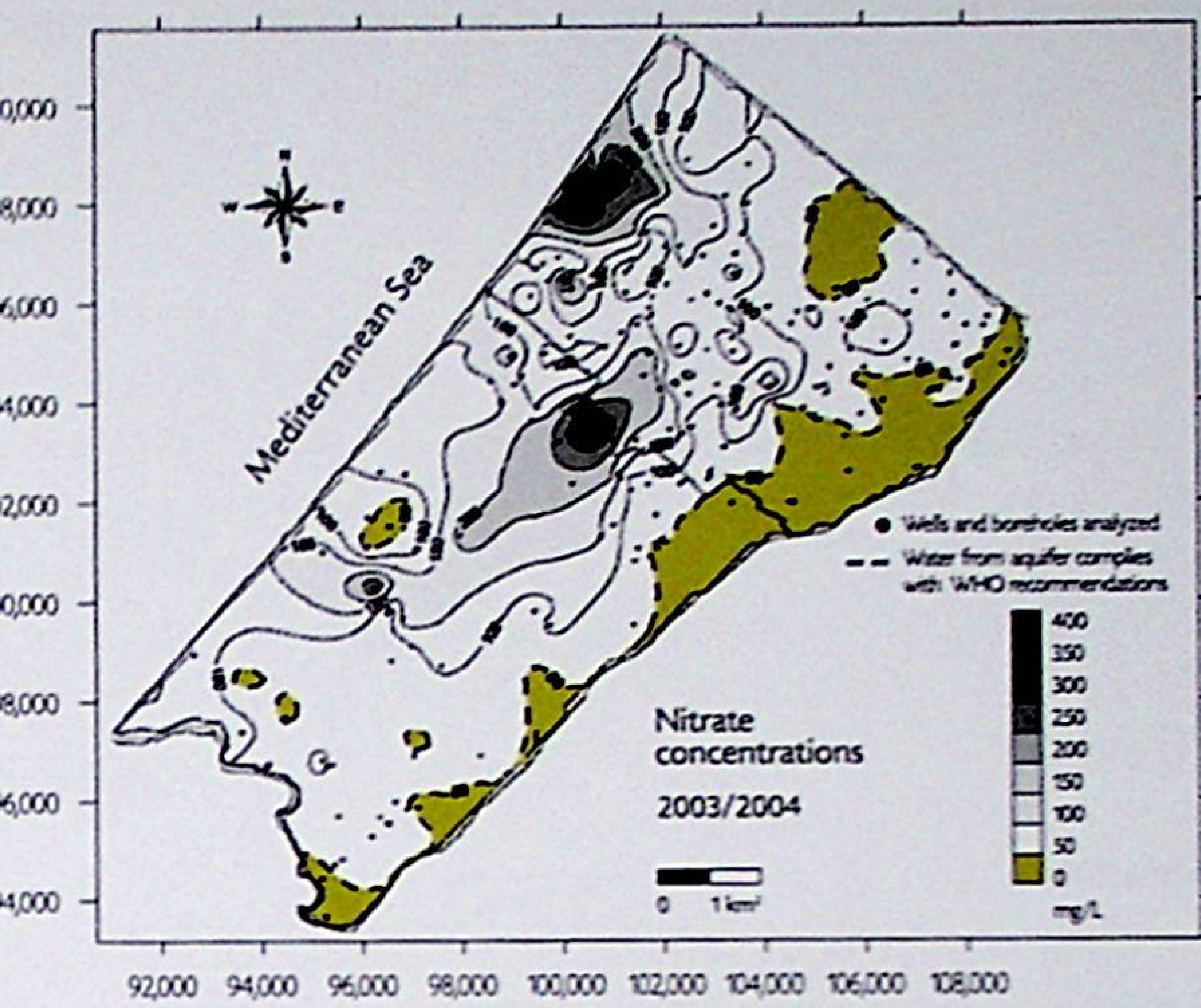
Below the areas covered by the cities of Gaza and Jabalia, the nitrate concentrations in 1994 were already 277 and 290 mg/litre, respectively, or 5 to 6 times the upper limit set by the WHO for drinking water (50 mg/l). In 1999 they had increased to 304 mg/l near Wadi Gaza and in the north-west of the Gaza Strip, near the sea. In 2003 the situation had even further deteriorated, with concentrations reaching over 300 mg/l, mostly due to defective or inexistent sanitation systems.

•••

Map 2 Evolution of nitrate concentrations in the Gaza Strip aquifer, south of Wadi Gaza







Source: Abu El-Naeem et al., 2009.

1.1.3. *Significant economic stakes*

The economic impact of poor management of transboundary aquifer systems

Groundwater can represent a major stake in the economic development of regions, affecting its agriculture, animal husbandry, industry, energy, and tourism sectors. However, any quantitative and qualitative disturbance of aquifers will compromise water use, whether this is for drinking-water supply, irrigation or industrial processes.

This economic impact can then be very serious, as such disturbances may require the deepening of wells, the search for new resources, the creation of new exploitation sites, the closure of industrial sites, etc. Today, no precise data are available concerning the specific economic impact of a poorly managed transboundary aquifer system, but only indicative estimates. Such an estimate made by the WHO in 2006 for Africa, for instance, shows that the economic loss resulting from unhealthy water is evaluated at about USD 28.4 billion, or around 5% of the African gross domestic product (GDP).

Though it is obvious that we should improve the evaluation of the economic impact of poorly managed aquifer systems, it is quite certain that the cost of inaction is very much higher than that of action. This is even truer in the case of transboundary aquifer systems, where a local problem ends up by becoming a regional one, whether quantitative or qualitative; the effects of overpumping or pollution commonly extend over large areas, or even the entire shared aquifer system, and thus can affect several or all concerned countries.

Box 5 Examples of economic impact

According to the results of a study by the World Bank in the Middle East and North Africa (MENA) region, overexploitation of groundwater reduces the value of national assets at a rate of 1 to 2% of GDP/year in certain countries, costing between 0.5 and 2.5% of GDP/year. In 2005, for instance, Jordan saw its assets reduce in value by 2.1% of its GDP, Yemen by 1.5%, Egypt by 1.3%, and Tunisia by 1.2%, all because of groundwater overpumping.

Source: World Bank, 2007.

The cost of cleaning up an aquifer system

The degradation of groundwater quality can have major negative economic repercussions for the concerned region, thus strongly hindering its development. Remediation of a contaminated aquifer is a technically difficult and time-consuming operation, with a high cost that varies in particular with: *(i)* The importance, constitution, configuration and volume of the concerned aquifer system; *(ii)* The extent and type of the pollution; *(iii)* The remediation measures deployed; and *(iv)* The socio-economic environment of the area affected.

In general, the cost of such depollution covers a wide range, from a few million to several hundreds of millions of euros, though such costs are generally well below the benefits for the affected regions that would be generated by remediating the resource. However, the most efficient economic approach is to anticipate such problems and correctly manage the precious water resources.

Box 6 Example of the cost of depolluting an aquifer system

The cost of remediating the strongly degraded shallow aquifers in the Kempen area of the Meuse Basin, straddling the boundary between Belgium and The Netherlands, was calculated for the needs of the European Water Framework Directive.

These aquifers were seriously polluted by heavy metals, in particular zinc and cadmium, caused by the historical activity of industrial smelting in this area since the 19th Century. The initial soil pollution resulted in pollution of the shallow aquifer systems.

Depending on the various possible remediation methods, the corresponding costs were estimated to fall between €4.5 and €13 million per hectare and per year, to which should be added capital investment costs of €4 to €36 million.

Source: Bouzit and Ansik, 2008.

1.1.4. *Groundwater: an often little known water resource*

Many aquifer systems, whether transboundary or not, remain very unequally understood at the scientific and technical level, and in many areas of the Earth they are even largely unknown. Their characteristics, functioning, potential and boundaries are commonly poorly understood by the persons in charge of their management. In most cases, no management instrument exists for aquifer systems or, if existing, its effective implementation is difficult because of a lack of data and knowledge, or even of competence.

This lack of understanding is reflected in the legal framework and status governing groundwater, which are often poorly defined on both national and international levels:

- *At the level of national law,* the trend is to recognize water as a common or public good, which confers to the State the power and responsibility of its management. However, though many countries today have adopted legislation covering water, this commonly focuses on visible water, *i.e.* surface water. Many countries have not yet adopted specific regulations for groundwater management;
- *At the level of international law,* the international legislation concerning groundwater is still embryonic, and only very few treaties, conventions or agreements between countries concern – or even mention – transboundary groundwater. This question was studied in detail in the first part of the Preliminary Works.

Finally, most territorial development plans do not mention groundwater, and if they do it is little – and poorly – taken into consideration. This increases the risk of interference and distribution conflicts, which can only be surmounted through integrated and collaborative management of the resource, involving all concerned players at local and national, or even supra-national levels where aquifer systems cross national borders.

Box 7 *Example of a very complex and little known system: the transboundary aquifer systems of the Lake Chad Basin*

The Lake Chad Basin contains at least five transboundary aquifer systems:

1. The sandy aquifer system of Quaternary-Pleistocene age;
2. The Pliocene-age sandy multi-layer aquifer system underlying Niger, Chad, Cameroon and Nigeria;
3. The sandy Continental Terminal aquifer system consisting of a northern part (Niger and Chad) and a southern part (Nigeria and Chad);
4. The deep Cretaceous sandstone aquifer system underlying Niger, Nigeria, Cameroon, Chad and the Central African Republic; and
5. The northern Paleozoic sandstone and limestone aquifer systems of Niger and Chad.

In this arid region, water problems are greatly exacerbated by the general context of drought, unequal distribution and vulnerability of the resource, and the intensive exploitation of groundwater. For a better knowledge of these aquifer systems it is thus necessary: to obtain a better understanding of the flux and turnover rate, to quantify the interactions between surface water and groundwater, to identify the trends in terms of aquifer levels and quality, and to evaluate the importance and impact of the pressures on and uses of this shared and sensitive resource.

Source: Second part of the Preliminary Works.

1.2. The specificities of groundwater and transboundary aquifer systems

1.2.1. *'Invisible' water resources that interact with the subsurface environment*

Whereas groundwater is one of the main wellsprings of life for mankind and ecosystems, the fact that it is invisible makes it difficult to appreciate its true value. This observation, though mundane, has far-reaching consequences:

- First, it is much more difficult to document – and this often imprecisely – the existence, location, origin, depth, extent, turnover rate, recharge areas, outlets, inter-communication, chemical composition, etc., of groundwater. Contrary to rivers, whose available flow rate is easily measured, the outflow of groundwater is often poorly known. The potential of aquifer systems and the limits to their use are generally unknown elements to those in charge of the resource, who can manage it only in a less than optimal manner, that may be even contrary to reasonable practice;
- Secondly, the access to groundwater and its exploitation remain relatively difficult and expensive, based on its depth and geological setting, even though recent progress now allows a wider range of players to access this resource;
- Finally, the quantitative and qualitative impacts of exploiting an aquifer system, impacts that have a three-dimensional knock-on effect in the subsurface, are not directly apparent and visible, and are therefore difficult to evaluate.

In addition, groundwater has the characteristic of being intimately related to the subsurface through which it flows, as well as to the overlying land. Regardless of whether such water is mobile and rechargeable, or immobile and fossil, it will interact with the ground, picking up minerals and chemical elements that determine its natural quality and geochemical background. Today, this natural quality commonly has been modified and degraded by human discharge, whether occasional or chronic; such discharge often contains pollutants that infiltrate the phreatic and deeper aquifers, with the long-term risk of rendering the groundwater unfit for human consumption, or for other uses such as agriculture and industry.

For these various reasons, the perception, understanding and representation of groundwater is particularly complex, both for the population and for officials and decision makers. The limits of sustainable exploitation and the direct or indirect impact of the pressures exerted on the resource are especially poorly controlled elements that are generally not considered during territorial planning and development. This in turn leads to wasteful use as well as to damage to the environment and to human health and activities.

1.2.2. *Complex functioning in a three-dimensional space*

An aquifer system is the field of action for two main phenomena: mass transfer and pressure transfer (Pennequin, 2000; 2002).

As for surface water, **mass transfer** covers two aspects: water flow and the transport of dissolved matter, including pollutants. Like surface water, flow governs the transport of dissolved matter, but – unlike surface water – such underground flow is in three dimensions (width, length and thickness), governed by the hydrogeological configuration of the subsurface and its degree of saturation.

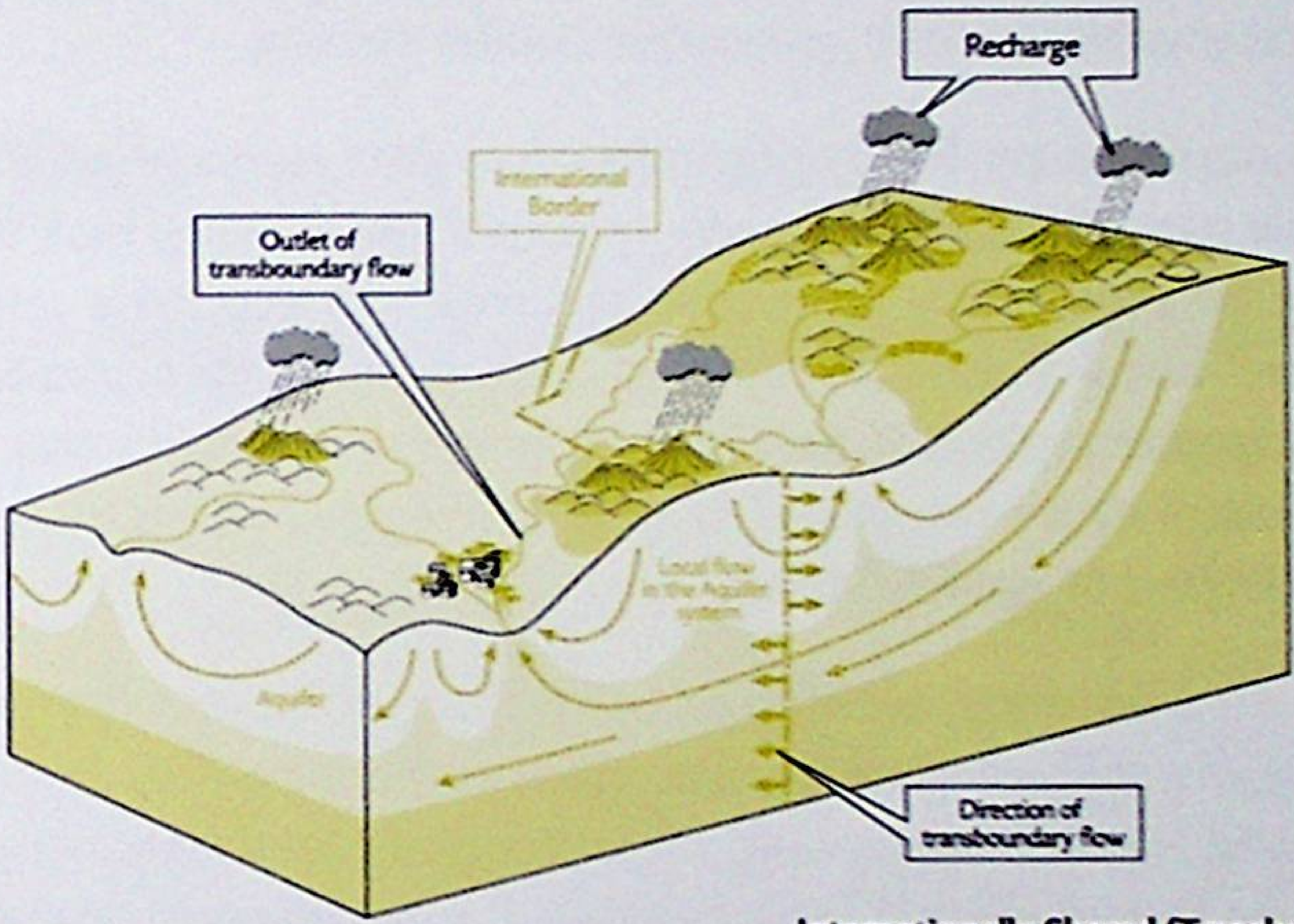
Pressure transfer is more specific to groundwater, being the propagation of dynamic influence – the variation of water level or pressure – that is independent of the natural flow direction. Because of this, any abstraction on one side of a border will influence the groundwater level – and thus well productivity – on the other side. In some cases, this can even reverse the natural flow direction.

Underground flow, the natural quality of water, displacement of pollutants and the consequences of pressure exerted on aquifers are thus very complex subjects. They depend upon the geological structure of the subsurface and its hydrodynamic properties, the capacity for interaction between the host rock and the water flowing through it. More general factors governing such flow are the overall geometry of the aquifer system, its characteristics and the sum of pressures and uses to which it is subject and that interfere among each other. All pressure exerted on an aquifer system and all pumping from it have potential repercussions on the system as a whole, such as lower water levels, reorientation of flow directions, changes in the natural quality of the water, contamination of wells, etc.

Therefore, in order to be able to set up a reasoned and sustainable management of an aquifer system, it is necessary to have a complete understanding of its characteristics and functioning, and of the stresses imposed on it. A too local vision of these points, in particular on one side of a political border, often results in an incomplete understanding. It does not make sense to only partially observe the changes of some variables (such as flow rate, water level, composition of water quality, etc.), and then to try and fix constraints (such as a polluting flow or a maximum allowable potentiometric drawdown) with just this local vision, which may even run counter to the actions that would be really necessary.

Diagram 5 *Complex functioning of a transboundary aquifer system*

Natural groundwater circulation can be quite different from one aquifer level to another. For instance, local (shallow) flow may cross a political boundary in one direction, whereas regional (deeper) flow may be in a different, or even opposite, direction. In addition, such natural circulation can be strongly disturbed by Man's actions that, through pumping from wells for instance, may artificially induce reverse flow in some areas, or modify the pressure fields on one side of a border causing water-level drops on the other side.



Source: Puri et al, 2001

Internationally Shared (Transboundary) Aquifer Resources Management UNESCO, ISARM (2001).

1.2.3. *The great inertia of aquifer systems*

Contrary to surface water, aquifer systems are generally characterized by great physical inertia. The qualitative and quantitative pressures exerted at a given moment may have a noticeable (visible) impact only years or even decades later. In the case of overexploitation of a system, the consequences may thus take a long time to be felt in some places. This is even more true for contaminant diffusion whose transfer is generally very slow; such contaminants can accumulate in the soil and the unsaturated zone, and take a long time before reaching the uppermost aquifer layer, through which they may migrate over years, or even decades, before arriving at distant water wells, including those destined for human consumption, and in topographic depressions containing lakes, wetlands and rivers.

Such aquifer-system inertia is still poorly understood and therefore little taken into account by the authorities in charge of water management. However, the remediation of a degraded aquifer is a difficult and very long operation, and is often impossible in view of the enormous costs involved.

1.2.4. *The fundamental distinction between aquifer systems containing rechargeable water and those with fossil water*

Two categories of aquifer systems exist: the *'renewable'* aquifer systems in which groundwater flows and is recharged over the seasons, and those that are only little recharged because of climatic reasons or their geological setting and which are called *'non-renewable'* or *'little-renewable'* aquifer systems.

Renewable aquifers are fed by precipitation in their recharge areas. In this case, the renewable part of this resource can be considered as being part of the natural flux that can be used under acceptable technical and economic conditions, the water 'reserve' being able to be replaced. Such systems are commonly found in humid or temperate regions, in particular accompanying streams that have natural year-round flow; they are rare in arid or semi-arid regions where, moreover, surface water is very limited or entirely absent.

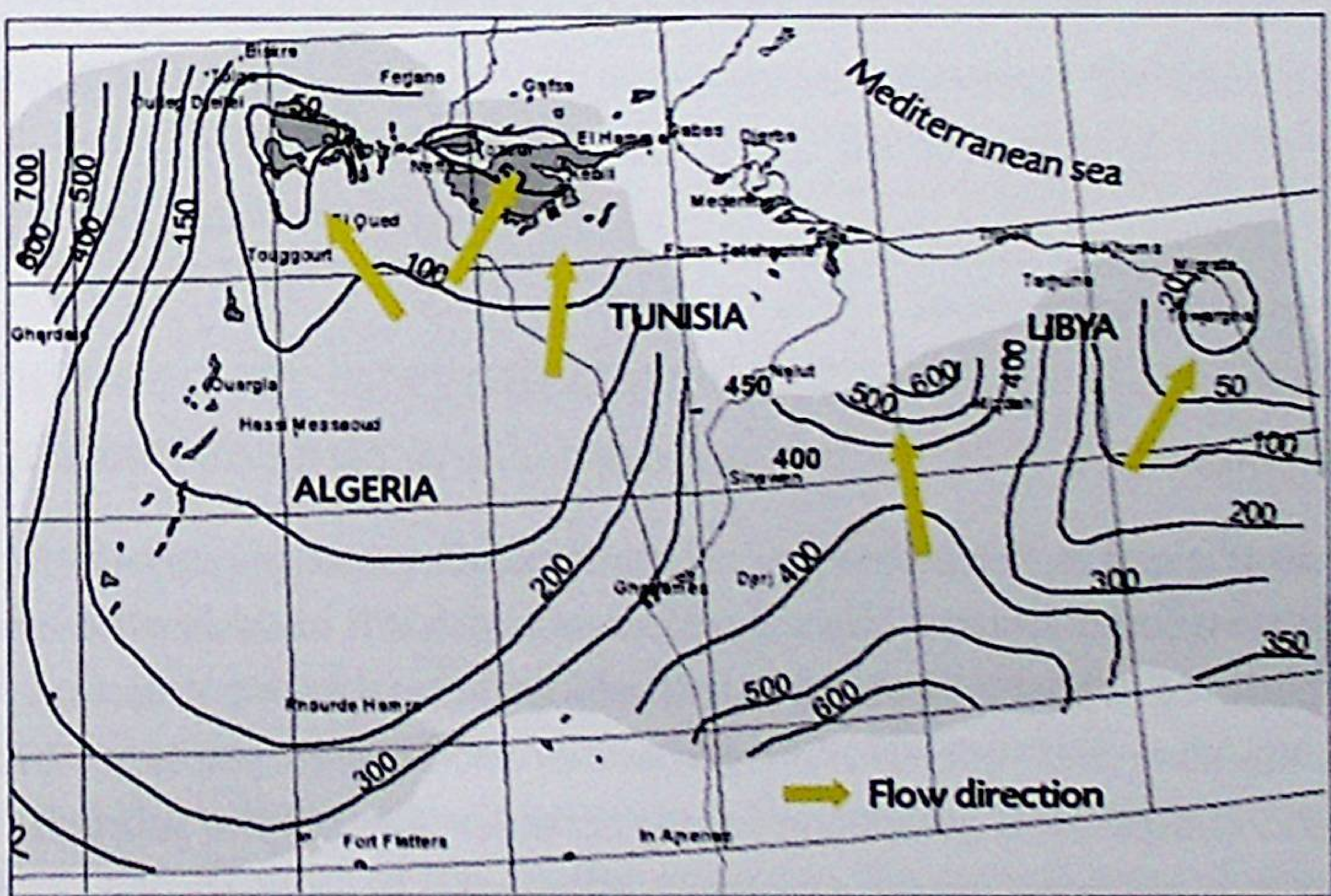
Non-renewable aquifers are little or not recharged, either because this is prevented by their hydrogeological characteristics, or because they are now found in arid to semi-arid areas that thousands of years earlier had a more humid climate. In this second type the water is said to be 'fossil'. All abstraction essentially corresponds to emptying the reservoir; initially, it will often only little affect natural outflow, even when such destocking is mainly due to hydraulic decompression, as in the case of a confined aquifer. In humid or temperate regions, non-renewable aquifers exist along permanent streams and renewable aquifers that are used preferentially. In arid or semi-arid regions, non-renewable aquifers are often the main, or even only, water resource that can be mobilized.

Box 8 Example of mining a 'fossil-water' transboundary aquifer system: the NWSAS

The very minor recharge of the NWSAS aquifer system, shared between Algeria, Tunisia and Libya, occurs in only a few areas such as the Mzab and the Atlas piedmont in Algeria, the Dahar in Tunisia and Djebel Nefussa in Libya. However, this recharge of around 1 billion m^3/year is negligible when compared to the theoretical reserves of the aquifer (about 60 billion m^3). The aquifer system can thus be described as containing almost fossil, or at least very little renewable, water, and the water levels of its constituent aquifers undergo inexorable lowering with their ongoing exploitation.

Map 3 Water levels and flow direction of the 'Terminal Complex' aquifer of the NWSAS

This map shows the outlets of the system toward the Algerian and Tunisian chotts, and toward the Jeffara aquifer in Libya.



Potentiometric contours

Source: OSS, 2008.

In practice, this aquifer system is intensely overdeveloped, as it is the only water resource of the three countries at these latitudes. Already in 2003, its development of 2.5 billion m^3/yr from close to 9,000 water points represented a volume of 2.5 times its recharge, without considering the natural flow toward aquifer outlets in the Algerian-

• • •

...

Tunisian chotts and submarine springs in the Gulf of Syrte, which together can be estimated at 1 billion m^3/yr and that should be added to the human abstraction. Such intensive exploitation is especially due to the strong population growth and rapid expansion of agriculture (about 40,000 hectares of irrigated crop land as well as fruit growing and greenhouses) in areas subject to high evaporation.

If this abstraction continues at the present rate, by 2050 the static water-levels will drop by 20 to 60 m. If it increases to try and satisfy growing demand, the drawdown may reach 50 to 300 m, based on geographic location and the aquifer formations of the system. Such a drop in static water levels would cause the disappearance of artesian flow, rendering its exploitation impossible in certain places (drying up of the foggaras in the south-west and of the Tunisian outlet in the north), and leading to seawater intrusion along the coast of Libya and Tunisia that would irreversibly deteriorate water quality. In addition to the problems in coastal areas, salinity would increase to the point of rendering the aquifer unusable elsewhere, especially in the densely populated areas of the chotts and the Jifara plain.

In order for this aquifer to continue functioning in a more sustainable manner, the decision must be taken today to limit or modify agricultural practice, or even to change the overall economic strategy. Abstraction means should be found that best preserve the aquifer levels and their quality. This implies a dialogue and coordinated actions between the three countries concerned.

Source: Part 1.6 of the Preliminary Works.

1.2.5. *Implications of the transboundary character of an aquifer system*

From a scientific and technical viewpoint, a transboundary aquifer system is no different from another aquifer system. The only difference is that it underlies the territory of several countries, whose political borders add additional constraints that render a full understanding and rational management of such shared resources even more delicate and complicated. States commonly consider water in the subsurface within their borders as a national resource over which they wish to retain absolute sovereignty. Some States even dispute the transboundary nature of certain aquifers that concern them, sometimes profiting from the uncertainties and imprecision of existing scientific knowledge.

In fact, the principle of national sovereignty should not affect groundwater in an absolute sense: water, whether underground or on surface, is by nature a fundamentally mobile and variable element, in time as well as in space. A country thus cannot manage 'its' transboundary groundwater without affecting – or being affected by – the management of its neighbours. As we are dealing with a single resource, its access and its equitable and lasting shared use is a necessity, at the risk of creating international tension, crises and conflicts that will run counter to the national interest of the concerned countries.

Finally, the collaborative management of transboundary aquifer systems is necessary, but much more complex and delicate than that of shared surface waters, because of:

- A lack of perception of the transboundary character by the authorities, managers and concerned populations;
- A common lack of precise data shared by all countries involved (nature, extent, functioning, interaction with surface water, exploitation potential, etc.);
- The common absence in the concerned States of a specific clear normative national framework for groundwater and of a national institution that is explicitly responsible for its management and that has the necessary means;
- In some cases, a lack of political will for implementing long-term management;
- An international legal framework that is still embryonic in this field; and
- Major needs of competence and indispensable funding, for developing and executing scientific studies, and setting up an appropriate normative and institutional framework.

1.3. The need for integrated management of transboundary aquifer systems

The fact of abstracting water from an aquifer system entails multiple consequences in all three dimensions of the subsurface. Based on its importance, all new withdrawal reduces – more or less distant and over the longer or shorter term – the flow rates of pre-existing springs, wells, boreholes and well fields, especially near the pumping well where it can create a drawdown cone in the aquifer. The multiplication of such abstractions can affect all of the aquifer system in the case of groundwater overexploitation, leading to the lowering and sometimes even catastrophic collapse of the potentiometric level. In some cases this can be accompanied by subsidence of the ground surface. If the aquifer system is renewable and communicates with regional rivers and springs, its overdevelopment decreases outflow to the latter, affecting their minimum flow rates during low-water or drought periods.

Reciprocally, a renewable aquifer system that communicates with surface waters will also be affected and might no longer be recharged if such surface water (rivers, lakes, ponds) is itself overexploited or polluted.

Concerning discharge, injection and infiltration of water into the subsurface, this has obviously the positive effect of recharging the aquifer systems, but it can also be a source of lasting contamination if such input is polluted or if certain conditions are met, such as in the case of the chotts cited above.

Regardless of use and reasons, all abstraction and discharge affecting a single hydrogeological unit (comprising both a renewable aquifer system and hydraulically related surface water) are hydro-interdependent. All depend, directly or indirectly, on the density and type of land use, urban development, agriculture (including animal husbandry, fishery and forestry), industry and energy production, transportation modes (river navigation), etc.

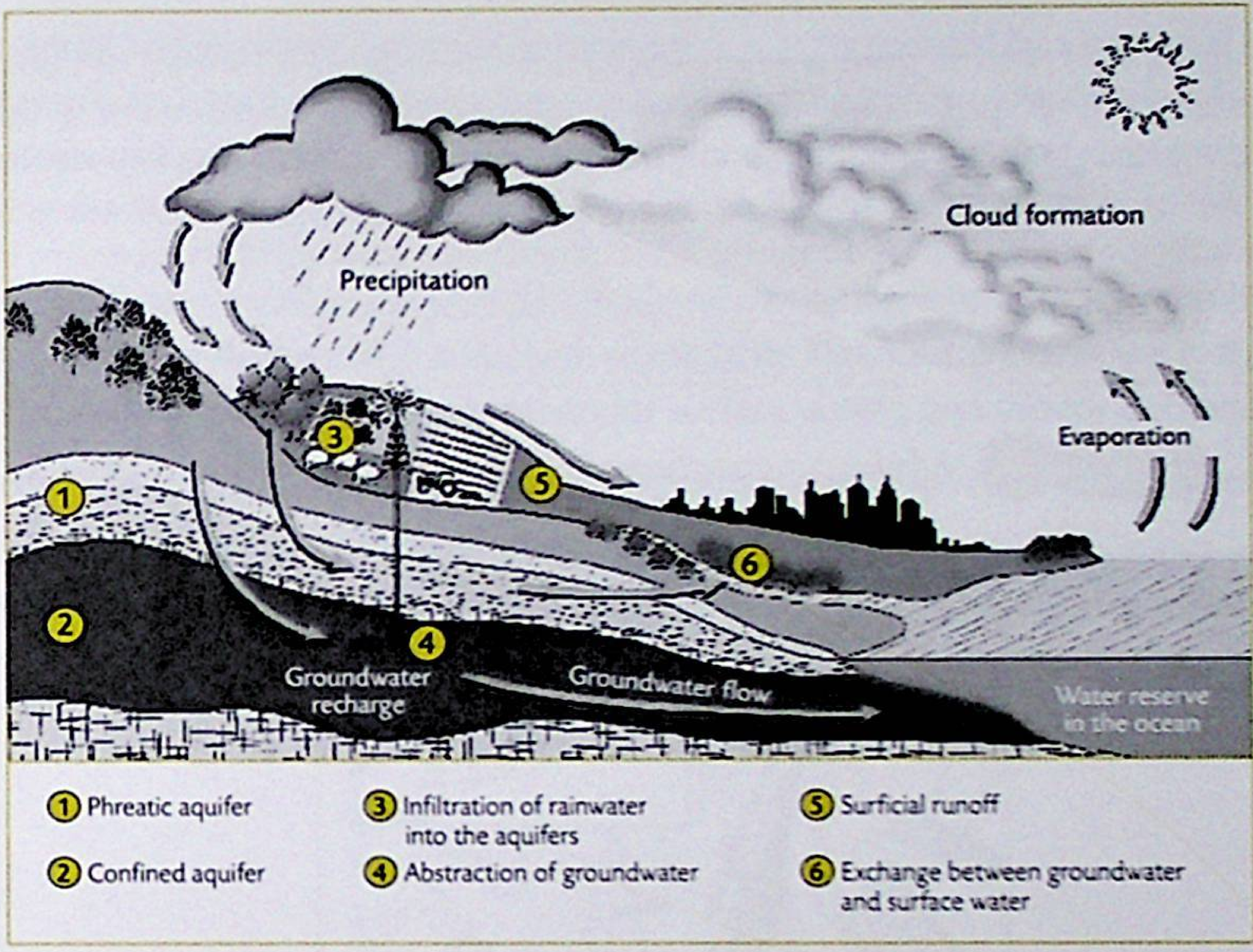
In every case, and everywhere, legitimate – but different and even opposed – interests must be conciliated. Such interests cover water use, users and even territories, and can be at all levels, local or national and even supra-national for transboundary waters.

Such collaborative management obviously should respect the principles of sustainable development, which aim at reconciling economic progress with social equity and respect of the environment. It should also fall within the principles of IWRM, defined by the Global Water Partnership [5] as *'a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems'*. Officially formulated for the first time in 1992 at Dublin during the International Conference on Water and Development, the concept of IWRM has been progressively strengthened within the international community over the past two decades. However, the 'groundwater' part is still too often neglected.

The IWRM is precisely the concept that makes it possible to come up with harmonious and evolving solutions, adapted to each case, by applying a set of complementary and coherent instruments that are presented in Part 2 of this Guidebook.

[5] See: Global Water Partnership Technical Advisory Committee, 2000.

Diagram 6 Water cycle: interaction between surface water and groundwater explains the necessity of resorting to an IWRM



Source: Adapted from Willoughby City Council (Australia, 2010).

Box 9 Example of still insufficient integrated management: the Mekong Basin

On April 5th, 1995, the countries of Cambodia, Laos, Thailand and Vietnam concluded a Cooperation Agreement for the Sustainable Development of the Mekong River Basin, creating the *Mekong River Commission*. China and Myanmar, the two other riverside States of the Mekong Basin, did not sign the Agreement but have been *Discussion Partners* since 1996. The Commission coordinates the Mekong Programme, adopted in 2004 and destined to apply the principles of the IWRM.

A document of strategic orientations for the development of the Mekong Basin water resources was drawn up. As far as groundwater is concerned, this document stresses the need for studies to improve knowledge and define the limits of sustainable use. These strategic orientations were the blueprint for actions set out in a Strategic Plan 2006-2010.

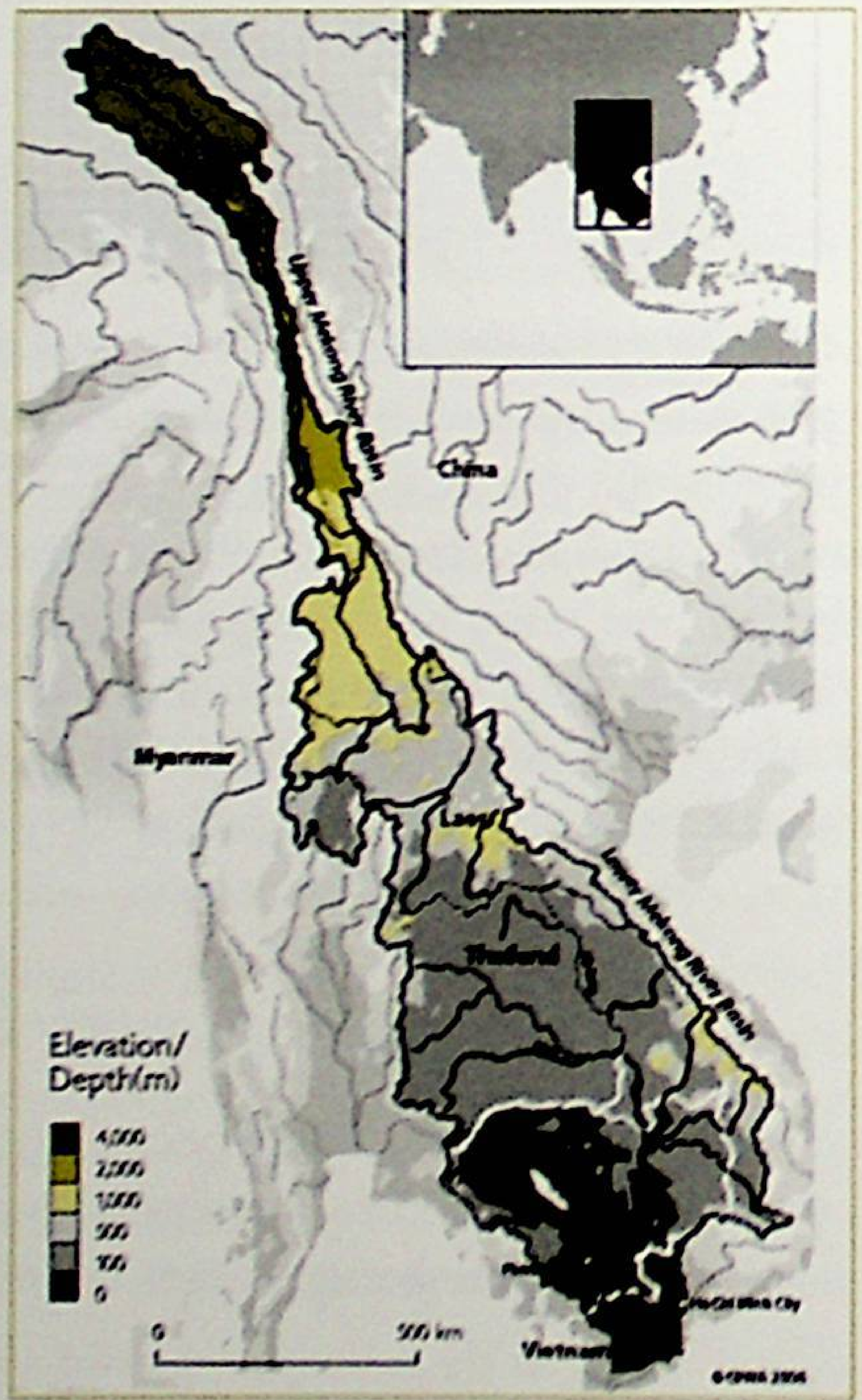
...

...

This Plan is accompanied by 18 priority projects, only one of which concerns the preservation of groundwater around the main cities. These strategic orientations were also used in the initiatives of funding organizations.

Unfortunately, most of these priority projects only concern surface waters. Notwithstanding the recent initiatives for a better consideration of aquifer systems, the groundwater of the Mekong Basin is still too little concerned by transboundary actions. However, as in many places surface water and groundwater are in hydraulic relation, such programmes should be based on a combined understanding of both systems in order to guarantee a long-term efficiency.

Map 4 *Mekong catchment basin*



Source: Global International Waters Assessment (GIWA), 2006.

Source: Second part of the Preliminary Works

All human activities use water. Water is also a material link of interdependence that creates solidarity among the beneficiary populations and physically relates them to their territory, in particular the groundwater that is part and parcel of the subsurface. This is the idea of *'hydrosolidarity'*.

Such social and territorial hydrosolidarity in space is accompanied by a temporal hydrosolidarity with future generations. For surface waters, hydrosolidarity clearly falls within the scope of a catchment basin, which in many countries is increasingly recognized and used as the appropriate scale for implementing an IWRM.

For groundwater, invisible and complex to identify and map, it is much more difficult to recognize and understand the same type of solidarity. Paradoxically, however, in this case the hydrosolidarity is even stronger than for surface waters, and this for two reasons:

- In the case of aquifers, hydrosolidarity extends through space in three dimensions;
- The complexity and slowness of the diffusion of quantitative and qualitative impacts through aquifer systems entails a long-term temporal hydrosolidarity, especially in the case of non-renewable aquifers.

2. The available Tools for Understanding and Managing Transboundary Aquifer Systems

Practice has shown that, for the efficient and reliable management of water resources, it is necessary to implement a set of complementary and coherent tools, in accordance with the basic concepts of sustainable development and of IWRM, including:

- *Scientific, technical and technological tools,* to improve the understanding of groundwater and transboundary aquifer systems;
- *Organizational and institutional tools,* to implement an IWRM;
- *Legal and administrative tools,* to ensure that the working environment and regulatory functions that are necessary for water resources will be in harmony across political borders;
- *Economic, financial and fiscal tools,* to mobilize the indispensable capital investments and ensure that the set common objectives will be reached;
- *Training and professional improvement tools,* to improve the skills of political decision makers, managers, and technical and administrative staff; and finally
- *Tools for participation and cooperation,* to ensure a completely transparent exchange of information and develop a long-lasting cooperation.

None of these six categories of tools is sufficient by itself. It is only by combining them that it will be possible to progress and reach satisfactory and lasting results.

These tools should be used in a parallel and progressive manner, at the local, national, transboundary and international levels that are necessary for shared aquifer systems. Such work must be based on natural geographic units that, for groundwater, are the hydrogeological basins. It should be kept in mind, however, that such basins do not always – and indeed rarely – correspond to the perimeters of aquifer systems.

2.1. Scientific and technical tools for investigations and studies

2.1.1. *Inventory of transboundary aquifer systems*

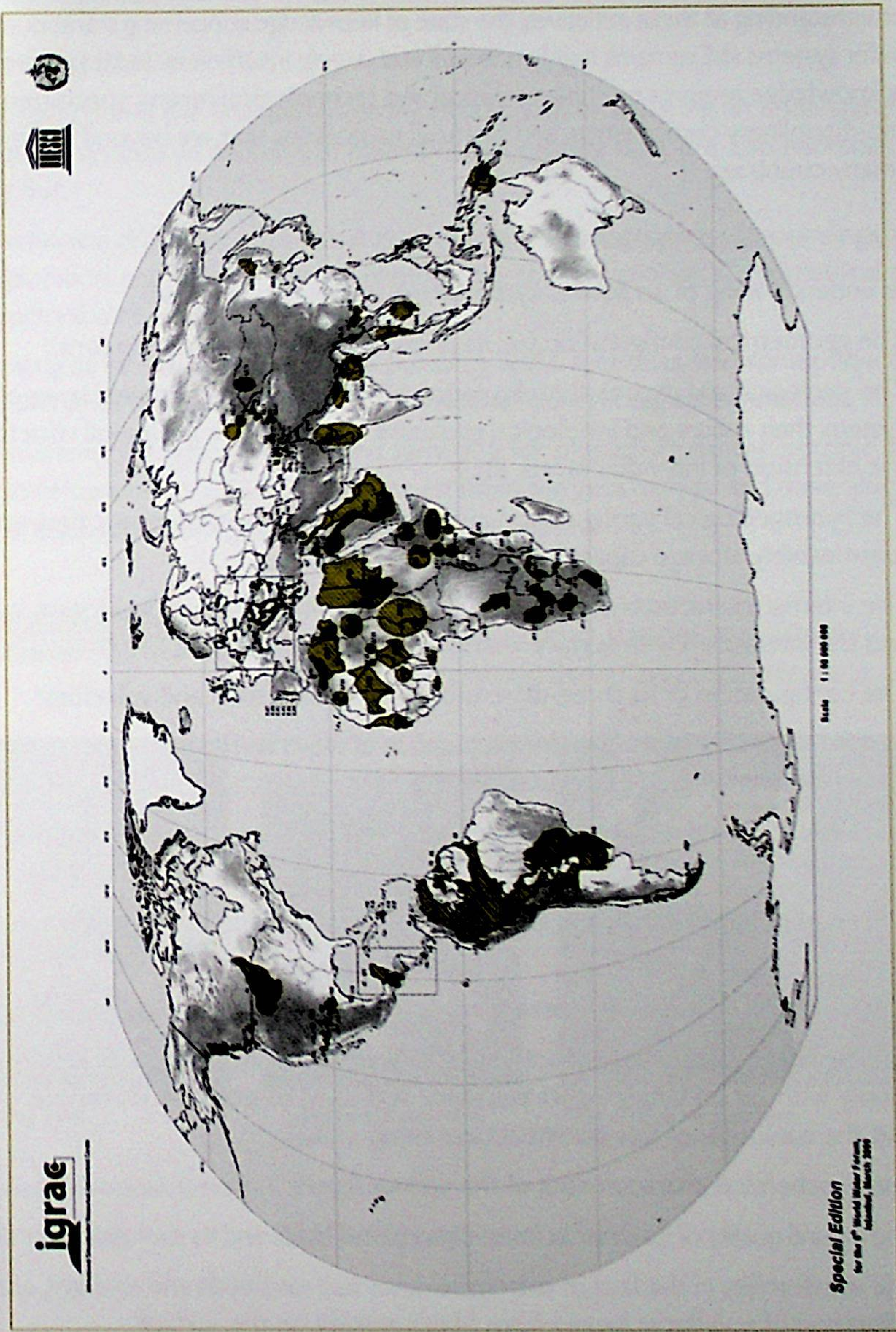
In the 1990s, the United Nations Economic Commission for Europe (UNECE) launched a first regional inventory of transboundary aquifer systems in European countries, which was extended to the Caucasus and Central Asia in 2007.

In 1999, the Worldwide Hydrogeological Mapping and Assessment Programme (WHYMAP) [6] was initiated with the aim of collecting, assembling and visualizing hydrogeological data at a global scale. WHYMAP is carried out jointly by UNESCO (International Hydrological Programme and International Geoscience Programme), the International Association of Hydrogeologists (IAH), the Commission of the Geological Map of the World, the International Atomic Energy Agency, the International Groundwater Assessment Center, the Global Runoff Data Centre and the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR, German federal institute for geosciences and natural resources), with participation from outside experts, in particular from BRGM. This work of mapping aquifer systems was fine-tuned on the African continent between 2003 and 2006, as part of the GIS-Africa project coordinated by BRGM and partially funded by the French Ministry of Foreign and European Affairs (MAEE).

In 2000 the ISARM project was launched under the aegis of UNESCO, which specifically covers transboundary aquifer systems. This programme has a long-term perspective and aims at promoting the scientific study of transboundary aquifer systems and their collaborative and sustainable management. It is implemented continent by continent through regional initiatives, in cooperation with other partners such as the Organization of American States on the American continent. Work already completed as part of the ISARM programme include a preliminary inventory of transboundary aquifer systems for the Americas, a preliminary inventory for Africa, and a detailed inventory for the Balkans and the south shore of the Mediterranean Sea. Today, over 270 transboundary aquifer systems have been inventoried worldwide, but many more are still undocumented. The results of this programme are described in detail in the first part of the Preliminary Works.

[6] www.whymap.org

Map 5 *The transboundary aquifer systems of the World (updated in 2009)*



Source: International Groundwater Assessment Center, 2009.

2.1.2. *Inventory of the needs for obtaining a better understanding of aquifer systems and their functioning*

Notwithstanding all these initiatives, the state of knowledge concerning transboundary aquifer systems still remains highly unequal and largely insufficient. In fact, improving our knowledge requires multiple technical and technological means, specialized and multi-disciplinary competence, and financial capabilities that are beyond the means of many countries.

Fields of required knowledge

The understanding of an aquifer system must in particular bear on:

- The geometrical configuration (*i.e.* its physical limits in three dimensions);
- The geological and structural configuration (identification of constituent layers of the system, their nature and lithological evolution in space, their geological structures, the extension of individual layers, etc.);
- The hydrogeological configuration and corresponding hydrodynamic parameters (permeability, storage capacity, etc.);
- The internal interactions (*i.e* between different constituent hydrogeological layers) and the interaction with surface waters, transboundary or not;
- The configuration of its three-dimensional flow orientation and velocities;
- Transfer times of pressure (dynamic propagation of waves and hydrodynamic pressures) and of mass (migration of pollutants, etc.);
- The areas of natural recharge and the climatic/meteorological data of the concerned region;
- The areas of natural discharge (streams, lakes, chotts, other downstream aquifers, etc.);
- The evolution of static water levels and flow rates through time and space;
- The overall and sector-based potential (*i.e.* which quantity the aquifer system can supply without endangering its existence and so as to preserve its various uses) and the evolution of this potential over time;
- The geochemical characteristics of the various layers;
- The natural quality of its water in three-dimensional space and its evolution over time;
- The vulnerability in the face of extreme events, such as floods and drought, and to infiltration of pollutants issuing from Man's activity on the surface;

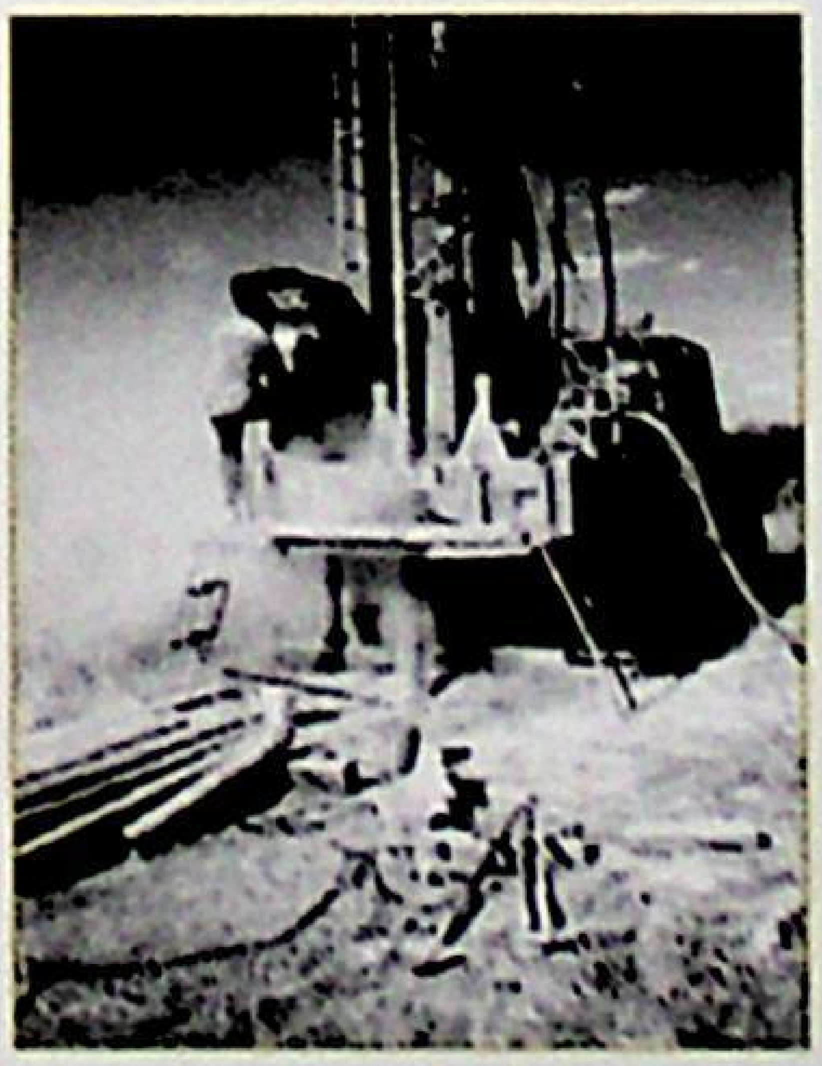
- The configuration of water demand, socio-economic fabric, and uses and pressures (water abstraction from confined aquifers, sources of pollution, etc.), and the evolution of these parameters over time.

Collecting the data

Data collection is the first, and most important, step in acquiring an understanding of aquifer systems. In addition to assembling all existing data, it is also necessary to carry out:

- Mechanical drilling to obtain stratigraphic information, geophysical soundings and exploration, and aerial or satellite photography to draw geological, geometrical and structural contours;
- Drilling of (observation) wells, test pumping and tracer tests, and spring-flow and aquifer-level measurements to determine the hydrogeological parameters;
- Geochemical logging in wells and sampling for physico-chemical, isotopic, and chlorofluorocarbon (CFC) analyses to establish the geochemical and mineralogical characteristics of the subsurface and of water quality.

Photos 1 2 3 *Examples of tools used in the field to obtain data and information on an aquifer system*



Drilling a well

Sampling and water-level measurements in a standpipe

Geophysical measurements (electrical sounding in Africa)

Source: BRGM Image Bank; © BRGM

It is also necessary to set up *permanent monitoring networks* to retrace and establish the evolution of the aquifer system over time. Two sets of parameters must be monitored in the field: parameters related to quantitative aspects, including flow rates (natural and pumped) and static water levels, as well as parameters related to water quality.

For the quantitative parameters, water-level recorders and flow meters must be installed or refurbished. For the qualitative measurements, specific quality-measuring networks are needed, or at least dedicated observation wells to take samples that will be subjected to bio-physico-chemical analyses. All measuring networks must be correctly sited and sized to provide representative data of the resource and its general evolution over time (Pennequin and Foster, 2008). It should be mentioned that some data are relatively easily accessible (water levels, water quality), whereas others, such as flow between different levels in an aquifer system, or between aquifers and rivers, will always be much more difficult to obtain and often have to be determined indirectly, for instance with the help of a mathematical model.

Setting up permanent measuring networks and collecting and processing the data requires not only the existence in the field of suitable equipment, but also of a minimum of public-service structures with a technical and administrative character. Such a permanent public structure, whether national or transboundary, can have different types of legal status; it can be a government service (part of a ministry) or an autonomous agency. This organization will be more or less elaborate, depending on the size of the country. If necessary, it will be equipped with over a network of local branch offices, being in a close and permanent liaison with the institutions involved in the management of water resources and use. This is often still far from the case where groundwater is concerned: a local organization, if it exists, is commonly fragile and rarely has a lasting existence.

Box 10 *Example of a project that made it possible to create a shared hydrogeological database: Management of the hydrogeological risk in the Lullemeden aquifer system*

The Lullemeden aquifer system underlies part of the Niger River Basin covering more than 500,000 km² (31,000 km² in eastern Mali, 434,000 km² in western Niger and 60,000 km² in north-western Nigeria). The project "Management of hydrogeological risk in the Lullemeden aquifer system", funded by the Global Environment Facility (GEF) and carried out under the aegis of the OSS, initially included two main technical components:

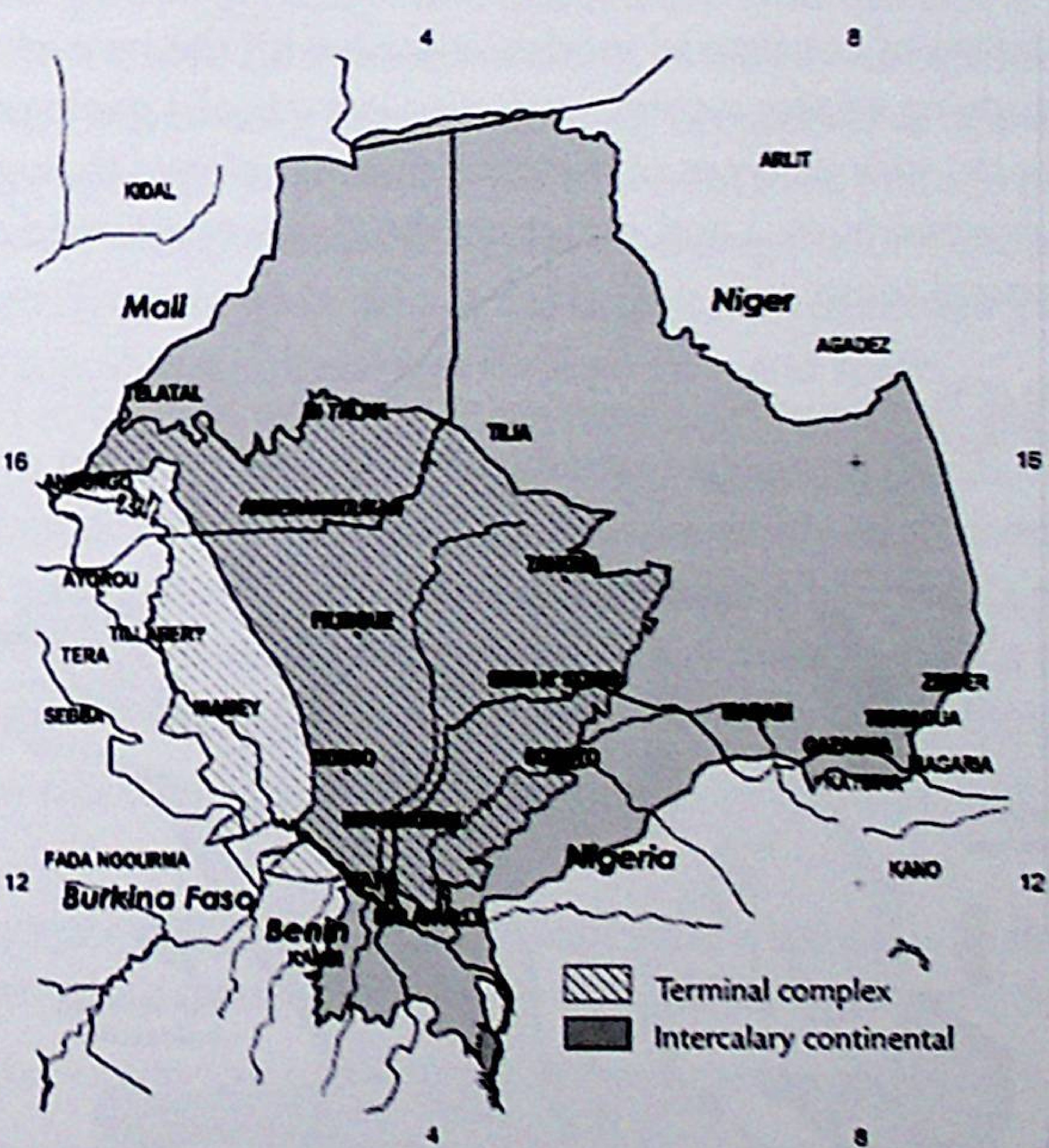
•••

...

- Component 1 aimed at evaluating the state of knowledge of the water resources (transboundary analysis and diagnosis, training in modelling, field studies on the recharge of the aquifer systems, and creation of a database);
- Component 2 aimed at setting up a consultation and collaboration mechanism between Mali, Niger and Nigeria for the management of the aquifer system.

The project has led to creating a specific database and Geographic Information System (GIS), carrying out a preliminary characterization of the resource with in particular the implementation of the first phase of an aquifer model (steady state) and, finally, proposing guidelines for installing an aquifer-monitoring network. The project started in 2004 and ended at Bamako in May 2008.

Map 6 *Schematic map of the Lullemeden aquifer system*



Source: OSS (2007).

Sources: Part 16 and the second part of the Preliminary Works.

Validation, organization and interpretation of data

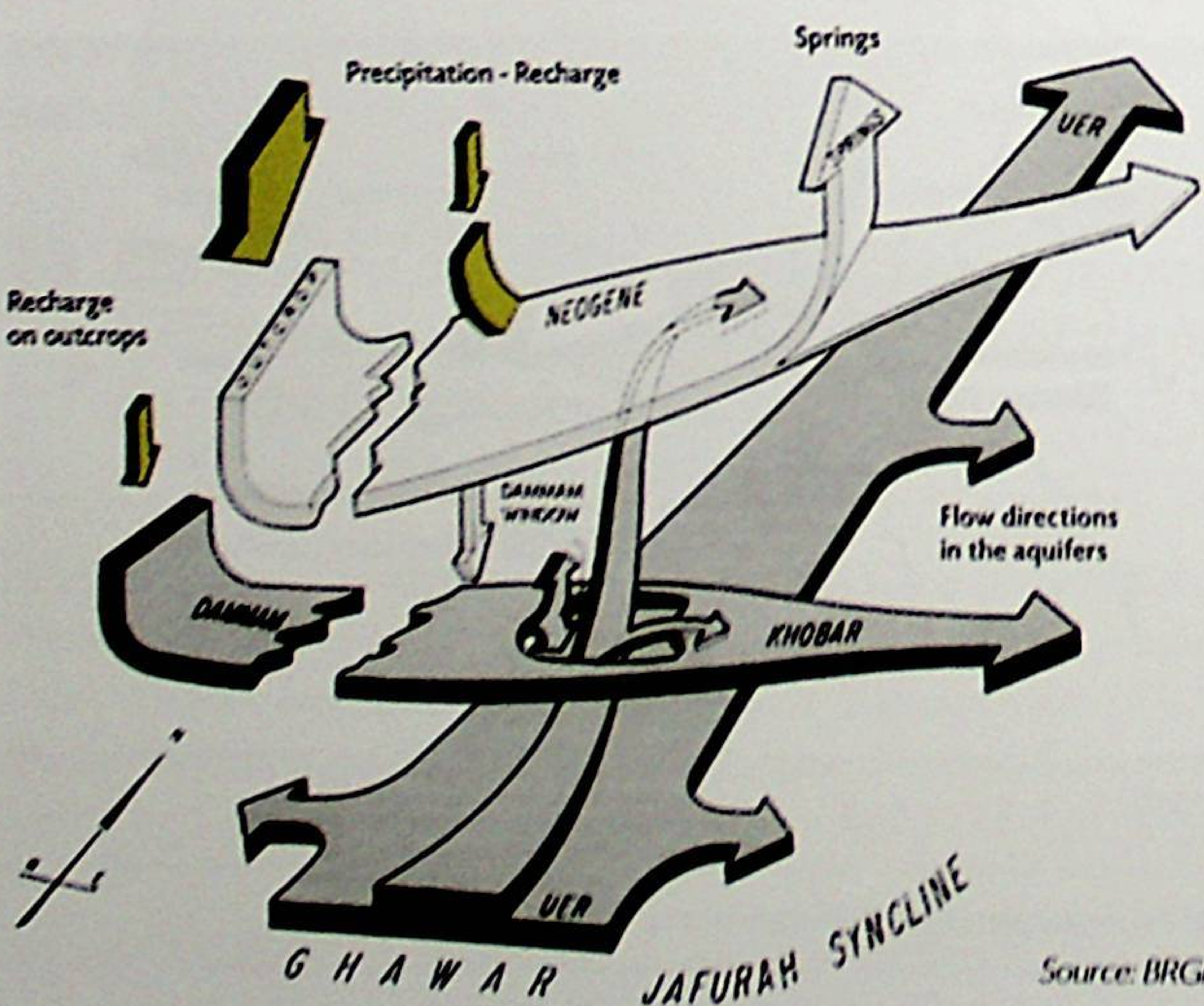
After collecting the data, their validation, organization and interpretation forms the second important step of the work. The data acquired in the field must be integrated into databases and GIS, for their later association in three-dimensional space and over time, with the aim of reconstituting the characteristics and operating modes of the resource under consideration.

Conceptual model or qualitative understanding of the resource

The conceptual model or qualitative understanding of a resource is the third step of the work. It generally consists of creating one or more conceptual models of the aquifer system, which make it possible to understand and trace back the main lines of its characteristics and functioning in a qualitative way. The conceptual model(s), covering three dimensions, make it possible to represent the reciprocal spatial relations of the different constituents of the aquifer system, and of the other natural or artificial compartments surrounding it.

The construction of conceptual models is done with the help of specific tools and means for studying aquifer systems, including in particular geological and hydrogeological syntheses, various types of thematic maps (geology, lithology, potentiometric contours, vulnerability, etc.), and, obviously, the above-mentioned databases and GIS in a more general sense.

Diagram 7 *Diagram or conceptual model of flow in the Al Hassa aquifer system, Saudi Arabia*



Source: BRGM, 1977.

The diagram shows the flow directions in the different hydrogeological formations of the Al-Hassa system. The confined Umm er Radhuma aquifer (UER on the diagram) supplies water to the Neogene aquifer and contributes to spring flow; it also recharges – but less so – the Khobar aquifer through the Dammam sedimentary hiatus.[7] The descending arrows represent recharge.

Mathematical models and management tools

The last step in assessing an aquifer system requires the creation of mathematical and digital tools. These will help better understand the functioning of hydro-systems and the evolution of the resource, and establishg the most suitable management procedures by reconciling as much as possible the interests of all players.

In addition to the fact that they help in determining certain physical parameters that are otherwise difficult to evaluate in the field (flow-velocity and flow-rate, volumes exchanged, etc.), a mathematical model effectively makes it possible to carry out a more-or-less precise general qualitative and quantitative synthesis of the functioning of the aquifer system in two or three dimensions, as well as its evolutionary trend over time. This then serves as a base for drawing up predictive scenarios of the future resource management. Such models are powerful tools that can provide both an overview of how the resource works, while also simulating the local impact of actions or pressures exerted (for instance as part of the exploitation or contamination of the resource), and of its progressive evolution through time and space.

In order to serve as management tools, the mathematical and digital models must first be correctly structured and sized, based on the previously established conceptual models, after which they should be calibrated for the set objectives, (a process that aims at rendering the model as close as possible to the reality it wishes to simulate). A variety of potential scenarios can then be created, and especially those for:

- Determining the resource potential in the framework of sustainable or tenable management;
- Testing the impact of different pumping and exploitation scenarios on flow rates and water levels, in terms of expressed requirements or planned economic development;
- Calculating the consequences of territorial development policies on the resource;
- Predicting the evolution of a pollution plume and evaluating its impact in terms of space and time;
- Establishing the modalities for protecting or remediating a contaminated resource.

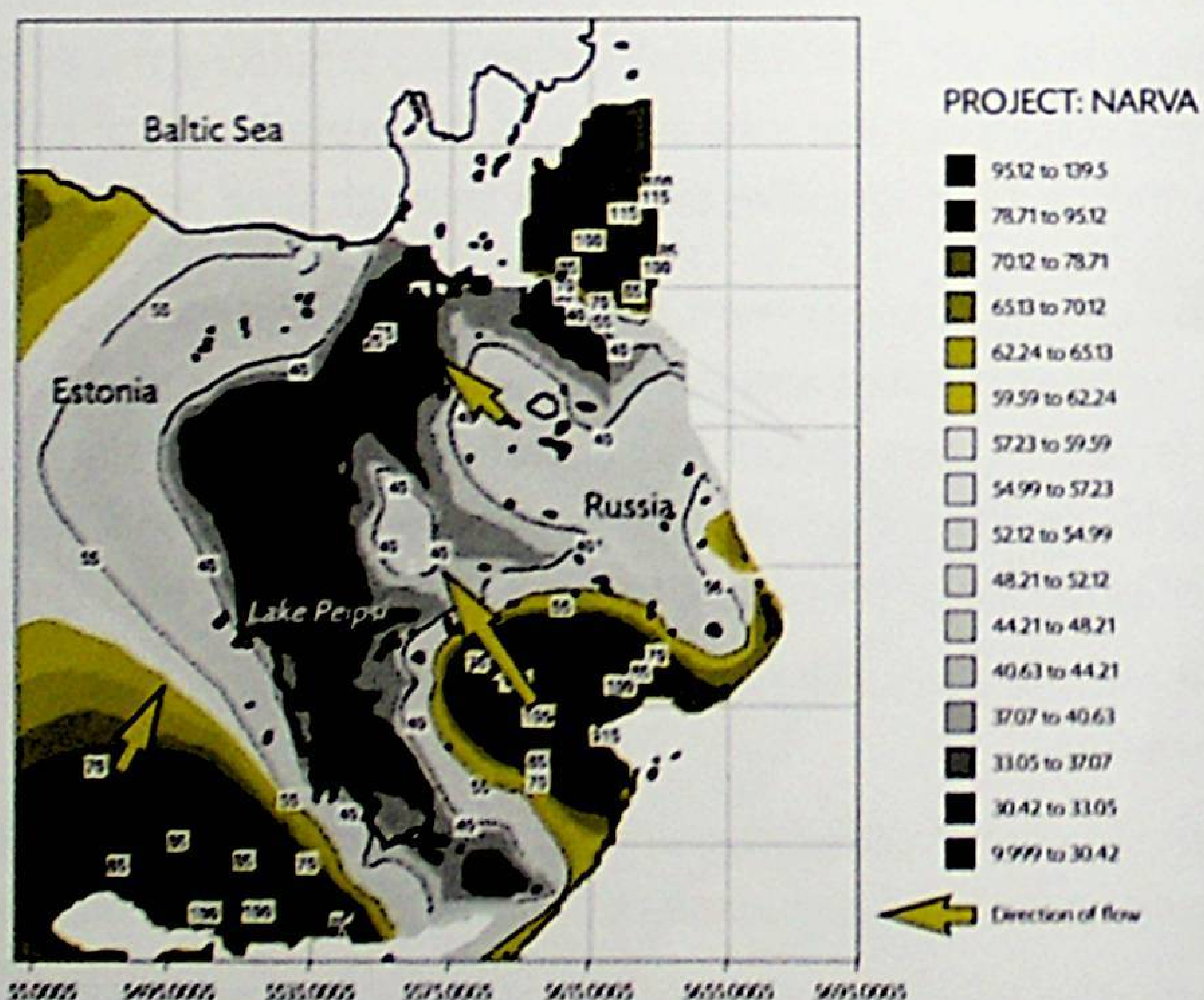
[7] Interruption of sedimentation, causing a chronological discontinuity between two layers.

Once analysed and interpreted, the results of the models and the simulated scenarios provide a valuable base for discussions and for setting up the mechanisms of dialogue and action.

Box 11 Example of the mathematical model for the transboundary Lake Peipsi (Russia-Estonia) aquifer system

As part of the study carried out by BRGM on management of the Lake Peipsi transboundary aquifer system (Russia-Estonia), funded by the French Global Environment Facility and the European Union, the adoption of mathematical models has provided each country with a vision of both local and transboundary conditions and functioning of the shared water resource.

Map 7 Calculated potentiometric map for the aquifer horizon in Ordovician rock, shared between Estonia and Russia



Source: BRGM, 2007.

2.2. Legal tools

2.2.1. *International legal tools*

At the international level, the only agreement that specifically concerns the joint management of a transboundary aquifer system is that of the Genevois aquifer, shared between France (Haute Savoie Department) and Switzerland (Geneva Canton) (*cf.* Box 22, hereafter, and Part 1 of the Preliminary Works). Groundwater is sometimes cited in agreements concerning transboundary surface waters, as are springs, but the aquifers themselves are rarely mentioned; the latter are generally indirectly evoked in certain international agreements on the tracing of borders or on mining-related questions.

There are, however, several initiatives in this field:

- 1989: The 'Bellagio' treaty project concerning transboundary groundwater specifically applies the principles set by the Helsinki rules, *i.e.* '*the management unit*' and the '*community of interests*' as well as '*the optimal use and conservation on a reasonable and equitable basis including the protection of the underground environment*'. Though this is an initiative by experts without legal value, it is not without interest.
- 1992: The Convention on the protection and use of transboundary watercourses and international lakes was adopted by the United Nations Economic Commission for Europe; called the Helsinki Convention it concerns all transboundary waters, including shared aquifer systems.
- 1997: The United Nations General Assembly adopted the Convention on the law of the non-navigational uses of international watercourses. This text is not in force yet because it has not been ratified by a sufficient number of States. In addition, its application to shared groundwater is limited, as it only covers groundwater associated with an international watercourse and sharing a common terminus.
- 2008: The United Nations General Assembly adopted a Resolution on the Law of Transboundary Aquifers (A/Res/63/124), including in annex the draft articles prepared by the UN International Law Commission.. This text benefits from the scientific and technical support and contribution of the International Hydrogeological Programme of UNESCO, with input from groups of experts and several qualified partners in this subject. The text, simply meant as an incentive, has no binding force but can serve as a reference to States.

2.2.2 National legal tools

In Europe, the various national legislations on water have widely transposed the European directives on this subject. In fact, water management in Europe has been legally well framed since the 1970s by means of about thirty directives concerning both water use and water discharge. The Water Framework Directive of 23 October 2000 has harmonized the whole. All water masses, including transboundary ones, whether on surface, underground or coastal, are covered by the *'good status'* objective to be reached by 2015, except in case of a duly justified dispensation. The text prescribes a management approach per catchment basin. It plans for the drawing up, for each national and international hydrographical district, of an inventory concerning all water masses, of a management plan defining the objectives, of a measurement programme fixing the actions needed for reaching the objectives, as well as of a public consultation. In addition, it defines a common method for *'monitoring'* the status of water masses, and another method for communicating the results obtained (*'reporting'*). This directive was completed by a daughter Directive of 12 December 2006, specifically concerning the protection of groundwater against pollution and deterioration. It sets criteria for evaluating the chemical status of water, and criteria for identifying significant and lasting upward trends of pollutant concentrations in groundwater as well as measures for preventing and limiting the indirect discharge (after percolation through soil or the subsurface) of pollutants into groundwater. Today, these directives have set a harmonized European framework for managing groundwater, which is a particularly valuable added value for the aquifer systems shared by several European countries.

Elsewhere, groundwater in many countries still does not have a clearly defined legal status and regime. Notable exceptions exist in some countries that have adopted a "Water Law", such as Morocco that, since the early 20th Century, has ranked its groundwater in the public domain of the State; the latter has the power to deliver authorizations for abstraction (concessions), which may be modified or negotiated by its tenant or by the owner of the ground concerned.

In each country, groundwater, like surface water, should be given a legal framework that allows for sufficient control by the public authorities, ensuring equitable and sustainable management of the resource as well as its quantitative and qualitative protection. It is also necessary to institute and enforce regulations by means of a system of authorizations or declarations. These should concern both abstraction from and discharge into the resource (called *Water Policing*), and the checking of activities that (might) have a direct or indirect negative impact in the short- or long-term on both surface- and groundwaters. This concerns in particular some agricultural and animal-farming practices, certain industrial or crafts installations, or others that might carry risks for the environment and water.

Such regulations obviously should be well adapted to the problems to be solved, and to the socio-economic, administrative and cultural context of the country in question.

2.2.3. The general legal principles of managing transboundary aquifer systems

The draft articles appended to Resolution 63/124 apply two fundamental rules of international water law to transboundary aquifers: *(i)* an *'Equitable and reasonable utilization'*, *(ii)* the *'Obligation not to cause significant harm'*.

'Equitable and reasonable utilization' implies that the concerned States manage the transboundary aquifer system so as to reach an equitable distribution of the resulting advantages. Reasonable utilization commonly is defined as *'sustainable'* or *'optimal'. In the case of transboundary aquifer systems, the common aim is to 'maximize the long-term advantages'* resulting from the use of shared water resources.

The rule of reasonable and equitable utilization requires for its implementation the consideration of certain factors. Article 5 provides an indicative list, stating that the weight of each factor should be specifically determined for each case. The list consists of the following factors:

(a) The population dependent on the aquifer or aquifer system in each aquifer State;

(b) The social, economic and other needs, present and future, of the concerned aquifer States;

(c) The natural characteristics of the aquifer or aquifer system;

(d) The contribution to the formation and recharge of the aquifer or aquifer system;

(e) The existing and potential utilization of the aquifer or aquifer system;

(f) The actual and potential effects of the utilization of the aquifer or aquifer system in one aquifer State on other aquifer States concerned;

(g) The availability of alternatives to a particular existing and planned utilization of the aquifer or aquifer system;

(h) The development, protection and conservation of the aquifer or aquifer system and the costs of measures to be taken to that effect;

(i) The role of the aquifer or aquifer system in the related ecosystem.

Paragraph 2 of Article 5 states: '*The weight to be given to each factor is to be determined by its importance with regard to a specific transboundary aquifer or aquifer system in comparison with that of other relevant factors. In determining what is equitable and reasonable utilization, all relevant factors are to be considered together and a conclusion reached on the basis of all the factors. However, in weighing different kinds of utilization of a transboundary aquifer or aquifer system, special regard shall be given to vital human needs.*'

The second rule of the '***Obligation not to cause significant harm***' requires from the concerned States that they take all appropriate measures for not causing significant damages to other States that use the same aquifer system.

These two fundamental rules, now recognized as customary for international watercourses, imply that the sovereignty of States on shared waters cannot be absolute, but is necessarily limited: their concrete application requires close cooperation between the concerned countries.

2.3. Institutional, administrative and organizational tools

The public authorities must exert an essential function of 'regulator' for the regulations concerning water resources and their various uses at different levels:

- *Access:* organizing access to water for all;
- *Public health:* establish and enforce quality standards for drinking water and for the discharge of urban and industrial effluents;
- *Public safety:* establish and enforce best practice in terms of design, construction and exploitation of works (boreholes), or in terms of regulating industrial installations that might present risks for the environment;
- *Competition:* fix a price scale for water where this is a marketable commodity (structure and level), and ensure a satisfactory balance between the virtues and excesses of economic competition in a domain that, by its nature, is easily subject to monopoly situations; be in charge of any public-private partnerships;
- *Protection:* ensure the protection of nature, fauna, flora and ecosystems: set objectives for water quality.

Obviously, based on the institutional and administrative organization of each country, various levels of responsibility exist in the field of water and its many uses. All catchment basins and aquifer systems, which form the natural geographic framework for water management, must somehow be taken into consideration, in conformity with the principles of IWRM.

First, it is indispensable that the public responsibilities in terms of groundwater are clearly defined and identified in the concerned countries, for instance within a specific administration or by a specialized autonomous public institution.

Secondly, it is also necessary to define the links between the entity that is responsible on a national level and those that apply the regulations in the field on local and regional levels.

In many countries, these preconditions are not met in an effective manner. Human means, technical competence and financial resources allotted in this field are commonly very limited. Sometimes, overlaps, dispersion and divergence may exist between several public institutions, and some countries have no structure at all that is clearly in charge of this domain.

Box 12 *Example of how groundwater management is organized in France*

In France, a national service is specifically in charge of groundwater: the Bureau of Groundwater and Water Resources that is part of the Directorate for Water and Biodiversity of the Ministry for Ecology. This service is in contact with the regional and departmental (provincial) services that implement water policy under the authority of the departmental and regional Prefects, the local representatives of the State. A Basin Coordinator Prefect coordinates the decentralized State services for implementing the regulations and official planning, through Development and Water Management master plans; under his authority, the officials working as Water Police ensure that the regulations in force are respected on the departmental level.

In addition, the National Office for Water and Aquatic Environments (ONEMA), supervised by the Ministry for Ecology, has the function of collecting, coordinating and synthesizing data on a national level, with the aim of periodic reporting on a European level.

Finally, catchment-basin institutions, such as Basin Committees and Water Agencies, ensure essential functions of dialogue, technical orientation and funding of the water sector.

As part of their various assignments, the above-mentioned organizations are assisted by scientific and technical public organizations, such as BRGM for groundwater.

2.4. Economic, financial and fiscal tools

Groundwater management in general and, even more so, that of transboundary aquifers, requires substantial financial means on both national and international levels. This often represents a problem in many developing countries.

For each use of water, a fair price should be paid for the service rendered. This should cover the capital investment costs and those of refurbishing installations, and the exploitation and maintenance costs of such installations, as well as at least part of external costs according to the 'polluter pays' principle. In many countries, innovating economic mechanisms are to be envisaged for funding this sector.

Three main funding sources are conceivable along the '3-T' rule: Tariffs (based on the principle of water pays water), Taxes (and fees), and Transfers (public assistance for development).

Among the different possible categories of economic tools, increasing importance should be accorded to the fiscal instrument of taxes. In fact, the behaviour of individual or collective economic agents that exploit or otherwise influence surface-water or groundwater resources, can be (re)oriented in one direction or another by means of financial or fiscal incentives established by the legislator of the country in question.

These incentives can act in two directions:

- *Attractive incentives,* in the form of financial assistance, can stimulate through credits (if necessary with a rebate), through subsidies for making the required investments (especially for mobilizing the resource and preventing or remediating pollution), through free insurance against exploration or drilling risks, or through rebates or tax holidays concerning the energy sources for pumping, etc. However, such assistance should be reasoned and coherent, in order not to encourage waste or overpumping of the water, nor to distort normal conditions of competition;
- *Negative incentives, or impositions,* such as restrictions through quotas or exploitation deterrents through fees on the abstraction of raw water, can be modulated by geographic area, season, or type of user, following a rational policy of allotting the resource. The taxing of acts that generate pollution according to the "polluter pays" principle today is widely accepted at the international level.

Box 13 Example of French basin institutions: Basin Committees and Water Agencies

In France, economic, financial and fiscal instruments for water management, both surface and underground, have been in use since the Law of 16 December 1964 on the sharing and distribution of waters. This law created new and highly original institutions on the French metropolitan territory: Basin Committees and Financial Basin Agencies, now called Water Agencies, in the six great hydrological basins of France. The Water Agencies are public establishments of the State that, under the aegis of their Basin Committee, act as real 'water banks'. They collect fees from users according to their water consumption and their discharge of pollutants. The collected funds are redistributed as subsidies or rebated loans to local authorities, industry and farmers, supporting projects that promote a rational use of water resources, combat pollution, and protect aquatic environments. In 2000, Water Offices were created on the same model in the French overseas departments and territories.

This approach of recovering costs through applying the 'polluter pays' principle is an essential component of the European Water Framework Directive adopted in 2000, which today is implemented in all member and neighbouring States of the European Union.

2.5. Training and professional improvement tools

In view of the highly complex tools required in the field of groundwater, capacity building is a key factor. Training and professional-improvement actions for technical and administrative staff, focusing on the collaborative management of shared waters and transboundary aquifer systems, are particularly useful.

In order to respond to this need, UNESCO's International Hydrological Programme has assembled a group of multidisciplinary experts to design a training module that specifically concerns transboundary aquifer systems. The objective of this course is to offer the different players involved in the management of a transboundary aquifer system a training in and basic notions of other disciplines than their own. During a first pilot session in October 2008, basic hydrogeological training was given to lawyers and decision-makers, and a basic course in law and international water law was proposed to hydrogeologists.

Since its creation in 1991, IOWater – whose vocation is to develop competence for a better management of water – supports countries that wish to set up or strengthen IWRM. It contributes in particular a long-standing experience of cooperation in the field of transboundary management of shared water resources. In its National Training Centre for Water Professionals, IOWater receives each year over 6,500 trainees (technicians, engineers, local elected officials) distributed over 845 training sessions. The sessions cover subjects as diverse as the execution, monitoring and maintenance of water boreholes, hydrogeology, aquifer monitoring, remediation of polluted groundwater, or the protection of drinking-water supply wells. IOWater also handles the secretariat and activities of the International Network of Water Training Centers, established in late 2008.

BRGM has created a similar tool for managing aquifer systems, especially transboundary ones, and offers a range of training courses in techniques related to the study of resources, their preservation, and the different available management tools.

In addition to these initiatives, several training centres in water-related work have been created elsewhere in the world over the past decade. Many such centres have been set up on the initiative of – or with technical and/or financial assistance from – France.

2.6. Tools for participation and cooperation

For the sake of efficiency and transparency, all involved parties should be consulted and involved in the decision-making process and the management of water resources. In order to reconcile the diverging interests of the many present and future users (farmers, industry, domestic users, environmental associations, etc.), it is particularly useful to set up advisory committees of users (formal and informal) and to organize public debates.

As far as transboundary cooperation is concerned, it will obviously be necessary to start manifold contacts between the countries interested in sharing experiences concerning their common resource, its management, the problems encountered, the risks run and the actions undertaken.

Box 14 Examples of existing transboundary basin organizations

Organizations involved in questions related to transboundary waters exist in most parts of the world. The oldest ones concern navigation on the great rivers, such as the Rhine, the Danube, the Congo, Niger and Senegal rivers, etc.

From the late 19th Century onward, the development of navigation, urban water supply, and electricity production from water power on shared watercourses, created the need for a second generation of transboundary organizations, such as the International Joint Commission established between the USA and Canada in 1909, and then between the USA and Mexico in 1944.

Over the past decades, a third generation of organizations has appeared that concern transboundary catchment basins, with enlarged and reinforced powers for implementing the integrated management of shared water resources. These include the Organization for the Development of the Senegal River (OMVS), the Niger Basin Authority (ABN), the Lake Chad Basin Commission, the International Commission on the Scheldt River and the Mekong River Commission.

It should be noted that all these transboundary organizations were created for shared surface waters. Little by little, some of these organizations have begun to take an interest in transboundary groundwater where this falls, at least partly, within their field of territorial action in view of the collaborative and overall management of all shared resources. Most of these transboundary organizations were studied during the Preparatory Works for this Guidebook.

To foster exchanges between counterpart specialists in the countries involved, international professional, scientific and academic organizations, such as the International Association of Hydrogeologists, can also play a very useful role.

Such technical contacts then should be enlarged to the diplomatic and political levels. To do so, international and regional organizations again can play the role of facilitator, or of mediator if necessary.

Box 15 The role of regional organizations in promoting cooperation for the management of transboundary waters

In many parts of the world, regional institutions play an important role of promotion, mediation and technical assistance in the management of transboundary waters. In Europe this is the case for the European Commission and the Council of Europe, but also for other, decentralized, regional bodies such as EUROMOT, the European network of local transboundary authorities. The United Nations Economic Commission for Europe (UNECE) spreads the management principles of shared transboundary waters as far as Eastern Europe and Central Asia, as part of the 1992 Helsinki Convention.

In Africa, several regional organizations are involved in the management of shared waters: in the south of the continent, the Southern Africa Development Community (SADC) promotes cooperation on transboundary waters, including groundwater, through its Protocol on Shared Watercourses. It has recently set up a commission for groundwater. In West Africa, the Economic Community of West African States (CEDEAO), with its Centre for the Coordination of Water Resources, plays a mediating role in political decision-making and provides technical assistance for certain steps in the setting up of collaborative management (data sharing and analysis, technical planning, drawing up investment plans, etc.). The same is true for the Economic and Monetary Community of Central Africa (CEMAC) that has created an innovating funding mechanism for the Congo–Oubangui–Sangha Basin.[8]

The Organization of American States (OAS) has been strongly involved in this field as well, in particular for the inventory and understanding of transboundary aquifer systems in South America.

Sources: Parts 1.1 and 1.2 of the Preliminary Works

[8] See Part 3 of this Guidebook for more explanations.

In addition to the above, international exchange networks, such as INBO and its specialized section for transboundary waters, the International Network of Transboundary Basin Organizations (INTBO, *cf.* Part 3, hereafter), and the many international events organized in the field of water [9] can help in proposing technical solutions for assisting political decision-making. Such collaboration platforms effectively provide a neutral space where it is possible to discuss sensitive subjects and develop both formal and informal relationships for stimulating confidence and cooperation.

After this, the official mechanisms for dialogue and the exchange and sharing of data, followed by consultation and then cooperation, must be progressively put in place. The final aim of all this work is to arrive at a general understanding of the problems, a common management strategy, and joint and coordinated actions.

[9] Among these manifestations we can cite: the World Water Forum that is held every three years, and the World Water Week, organized every year at Stockholm.

3. Methodological Approach and Mechanisms Proposed for a Joint Management of Transboundary Aquifer Systems

Because of the stakes presented in Part 1, the joint management of transboundary aquifer systems has become a subject that cannot be ignored. Because of the complexity of this subject and the variety of potential scenarios, the proposed approaches and mechanisms should be adapted to each specific case, as well as being pragmatic, many-sided and progressive.

A collaborative, equitable and durable management of transboundary aquifer systems not only requires considerable technical competence and financial means, but also, and especially, a political will of the involved countries that is sufficiently strong and persevering, without which nothing can be done. The commitment of the other stakeholders (non-governmental players, international organizations, etc.) for implementing the management modalities in place is necessary as well. In fact, the actions to be carried out with the range of available tools (described in the second part of this Guidebook) should be carried out not only on the local, national, and transboundary levels, but in certain cases or for some aspects also on a truly international level.

The actions discussed hereafter can be achieved in a successive or, if possible, simultaneous manner on the national level by local authorities, on the transboundary level by the States involved, and on the level of the international community.

3.1. At the national and local levels

The authorities responsible at local and national levels are the closest to the field and the concerned populations. For that reason, they should be closely involved when drawing up plans for the collaborative management of a transboundary aquifer system; after all, they will be primarily responsible for implementing the concrete actions to be carried out.

3.1.1. *Clarify the roles and responsibilities of local institutions*

It is impossible to hope that the management of a transboundary aquifer system will be improved if groundwater management is not already sufficiently taken into account on the local and national levels. Therefore, groundwater must have a recognized status in each country (including those where groundwater is still little exploited), and it should be perceived as a natural resource that must be preserved. This requires:

- First, the elaboration of a legislative and regulatory framework that clearly defines the legal regime of groundwater, especially in terms of the rights applicable to urban and rural land. Legally, the regime governing groundwater should be distinct from land regulations, with which it should be coordinated;
- Secondly, the definition in each country of the responsibilities of the various competent public institutions (ministries, offices, agencies, etc.) and their connecting links;
- Thirdly, the transfer by the State to the services in charge of these questions, of the competence and necessary technical and financial tools for accomplishing their tasks (studies, modelling, planning, etc.) and for enforcing national and local regulations.

To this end, the authorities of each country sharing a same aquifer system can use all or part of the range of available tools (*cf.* Part 2, above), including in particular all actions toward professional training, whether initial or continued.

3.1.2. *Improve the understanding of transboundary aquifer systems*

The scientific understanding of groundwater, and especially transboundary water, is a long-term undertaking, as some of its inherent parameters – or those that affect it – vary with time (in particular the terms of exploitation and recharge), with current use, and with local climatic conditions. Such understanding must be improved as much as possible by using the possibilities offered by modern technical and technological means, but also by developing exchanges and collaboration between the concerned countries.

At the local and national levels, such knowledge is by necessity underpinned by the collecting of all available scientific and technical data and information. Based on the observed gaps in this knowledge, the data should be completed through specific actions according to needs. The objective is to progressively make available all data and information indicated in Part 2 above.

All data must be collected in such a manner as to be accessible for efficient interpretation and use, followed by sharing between the different players of the concerned countries. To this end, it is commonly necessary to create databases and GIS. After that it is recommended to create suitable mathematical models, to help understand the behaviour of the aquifer system and to define its functioning, or to simulate development scenarios, the consequences of territorial-development policy, or the impact of quantitative and qualitative pressures on the resource.

For the correct determination of how an aquifer system functions – as well as of the consequences of its various utilizations and the pressures exerted on it – it is necessary to comprehend the system as a whole. For this, the scale of the catchment basin is often used, but this does not always coincide with the true hydrogeological extension of the aquifer system. Based on the interactions between groundwater and surface water, as well as on the real boundaries of the aquifer system, the most appropriate scale of investigations can be determined: in most cases this will be the useful expanse of the aquifer system or the hydrogeological basin, at an international scale in the case of transboundary aquifer systems.

In the case of a transboundary resource, the modelling work requires that the riparian countries sharing this resource share their relevant data. National input is a starting point, but cooperation between the riparian countries becomes necessary for the correct understanding of a transboundary aquifer system and for drawing up pertinent management rules.

3.1.3. *Information, participation and dialogue between the different players and users*

Modern water management cannot be imposed in an authoritative manner: it must be based on the effective participation of all parties and the creation of an efficient mechanism for collaboration. Nevertheless, the complexity and sensitivity of the problems posed by the management of groundwater in general and of transboundary aquifer systems in particular, require major programmes for education, raising awareness and information of officials, users and the population in general. In this context, the very specific cultural – but highly diverse – dimension attached to water all over the world should be mentioned. It is especially necessary to make people aware of the independent nature of both problems and possible solutions, of the need for a true 'hydrosolidarity' between neighbouring populations sharing the same waters, and of the long-term cooperation process that is needed from the perspective of sustainable development. Each player should be perfectly aware of the economic, social and strategic interest of such cooperation, and of the positive and concrete benefits for everyone.

Each project or programme concerning groundwater should thus include a section on informing and training the concerned parties, in order to prepare them for joint meetings where they can express their wishes and needs. Obviously, such sections should be adapted to the initial level of knowledge of the players in question.

Several principles can be distinguished in this field:

- If need be, ***train and inform*** the concerned local authorities, and the representatives of various types of users and of associations for the protection of nature or representative of the collective interests composing civil society;
- ***Promote*** with managers and users an awareness of the general interest, public welfare and importance of preserving water and environmental quality as related to public health; explain the idea of '*equitable utilization*';
- ***Adopt*** a participative approach for training, by mobilizing local competence and capabilities in each educational programme.

3.1.4. *Involve the relevant local and regional authorities*

As stated before, groundwater is intimately related to the subsurface and therefore forms part and parcel of the underlying territory. Local and regional authorities, which are both close to the field and its inhabitants that use such resources, should be involved in their management, including where transboundary aquifer systems are concerned. Experience clearly shows that such local and regional official bodies can play a highly useful role and that keeping them away from the decision-making process only aggravates the difficulties.

In this respect, it is significant to observe the decisive action played by local authorities in two interesting examples of the collaborative management of transboundary aquifer systems: that of the Genevois, shared between France and Switzerland, and that of the Carboniferous limestone that underlies both Belgium and France.

The involvement of local authorities corresponds to the application of the subsidiarity principle – encouraged by the European Water Framework Directive – according to which a responsibility should be shouldered by the lowest possible level of public authority that has the competence of resolving the problem, in other words the level that is the most pertinent and closest to citizens. Over the past years, many countries have adopted decentralization measures of formerly centralized powers, which have considerably increased the responsibility level of local officials, in particular for moving the management of public services closer to the users that benefit from them. At the same time, these local authorities have developed a new form of 'decentralized' international cooperation at their level that covers many fields, including very often water and sanition.

As part of the dynamics of this two-fold evolution, local authorities must be empowered and encouraged to start such decentralized cross-border cooperation, favouring the collaborative management of the shared underground (and surface!) water resources upon which they directly depend.

The experience obtained in decentralized cross-border cooperation by the French Operational Transboundary Mission in Europe (see below), might be useful in the field of shared groundwaters.

Box 16 *Example of decentralized cross-border cooperation in Europe*

Cross-border cooperation has been particularly developed between the Member States of the European Union thanks to the policy of Community cohesion.

France, in 1997, set up the MOT (Operational Transboundary Mission), under the aegis of DATAR, the Delegation for Territorial Development and Regional Action. MOT promotes the emergence and implementation of structural transboundary projects at a local level, by favouring the articulation of territories on both sides of the borders with its nine neighbouring countries. Initially, its action concerned five pilot sites: Lille Métropole, the three Eurodistricts of Alsace (Saint-Louis/Bâle, Mulhouse-Colmar-Freiburg-im-Breisgau and Strasbourg/Kehl), the French-Genevois Space, the Côte d'Azur metropolis of Menton-Ventimiglia, and the Bayonne-San Sebastian conurbation.

Since then, MOT has also developed the following cross-border cooperation projects in the field of water:

- The Mixed Syndicate for Study and Development of the Garonne (SMEAG, Spain/France), creating a transboundary observatory of the Garonne as part of the Interreg 3A project;[10]
- The Semois/Semoy River Contract (Belgium/France);[11]
- Upper Rhine Conference on river and aquifer waters (Germany/France/ Switzerland).[12]

This rich and diversified experience in the economic, social and cultural fields has led the MOT to open itself up to the European level, to become EUROMOT with a German director general.

[10] *Cf.* www.garona-i-garonne.com.
[11] *Cf.* www.semois-semoy.org.
[12] *Cf.* www.conference-rhin-sup.org.

3.2. On the transboundary level

3.2.1. *Preliminary technical contacts*

In order to improve the understanding of their shared aquifer systems as well as the governance of their water resources, the relevant countries should progressively develop contacts.

In many case histories, the first contacts were made on an informal level by technicians working in the same fields in their respective countries. Such preliminary exchanges allow the national services to better know each other and together evaluate the different technical aspects of the question, so as to be able to convince their superiors of the need and interest of organizing permanent transboundary collaboration. The latter may be necessary, either because the collected data show that the problems (potentially) affecting the shared resource can only be solved together, or because the existence of major stakes has been demonstrated, such as groundwater mining, pollution, lack of water, etc.), with the risk of an actual or potential international dispute.

Such preliminary dialogue is virtually indispensable. In fact, most of the deadlock that occurs during negotiations comes from contacts that were made too late, from too large socio-economic differences between the countries, or from a hegemonic position of one of the parties. In such cases, the intervention – at the request of the concerned countries – of international, multilateral or regional institutions can help in unblocking the situation and suggesting solutions. The idea of 'equitable utilization' must be presented by, and explained and discussed in the presence of, a mediator.

After this first phase of informal contacts between technical officials, the preparation of more formal meetings between the competent institutions of each country can be discussed.

3.2.2. *Holding official meetings*

'Official' meetings should include representatives of the concerned States at the invitation of one of them. During this second step, it is even more important to associate multilateral or regional institutions, delegates from the United Nations and friendly countries, development agencies or funding organizations that might make a technical and/or financial contribution. Such meetings should aim at:

- Sharing knowledge: national and transboundary problems concerning transboundary groundwater resources, in relation with surface waters if warranted;
- Agreeing on the common short-, medium- and long-term objectives;

- Exchanging on possible collaborative actions, highlighting the stakes, possible economic benefits, and advantages and gains resulting from a constructive cooperation between the relevant countries. The following subjects might be discussed:
  - Necessary actions for obtaining an understanding of the hydrogeological mechanisms at work and their economic and societal implications (harmonizing data-collection supports and creating an observatory for transboundary waters);
  - Definition of national policy with rules imposed by the new mechanisms to be set up and by international conventions;
  - Study of collaboration mechanisms and of the possible ways of cooperation, including the collection, exchange and exploitation of data, and the adaptation or creation of an organization in charge of transboundary groundwater (and possibly surface water), with joint availability of the necessary means for an equitable and lasting development of the shared water resources;
- Discussing and deciding upon the cost of this cooperation and the sharing of corresponding expenses, and on the timetable to be respected.

The arrangements to be planned should be sufficiently flexible to be able to evolve over time and in terms of any changes in the economic, social and even political conditions.

3.2.3. *Collecting, organizing and sharing data in a harmonized framework*

A transboundary measurement network should be created that can show any quantitative and/or qualitative changes in the resource as needed. This network can be based upon existing national, regional or local ones, but these very often have to be completed for operations to run smoothly. Measurement campaigns should be as much as possible synchronized and the data should be exchanged between the relevant countries at regular intervals. To allow the exchange of data (and metadata), they should be collected and organized on support media (databases, GIS) that can be processed by each relevant country for an optimal understanding and management of the shared resources. Harmonizing such monitoring, observation and information systems for water, as well as the harmonization of data and their supports, are difficult, lengthy and expensive operations, which however are necessary for a complete and efficient sharing of the data (interoperability of systems) and knowledge, as well as a correct monitoring of all actions. The development of such cooperation should lead to the definition and adoption of common standards for the creation of true observatories for transboundary waters.

Box 17 Example of the coordination of information systems: the case of the NWSAS

The NWSAS (North Western Sahara Aquifer System) is a resource that is almost entirely non-renewable. Since the early 1980s, groundwater abstraction has exceeded the natural recharge of the system. To avoid further aggravation of this phenomenon, the three relevant countries (Algeria, Libya and Tunisia) have decided to collaborate to ensure the joint management of the aquifer system, and coordinate their research, data sharing, updating of models, definition of common indicators, and action plans for areas at risk. The NWSAS project, launched in 1999 and finished in 2009, has among other points contributed to:

- The construction of a regional hydrogeological model for managing the aquifer, as well as three local sub-models (Jifara, Biskra, Western Basin);
- The creation of a database connected to a GIS and to models, as well as specific databases for the three sub-models;
- The construction of a geographic server;
- The design of a potentiometric network that was validated and identified in the field before being integrated in the national networks of each country.

In 2002, the three countries approved a common declaration and adopted a first outline of a technical structure for temporary collaboration as well as its attributions. This first declaration was followed in 2006 by a second that planned the establishment of a permanent structure called 'Permanent collaboration mechanism for the SASS'. This structure was put in place in 2008 with a revolving coordination and the main assignment of providing a framework for exchange and cooperation between the three countries through:

- The production of indicators concerning the resource and water demand;
- The drawing up of water-resource management scenarios for development in the basin;
- The strengthening and updating of common databases through the exchange of data and information;
- The development and management of common observation networks of the aquifer system.

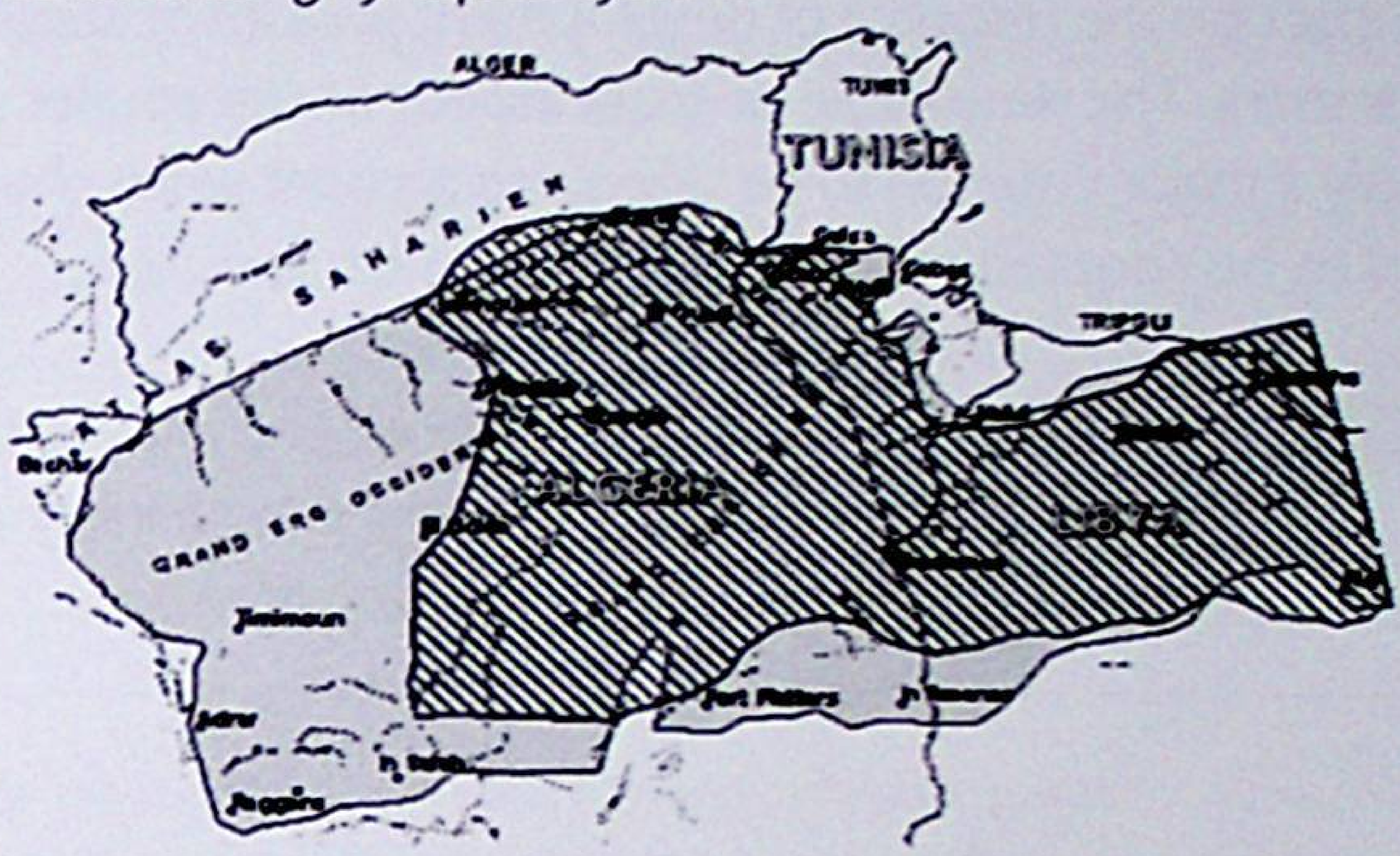
For the implementation of its assignments, the collaborative mechanism specifically aims at outlining the common studies and research, defining the procedures for data exchange, updating and running the models, identifying risk areas and formulating appropriate proposals, ensuring training, information and awareness-raising actions, etc. This collaborative mechanism represents a fairly advanced cooperation process, and the NWAS project is generally perceived as a success.

•••

...

Map 8 *Aquifer system of the northern Sahara*

Geographic distribution of the 'Terminal Complex' (hatching) and 'Intercalary Continental' (grey) aquifer systems.



Source: OSS, 2008.

Source: Part 16 of the Preliminary Works.

3.2.4. *Creating common management tools*

The management of an aquifer system requires the creation of specific tools, commonly mathematical or digital models, or in some cases integrated models that include all physical, environmental and socio-economic aspects.

It is in fact necessary to quantify and qualify the characteristics and functioning of the resource, and to simulate the impact of its use and of the public policies for planning and socio-economic development. This then provides the necessary elements for comparing the possible options, making informed choices, defining a strategy, and arriving at a (master) plan for the development and management of the considered waters. This plan should define the actions to be carried out, the means to be deployed, and the timetable to be respected.

To be used for management ends, the models must be correctly structured, dimensioned and calibrated in order to represent the simulated hydro-system with a degree of reliability and precision that agrees with the set objectives. To this can then be added further economic or human-behaviour models, or modules to assist the collaborative efforts, and create complete tools to support the management of the resource.

The creation of common tools to support the management of shared aquifer systems is not only recommended in order to obtain the quantified and reliable elements needed for drawing up management plans, but also because such tools often create a field of pertinent collaboration between technicians of the riparian countries. They thus foster dialogue between all players on either side of the border(s), in particular through providing graphs, maps and diagrams that help in providing simple explanations of the impact on the resource of development policies or specific actions by the different partners. The renewable or fossil aspect of the aquifer system being studied is obviously a major criterion to be taken into account when choosing the exploitation strategies to be adopted and the utilization to be favoured.

Box 18 *Which uses should be favoured for the sustainable or lasting management of a transboundary aquifer system? A few indications in terms of aquifer type.*

The distinction between aquifer systems with renewable water and those with fossil water is of fundamental importance for both the choice of a management model and the choice of the utilization(s) to be favoured.

1. ***Renewable aquifer systems,*** whose water often is of a better, more stable and better protected quality than surface water, should preferably be used for high-end purposes, starting with human consumption. Nevertheless, they should always be managed in a balanced and sustainable manner, without overdevelopment, if necessary with periodic recharge from pre-treated water.
2. ***Non-renewable aquifer systems*** must be differentiated by whether they occur in humid or temperate regions, or in arid or semi-arid regions:

- In humid or temperate regions, with permanent streams and renewable aquifer systems, the non-renewable aquifer systems generally have no need to be used; it is preferable to leave them intact, by considering them as safety and precaution reserves, whose exploitation should only happen as a last resort, and then in a rigorous and parsimonious manner;
- In arid or semi-arid regions, where non-renewable aquifer systems represent the main – or only – available water resource, their management is particularly sensitive. In the short and medium terms, the exploitation of such resources – which in any case is not sustainable – should be very rigorous and economical, considering the needs of future generations and the long term. Other, supplementary, solutions can be sought, such as the storage of surface water or utilization of so-called unconventional water resources (desalination of salt water, reuse of treated wastewater, the harvesting of rainwater, etc.). In this case, priority use should be for human consumption, agricultural production for feeding local populations, and industrial activity in terms of the options for economic policy of the relevant countries.

•••

...

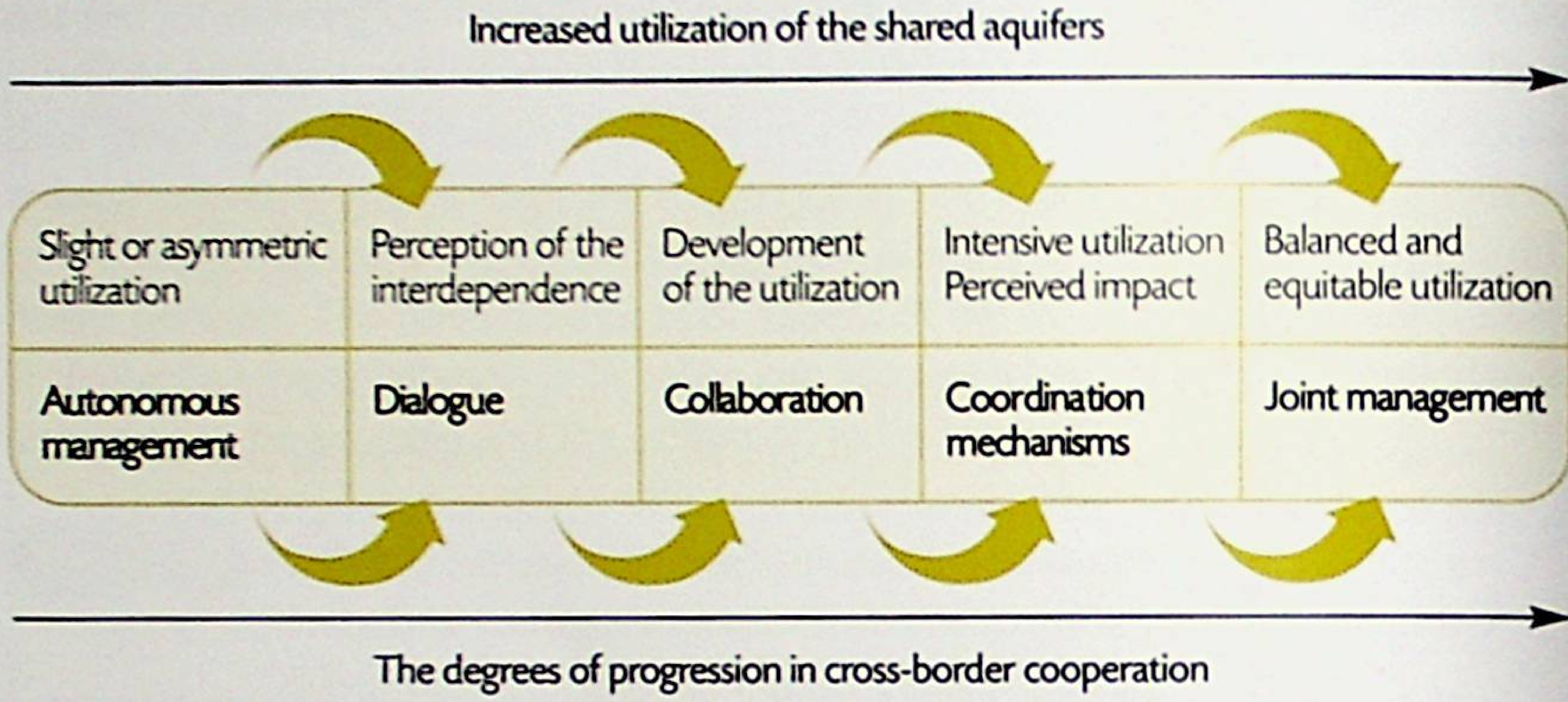
This distinction between renewable and non-renewable aquifer systems, transboundary or not, thus entails major differences in the corresponding management types on both the levels of resource evaluation and of exploitation strategy. If it is possible to adopt a conservative strategy (*i.e.* preventing groundwater mining) for aquifer systems with a renewable resource, it will never be possible to have a truly sustainable major exploitation for non-renewable aquifer systems, where choices will have to be particularly strict.

This distinction implies that it is preferable to speak of an *'equitable distribution of average transboundary flux'* or of a *'flowrate that can be abstracted on each side of the border'* for renewable aquifer systems, and of *'equitable sharing of influence transfer (water-level lowering) determined by destorage'* for aquifer systems with a non-renewable resource, a concept that is obviously only valid on a temporary basis.

3.2.5. *From simple dialogue to collaborative planning and joint management*

Transboundary relations can involve different degrees of cooperation. In the case of a weak or asymmetrical utilization of the resource, with little or no perceived impact on either side of the border, an autonomous management at national level may be sufficient. In this case the cross-border cooperation will be limited to a simple periodic exchange of information, or a brief consultation, at a frequency determined by context and needs. On the other hand, in situations of intense abstraction with marked real or potential repercussions on either side of the border, one must have solid and efficient collaborative mechanisms, or a common institutional transboundary structure for joint management of the resource.

Diagram 8 *Sketch of the type of situations*



Source: Adapted from Alker et al., 2008 by the Académie de l'Eau

In Europe, for instance, the Water Framework Directive has formalized this procedure by asking the States to draw up a single management plan for each international hydrological district, or, failing that, to ensure the coordination of management plans covering the parts of the international hydrological district located on their respective territories.

In addition, it is necessary to associate all players who facilitate and ensure the concrete field application of the planned measures.

3.3. Recommended actions at the level of the international community

3.3.1. *Strengthen international law on transboundary groundwater*

General international law encourages States to cooperate. For shared surface- or ground-waters, this incentive finds many applications that range from the organization of data exchange between riparian States to the implementation of common decision-making and management mechanisms.

Notwithstanding the major advance in December 2008 represented by the adoption by the United Nations General Assembly of Resolution A/RES/63/124 concerning the law of transboundary aquifers, the two fundamental rules governing International Water Law in general[13] and the International Law on Transboundary Aquifers in particular (as codified by the International Law Commission) are not yet binding. This may happen over time if they are the subject of numerous applications that will enter them progressively into Customary International Law. They can also be integrated into an agreement between countries sharing an aquifer system or in a specific international convention that should be ratified by a sufficient number of States.

It is important that the international organizations encourage the development and application of international law concerning transboundary groundwaters. It is particularly desirable that the principles laid down in Resolution A/RES/63/124 be widely applied, thus obtaining the status of customary law. In any case, the United Nations General Assembly has put on the provisional agenda for its 66th session (in September 2011) a question entitled *The Law of Transboundary Aquifers*, in order to examine in particular '*the question of the form that might be given to the draft articles*'.

3.3.2. *Encourage and provide diplomatic and technical support to the relevant countries*

Experience has shown that multilateral international or regional institutions, development agencies, funding organizations, and certain research and cooperation institutes can play a very positive and constructive role in promoting the collaborative management of transboundary water resources. This was clearly shown in the case of the transboundary catchment basins of the Indus, Mekong, Danube, and Nile rivers, and of the Aral Sea, the SASS, etc. Such structures can intervene just as efficiently for transboundary groundwaters; some have already acquired experience in this field and can, at the request of the relevant countries, make proposals and be of an undeniable

[13] See Part 2 of this Guidebook.

support for completing the relevant initiatives. In this respect we can mention UNESCO, the United Nations Commission for Europe, the European Commission, as well as institutions such as BRGM and BGR for the more technical aspects.

These organizations hold strong specific trump cards: they are neutral and objective, and can thus play the role of mediator; they have a long-standing experience of influence diplomacy through dialogue and persuasion; and, finally, they have worldwide networks of high-level multidisciplinary competence.

3.4. Nature and functions of an organization for managing transboundary groundwater (possibly including surface water) to be created or strengthened

Rather than creating another new organization from scratch, it is better – when possible and reasonable – to attach it to a pre-existing supranational or regional structure, whose field of competences may have to be adapted or enlarged to that of transboundary groundwaters. This is especially the case where a competent institution exists for managing surface waters in a catchment basin shared between several countries.

Certain transboundary basin organizations do not cover all the countries concerned by a shared aquifer system, or countries concerned by a single transboundary aquifer system may fall under different basin organizations. Such organizations might, depending on the case, not only be thematically enlarged to cover shared groundwater, but also be geographically extended. In that case they become *'Management organizations of transboundary surface- and ground-waters'*. It is also probable that such organizations develop relations between them in order to allow the overall coordination of a transboundary aquifer system. In any case, it will always be necessary to add specific complementary know-how on groundwater to the existing fields of competence.

Where no transboundary basin organization exists, the requirements related to the collaborative management of a shared aquifer may lead to the creation of such an organization. In arid regions without surface water, for instance, *'Management organizations of transboundary groundwater'* may be set up. To serve as a support for dialogue, followed by cooperation and then common management, such new coordination mechanisms can be defined in a founding agreement whose signatories will be the concerned States.

In fact, today only one working example exists of an organization for the joint management of transboundary groundwater: this is the case of the Genevois aquifer that is shared between France and Switzerland, as is discussed at the end of Part 3.

3.4.1. *Possible structure of an organization for managing transboundary groundwater (possibly including surface water)*

Once operational, a *'Management organization of transboundary surface- and ground-waters'* should comprise the following governance bodies:

- *An Assembly* composed of members designated by the States (ministers or even Heads of State) and associated bodies that periodically elects its President (possibly revolving between the members of each State);
- *A Board of Directors* (or equivalent body);
- *A body in charge of any legal proceedings*;
- *Working groups* that may be permanent for treating general problems and that meet periodically, or *ad hoc* groups for treating more specific and occasional problems;
- *A Permanent Secretariat*, a preferable condition for efficient operations;
- *A body in charge of communication*, exchanges and consultations.

The founding agreement should define the role of each of these bodies, the extent of their powers, as well as procedures for adopting decisions or recommendations (unanimity, qualified majority, etc.). It should also define the periodicity of meetings of the non-permanent bodies (Assembly, Board and Working groups), as well as the headquarters of the Permanent Secretariat. Additional bodies may also be planned for, such as a National Committee that assists the Working groups and a Consulting group with delegates from similar friendly international organizations.

3.4.2. *Possible functions of an organization for managing transboundary groundwater (possibly including surface water)*

A *"Management organization of transboundary surface- and ground-waters"* may have responsibilities of varying natures that should be clearly defined:

- *Technical responsibilities*, such as collecting, interpreting and exchanging scientific data, coordinating the planning and implementation of projects, and monitoring and controlling the use and quality of water;
- *Economic and financial responsibilities*, such as searching for, setting up and managing national and possible international (bilateral, regional and multilateral) funding, and distributing the costs and benefits of the actions;

- *Legal and administrative responsibilities,* such as the design and implementation of harmonized rules and procedures concerning the management of shared waters, in close cooperation with the various national institutions of the member countries;
- *Political responsibilities* with decision-making powers.

The experience of existing organizations leads to suggest other functions that might be attributed to such a *Management organization of transboundary surface- and ground-waters*:

- Consulting functions for stating opinions and suggestions and, if warranted, making recommendations;
- Operational responsibilities concerning wells and other engineering structures;
- Functions for the prevention and resolution of conflicts, as mediation and arbitration between parties;
- Educational, animation and training functions ;
- Responsibilities in terms of implementing participative actions for the integrated management of the water resources.

Box 19 Example of an institutional organization that has resulted in successful cooperation for the management of transboundary waters: the International Commission on the Scheldt River (CIE)

The Scheldt is a 355-km-long European river that traverses 3 countries and 7 regions, before flowing into the North Sea. In order to strengthen cross-border cooperation between the different stakeholders, and preserve and improve the quality of the river, France, the Walloon Region, the Flemish Region, the capital Region of Brussels and the Netherlands in 1995 set up the *"International Commission on the Scheldt River"*.

After an initial assessment of water quality in the Scheldt, two operations were carried out: *(i)* the creation of a homogeneous measuring network composed of 14 measuring stations along the river, and *(ii)* the setting up of a common warning system to guarantee the rapid circulation of information as soon as accidental pollution with potential transboundary repercussions is detected.

The transboundary management of the Scheldt Basin was reorganized on 3 December 2002 by the signing of the Treaty of Ghent, which integrates the new requirements of the European Water Framework Directive (WFD). The Kingdom of Belgium became the sixth contracting party to this new Treaty, which created the *"International Scheldt River Basin District"*. In addition to the river waters of the Scheldt Basin, this district comprises the associated groundwater and coastal waters. The treaty explicitly mentions joint management and coordinates surface water and groundwater in accordance with the WFD requirements.

Between 2003 and 2005, as part of the Interreg IIIB North West Europe programme, the European Scaldit [14] pilot project established a very advanced cross-border cooperation between the parties, according to a precise action plan that included the characterization of the river district, the management of information and data, water management and territorial development, communication and knowledge, and the preparation of a management plan for the Scheldt. In this pilot project, the Scheldt River Basin District is one of the test basins designated for evaluating the applicability of the WFD, in particular for the characterization and management measures of shared groundwater resources.

•••

[14] *Cf.* http://www.scalditproject.nl/pages/index_content_hr_fr.html

...

Map 9 International Scheldt River Basin District

- Scheldt RBD
- National borders
- Regional borders
- Major towns
- Streams
- Artificial canals
- Lakes

Source: Scaldit, December 2004.

Source: Part 16 of the Preliminary Works.

3.4.3. Conceivable legal framework

Territorial competence

The territorial competence of a *'Management organization of transboundary surface- and ground-waters'*, or of any other new mechanism to be created, should cover all of the shared aquifer system, in accordance with the recommendations of IWRM. In case this is impossible, the territorial competence of this organization will, initially, only cover part of the system under consideration.

Legal status

The legal status of the new organization should be formally defined, both from the viewpoint of international law and from that of the internal legal organization and institutions of each country. It is necessary to precisely define the structure of this type of organization, especially the place, form and degree of implication of the member States. In the case of attachment to a pre-existing structure, such as a transboundary basin organization, the existing agreements concerning shared surface waters should be extended to groundwater.

Box 20 *Example: Legal status of the European Grouping of Territorial Cooperation*

The Council of Europe, which is especially active in the domain of cross-border cooperation, adopted in 1980 the 'Madrid Outline Convention on Transfrontier Co-operation between Territorial Communities or Authorities'. From its side, the European Commission has proposed, and obtained from the European Parliament in 2006, the creation of a new institutional tool, the 'European Grouping of Territorial Cooperation', a legal entity endowed with a financial autonomy, open to Public authorities and their partners that wish to develop cross-border cooperation in all domains, including that of shared waters.

Operating rules and procedures

From the start and depending upon the context, it is necessary to clearly establish the internal rules for preparing decisions, consultation methods, procedures, and the levels for taking technical, financial or political decisions.

In addition to the internal rules, one should clarify the relations to be developed with the main outside interlocutors and partners (international, multilateral or regional institutions, funding organizations, non-member but potentially future member States, local communities and authorities, private sector, etc.).

Participation of the different stakeholders in discussions and decisions

The participation of regional and local community representatives and of users is highly desirable. The proposed measures should not only benefit from a consensus by the States, but they should also correspond to the wishes and real needs of the users, who will finally have to pay for them directly (the cost of the services) and indirectly (as taxes). Even if such players generally are not signatories of the international agreement, their participation must be planned for, especially within working groups.

3.4.4. Necessary funding for implementation and long-lasting operation

The distribution, in percentage terms, of the cost of setting up and operating a *Management organization of transboundary surface- and ground-waters* between the signatory parties should be defined by the founding agreement (fixing the amount of the expenditures can be the responsibility of the Assembly, based on proposals from the Permanent Secretariat and the Board of Directors). The Assembly also sets the budget for any common works and their distribution between the parties, for investments, as well as for operating and maintenance costs of the installations. The possible funding sources of the organization include:

- An initial allocation and yearly subsidies allocated by the Member States;
- Possible contributions from regional economic organizations that wish to boost the management of shared water resources (for instance ECOWAS, ECCAS or SADC);
- Possible outside financial assistance for investments (grants or loans at a reduced rate and for a preferential duration);
- In the longer term, licence fees from the application of the 'polluter pays' and/or 'user pays' principles, corresponding to fiscal taxes that punish pollution and water waste, as for instance levied by the French Water Agencies.

The selection of economic tools is not without importance. In case the organization in question has benefited from outside financing for its creation and initial operation, it is indispensable to plan for in-house and sustainable resources that ensure an existence that is independent of outside aid. It is in fact crucial for the organization to have financial means that allow it to exercise its functions in an autonomous and neutral manner and from a perspective of sustainability.

Box 21 Example of an innovating funding mechanism: financing of the international Commission of the Congo-Oubangui-Sangha Basin (CICOS) by taxing exchanges

CICOS was set up on 6 November 1999 by an Agreement creating a uniform fluvial regime, signed by the Heads of State of the Republic of Cameroon, the Central African Republic, the Republic of the Congo and the Democratic Republic of the Congo, as well as by its Addendum, also signed by the four Heads of State on 22 February 2007. CICOS is responsible for the sustainable management of the waterways, and for promoting and guaranteeing IWRM in the Congo Basin.

The Heads of State and Government of the CEMAC have adopted a mechanism for autonomous financing, which is the Community Integration Tax (TCI) levied on imports. Cameroon, the Central African Republic and Congo (members of CEMAC) contribute to CICOS through the TCI, which represents 70% of CICOS funding, not counting projects. The Democratic Republic of the Congo, not being a CEMAC member, contributes directly.

Map 10 The Congo Basin, second-largest catchment basin in the world

Source: CICOS, 2008

3.4.5. Networks for sharing experience

Within the INBO (International Network of Basin Organizations, 188 members in 68 countries) created in 1994, the organizations and commissions for transboundary rivers have created a group for the exchange of information and to help set up and operate new cross-border organizations. This is the INTBO, today counting representatives from over 40 countries from all regions in the world. Since its founding meeting in November 2002 at Thonon-les-Bains (France), the INTBO has met three times: in November 2004 at Dakar (Senegal), in March 2007 at Johannesburg (South Africa) and in January 2010 again at Dakar. The Dakar Declaration, adopted on 22 January 2010 by the General Assembly of INBO, stresses the need for better groundwater – especially transboundary – management and a better dove-tailing with surface-water management.

It is strongly suggested that existing or future organizations, specialized in the collaborative management of transboundary aquifer systems, become members of the INBO, and the INTBO, so as to strengthen the exchange of information and experience in this domain.

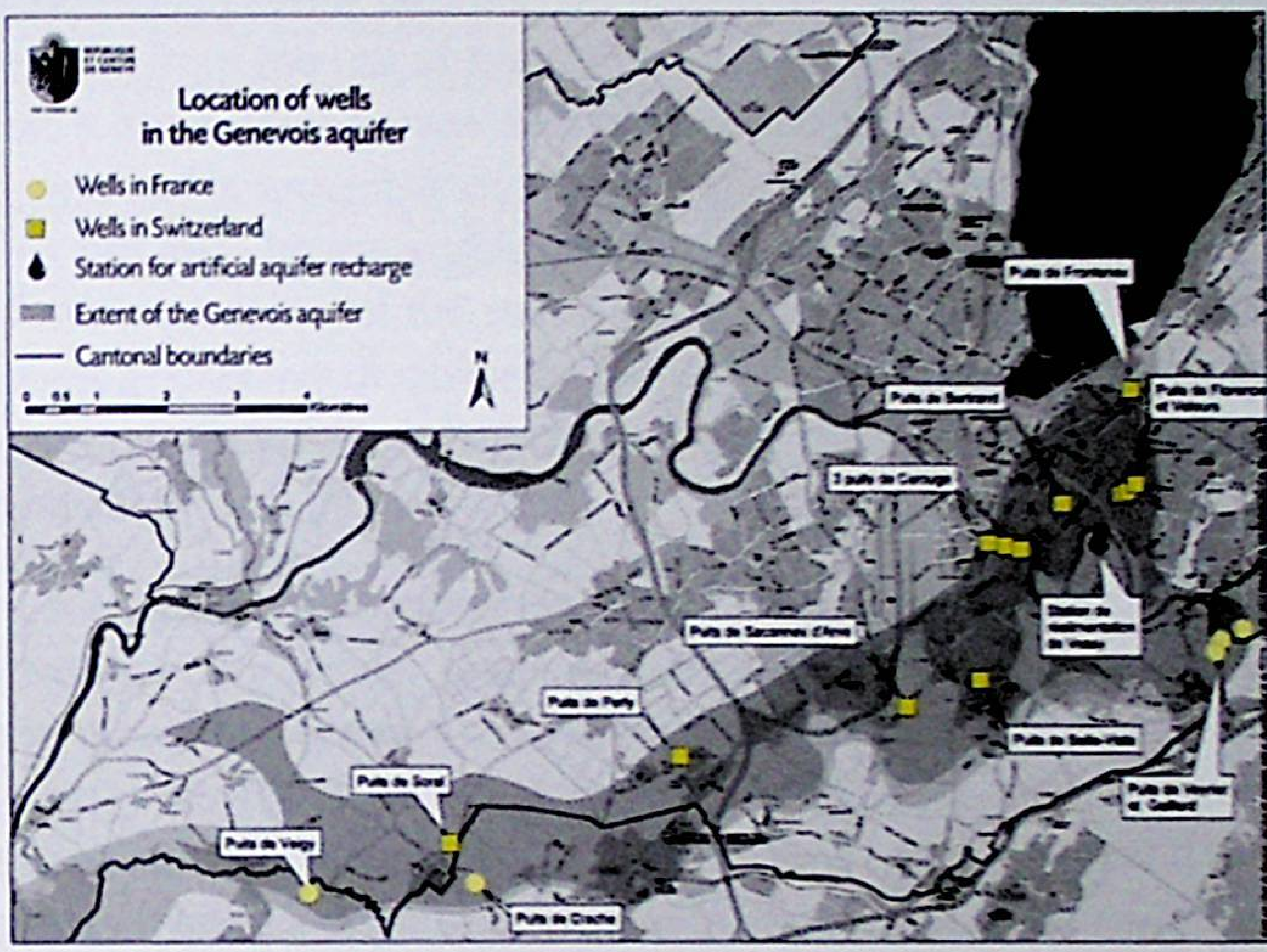
Box 22 *A very rare example of bilateral agreement on managing a transboundary aquifer system: the French-Swiss Genevois aquifer*

The Genevois aquifer is a transboundary aquifer system, located south of Lake Geneva and south of the Rhone River, with a length of about 19 km and a surface area of around 30 km². Much of the aquifer lies between the Rhone and Arve rivers and is mostly tapped for providing drinking water, supplying about 20% of greater Geneva.

From 1960 onward, increased pumping caused a strong lowering of the average aquifer level, about 7 m in 20 years, fostering plans for the artificial recharge of the aquifer with Arve water. At that point, the Swiss Canton of Geneva started negotiations with the French Department of Haute Savoie for carrying out studies into this artificial recharge: this gave rise to an original decentralized transboundary cooperation project. The negotiations led to the signing, on 9 June 1978, of an agreement between the Canton de Geneva and the Prefect of Haute Savoie, called the Agreement for the Protection, Utilization, and Recharge of the French-Swiss aquifer of the Genevois.

...

Map 11 *Genevois aquifer system*



Source: Canton of Geneva, Service de geologie, sols and dechets, 2009.

This first Agreement, of a duration of 30 years, created a Commission for Exploitation of the Genevois aquifer, composed of three Swiss members and three French members.

The task of this Commission is to propose a yearly programme for aquifer utilization. It gives its technical opinion on the construction of new equipment or its modification, and it verifies the construction costs and operating expenses of the recharge installations. All abstraction installations are equipped with instruments for making volumetric and aquifer-level measurements. The Agreement stipulates that the Canton of Geneva looks after the construction and exploitation of the artificial recharge station, of which it remains the single owner. The Agreement further stipulates that the French communes cannot abstract more than 5 million m^3/year, 2 million of which are exempt from payment. Each party must give an estimate to the Commission of its abstraction from the aquifer. The Agreement also stipulates the calculation of the French share of the artificial-recharge costs for each year. Finally, quality control and a warning network in case of accidental pollution are planned for.

...

On 18 December 2007, the first Agreement was replaced by a new one, again for a duration of 30 years, which includes almost the same terms as the first one. The signatories in this case were, for Switzerland, the Canton of Geneva and, for France, the Associations of Local Authorities of the Annemasse and Geneva regions, and the Municipality of Viry; the second Agreement was thus directly signed between territorial authorities.

Today, the French-Swiss Genevois aquifer system is the most advanced example of the joint management of a transboundary groundwater resource.

Source: Part 16 of the Preliminary Works.

Conclusions

Because of increasingly strong pressures on water resources, an equitable sharing of the benefits deriving from the use of transboundary aquifer systems is an indispensable precondition. It is necessary to raise awareness of the incalculable value of the natural heritage represented by groundwater, a highly fragile and commonly poorly known environment that can easily be irreversibly damaged by short-term management practices. Because of the importance of the stakes, the stakeholders are encouraged to adopt and implement a collective discipline at all (local to supra-national) scales, in order to obtain the necessary understanding of these precious resources as well as for their optimal exploitation and protection.

To this end, the first step consists in improving as much as possible the understanding of such transboundary aquifer systems, using all available powerful scientific and technical tools. It will be necessary to raise the awareness level of – and even to provide complementary training to – the stakeholders, in order for them to be completely aware of the situation in general, and of the problems encountered and the risks run if the countries sharing a single aquifer system exploit this system without collaborative management.

Once the interdependence of these countries has been recognized and accepted, the second step consists in establishing contact between them, first technical and then diplomatic. This step allows the exchange of viewpoints, the development of confidence and solidarity relations, the sharing of information, and the coherent, pragmatic and progressive implementation of the various tools presented in this Guidebook.

International organizations can be useful for assisting in this process, by providing their advice and assistance, and by encouraging the development and implementation of international law concerning transboundary groundwater. The local and territorial authorities of the relevant countries can play an important role as well, by developing initiatives and actions of pertinent transboundary cooperation.

Existing organizations for the management of transboundary surface waters are obviously logical vehicles for extending their territorial field of action to the aquifer systems that concern them. They generally have a most useful experience, institutional framework, and network of international relations, and can easily extend and reinforce their competence into the field of groundwater. The relevant countries might thus institutionalize their cooperation within *'Management organizations of transboundary surface- and ground-waters'*. Pilot projects will allow the further development of the tools presented in this Guidebook and will help increase general knowledge of these resources. The lessons learnt from these experiences might be further developed and shared through professional training networks.

However, to succeed in this multilateral approach, the relevant countries must show a strong and long-lasting political will.

Appendix 1

Case histories having served to establish this Methodological Guidebook

Table 1 provides a synthesis of the main case histories studied during the preparatory work for this Guidebook. It presents several more-or-less advanced initiatives in the field of managing shared transboundary underground water resources. The list of examples is not exhaustive, but it is representative of the great diversity of situations encountered in this field all over the world. Most of the agreements signed between countries sharing a same aquifer system in fact only concern surface waters. Nevertheless, the advances in transboundary cooperation – even when only concerning surface water – must be encouraged, as they go in the direction of a greater collaboration between countries. This, in turn, will lay the foundations for an indispensable relation of mutual confidence that can then be enlarged to cooperation in the field of shared aquifer systems.

The individual cases were treated in parts 1.6 and 2 of the Preparatory Works. Part 1.6 presented cases that had already given rise to projects; Part 2 described cases with high stakes, but in which a process of transboundary cooperation is initiated.

Table 1 *Summary of case studies*

Name of the aquifer system	Relevant countries	Main stakes	Advances in cross-border cooperation
Taoudeni-Tanezrouft Basin	• Mauritania (south and centre-east parts) • Mali (most of the country) • Burkina Faso (north-west) • Algeria (Tanezrouft in the south)	• Water supply for human consumption and various other uses (domestic, animal herding, market gardening, small-scale irrigation). • Water pollution, especially through mining activities.	• No collaborative action is taken by the relevant countries. Organizations exist around the aquifer system that manage international river systems, and to which certain countries belong: OMVS for Mali and Mauritania; ABN for Burkina Faso, Mali and Niger; SASS for Algeria. These organizations might be a suitable framework for further discussion. •••

Name of the aquifer system	Relevant countries	Main stakes	Advances in cross-border cooperation
Aquifer systems of the Lake Chad Basin	• Chad • Niger • Nigeria • Cameroon • Central African Republic • Sudan • Algeria • Libya (a very small part)	• Drought, desertification and drying up of water resources. • Drying up of Lake Chad whose surface area was reduced by 90% in 40 years. • Groundwater levels have been lowered since 20 years. • Salinity of the Pliocene aquifer; high fluor concentrations in Nigeria; contamination of wells by nitrates.	• Lake Chad Basin Commission (CBLT), created in 1964 by the countries bordering Lake Chad (Cameroon, Niger, Nigeria, Chad) (Fort Lamy Agreement). The Central African Republic joined in 1994 and Sudan in 2000. The Agreement has not created any obligation for the shared management of the basin resources; however, the CBLT plays an important role of coordination.
Aquifer systems of the Lullemeden Basin	• Niger • Nigeria • Mali • Algeria To a lesser extent: • Benin and Burkina Faso	• Pollution from mining – especially uranium mining – and from pesticides and solid and liquid waste. • Overexploitation through the exponential increase of abstraction rates that exceed average recharge. • Lowering of the potentiometric level and degradation of resource quality.	• The project *"Management of hydrogeological risk in the Lullemeden aquifer system"* has improved the hydrogeological understanding of the aquifer system (2004-2008). • The draft treaty of 20 June 2009 aims at setting up a specific planning mechanism for the Lullemeden aquifer system by 2011 (not yet formally adopted by the relevant States).
Aquifer systems of the Senegal-Mauritania Basin	• Senegal • Mauritania • The Gambia • Guinea-Bissau	• Recharge deficit and lowering of the watertable, because of arid climate and population growth. • Salinization of water and agricultural land, in particular in Mauritania and in the lower valley and delta of the Senegal River. • Pollution through waste-water discharge, pesticides and fertilizers, especially in Senegal. • Pollution from mining in Guinea, Mali and Senegal. • Natural fluor pollution, especially in Senegal.	• Absence of a formal agreement between the Basin countries and of a data exchange on the quantitative and qualitative evolution of the aquifers, but two organizations exist for the management of shared rivers: OMVS and OMVG. • Planning dynamics have existed for a long time and the governance set up for basin management is evolving toward actions for protecting the aquifers. •••

Name of the aquifer system	Relevant countries	Main stakes	Advances in cross-border cooperation
Aquifer systems of the coastal Ghana-Togo-Benin Basin	• Ghana • Togo • Benin • Nigeria (to a lesser extent)	• Increased drinking water requirements because of high population density and unbridled urban development in the coastal areas. • Recharge deficit due to less rainfall and more urban development whereby surfaces become impermeable. • Exhaustion and salinization of the coastal aquifer systems, and pollution. • Pollution of mining, and industrial and domestic waste origin, especially in the coastal area. • Multiplication of wells without qualitative or quantitative controls.	• Today, there is no planning structure at the scale of the aquifer system between the three countries Ghana-Togo-Benin, but they are part of the *Volta Basin Authority* (VBA) set up in 2009 after the 2007 agreement came into force. This Authority also comprises Burkina Faso, Côte-d'Ivoire and Mali.
NWSAS	• Algeria • Tunisia • Libya	• Lowering of aquifer levels, resulting in a decrease in artesian flow and, in the long term, the drying up of shallow wells and foggaras. • Drying up of outlets of the two aquifer systems. • Excessive phreatic rise in some places as a result of wastewater discharge. • Degradation of water quality. • Salinization of soil (impact on agriculture).	• A common research programme has led to the creation of technical tools for the regional management of the aquifer (hydrogeological studies, database, GIS, hydrogeological model), and to the signing of a formal planning agreement between the three countries in 2002 and 2006. • In 2008, a permanent structure called *"Permanent planning mechanism for the northern Sahara aquifer system"* was created, which today represents a fairly accomplished cooperation process, even though this is not yet a common management tool.
Aquifer system of the Nubian Sandstone	• Libya • Egypt • Chad • Sudan	• Overexploitation especially because of agricultural, but also of domestic, use.	• Signing in 1992 of an agreement creating a 'Joint authority for the study and development of Nubian Sandstone aquifer water', between Egypt and Libya, joined in 1996 by Sudan and in 1999 by Chad; three projects were carried out in 1998, 2004 and 2006 (ongoing) that led to generally important technical results. • The actions carried out as part of the cooperation process gave more mixed results. •••

Name of the aquifer system	Relevant countries	Main stakes	Advances in cross-border cooperation
Aquifer system of the Stampriet	• Namibia • Botswana • South Africa	• In Namibia, the Stampriet is the main source of fresh water for agricultural activities (cattle watering and a little irrigation). It is little used in South Africa and Botswana. • Aquifer quality deteriorates to the east, with a progressive salinization from Namibia to Botswana. In the future, the greatest demand will probably come from Namibia.	• In 2008, a project for a joint hydrogeological study, a model for aquifer-system management and groundwater-management plan was presented to SADC by technical teams of the three countries. At present, no transboundary management system exists, but a proposal is being drafted by the Orange-Senqu River Basin Commission (ORASECOM), to which the three countries belong. This proposal should also include the transboundary Ramotswana Dolomitic aquifer shared between Botswana and South Africa, and should thus associate the Limpopo Commission. This is the first initiative of cooperation on transboundary aquifers in southern Africa.
Aquifer system of the Guarani	• Brazil • Argentina • Paraguay • Uruguay	• Diffuse pollution due to the increasing use of fertilizers and pesticides. • Overexploitation of the resource causing the lowering of static water levels. • Point pollution related to the presence of industrial complexes and petroleum industry. • Pollution due to the inadequacy of wastewater treatment plants in urban areas. • Risk of saline intrusion around Rio Uruguay.	• The 'Project for environmental protection and sustainable development of the Guarani aquifer system', launched in 2003 and closed in 2009, appears to be a success, having set in motion a cooperation process between the four countries. It has led to a better scientific understanding of the aquifer system, to setting up a regional monitoring network and to creating local, national and international information systems. Thanks to four pilot projects, four aquifer management models were developed, and four local commissions were set up to help manage the aquifer system. The four States signed an agreement on the aquifer in August 2010.
Transboundary aquifers of the Mekong Basin	• China (Provinces of Qinghai and Yunnan) • Myanmar (extreme north-east) • Laos • Thailand • Cambodia • Vietnam	• Economic development and increased water demand. • Overexploitation and salinization of aquifer systems. • Pollution of aquifer systems and degradation of ecosystems.	• Cooperation agreement for the sustainable development of the Mekong River Basin, signed in 1995 between Cambodia, Laos, Thailand and Vietnam, creating the Mekong River Commission. • China and Myanmar have been, since 1996, 'discussion partners' of the agreement, which only concerns the Mekong waters and does not mention groundwater. • • •

Name of the aquifer system	Relevant countries	Main stakes	Advances in cross-border cooperation
Aquifer system of the Upper Rhine	• France • Germany • Switzerland	• Highly vulnerable aquifer that corresponds to an area of intensive agriculture and high population density. Agriculture is the main source of pollution (nitrates, pesticides such as atrazine). Chemical pollution (chlorides) is due to potassium mining in Alsace. Over 30 years after the Benfeld-Erstein accident in 1970 (carbon tetrachloride spill), this pollution renders some parts of the aquifer still unfit for consumption.	• The Bonn Agreement of 22 October 1975 between France, Germany and Switzerland set up an *'Intergovernmental Commission'* and an institutional framework for cross-border cooperation in the Upper Rhine valley. • The *'Agreement for Protection of the Rhine'*, signed in 1999, replaces the preceding agreements; in this new agreement, the parties in the International Commission for Protection of the Rhine have decided to extend their common actions to the Rhine catchment and groundwater.
Aquifer system of the Carboniferous	• France • Belgium (Wallonia and Flanders)	• Aquifer very much used for drinking water and industrial abstraction, which until recently led to an important lowering of the watertable, as well as causing local subsidence. Diffuse pollution is a potential risk. • The aquifer has natural fluor pollution. • The existence of karst-conduit communications with the Scheldt River, itself polluted, renders the aquifer highly vulnerable to pollution.	• In 1994, France, the Flemish Region, the Walloon Region, the Brussels-Capital Region and the Netherlands created the *International Commission for the protection of the Scheldt River* (CIPE), which in 2002 became the *International Commission of the Scheldt* (CIE) with the integration of Belgium. The new Ghent Agreement incorporates the requirements of the WFD and covers groundwater. In 1997, a cooperation agreement concerning the Carboniferous aquifer was signed between the Walloon and Flemish regions. In addition, a French-Belgian study on characterizing the aquifer system was carried out in the early 2000s. Two meetings were held in Tournai in 2002 and 2007, the first creating a Transboundary Observatory of the Carboniferous Aquifer, the second confirming the need to sign a tripartite agreement (France-Wallonia-Flanders). •••

Name of the aquifer system	Relevant countries	Main stakes	Advances in cross-border cooperation
Aquifer system of the Genevois	• Switzerland • France	• Contamination risk because of urban pressure (hydrocarbons, chlorinated solvents). In Switzerland there is also nitrate pollution. The increasing pressure from agricultural and drinking-water abstraction can constitute a risk. Moreover, degradation in the quality of Arve river water would put a stop to recharge: the risk thus is especially quantitative.	• A 30-year agreement was signed in 1978 between the Canton of Geneva and the Prefect of Haute Savoie, for the protection, utilization, and recharge of the French-Swiss Genevois aquifer, also creating a commission for managing the aquifer. The agreement, simple from an institutional viewpoint but highly technical, was renewed for another 30 years in 2008, and is, without doubt, the foremost example, today, of the joint management of a transboundary groundwater resource.
Aquifer system of the Gaza Strip mountains and coastal area	• Israel • Palestinian Territories	• Serious stakes related to groundwater mining and pollution, accentuated by the Israeli-Palestinian conflict. Natural flow decreases and salt-water wedges increasingly develop in the coastal-aquifer system. Major environmental problems will occur in the near future. The situation is particularly dramatic for the coastal-aquifer system, of which only 5 to 10% of the water can be rendered fit for drinking.	• The efficiency of the *Joint Water Commission* (JWC), created in 1994 by the Oslo Agreements, is compromised by: - The need to obtain unanimous agreement for each action; - The need to obtain the agreement from Israel for work in the Palestinian Territories; and - The lack of power of the JWC, which is not allowed to rule on what happens on Israeli soil. • The Geneva Agreement of 2003, of extra-governmental origin and without legal value, has an Annex 10 on water which contains a project concerning the definition of a maximum quantity of annual abstractions from the Mountain aquifer for each of the two parties.

Appendix 2

Resolution 63/124 on the Law of Transboundary Aquifers

United Nations A/RES/63/124

General Assembly

Distr.: General
15 January 2009

Sixty-third session
Agenda item 75

Resolution adopted by the General Assembly

[*on the report of the Sixth Committee (A/63/439)*]

63/124. The law of transboundary aquifers

The General Assembly,

Having considered chapter IV of the report of the International Law Commission on the work of its sixtieth session,[1] which contains the draft articles on the law of transboundary aquifers,

Noting that the Commission decided to recommend to the General Assembly (*a*) to take note of the draft articles on the law of transboundary aquifers in a resolution, and to annex the articles to the resolution; (*b*) to recommend to States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers on the basis of the principles enunciated in the articles; and (*c*) to also consider, at a later stage, and in view of the importance of the topic, the elaboration of a convention on the basis of the draft articles,[2]

Emphasizing the continuing importance of the codification and progressive development of international law, as referred to in Article 13, paragraph 1 (*a*), of the Charter of the United Nations,

Noting that the subject of the law of transboundary aquifers is of major importance in the relations of States,

Taking note of the comments of Governments and the discussion in the Sixth Committee at the sixty-third session of the General Assembly on this topic,

1. *Welcomes* the conclusion of the work of the International Law Commission on the law of transboundary aquifers and its adoption of the draft articles and a detailed commentary on the subject;

2. *Expresses its appreciation* to the Commission for its continuing contribution to the codification and progressive development of international law;

3. *Also expresses its appreciation* to the International Hydrological Programme of the United Nations Educational, Scientific and Cultural Organization

[1] *Official Records of the General Assembly, Sixty-third Session, Supplement No. 10* (A/63/10).
[2] Ibid., para. 49.

and to other relevant organizations for the valuable scientific and technical assistance rendered to the International Law Commission;[3]

4. *Takes note* of the draft articles on the law of transboundary aquifers, presented by the Commission, the text of which is annexed to the present resolution, and commends them to the attention of Governments without prejudice to the question of their future adoption or other appropriate action;

5. *Encourages* the States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers, taking into account the provisions of these draft articles;

6. *Decides* to include in the provisional agenda of its sixty-sixth session an item entitled "The law of transboundary aquifers" with a view to examining, inter alia, the question of the form that might be given to the draft articles.

67th plenary meeting
11 December 2008

Annex

The law of transboundary aquifers

...

Conscious of the importance for humankind of life-supporting groundwater resources in all regions of the world,

Bearing in mind Article 13, paragraph 1 (*a*), of the Charter of the United Nations, which provides that the General Assembly shall initiate studies and make recommendations for the purpose of encouraging the progressive development of international law and its codification,

Recalling General Assembly resolution 1803 (XVII) of 14 December 1962 on permanent sovereignty over natural resources,

Reaffirming the principles and recommendations adopted by the United Nations Conference on Environment and Development of 1992 in the Rio Declaration on Environment and Development[4] and Agenda 21,[5]

Taking into account increasing demands for freshwater and the need to protect groundwater resources,

Mindful of the particular problems posed by the vulnerability of aquifers to pollution,

Convinced of the need to ensure the development, utilization, conservation, management and protection of groundwater resources in the context of the promotion of the optimal and sustainable development of water resources for present and future generations,

---

[3] Ibid., para. 51.

[4] *Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3–14 June 1992*, vol. I, *Resolutions Adopted by the Conference* (United Nations publication, Sales No. E.93.I.8 and corrigendum), resolution 1, annex I.

[5] Ibid., annex II.

Affirming the importance of international cooperation and good-neighbourliness in this field,

Emphasizing the need to take into account the special situation of developing countries,

Recognizing the necessity to promote international cooperation,

...

Part one
Introduction

Article 1
Scope

The present articles apply to:

(*a*) Utilization of transboundary aquifers or aquifer systems;

(*b*) Other activities that have or are likely to have an impact upon such aquifers or aquifer systems; and

(*c*) Measures for the protection, preservation and management of such aquifers or aquifer systems.

Article 2
Use of terms

For the purposes of the present articles:

(*a*) "aquifer" means a permeable water bearing geological formation underlain by a less permeable layer and the water contained in the saturated zone of the formation;

(*b*) "aquifer system" means a series of two or more aquifers that are hydraulically connected;

(*c*) "transboundary aquifer" or "transboundary aquifer system" means, respectively, an aquifer or aquifer system, parts of which are situated in different States;

(*d*) "aquifer State" means a State in whose territory any part of a transboundary aquifer or aquifer system is situated;

(*e*) "utilization of transboundary aquifers or aquifer systems" includes extraction of water, heat and minerals, and storage and disposal of any substance;

(*f*) "recharging aquifer" means an aquifer that receives a non-negligible amount of contemporary water recharge;

(*g*) "recharge zone" means the zone which contributes water to an aquifer, consisting of the catchment area of rainfall water and the area where such water flows to an aquifer by run-off on the ground and infiltration through soil;

(*h*) "discharge zone" means the zone where water originating from an aquifer flows to its outlets, such as a watercourse, a lake, an oasis, a wetland or an ocean.

Part two
General principles

Article 3
Sovereignty of aquifer States

Each aquifer State has sovereignty over the portion of a transboundary aquifer or aquifer system located within its territory. It shall exercise its sovereignty in accordance with international law and the present articles.

Article 4
Equitable and reasonable utilization

Aquifer States shall utilize transboundary aquifers or aquifer systems according to the principle of equitable and reasonable utilization, as follows:

(*a*) They shall utilize transboundary aquifers or aquifer systems in a manner that is consistent with the equitable and reasonable accrual of benefits therefrom to the aquifer States concerned;

(*b*) They shall aim at maximizing the long-term benefits derived from the use of water contained therein;

(*c*) They shall establish individually or jointly a comprehensive utilization plan, taking into account present and future needs of, and alternative water sources for, the aquifer States; and

(*d*) They shall not utilize a recharging transboundary aquifer or aquifer system at a level that would prevent continuance of its effective functioning.

Article 5
Factors relevant to equitable and reasonable utilization

1. Utilization of a transboundary aquifer or aquifer system in an equitable and reasonable manner within the meaning of article 4 requires taking into account all relevant factors, including:

(*a*) The population dependent on the aquifer or aquifer system in each aquifer State;

(*b*) The social, economic and other needs, present and future, of the aquifer States concerned;

(*c*) The natural characteristics of the aquifer or aquifer system;

(*d*) The contribution to the formation and recharge of the aquifer or aquifer system;

(*e*) The existing and potential utilization of the aquifer or aquifer system;

(*f*) The actual and potential effects of the utilization of the aquifer or aquifer system in one aquifer State on other aquifer States concerned;

(*g*) The availability of alternatives to a particular existing and planned utilization of the aquifer or aquifer system;

(*h*) The development, protection and conservation of the aquifer or aquifer system and the costs of measures to be taken to that effect;

(*i*) The role of the aquifer or aquifer system in the related ecosystem.

2. The weight to be given to each factor is to be determined by its importance with regard to a specific transboundary aquifer or aquifer system in comparison with that of other relevant factors. In determining what is equitable and reasonable utilization, all relevant factors are to be considered together and a conclusion reached on the basis of all the factors. However, in weighing different kinds of utilization of a transboundary aquifer or aquifer system, special regard shall be given to vital human needs.

Article 6
Obligation not to cause significant harm

1. Aquifer States shall, in utilizing transboundary aquifers or aquifer systems in their territories, take all appropriate measures to prevent the causing of significant harm to other aquifer States or other States in whose territory a discharge zone is located.

2. Aquifer States shall, in undertaking activities other than utilization of a transboundary aquifer or aquifer system that have, or are likely to have, an impact upon that transboundary aquifer or aquifer system, take all appropriate measures to prevent the causing of significant harm through that aquifer or aquifer system to other aquifer States or other States in whose territory a discharge zone is located.

3. Where significant harm nevertheless is caused to another aquifer State or a State in whose territory a discharge zone is located, the aquifer State whose activities cause such harm shall take, in consultation with the affected State, all appropriate response measures to eliminate or mitigate such harm, having due regard for the provisions of articles 4 and 5.

Article 7
General obligation to cooperate

1. Aquifer States shall cooperate on the basis of sovereign equality, territorial integrity, sustainable development, mutual benefit and good faith in order to attain equitable and reasonable utilization and appropriate protection of their transboundary aquifers or aquifer systems.

2. For the purpose of paragraph 1, aquifer States should establish joint mechanisms of cooperation.

Article 8
Regular exchange of data and information

1. Pursuant to article 7, aquifer States shall, on a regular basis, exchange readily available data and information on the condition of their transboundary aquifers or aquifer systems, in particular of a geological, hydrogeological, hydrological, meteorological and ecological nature and related to the hydrochemistry of the aquifers or aquifer systems, as well as related forecasts.

2. Where knowledge about the nature and extent of a transboundary aquifer or aquifer system is inadequate, aquifer States concerned shall employ their best efforts to collect and generate more complete data and information relating to such aquifer or aquifer system, taking into account current practices and standards. They shall take such action individually or jointly and, where appropriate, together with or through international organizations.

3. If an aquifer State is requested by another aquifer State to provide data and information relating to an aquifer or aquifer system that are not readily available, it

shall employ its best efforts to comply with the request. The requested State may condition its compliance upon payment by the requesting State of the reasonable costs of collecting and, where appropriate, processing such data or information.

4. Aquifer States shall, where appropriate, employ their best efforts to collect and process data and information in a manner that facilitates their utilization by the other aquifer States to which such data and information are communicated.

Article 9
Bilateral and regional agreements and arrangements

For the purpose of managing a particular transboundary aquifer or aquifer system, aquifer States are encouraged to enter into bilateral or regional agreements or arrangements among themselves. Such agreements or arrangements may be entered into with respect to an entire aquifer or aquifer system or any part thereof or a particular project, programme or utilization except insofar as an agreement or arrangement adversely affects, to a significant extent, the utilization by one or more other aquifer States of the water in that aquifer or aquifer system, without their express consent.

Part three
Protection, preservation and management

Article 10
Protection and preservation of ecosystems

Aquifer States shall take all appropriate measures to protect and preserve ecosystems within, or dependent upon, their transboundary aquifers or aquifer systems, including measures to ensure that the quality and quantity of water retained in an aquifer or aquifer system, as well as that released through its discharge zones, are sufficient to protect and preserve such ecosystems.

Article 11
Recharge and discharge zones

1. Aquifer States shall identify the recharge and discharge zones of transboundary aquifers or aquifer systems that exist within their territory. They shall take appropriate measures to prevent and minimize detrimental impacts on the recharge and discharge processes.

2. All States in whose territory a recharge or discharge zone is located, in whole or in part, and which are not aquifer States with regard to that aquifer or aquifer system, shall cooperate with the aquifer States to protect the aquifer or aquifer system and related ecosystems.

Article 12
Prevention, reduction and control of pollution

Aquifer States shall, individually and, where appropriate, jointly, prevent, reduce and control pollution of their transboundary aquifers or aquifer systems, including through the recharge process, that may cause significant harm to other aquifer States. Aquifer States shall take a precautionary approach in view of uncertainty about the nature and extent of a transboundary aquifer or aquifer system and of its vulnerability to pollution.

Article 13
Monitoring

1. Aquifer States shall monitor their transboundary aquifers or aquifer systems. They shall, wherever possible, carry out these monitoring activities jointly with other aquifer States concerned and, where appropriate, in collaboration with competent international organizations. Where monitoring activities cannot be carried out jointly, the aquifer States shall exchange the monitored data among themselves.

2. Aquifer States shall use agreed or harmonized standards and methodology for monitoring their transboundary aquifers or aquifer systems. They should identify key parameters that they will monitor based on an agreed conceptual model of the aquifers or aquifer systems. These parameters should include parameters on the condition of the aquifer or aquifer system as listed in article 8, paragraph 1, and also on the utilization of the aquifers or aquifer systems.

Article 14
Management

Aquifer States shall establish and implement plans for the proper management of their transboundary aquifers or aquifer systems. They shall, at the request of any of them, enter into consultations concerning the management of a transboundary aquifer or aquifer system. A joint management mechanism shall be established, wherever appropriate.

Article 15
Planned activities

1. When a State has reasonable grounds for believing that a particular planned activity in its territory may affect a transboundary aquifer or aquifer system and thereby may have a significant adverse effect upon another State, it shall, as far as practicable, assess the possible effects of such activity.

2. Before a State implements or permits the implementation of planned activities which may affect a transboundary aquifer or aquifer system and thereby may have a significant adverse effect upon another State, it shall provide that State with timely notification thereof. Such notification shall be accompanied by available technical data and information, including any environmental impact assessment, in order to enable the notified State to evaluate the possible effects of the planned activities.

3. If the notifying and the notified States disagree on the possible effect of the planned activities, they shall enter into consultations and, if necessary, negotiations with a view to arriving at an equitable resolution of the situation. They may utilize an independent fact-finding body to make an impartial assessment of the effect of the planned activities.

Part four
Miscellaneous provisions

Article 16
Technical cooperation with developing States

States shall, directly or through competent international organizations, promote scientific, educational, technical, legal and other cooperation with developing States for the protection and management of transboundary aquifers or aquifer systems, including, inter alia:

(*a*) Strengthening their capacity-building in scientific, technical and legal fields;

(*b*) Facilitating their participation in relevant international programmes;

(*c*) Supplying them with necessary equipment and facilities;

(*d*) Enhancing their capacity to manufacture such equipment;

(*e*) Providing advice on and developing facilities for research, monitoring, educational and other programmes;

(*f*) Providing advice on and developing facilities for minimizing the detrimental effects of major activities affecting their transboundary aquifer or aquifer system;

(*g*) Providing advice in the preparation of environmental impact assessments;

(*h*) Supporting the exchange of technical knowledge and experience among developing States with a view to strengthening cooperation among them in managing the transboundary aquifer or aquifer system.

Article 17
Emergency situations

1. For the purpose of the present article, "emergency" means a situation, resulting suddenly from natural causes or from human conduct, that affects a transboundary aquifer or aquifer system and poses an imminent threat of causing serious harm to aquifer States or other States.

2. The State within whose territory the emergency originates shall:

(*a*) Without delay and by the most expeditious means available, notify other potentially affected States and competent international organizations of the emergency;

(*b*) In cooperation with potentially affected States and, where appropriate, competent international organizations, immediately take all practicable measures necessitated by the circumstances to prevent, mitigate and eliminate any harmful effect of the emergency.

3. Where an emergency poses a threat to vital human needs, aquifer States, notwithstanding articles 4 and 6, may take measures that are strictly necessary to meet such needs.

4. States shall provide scientific, technical, logistical and other cooperation to other States experiencing an emergency. Cooperation may include coordination of international emergency actions and communications, making available emergency response personnel, emergency response equipment and supplies, scientific and technical expertise and humanitarian assistance.

Article 18
Protection in time of armed conflict

Transboundary aquifers or aquifer systems and related installations, facilities and other works shall enjoy the protection accorded by the principles and rules of international law applicable in international and non-international armed conflict and shall not be used in violation of those principles and rules.

Article 19
Data and information vital to national defence or security

Nothing in the present articles obliges a State to provide data or information vital to its national defence or security. Nevertheless, that State shall cooperate in good faith with other States with a view to providing as much information as possible under the circumstances.

List of Acronyms and Abbreviations

AFD	Agence française de développement *(French Development Agency)*
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe *(Federal German Institute for Geosciences and Natural Resources)*
BRGM	Bureau de recherches géologiques et minières *(French Bureau of Geological and Mining Research)*
CBLT	Commission du Bassin du Lac Tchad *(Lake Chad Basin Commission)*
CFC	Chlorofluorocarbons
CICOS	Commission Internationale du Bassin Congo-Oubangui-Sangha *(International Commission for the Congo-Oubangui-Sangha Basin)*
CIE	Commission Internationale de l'Escaut *(International Commission for the Scheldt River)*
CIPE	Commission Internationale pour la protection de l'Escaut *(International Commission for the Protection of the Scheldt)*
DATAR	Delegation à l'aménagement du territoire et à l'action régionale *(French Government delegation for territorial development and regional action)*
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EUROMOT	Réseau européen d'autorités locales transfrontalières *(European network of local transboundary authorities)*
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
INBO	International Network of Basin Organizations
INWTC	International Network of Water Training Centres
IOWater	International Office for Water
IWRM	Integrated Water Resources Management
GWP TAC	Global Water Partnership Technical Advisory Committee
IAH	International Association of Hydrogeologists

IHP	International Hydrological Programme (UNESCO)
ISARM	Internationally Shared Aquifer Resources Management
MAEE	Ministère français des Affaires étrangères et européennes *(French Ministry for Foreign and European Affairs)*
MOT	Mission operationnelle transfrontalière *(Operational transboundary mission)*
NBA	Niger Basin Authority
NWSAS	North-Western Sahara Aquifer System
OAS	Organization of American States
OMVG	Organisation pour la mise en valeur du fleuve Gambie *(Organization for the development of the Gambia River)*
OMVS	Organisation pour la mise en valeur du fleuve Senegal *(Organization for the development of the Senegal River)*
ONEMA	Office national de l'eau et des milieux aquatiques *(French national office for water and aquatic environments)*
ORASECOM	Orange – Senqu River Basin Commission
OSS	Observatoire du Sahara et du Sahel *(Sahara and Sahel Observatory)*
INTBO	International Network of Transboundary Basin Organizations
SADC	Southern Africa Development Community
SASS	Système aquifère du Sahara septentrional *(North-Western Sahara Aquifer System)*
SMEAG	Syndicat mixte d'étude et d'aménagement de la Garonne *(Regional association for the study and development of the Garonne River)*
TCI	Taxe communautaire d'intégration *(ECCAS Community tax for integration)*
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
VBA	Volta Basin Authority
WFD	Water Framework Directive
WHO	World Health Organization
WHYCOS	World Hydrological Cycle Observing System
WHYMAP	Worldwide Hydrogeological Mapping and Assessment Programme

Glossary[15]

Abstraction: Withdrawal of groundwater by any means.

Aquifer: Water-bearing bed or stratum of permeable rock comprising a saturated zone that is sufficiently conductive for groundwater to allow significant flow through the rock and the abstraction of appreciable quantities of water. An aquifer can contain an unsaturated zone.

Aquifer horizon (or aquifer layer): Specific water-bearing layer of sedimentary rock, in particular within a multi-layer aquifer system.

Aquifer system: Aquifer or unit of aquifers and semi-permeable bodies (aquitards), all parts of which are in continuous hydraulic connection, and that is confined by boundaries that are an obstacle to all propagation of appreciable influence to the outside, over a given period of time. An aquifer system is both the medium of groundwater flow according to the distribution of potential (hydraulic head), and the medium of propagating natural or artificial influences.

Aquitard: Semi-permeable layer between two permeable layers, impeding vertical flow of groundwater between the latter.

Artesian flow: Phenomenon of natural outflow of groundwater under pressure as the potentiometric level of the aquifer is above local ground level.

Bottom water level: Lowest average water level in a stream.

Catchment basin (or area): Delimited territory, drained by a stream and its tributaries of which it is the water-supply area. Each catchment basin is geometrically defined in terms of a given point on a stream (e.g. a river mouth), a contour line (watershed), and a surface area.

Catching (see also Tapping): All actions of abstracting groundwater, whether by gravity (tapping of a spring or from a tunnel) or by drawing from a well.

Chott: Closed depression in arid areas of North Africa, of tectonic or even aeolian origin, whose bottom is occupied by a dry marsh with salty soil (Sabkha), and where episodic runoff and groundwater of deeper origin evaporate.

[15] Sources: Vaubourg and Marzat, 1997; Marzat, 2008; Petit dictionnaire Larousse illustré, 2004.

Confined aquifer: Part or all of a groundwater body that has no free surface (watertable) and is everywhere subject to a higher than atmospheric pressure, and whose potentiometric surface is above the roof of the aquifer.

Coastal aquifer: Groundwater body in a coastal domain, generally unconfined and limited by an interface between fresh water and salt water.

Decompression: Lowering the head of a confined aquifer.

Depletion (also destorage): Decrease of water reserves contained in an aquifer due to abstraction over a given period.

Depression: see Groundwater lowering.

Drainage network: System or network of surface streams draining a catchment area.

Endorheic (adj.): Stream that does not reach the sea, but ends in a closed depression.

Foggara: Tunnel for catching groundwater through gravity, generally for irrigation use, in Algeria and Tunisia; also called Qanat in Iran (country of origin), Karez in China and Central Asia, or Rhettara in Morocco.

Fossil water: Groundwater that has been present in an aquifer for centuries or even millenia, because of a very slow displacement velocity and/or a long distance from a recharge area.

Geochemical background: Small concentrations of various chemical substances deriving from natural processes of geological, biological or atmospheric origin. Concept related to that of the natural qualitative state of surface- or ground-waters.

Groundwater: Water within the saturated zone of an aquifer, all parts of which are hydraulically connected.

Groundwater lowering: Action of temporary or permanent lowering of the potentiometric surface of an aquifer in a specific area, to facilitate certain subsurface construction work.
Remark: When the lowering of the water level in a specific area is the result, rather than the objective, of exploitation of the aquifer, it is commonly called depression.

Groundwater mining: *In the narrow sense:* Unbalanced exploitation of an aquifer, where abstraction exceeds the induced decrease of hydraulic head, causing a decrease in the water reserve.
In a wider sense: All groundwater overexploitation that has a harmful effect on users, third parties or the environment.

Hydrodynamic properties: Physical characteristics of an aquifer environment that govern its aptitude for containing and conducting water, and for transmitting pressure changes, which are defined by the structural parameters porosity, storage coefficient and permeability.

Isotopic analysis: Determination of the isotopic compositions of the atomic constituents of water molecules or of the solutes they contain, and especially of stable and unstable isotopes, such as Deuterium D, Tritium 3H, Oxygen 18, Carbon 13 or Carbon 14.

Hydraulic (adj.): Concerning water movement, using its static or dynamic energy.

Hydrogeological (adj.): Concerning hydrogeology, covering knowledge of and research into groundwater.

Hydrographic (adj.): Concerning hydrography, the physical geography of continental (surface) water. See also: Drainage network.

Hydrosolidarity: Existing relationship between two or more persons, communities or States that, in view of an interdependent link covering shared surface and/or underground water resources, have a reciprocal interest in cooperating and collaborating in order to reach common objectives.

Interfluve area: Relief that separates stream valleys.

Karst: Solution cavities in limestone and similar rock, resulting from the most subterranean dissolving action of (slightly acid) waters. Karst networks can consist of interlinked tunnels, caves and minor pathways for water. Sinkholes can develop on surface above karst cavities.

Lowering of the water level: Downward movement, natural or determined by pumping, of the potentiometric level of groundwater. Amount of the decline over a given period and defined in observation wells.

Mass transfer: Displacement and translation of a defined surface or underground water volume, under the effect of flow in a stream or an aquifer, and over a given duration.

Maximum potentiometric drawdown: Maximum technically possible lowering of the watertable in a given point of an aquifer, under the effect of abstraction.

Observation well (also Water-level gauge): Borehole for measuring the water level at a given point of an aquifer. Gauge: Instrument for recording variable parameters, in this case a free water level or a pressure.

Observation-well network: Set of observation wells for the periodic monitoring of water levels in one or more aquifer systems of a given territory.

Outlet: Place where a permanent or temporary water flow comes out of an aquifer, with a generally fixed level and variable flowrate: spring, discharge area, or drainage by a stream.

Percussion borehole: Borehole, generally of reduced diameter, drilled to obtain information or samples of the subsurface, and that can be used as observation well after installing a piezometer.

Phreatic aquifer: Unconfined aquifer at shallow depth (generally down to several metres), that is accessible and exploitable from dug wells.

Physico-chemical analysis: Identification of the quantitative ionic composition of the solutes present in a water sample, or of other physical characteristics such as conductivity.

Piezometer: Water-level gauge or pressure gauge. French usage: observation well.

Pollution: *In the active sense* (polluting action): Introduce physical, chemical or biological agents into a natural aquatic environment, provoking modifications of this environment by reducing the possibilities of its use by Man, and/or by disturbing aquatic ecosystems.
In the passive sense (polluted condition): The presence in water of products and effects caused by human activity, which render it improper for its use by Man, and/or disturb aquatic ecosystems.

Potentiometric level: Upper level of the static liquid column that balances the hydrostatic pressure at the point to which it refers. It is materialized by the free water level in an open vertical tube at a given point (water level gauge). Its elevation is defined either by its height above a general level, commonly sea level, or by its height above the aquifer hanging wall in the case of a confined aquifer.

Pressure transfer: Displacement of a pressure change in a fluid, particularly in the water mass of a confined aquifer.

Propagation of influence: Displacement of a variation in hydraulic head (potentiometric level) of natural or artificial origin, away from its place of origin and in the unsteady state.

Qanat: (see Foggara).

Recharge area (of an aquifer): Area where continuous or occasional replenishment of water occurs that feeds a defined aquifer, especially a partially confined aquifer that is not recharged over its entire overlying ground surface.

Renewable/non-renewable (groundwater) resource: A water resource is renewable when it is supplied by the catching of natural flow, and non-renewable when it is abstracted from an aquifer reserve that, by definition, is not replenished in the long term.

Reorientation of flow: Change in the direction of flow lines in groundwater, due to a transformation in the potentiometric surface under the effect of abstraction or artificial recharge.

Resilience: Capability of a stream or groundwater body to spontaneously recover in quantity and/or quality, after a temporary disturbance, especially accidental pollution.

Riparian ecosystem: Ecosystem composed of flora and fauna on the banks of a stretch of water (stream, lake, etc.).

Sabkha: See Chott.

Saturated zone: Aquifer level that is saturated with water.

Topographic depression: Area with an elevation below that of its environment, which can form a closed depression (see Chott).

Tracing: Experimental procedure for showing and observing the real displacement of groundwater in an aquifer following one or more trajectories defined between a point of origin and one or more detection points, using artificial tracers that mark the water.

Underground water resources: Accessible groundwater that is technically and economically exploitable, and of usable quality, without unacceptable impact on surface water or its associated ecosystems.

Unsaturated zone: Aquifer zone above the static water level, where air may partially fill the interstitial areas.

Water quality: Aptitude of water, determined by its physical, chemical, biotic or organoleptic characteristics, to serve for a well-defined use or allow the functioning of a given aquatic environment.

Waterborne disease: Illness that can be ascribed to pathogenic or parasitic agents for which water is the vector or the generating environment, such as malaria, bilharzia or cholera.

References

N.B.: *The following references do not represent an exhaustive bibliography of all existing publications on transboundary aquifers.*

Reference works and guidebooks

General subjects (concepts, inventories, management)

ALKER, M., M. GROSSMANN, E. HERRFAHRDT-PÄHLE, W. SCHEUMANN, O. SCHMIDT, T. STEYRER AND I. THEESFELD (2008), *Conceptualizing cooperation on Africa's transboundary groundwater resources,* Deutsches Institut für Entwicklungspolitik, Bonn.

ALMAQQY, A. AND Z. BUZAS (1999), *Inventory of Transboundary Groundwaters,* UN/ECE Task Force on Monitoring & Assessment, Lelystad http://iwacportal.org/File//downloads/inventory_transboundary_groundwaters.pdf

AURELI, A. AND J. GANOULIS (2005), *The UNESCO project on internationally shared aquifer resources management (UNESCO/ISARM): overview and recent developments,* in *STOURNARAS G. et al.* (eds) Proc. 7th Hellenic Hydrogeological Conference, Vol II, pp.35-46, Hellenic Chapter of IAH, Athens.

DARNAULT, C. (ed.) (2008), *Overexploitation and Contamination of Shared Groundwater Resources,* Springer, Dordrecht.

FOSTER, S. AND D.P. LOUCKS (eds) (2006), *Non-renewable groundwater resources: A guidebook on socially-sustainable management for water policy makers,* IHP Groundwater Series No. 10, http://unesdoc.unesco.org/images/0014/001469/146997E.pdf.[16]

GWP TAC (2000), *Integrated management of water resources.* Global Water Partnership, Background Paper No. 4, Stockholm.

IGRAC (2009), *Transboundary aquifers of the world, update 2009,* Special edition for the 5th World Forum on Water, Istanbul 2009 (/www.isarm.net/publications/313#).

[16] In addition to the scientific chapters on non-renewable groundwater, this work contains several case histories, in particular on the NSAS and the NWSAS.

MARGAT, J. (2008), *Les eaux souterraines dans le monde*, BRGM Editions, Orleans.

PENNEQUIN, D. (2000), *Transport of pollutants in aquifers; principal operating mechanisms and applied numerical or mathematical modelling*, Houille Blanche, 2000(6), 67-73.

PENNEQUIN, D. (2002), *Fonctionnement des hydrosystèmes*, Annales des Entretiens de l'Environnement, APESA, Pau, France.

PENNEQUIN, D. AND S. FOSTER (2008), *Groundwater quality monitoring: the overriding importance of hydrogeologic typology (and need for 4D thinking), Chapter 5.1, The Water Framework Directive: Ecological and Chemical Status Monitoring*, John Wiley and Sons Ed., Hoboken.

PENNEQUIN, D. (2010), *Management of transboundary aquifer systems: a worldwide challenge, a need for increased concertation and political support*, Proc. 3rd International Conference on Managing Shared Aquifer Resources in Africa, UNESCO/IHP, Tripoli, Libya, 25-27 May 2008.

PENNEQUIN, D. AND H. MACHARD DE GRAMONT (IN PRESS): *Implementation of the Water Framework Directive concepts at the frontiers of Europe for transboundary water resources management: illusion or reality?*, 4th International Symposium on Transboundary Waters Management, Thessaloniki, Greece, 15-18 October 2008.

PURI, S., B. APPELGREN, G. ARNOLD, A. AURELI, S. BURCHI, J. BURKE, J. MARGAT AND P. PALLAS (2001), *Internationally Shared (Transboundary) Aquifer Resources Management, Their Significance and Sustainable Management, A Framework Document*, IHP-VI, Paris, http://unesdoc.unesco.org/images/0012/001243/124386e.pdf.

PURI, S. AND A. AURELI (eds) (2009), *Atlas of Transboundary Aquifers, Global Maps, Regional Cooperation and Local Inventories*, UNESCO-IHP Paris, http://www.isarm.net/publications/323.

RHONE-MEDITERRANEAN AND CORSICA WATER AGENCY (2010),
Web site: http://www.eaurmc.fr/pedageau/les-milieux-aquatiques/les-zones-humides/le-fonctionnement-dune-zone-humide.html.

STEPHAN, R.M. (2010), *La coopération transfrontalière sur les eaux souterraines: un processus en évolution*, Dynamiques Internationales No 2., http://www.dynamiques-internationales.com/publications/numero-2-janvier-2010/.

UNECE (2000), *Guidelines on Monitoring and Assessment of Transboundary Groundwaters*, Task Force on Monitoring and Assessment, Lelystad, Netherlands, http://www.unece.org/env/water/publications/documents/guidelinesgroundwater.pdf.

UNECE (2007), *Our Waters: Joining Hands across Borders, First Assessment of Transboundary Rivers, Lakes and Groundwaters*, New York and Geneva, http://unece.org/env/water/publications/pub76.htm.[17]

VAUBOURG, P. AND J. MARGAT (1997), *Lexique d'Hydrogéologie Français-Anglais/English-French*, Manuels & Méthodes No. 29, BRGM Editions, 264 p.

WORLD BANK (2007), *Making the Most of Scarcity: Accountability for Better Water Management Results in the Middle East and North Africa, MENA Development Report*, World Bank, Washington, D.C.

Legal publications

BURCHI, S. AND K. MECHLEM (2005), *Groundwater in International Law*, UNESCO, FAO, Rome, ftp://ftp.fao.org/docrep/fao/008/y5739e/y5739e00.pdf.

DA FRANCA, N., R.M. STEPHAN, M.C. DONOSO, A. GONZALEZ, L. DEL CASTILLO-LABORDE, M. MILETO, A. AURELI AND L. UGAS (2008), *Marco legal e institucional en la management de los sistemas acuiferos transfronterizos en las Americas*, Programa UNESCO/OEA ISARM Americas No. 2, Montevideo, Washington D.C., http://unesdoc.unesco.org/images/0015/001589/158963s.pdf.[18]

STEPHAN, R.M. (2006), *Evolution of international norms and values for transboundary groundwater governance*, in TURTON, A.R., D. ROUX, M. CLAASSEN and J. HATTINGH (eds), *Governance as a Trialogue: Government-Society-Science in Transition*, Springer-Verlag, Berlin.

STEPHAN, R.M. (2008), *The new legal framework for groundwater under the EU Water Framework Directive and Daughter Directive*, ICFAI University Press, Hyderabad.

STEPHAN, R.M. (2009), *Groundwater monitoring in international conventions and agreements* in QUEVAUVILLER P., A.M. FOUILLAC, J. GRATH and R. WARD (eds) *(2009)*, *Groundwater quality assessment and monitoring*, John Wiley & Sons Ed., Hoboken.

[17] This publication includes an inventory of 51 transboundary aquifers in SE Europe (in collaboration with the chair of UNESCO INWEB and Aristotle University of Thessalonika) and 18 in the Caucasus region and Central Asia.

[18] An English translation is available. This publication provides a complete inventory of the legal and institutional situation of 22 countries on the American continent concerning transboundary aquifers, on both cross-border and national levels.

Case histories

Abu El-Naeem, M.F., Z. Abu Heen and K. Tubail (2009), *Factors behind groundwater pollution by nitrate in North Governorates of Gaza Strip (1999-2004),* Thirteenth International Conference for Water technology (IWTC 2008), held in Alexandria, Egypt, 27-30 March, 2008.

Appelgren, B. (ed) (2004), *Managing Shared Aquifer Resources in Africa,* Series on Groundwater No. 8, IHP-VI, UNESCO, Paris, Proceedings of the Second Conference on Transboundary Aquifers in Africa, Tripoli, June 2002, http://unesdoc.unesco.org/images/0013/001385/138581m.pdf.

Bouzit, M. and E. Ansik (2008), *Socio-economic analysis integrating soil-water system modelling for the Kempen region – heavy metal pollution in groundwater,* Aquaterra, BRGM.

BRGM (1977), *Al Hassa Development Project , study of water resources and management programme,* Saudi Arabian Ministry for Water and Agriculture.

BRGM (2006), *Hydrogeological map of the Sultanate of Oman,* study carried out in partnership with the ECO Company.

BRGM (2007), *Management of the Lake Peipsi transboundary basin – Hydrogeological model of the Narva Basin and Lake Peipsi* (project funded by the French Global Environment Facility, the European Union and BRGM).

Da Franca, N., M. Miletto, M.C. Donoso, A. Aureli, S. Puri, O. Tijchneider and A. Rivera (2007), *Sistemas Acuiferos transfronterizos en las Americas: Evaluacion preliminar,* Programa UNESCO/OEA ISARM Americas No. 1, Montevideo, Washington D.C., http://www.oas.org/dsd/Water/Documentos/Sistemas%20Acu%C3%ADferos%20Transfronterizos%20en%20las%20Am%C3%A9ricas.pdf.[19]

Ferragina, E. and F. Greco (2008), *The Disi project: an internal/external analysis,* Water International, December, pp. 451-463, Routledge, Abingdon.

Geneva Canton (2009), *Map of wells in the Genevois aquifer,* supplied by Mr. Gabriel de Los Cobos, Service de géologie, sols and dechets.

GIWA (2006), *Global International Waters Assessment – Mekong River,* GIWA Regional Assessment 55, http://www.unep.org/dewa/giwa/areas/reports/r55/giwa_regional_ assessment_55.pdf.

[19] This publication represents a first atlas of transboundary aquifers on the American continent.

OSS (2004), *Gestion concertée d'une ressource partagée – Cas du système aquifère du Sahara septentrional, Gestion de la rareté de l'eau dans la région du Moyen Orient et Afrique du Nord*, OSS presentation at the FIDA, Rome (February 2004).

OSS (2007), *Système aquifère des Lullemeden (Mali-Niger, Nigeria), Gestion concertée des ressources en eau d'un aquifère transfrontalier sahélien*, Collection Synthèse.

OSS (2008), *Système aquifère du Sahara septentrional, Gestion concertée d'un aquifère transfrontalier*, Collection Synthèse.

Pennequin, D. and H. Machard de Gramont (2006), *Application of the WFD concept at the frontiers of Europe for transboundary resources management: illusion or reality?*, International Symposium on Aquifer Systems Management - 30 May-1 June 2006, Dijon.

Scaldit (2004), Project INTERREG, *Analyse transnationale de l'état des lieux du District hydrographique international de l'Escaut*, http://www.isc-cie.com/members/docs/documents/19400.pdf.

Scheumann, W. and E. Herrfahrdt-Pähle (eds) (2008), *Conceptualizing cooperation on Africa's transboundary groundwater resources*, German Development Institute, Bonn, http://www.die-gdi.de/CMS-Homepage/openwebcms3.nsf/(ynDK_contentByKey)/ANES-7FJFVT/$FILE/Studie%2032.pdf.

Abu El-Naeem, M.F., Z. Abu Heen and K. Tubail (2009), 13th International Conference on Water Technologies, Hurghada, Egypt, Technologies de l'Eau.

UNESCO/OSS, ISARM-Africa (2006), *Ressources en eau et gestion des aquifères transfrontaliers de l'Afrique du Nord et du Sahel*, IHP Series on Groundwater No. 11.[20]

Zaicheng, H., W. Hao and C. Rui (2006), *Transboundary Aquifers in Asia with special emphasis to China*, UNESCO, Beijing, http://www.isarm.net/dynamics/modules/SFIL0100/view.php?fil_Id=221.

[20] This CD contains a monographic study of several transboundary aquifers in North Africa and the Sahel, such as the NWSAS, the Nubian Sandstone system, the Lullemeden aquifer system, the aquifer system of the Taoudéni-Tanezrouft Basin, and the Senegal-Mauritania aquifer system.

Regulatory texts

- Convention on the Law of the Non-Navigational Uses of International Watercourses, adopted by the General Assembly of the United Nations (1997).
- Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992) of the United Nations Economic Commission for Europe (UNECE).
- Framework Directive 2000/60/EC of the European Parliament and Council of 23 October 2000 for a Community policy in the field of water.
- Protocol on Shared Watercourse Systems of the Southern African Development Community, SADC (2000).
- Resolution on the Law of Transboundary Aquifers adopted by the General Assembly of the United Nations (11 December 2008, A/Res/63/124).

Internet sites

- Agence Française de Développement: www.afd.fr
- Académie de l'eau: www.academie-eau.org
- BRGM, Bureau de recherches géologiques and minières: www.brgm.fr
- International Office for Water: www.oieau.org
- ISARM Project: www.isarm.net
- Réseau international des centres de formation aux métiers de l'eau: www.ricfme.org
- International Network of Basin Organizations: www.riob.org
- International Network of Water Training Centers: www.ricfme.org

List of authors

Hubert MACHARD DE GRAMONT is a hydrogeologist. After attending the University of Paris VI, he started work on water resources studies abroad, especially in the Middle East and several African countries. Initially working as an independent consultant, he joined Arlab, a research department of the Lyonnaise des eaux Group in 1977. From 1989 onward, he worked for French Cooperation with several water directorates in African countries. Since 1998, he has been employed as project manager by BRGM.
Contact: h.machard@brgm.fr

Coralie NOEL was educated at the National Agronomic Institute of Paris-Grignon and the Graduate Institute for Rural, Water and Forest Engineering (now part of AgroParisTech), and holds a higher degree in Environmental and Town-Planning Law from the Sorbonne. For the past 10 years she has studied subjects concerning water, the environment, health, and risk management. She has worked in several ministries as well as regional administrative offices. After several years as Deputy Director of the International Office for Water, she has joined the Ministry of Overseas France as Head of the Ecology, Housing, and Sustainable Development Service.
Contact: coralie.noel@hotmail.fr

Jean-Louis OLIVIER holds degrees from the French École Polytechnique and the École Nationale des Ponts and Chaussées (now ParisTech). He has held several positions at a senior level in territorial, regional and urban development, and in resource management and water use, both in the public sector in France and abroad – including at the World Bank – and in the private sector. At present, he is Secretary General of the French Académie de l'eau and a member of numerous associations in the field of water.
Contact: academie@academie-eau.org

Didier PENNEQUIN holds degrees from the University of Wisconsin/Madison (USA) and the French École supérieure d'électricité. After having started his career as a research scientist in the USA, he worked for 17 years in the private sector in France, in particular with the Johnson Screens, SYBEL and Suez-Lyonnaise des eaux groups. Since 2001 he has been Head of the BRGM Water Division. A member of several professional associations, he is Vice-President Europe of the International Association of Hydrogeologists (IAH).
Contact: d.pennequin@brgm.fr.

Martina Rama, an Italian national, studied at the University of Bologna, and holds a diploma from the Institute of Political Sciences in Paris ('SciencesPo') covering the subjects of environment, sustainable development and risks. She started her career at UNESCO before being appointed as executive in the permanent staff of the Académie de l'eau.
Contact: martinarama@hotmail.com

Raya Marina Stephan is a lawyer with extensive professional experience in water law, specifically concerning transboundary aquifers. As a consultant with the International Hydrological Programme of UNESCO, she coordinates the legal component of the ISARM (International Shared Aquifer Management Resources) project. She has in particular participated in the Working Group that assisted the International Law Commission during the drawing up of articles on the law governing transboundary aquifers. She is active in various projects concerning groundwater, transboundary or other, for the coordination and management of legal activities.
Contact: R.stephan@unesco.org

Toward a Joint Management of Transboundary Aquifer Systems

Aquifer systems, which can contain a major part of the accessible water resources of a country, are often imperfectly known.

However, and much more commonly than transboundary rivers, many aquifers are shared between several countries that use this resource in an independent and generally intensive manner, for supplying drinking water and for industrial purposes, and especially for irrigated agriculture. The use of such resources is often poorly controlled and, in many cases, leads to over-pumping and pollution phenomena; these in turn can cause local tensions, which can even escalate into crises and conflicts between countries.

For this reason, it is necessary today to improve our knowledge and understanding of such aquifer systems, and to promote a collaborative, equitable and sustainable management of these resources.

This is the objective of this Methodological Guidebook, which presents an overview of the various types of instruments that can be used for obtaining the required knowledge, and proposes a progressive, many-sided and pragmatic approach to the management side of the problem. This should help in reaching the necessary objectives from a viewpoint of serving the common interest of all involved parties.

A Collective Work

CONTACT
Karine FROUIN
Water and Sanitation Division, AFD
frouink@afd.fr
eau_assainissement@afd.fr

A SAVOIR