# A **blue goldmine** in need of protection


© Jean O'Sullivan/UNESCO

*Street scene in Cotonou, Benin's largest city. In 2002, hydrogeologists from Benin learned that the aquifer providing water for Cotonou extended across the border into Togo. Both countries have expressed interest in developing a framework to manage this aquifer jointly. The aquifer will become increasingly important as rainfall in the region declines with climate change*

**Beneath our feet run aquifers which can span thousands of kilometres. Like rivers, aquifers cross national borders and can be shared by two or more countries. Unlike rivers, little is known about transboundary aquifers. Nor are there many specific international rules and conventions governing the shared management of these aquifers.**

**In 2002, UNESCO set out to map the world's aquifers, within a project for Internationally Shared Aquifer Resources Management (ISARM). Together with the International Association of Hydrologists (IAH), FAO, regional partners and national experts, UNESCO's International Hydrological Programme (IHP) has spent the past five years overseeing an inventory of transboundary aquifers around the world.**

**The African survey was the first to get under way. It uncovered 38 transboundary aquifers, five of which had never been identified before. Progress towards completing the survey in West Africa was assessed at a UNESCO workshop in Cotonou (Benin) on 30 May – 1 June this year. The meeting recommended preparing an atlas of the sub-region's internationally shared aquifers by 2009.**

Organized by UNESCO's Accra office and the IAH, in cooperation with the International Groundwater Resources Assessment Centre in the Netherlands, the June workshop analysed the information amassed thus far and prepared the final collection of data for the sub-regional inventory. Once completed, this inventory will form part of a GIS database of transboundary aquifers in the sub-region.

Hydrogeologists from Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Mauritania, Niger, Nigeria, Togo and Senegal then gave a status report on the data and information available on shared aquifers in their home countries. The case of Côte d'Ivoire is typical, in that it illustrates the kind of problems countries in the sub-region will need to tackle if they are to protect their precious resource.

## The case of Côte d'Ivoire

The Gulf of Guinea has two shared aquifer systems composed of two large sedimentary basins, the Tano and Keta Basins. The Tano Basin extends from the coastal town of Fresco in Côte d'Ivoire to the town of Axim in Ghana. The aquifer covers 2.5% of Côte d'Ivoire's territory.

There are three types of aquifer in the Tano Basin. The Quaternary aquifers (younger than 1.8 million years [Ma]) are very vulnerable to pollution because the surface of the aquifer is close to ground level. The second type is the Mio-Pliocene (5–8 Ma) or Continental Terminal aquifer. This is the one which provides Abidjan and the surrounding region with drinking water. The third type of aquifer dates from the Late Cretaceous (94 Ma). This holds the reservoir of mineral water in Côte d'Ivoire that is exploited by the Société africaine d'exploitation d'eau minérale. It is the most enigmatic of the aquifers, as neither its geometry, volume, level, nor lateral extent are known.

Most of Côte d'Ivoire's major cities lie on the coast. These include Abidjan, Bonoua and Aboisso. The region also sports numerous industrial plantations producing pineapple, rubber and palm oil, as well as the Afema goldmine in Aboisso, all of which consume large quantities of water.

Studies of groundwater in the Abidjan area have revealed a concentration of nitrates ($NO_3^-$), ammonium ($NH_4^+$) and aluminium ($Al^{3+}$) in excess of WHO standards for drinking water on the plateau, in Adjamé and in the western zone. This chemical pollution is caused by the use of pesticides and fertilizers in the plantations. Fishermen are also polluting the lagoons in the region with pesticides. Other lagoons are contaminated by gold mining, including the Afema Lagoon and Aby Lagoon in neighbouring Ghana. The pollution of surface waters with chemicals and domestic waste threatens both human health and aquatic biodiversity.

With annual growth of about 2% per year, Côte d'Ivoire's population of 18 million is expected to climb to 24 million by 2025. Just under half the population now lives in urban areas.

Abidjan itself has a rapidly growing population estimated at 3.2 million in 1999. The city's aquifer is coming under stress from a variety of factors tied to its rapid urbanization: the construction of buildings and

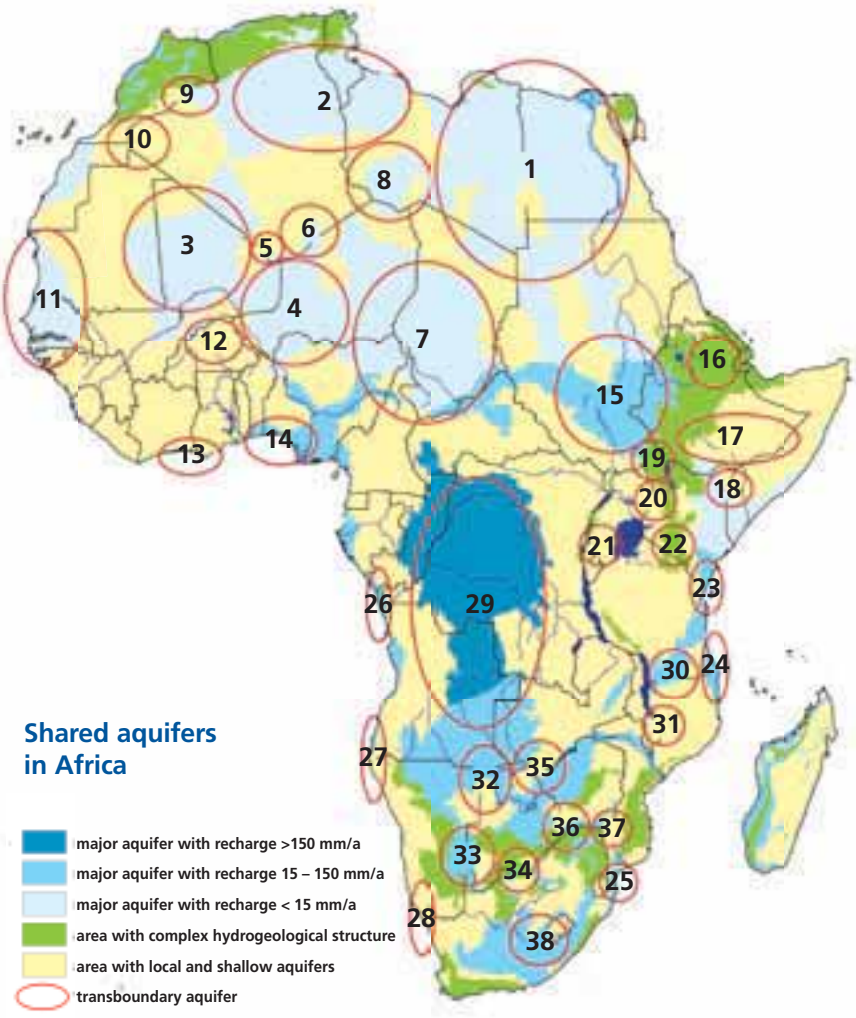

*Downtown Accra, the capital of Ghana, in 2004. The ISARM survey uncovered a major aquifer shared by Ghana and Côte d'Ivoire. Hydrologists from Côte d'Ivoire had already begun studying the aquifer, which provides 80% of the local population's water needs, but experts from Ghana learned during the survey that the aquifer crossed into their territory. There are plans to manage the shared resource jointly*

infrastructure on land previously covered with vegetation is rendering the ground impermeable to rainwater; this, combined with the anarchic occupation of land by slum dwellings, is making it difficult to access the water wells to monitor groundwater in the aquifer and is contributing to the drop in recharge of the aquifer.

The absence of systems for water treatment or the disposal of household waste means that waste water is emptied directly into rivers and other surface waters. The aquifer is also being polluted by agriculture on the outskirts of the city.

The strong demand for water in Abidjan means that the city's groundwater supply will soon be over-extended. It is envisaged to begin using the groundwater which serves the nearby town of Bonoua but, here again, this could rapidly lead to over-use. The amount of water drawn from the Bonoua source has already more than doubled, from 767 767 $m^3$ in 1990 to 1 836 699 $m^3$ in 2000.

Another serious problem concerns saltwater intrusion, which is probably responsible for the strong presence of chlorine in the coastal aquifer.




| No. | Name of aquifer system | Countries underlain by aquifer system |
|---|---|---|
| 1 | Nubian Sandstone Aquifer System | Chad, Egypt, Libya, Sudan |
| 2 | Northwest Sahara Aquifer System | Algeria, Libya, Tunisia |
| 3 | Taoudéni Basin | Algeria, Mali, Mauritania |
| 4 | Iullemeden Aquifer System | Mali, Niger, Nigeria |
| 5 | l'Air Cristalline Aquifer | Algeria, Mali, Niger |
| 6 | Tin-Séririne Basin | Algeria, Niger |
| 7 | Chad Basin | Central African Republic, Chad, Cameroon, Niger, Nigeria |
| 8 | Mourzouk-Djado Basin | Chad, Libya, Niger |
| 9 | Errachidia Basin | Algeria, Morocco |
| 10 | Tindouf Aquifer | Algeria, Morocco |
| 11 | Senegalo-Mauritanian Basin | Gambia, Guinea-Bissau, Mauritania, Senegal |
| 12 | Liptako-Gourma Aquifer | Burkina Faso, Niger |
| 13 | Coastal Sedimentary Aquifer | Ghana, Côte d'Ivoire |
| 14 | Coastal Sedimentary Aquifer | Benin, Nigeria, Togo |
| 15 | Upper Nile Basin | Ethiopia, Sudan |
| 16 | Awash Valley Aquifer | Djibouti, Ethiopia |
| 17 | Ogaden-Juba Aquifer | Ethiopia, Kenya, Somalia |
| 18 | Merti Aquifer | Kenya, Somalia |
| 19 | Rift Aquifers | Kenya, Tanzania, Uganda |

| No. | Name of aquifer system | Countries underlain by aquifer system |
|---|---|---|
| 20 | Mount Elgon Aquifer | Kenya, Uganda |
| 21 | Kagera Aquifer | Tanzania, Uganda |
| 22 | Kilimanjaro Aquifer | Kenya, Tanzania |
| 23 | Coastal Sedimentary Basin | Kenya, Tanzania |
| 24 | Coastal Sedimentary Basin | Mozambique, Tanzania |
| 25 | Limpopo Basin | Mozambique, Swaziland |
| 26 | Coastal Sedimentary Basin | DR of Congo, Angola |
| 27 | Coastal Sedimentary Basin | Angola, Namibia |
| 28 | Coastal Sedimentary Basin | Namibia, South Africa |
| 29 | Congo Intra-cratonic Basin | DR of Congo, Angola |
| 30 | Karoo Sandstone Aquifer | Mozambique, Tanzania |
| 31 | Shire Valley Alluvial Aquifer | Malawi, Mozambique |
| 32 | Northern Kalahari/Karoo Basin | Angola, Botswana, Namibia, Zambia |
| 33 | SE Kalahari/Karoo Basin | Botswana, Namibia, South Africa |
| 34 | Ramotswa Dolomite Basin | Botswana, South Africa |
| 35 | Nata Karoo Sub-basin | Botswana, Namibia, Zimbabwe |
| 36 | Tuli Karoo Sub-basin | Botswana, South Africa, Zimbabwe |
| 37 | Medium Zambezi Aquifer | Botswana, Mozambique, South Africa, Zimbabwe |
| 38 | Karoo Sedimentary Aquifer | Lesotho, South Africa |

## Towards a map of the world's transboundary aquifers

In the five years since ISARM was launched, regional surveys have been completed for the Americas, Western Europe and the Euro-Mediterranean region. Each regional survey marks an important step towards a global inventory and database which will offer assessments of the water quantity and quality of every transboundary aquifer in the world. The inventory will also provide detailed case studies of innovative techniques for managing these resources from a technical, socio-economic and legal perspective.

The African inventory was the first to get under way, at a workshop in June 2002 which launched a regional network of more than 200 experts from 25 African countries. This workshop was organized in Tripoli by UNESCO and the General Water Authority of the Libyan Arab Jamahiriya. The first sub-regional workshop to monitor progress took place in January this year and involved the countries of the Southern African Development Community.

Later this year, UNESCO and the Organisation of American States will be publishing a preliminary assessment of their three-year joint project on transboundary aquifer systems in the Americas (see *A World of Science*, July 2005).

The Balkans project is run by UNESCO Chairholder Prof. Jacques Ganoulis at the Aristotle University of Thessaloniki in Greece and the International Network of Water–Environment Centres for the Balkans, with UNESCO-IHP support. In 2003, Prof. Ganoulis presented the results of the first phase during a workshop at which experts from the UNESCO-IHP, UN Economic Commission for Europe and national experts from Southeastern Europe began work on an atlas of transboundary aquifers in the region. Progress towards this goal was monitored at a second workshop in April this year.

A preliminary assessment of transboundary aquifers in Asia was presented last October, with a special focus on China. The assessment was made public during a session on Transboundary Aquifers in Asia organized by UNESCO at an IAH Congress in Beijing.

This has forced the population to abandon certain wells. Hydrologists have detected this phenomenon in Jacqueville, the Abidjan plain and farther to the east in the region of Adiaké.

The central problem is the inadequacy of the national legislation framework. Laws covering the environment, the water and mining sectors have been adopted but have not yet entered into force. Côte d'Ivoire has ratified a number of international legal instruments related to water but these tend to cover seawater and surface waters.

### Why cleaning up a polluted aquifer is so hard to do

The groundwater contained in the world's aquifers represents 30% of the world's supply of freshwater, compared to just 0.3% for lakes and rivers. Yet groundwater studies in general have been sorely lacking, despite groundwater's obvious value and the fact that many countries rely upon it for 80% of their needs, like Mauritania. Even in more humid regions, people are becoming increasingly dependent upon groundwater because of severe pollution of rivers or surface water.

Although aquifers offer extremely safe and reliable resources, they are fragile. It is extremely difficult, if not impossible, to clean up an aquifer once it has been polluted by sewage and chemicals that seep down from communities, factories and farms. Moreover, the sources of urban pollution are becoming more diverse; these now include organic pesticides, nitrates, heavy metals and waterborne pathogens.

'It is economically impractical and may sometimes even be technically impossible to clean up urban aquifers once they have become polluted,' explains UNESCO programme specialist Emmanuel Naah, who works from UNESCO's Regional Bureau for Science in Nairobi (Kenya). 'Consequently, in the long term, polluted urban groundwater will either be abandoned, leading to acute water shortages, or require complex and expensive treatment systems to avoid placing public health in jeopardy.'

Africa's urban population has nearly tripled since 1970, with 35 cities now accommodating more than a million inhabitants. This rural exodus has been exacerbated by severe climatic conditions, desertification and poverty.

© Moussa, ENDA Dakar

### An early warning system for polluted city aquifers

In 2002, UNESCO's Nairobi office and UNEP initiated a project to assess the impact of pollution on aquifers in Abidjan and eight other major African cities: Dakar (Senegal), Ouagadougou (Burkina Faso), Bamako (Mali), Cotonou (Benin), Keta (Ghana), Mombasa (Kenya), Addis Ababa (Ethiopia) and Lusaka (Zambia).

The project has developed methodologies for assessing groundwater vulnerability, identifying pollution hotspots and major threats. It has also set up an early warning system made up of a network of African scientists and is building awareness among decision-makers in the public and private sectors of the dangers of such practices as indiscriminate waste disposal.

'The idea was to provide a robust system of monitoring,' recalls Naah, 'to give legislators and water managers early warning so that they could take timely action against pollution.' The project is being developed further, in line with the recommendations of an evaluation workshop in Cape Town (South Africa) in November 2005.

### Filling a legal vacuum

If transboundary aquifers are difficult to map from a scientific perspective, political factors can further complicate the process. Governments are often reluctant to admit that other countries share the aquifers they rely upon for drinking water and irrigation. Despite a growing body of international rules and conventions concerning shared rivers, these do not apply fully to aquifers.

Until recently, international law had paid little attention to groundwater and transboundary aquifer systems. In the only global convention so far on the use of water resources, the UN Convention on the Law of Non-navigational Uses of International Watercourses adopted in May 1997, groundwater is considered only when related to a surface water body, as in most inter-state treaties and agreements on transboundary waters. However, things are changing.

In 2006, the United Nations' International Law Commission adopted at first reading a full set of draft articles on the law of transboundary aquifers[8], prepared with the scientific and technical support of the IHP. As part of this effort, UNESCO and FAO co-published a compilation of binding and non-binding international agreements involving groundwater the same year (*see box for examples*).

The draft articles include the core principles of international water law: the equitable and reasonable utilization and the no-harm rule. They also include the general principle of international law: the obligation to cooperate, translated in a practical manner in the case of transboundary aquifers through the regular exchange of data. The draft articles then codify specific principles for the management of transboundary aquifers such as monitoring, the protection and preservation of transboundary aquifers, and direct cooperation with developing States or through a competent international body like UNESCO. The draft articles have been circulated to the Member States of the United Nations for comment by 1 January 2008.

ISARM is encouraging governments to set up plans and, in some cases, commissions to manage shared resources jointly with their neighbours and to protect the environment. There are also plans to broker legal agreements to protect the aquifers further.

Raya Stephan[9], Abou Amani[10] and Amy Otchet

## The case of North Africa

Government representatives have recognized the need to develop a legal agreement covering the Nubian Sandstone Aquifer System, which spans Libya, Egypt, Chad and Sudan. This can be divided into two major reservoirs: the oldest and most extended reservoir, the Nubian Aquifer System, and the Post-Nubian Aquifer System.

The two reservoirs combined contain approximately 373 000 km$^3$ of fossil water which is thousands, perhaps even millions, of years old. This is the liquid legacy of a bygone era, when the barren Sahara was a lush savannah about 10 000 years ago. The rains that fed the region disappeared some 3000 years ago, leaving phenomenal but finite water supplies known as fossil water, which the Libyan government began mining in 1991 through the world's largest civil engineering project, the Great Man-Made River Project. Once used however, fossil water is gone forever, which is why controversy surrounds the mining of it.

In 2000, Chad, Egypt, Libya and Sudan joined the Programme for the Development of a Regional Strategy for the Utilization of the Nubian Sandstone Aquifer System. The programme was run by the Centre for Environmental Development of the Arab Region and Europe, based in Cairo. A second agreement binding Algeria, Libya and Tunisia established a Consultative Mechanism for the Northwestern Sahara Aquifer System in 2002. Details of these and other agreements may be found in *Groundwater in International Law*, published jointly by UNESCO and FAO last year.

*Request a copy from:*
*a.aureli@unesco.org or r.stephan@unesco.org*

*Known as 'the pearl of the desert', the city of Ghadamès stands in an oasis. It is one of the oldest pre-Saharan cities. Libya's Great Man-Made River project delivers about 500 000 m$^3$ of water a day to Libya's coastal cities, home to most of the population, through a network of concrete pipes 4 m in diameter. This artificial 'river' lies under the desert and covers a total length of 3500 km*

*Facing page:* left*: women drawing water from a well outside the village of Sarkin Yamma Gabi Maradi in Niger;* centre*: a young herdsmen with donkeys and cattle around a water trough near the same well;* right*: a water tower built in the Nigeran village of Tibiri Maradi after the village wells were contaminated by fluoride of primarily geological origin*

8. www.un.org/law/ilc – *under Report, then Shared Natural Resources*
9. *Water Law Specialist and Consultant for the UNESCO-IHP in Paris: r.stephan@unesco.org*
10. *Programme Specialist for Science in UNESCO's Accra Office: a.amani@unesco.org*