

Hydrogeology of Benin

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From the 17th to 19th century the main political entity in the area of central present-day Benin was the Kingdom of Dahomey, a military power in the region and an active participant in the trans-Atlantic slave trade. This contact with the New World has made a lasting contribution to Benin's culture. The Kingdom of Dahomey, and the city-state of Porto-Novo on the coast, were incorporated in the colony of French Dahomey in 1894. Independence from France was won as the country of Dahomey in 1960, after which was a period of civil and military unrest, culminating in the proclamation of a Marxist-Leninist state in 1975, when the country was renamed the People's Republic of Benin. A change to multi-party democratic political system in 1991 saw the country officially renamed the Republic of Benin.

Benin's economy is heavily dependent on agriculture. Most of the population is employed in subsistence agriculture, and commercial agriculture for export is a key contributor to the economy, particularly cotton, which accounts for around 40% of GDP and 80% of official export receipts. Other agricultural products are also important economically, including wood. The service sector is the largest single contributor to GDP, driven by trade and transportation links with neighbouring countries, and tourism. Petrochemical exports were significant in the 1980s, when offshore reserves were extracted, but these operations declined in the 1990s, although Benin is exploring the possibility of revamping petrochemical production post 2020.

Average annual rainfall in Benin is relatively high, but varies considerably by season as well as across the country. The south of Benin, in particular, has good surface water resources in perennial rivers, but groundwater is widely used across the country in rural and urban areas for domestic water supply. The capital Cotonou depends extensively on groundwater. Aquastat figures (see below) show relatively high rates of access to improved water sources, but Benin government figures, which use a different definition of access, show much lower rates: 57% in urban areas and 55% in rural areas in 2009.

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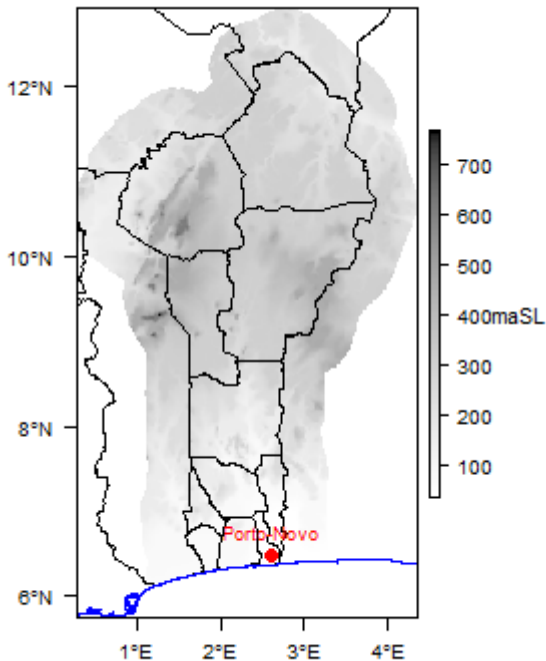
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Geographical setting



Benin. Map developed from USGS GTOPOPO30; GADM global administrative areas; and UN Revision of World Urbanization Prospects. For more information on the datasets used to develop the map see the [geography resource page](#)

General

Benin extends from the Atlantic Ocean (Gulf of Guinea) in the south to the Niger River in the north, a distance of around 700 km. The country is relatively flat, with a granitic plateau in the centre of the country which rises to the Atakora mountain range in the north-west. The highest point is at an elevation of 658 m above sea level.

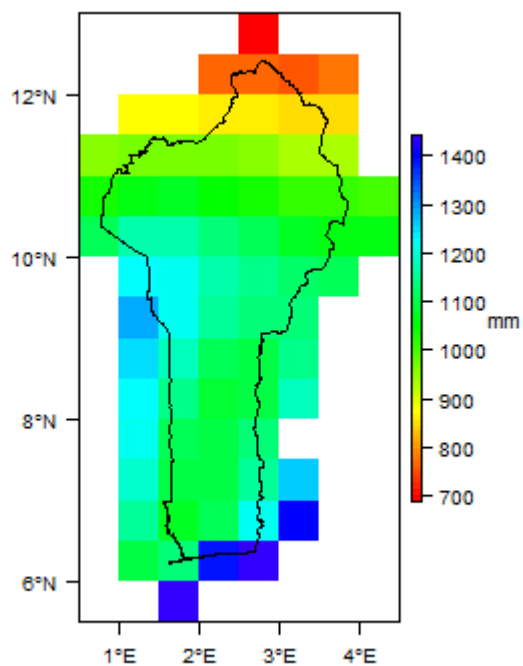
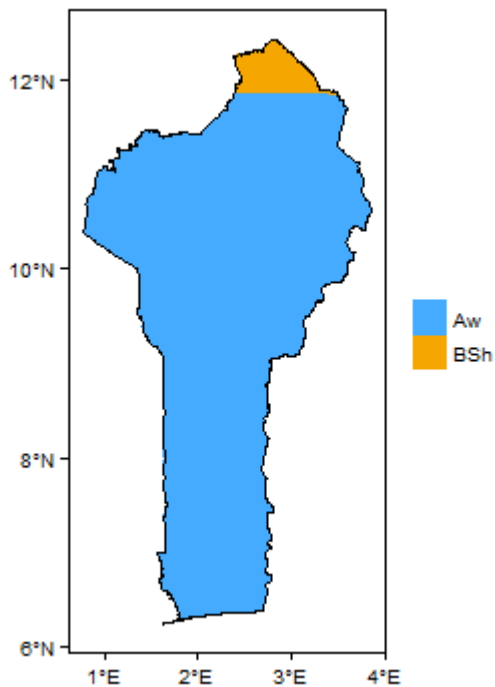
Capital city	Porto Novo
Region	West Africa
Border countries	Nigeria, Niger, Burkina Faso, Togo
Total surface area*	114,760 km ² (11,476,000 ha)
Total population (2015)*	10,880,000
Rural population (2015)*	6,098,000 (56%)
Urban population (2015)*	4,782,000 (44%)
UN Human Development Index (HDI) [highest = 1] (2014)*	0.4796

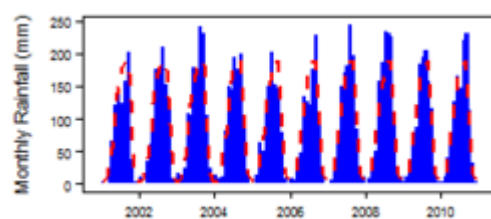
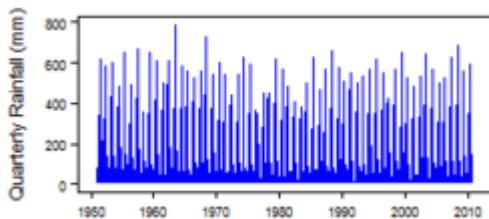
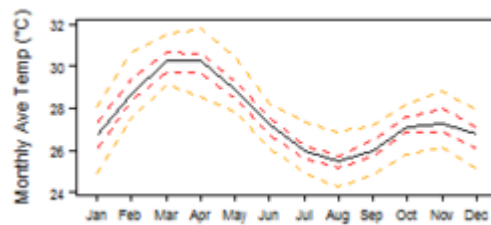
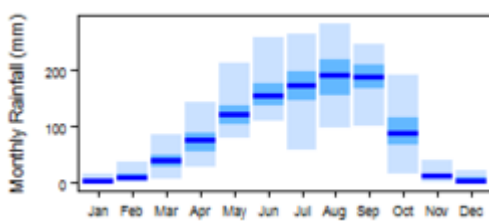
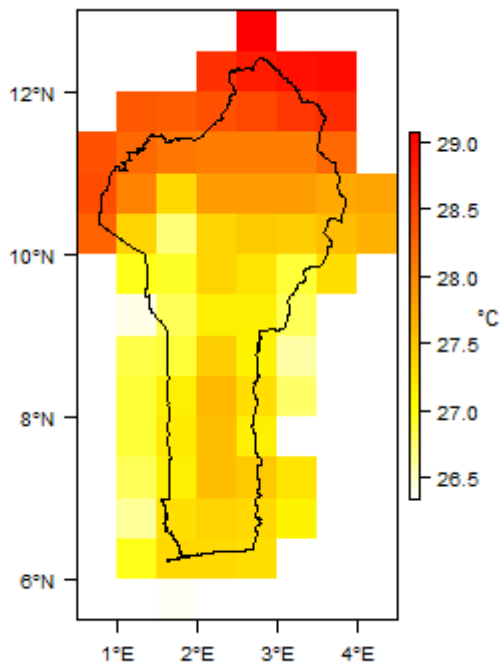
* Source: [FAO Aquastat](#)

Climate

The majority of the country is classified as a tropical savannah climate, apart from the far north, which transitions into a hot and arid climate towards the Sahel region. Average annual rainfall across the majority of the country is between 1000 and 1100 mm. This decreases in the northern zone to almost 700 mm per year. Average temperatures also show a north-south transition, increasing by a relatively small amount towards the north.

There are temporal changes in precipitation and temperature throughout the year. The principal rainy season occurs between April and August, and a second, shorter and less intense rainy season occurs during September and October.





More information on average rainfall and temperature for each individual climate zone can be found on the [Benin climate page](#).

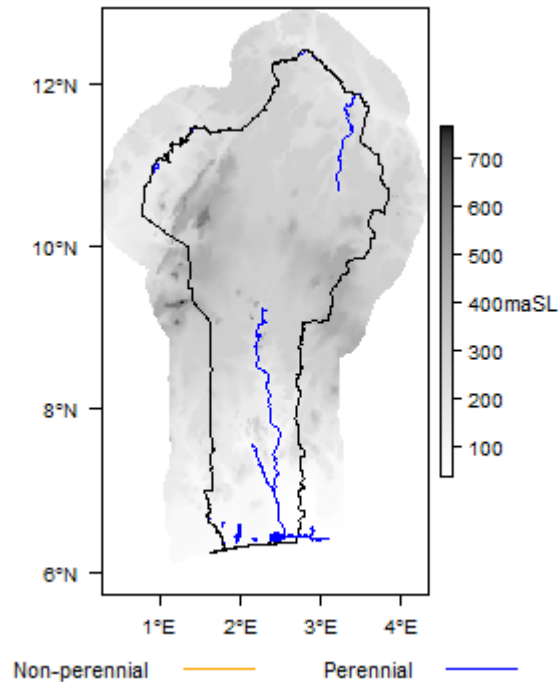
These maps and graphs were developed from the CRU TS 3.21 dataset produced by the Climatic Research Unit at the University of East Anglia, UK. For more information see the [climate resource page](#).

Surface water

The main rivers in the north of Benin are tributaries of the Niger River, and flow northwards, out of the country. The main perennial river in the south of Benin is the Oueme River, which, along with some other smaller rivers, drains into the network of lagoons which has developed along the coast - there is no natural river discharge directly into the Atlantic Ocean.

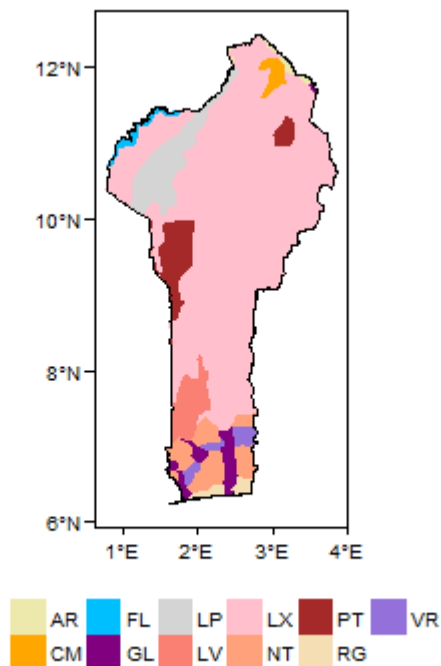
The General Directorate of Water (DG-Eau) maintains 48 river flow gauging stations across Benin. Records cover the period 1950-2014, with daily observations. River flow data are stored in the Department of Water Information within the DG-Eau.

The Early Warning System (SAP) project also collects river flow data.



Major surface water features of Benin. Map developed from World Wildlife Fund HydroSHEDS; Digital Chart of the World drainage; and FAO Inland Water Bodies. For more information on the datasets used to develop the map see the [surface water resource page](#)

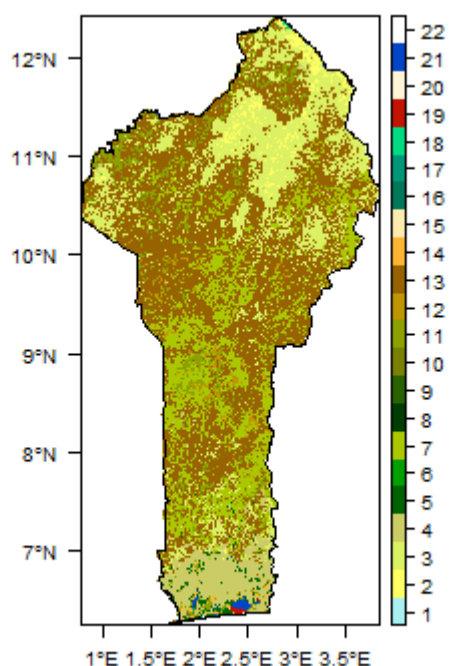
Soil



Lixosols are the dominant soil type in Benin, reflecting stable geological conditions, a savannah climate and grassland vegetation. Leptosols are found in the mountainous region in the north-west of the country while arenosols (large sand deposits) occur in the Sahel region along the north-eastern border. Productive nitisols have developed on the alluvium in the coastal region. On the sandbars and lagoons of the coastal region are gleysols and arenosols.

Soil map of Benin, from the European Commission Joint Research Centre: European Soil Portal. For more information on the map see the [soil resource page](#)

Land cover



Land cover map of Benin, from the European Space Agency GlobCover 2.3, 2009. For more information on the map see the [land cover resource page](#)

Water statistics

	2001	2002	2008	2014	2015
Rural population with access to safe drinking water (%)					72.1
Urban population with access to safe drinking water (%)					85.2
Population affected by water related disease	No data	No data	No data	No data	No data
Total internal renewable water resources (cubic metres/inhabitant/year)				946.7	
Total exploitable water resources (Million cubic metres/year)	No data	No data	No data	No data	No data
Freshwater withdrawal as % of total renewable water resources	0.4926				
Total renewable groundwater (Million cubic metres/year)				1,800	
Exploitable: Regular renewable groundwater (Million cubic metres/year)	No data	No data	No data	No data	No data
Groundwater produced internally (Million cubic metres/year)				1,800	
Fresh groundwater withdrawal (primary and secondary) (Million cubic metres/year)	41				
Groundwater: entering the country (total) (Million cubic metres/year)	No data	No data	No data	No data	No data
Groundwater: leaving the country to other countries (total) (Million cubic metres/year)	No data	No data	No data	No data	No data
Industrial water withdrawal (all water sources) (Million cubic metres/year)	30				

Municipal water withdrawal (all water sources) (Million cubic metres/year)	41				
Agricultural water withdrawal (all water sources) (Million cubic metres/year)	59				
Irrigation water withdrawal (all water sources) ¹ (Million cubic metres/year)	45				
Irrigation water requirement (all water sources) ¹ (Million cubic metres/year)			10.8		
Area of permanent crops (ha)				500,000	
Cultivated land (arable and permanent crops) (ha)				3,200,000	
Total area of country cultivated (%)				27.88	
Area equipped for irrigation by groundwater (ha)		2,193			
Area equipped for irrigation by mixed surface water and groundwater (ha)	No data	No data	No data	No data	No data

These statistics are sourced from [FAO Aquastat](#). More information on the derivation and interpretation of these statistics can be seen on the [FAO Aquastat website](#).

Further water and related statistics can be accessed at the [Aquastat Main Database](#).

¹ More information on [irrigation water use and requirement statistics](#)

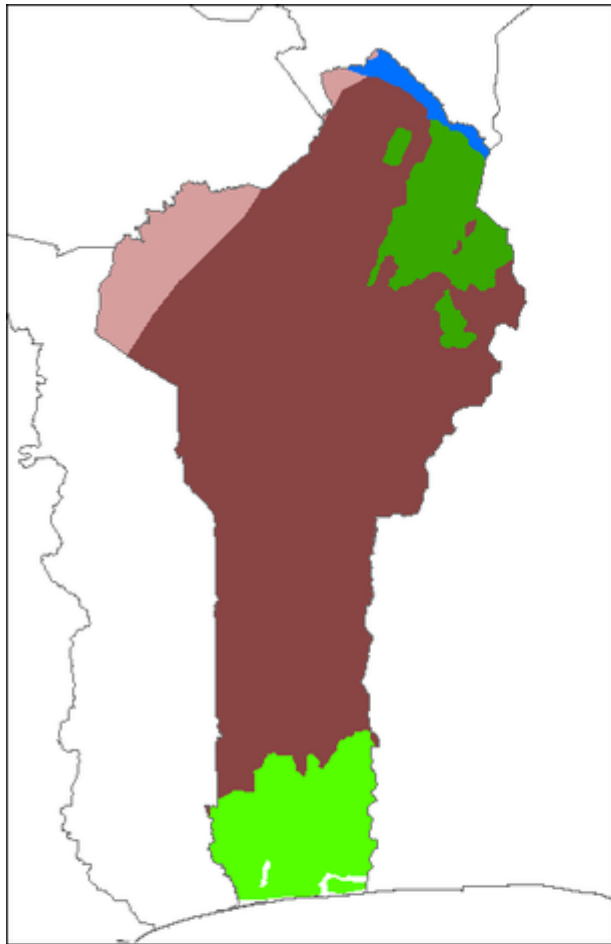
Geology

This section provides a summary of the geology of Benin. More detail can be found in the references listed at the bottom of this page. Many of these references can be accessed through the [Africa Groundwater Literature Archive](#).

The geology map on this page shows a simplified version of the geology of Benin at a national scale, based on 1:5 000 000 scale mapping (see the [Geology resource page](#) for more details).

[Download a GIS shapefile of the Benin geology and hydrogeology map.](#)

A more detailed geological map at 1:200 000 scale was produced by BRGM (1978).



Benin - Geology

- Unconsolidated sedimentary
- Sedimentary - Coastal basin, sometimes with unconsolidated cover
- Sedimentary - lullemeden basin, sometimes with unconsolidated cover
- Precambrian Mobile/Orogenic Belt
- Precambrian Metasedimentary

Geology of Benin at 1:5million scale. Developed from USGS map (Persits et al. 2002). For more information on how the map was developed see the [Geology resource page](#). [Download a GIS shapefile of the Benin geology and hydrogeology map](#).

Geological environments			
Key formations	Period	Lithology	Structure
Unconsolidated sedimentary			
Alluvium	Quaternary	Sand, clay, silt and sometimes gravel deposits, forming outwash fan, channel and floodplain deposits along river channels.	Variable thickness but generally less than 100 m.
Sedimentary - coastal basin			

Benin Sedimentary Coastal Basin	Lower Cretaceous-Quaternary	Marine deposits (sandstone, limestone, clay, marl and conglomerate) belonging to the Keta Basin, deposited along the Atlantic coast of Ghana, Togo, Benin and Nigeria. Fine-grained unconsolidated lacustrine sediments are also deposited along the coast.	Marine deposits have highly variable thickness (10-2000 m). Unconsolidated coastal deposits are on average 50 m thick.
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Sedimentary - Iullumeden Basin

Were, Goungoun, Kandi, Sende & Continental Terminal formations	Lower Palaeozoic-Cretaceous	Conglomerate, sandstone, siltstone and clay. These continental deposits, belonging to the southern part of the Iullemeden Basin, also occur in Nigeria, Niger and Mali.	Variable thickness (20-400 m). The Continental Terminal Formation contains small extensional features.
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Precambrian metasedimentary

Voltaian (or Pendjari) Basin	Late Precambrian-Lower Palaeozoic	Sandstones, shales and siltstones.	Highly variable thickness.
Buem (volcanic-sedimentary) Series	Late Precambrian	Sandstone, quartzite, rhyolite and andesite	Highly variable thickness (estimated 250-2000 m).

Precambrian Mobile/Orogenic Belt

Basement Complex	Precambrian	Crystalline gneiss and granulite with granite and syenite intrusions. Highly metamorphosed and deformed during several orogenic phases which gave rise to various episodes of igneous activity.	Often intensely folded. Folds are generally isoclinal. Not generally steeply dipping.
Atacora, Kande and Kouande series	Precambrian	Quartzite and schist. Highly metamorphosed during the Panafrican Orogeny.	

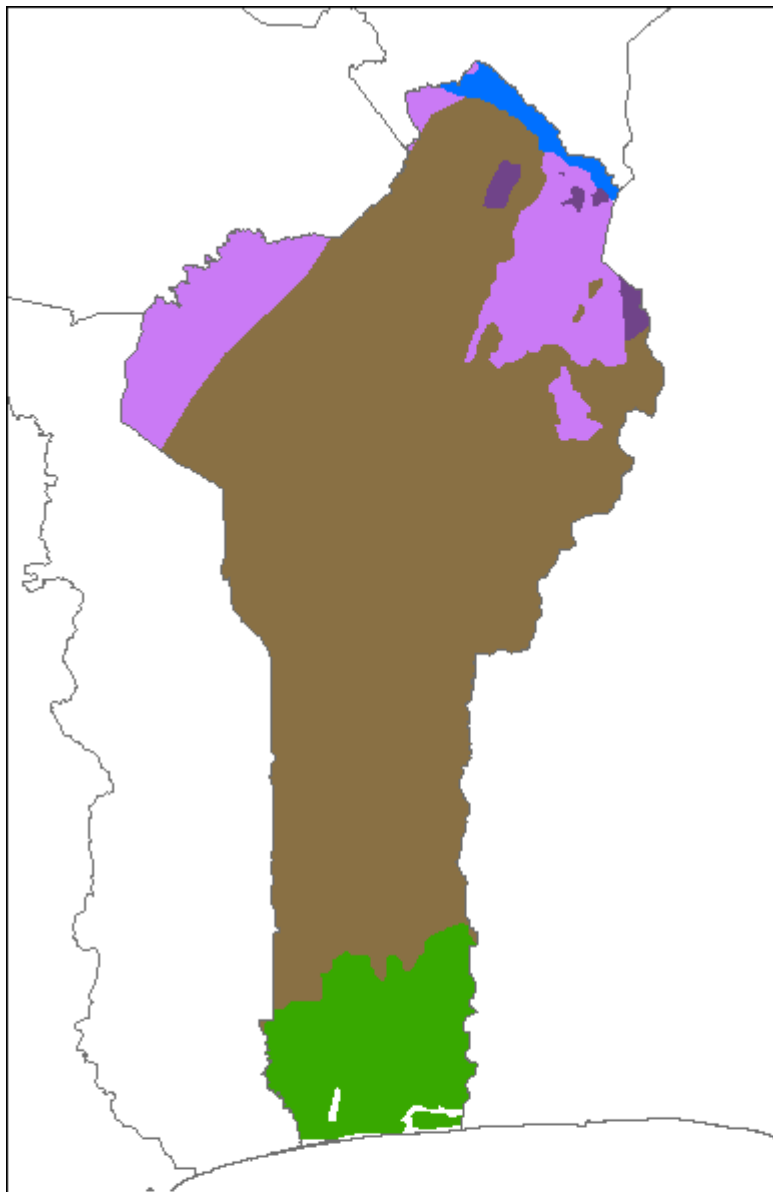
Hydrogeology

This section provides a summary of the hydrogeology of the main aquifers in Benin. More information is available in the references listed at the bottom of this page, many of which can be accessed through the [Africa Groundwater Literature Archive](#).






The hydrogeology map on this page shows a simplified version of the type and productivity of aquifers in Benin at a national scale(see the [Hydrogeology map](#) resource page for more details).

[Download a GIS shapefile of the Benin geology and hydrogeology map.](#)

More detailed hydrogeological maps, at 1:500,000 scale and 1:200,000 scale, are produced by GIZ Germany/DGEau Benin (Achidi et al., 2012).



Benin - Aquifer Type and Productivity

-  Unconsolidated - High
-  Sedimentary Intergranular - High
-  Sedimentary Intergranular/Fracture - High
-  Sedimentary Intergranular/Fracture - Moderate
-  Basement - Low

Hydrogeology of Benin at 1:5million scale. For more information on how the map was developed see the [hydrogeology map](#) resource page. [Download a GIS shapefile of](#)

[the Benin geology and hydrogeology map.](#)

Unconsolidated

Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
Alluvial and barrier beach deposits	<p>The alluvial and barrier beach deposits of Benin are highly variable both laterally and vertically. The alluvial deposits are found along the major river valleys, the most significant of which is the River Niger valley in the north. The barrier beach deposits are found along the coast and are dominated by relatively impermeable clays. However, interbedded, generally poorly sorted, coarser grained sands and gravels can form aquifers of local importance along the coast. Yields are highly variable but are often reported around 5 l/s, and sometimes higher from sand and gravel layers. Transmissivity is generally 10 to 400 m²/d. Storage coefficient is typically 10⁻² to 10⁻¹. The thickness of the unconsolidated aquifers typically varies between 10 and 20 m. The water table is generally shallow, less than 7 m below ground level. Boreholes are typically drilled to depths of 5 to 20 m.</p>	There are no known issues with water quantity and availability.	<p>The unconsolidated deposits are particularly vulnerable to contamination from latrines and agriculture. Saline intrusion is an issue in the littoral area and high salinity is also reported in parts of the alluvial aquifer along the Oueme River valley.</p>	Recharge is not well quantified.

Coastal sedimentary basin aquifers (consolidated sedimentary - intergranular flow)

Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
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Coastal sedimentary basin aquifers	<p>There are four main aquifers in the Coastal Basin, and they are the main source of drinking water for southern Benin. They are, in order of decreasing age, the Upper Cretaceous, Paleocene, Continental Terminal and Quaternary aquifers. They are separated by low permeability clays and marls, and may be confined or unconfined depending on the local geology. Yields are generally 2 to 50 l/s. Transmissivity is generally 80 to 900 m²/d. Storage coefficient is typically 10⁻⁶ to 10⁻⁵. The coastal sedimentary aquifers typically range from 20 to 150 m thick, with boreholes extending to depths of 10 to 100 m. Where the aquifers are unconfined, the water table depth may vary from 5 to 50 m below ground level.</p>	Storage decreases where aquifer thickness is low (typically towards the upstream limits), which can lead to issues with groundwater availability.	Total dissolved solids (TDS) is generally less than 500 mg/l and usually around 200 mg/l. pH is typically neutral to acidic. Saline intrusion is an issue in the littoral zone. Unconfined aquifers are particularly vulnerable to contamination from latrines and agriculture, especially where the water table is very shallow.	Recharge is not well quantified.
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Sedimentary - Kandi (Iullemeden) Basin and Precambrian - Voltaian (or Pendjari) Basin aquifers (consolidated sedimentary - intergranular and fracture flow)

Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
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Kandi Basin (Iullemeden) aquifer and Voltaian (or Pendjari) Basin aquifer	<p>The Kandi Basin can be divided into two principal aquifers: a younger Cretaceous sandstone aquifer, and an underlying Cambro-Ordovician sandstone aquifer. The two aquifers are separated by low permeability fine sandstones and argillites of Silurian age. The Cretaceous aquifer comprises coarse sandstone; groundwater is unconfined and in hydraulic continuity with overlying unconsolidated alluvial deposits along the Niger River.</p> <p>The underlying Cambro-Ordovician aquifer is also composed of coarse sandstone and is largely confined. It becomes unconfined in the south and west of the basin where the sandstone outcrops adjacent to Precambrian basement.</p> <p>The Voltaian Basin aquifer has similar regional characteristics to the aquifers in the Kandi Basin.</p> <p>Yields are rarely higher than 1.5 l/s. Transmissivity varies from <1 to >600 m²/d.</p> <p>The total thickness of these aquifers is unknown. Boreholes typically vary in depth from 30 to 100 m. Where unconfined, the depth of the water table varies between 5 and 45 m below ground level.</p>	There are no known issues with water quantity and availability.	Conductivity, and thus total dissolved solids, is generally lower for the unconfined Cretaceous aquifer with values of 25–60 microsiemens per cm reported for the upper aquifer and 130–425 microsiemens per cm reported for the lower aquifer.	Recharge is not well quantified.
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Basement

Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
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Basement Complex Sandstone (central Benin) and Atacora Series (north-west Benin)	<p>Basement aquifers have very low intergranular permeability in their unweathered state. Aquifer productivity depends on the development of a weathered zone. Coarser-grained granites and gneiss generally weather to a more permeable sandy material which typically forms a low to moderate productivity aquifer. Weathered areas typically form shallow basins separated by largely unweathered rock. The presence and thickness of the weathered zone is highly variable, but is best developed on plateaus (often 10 to 30 m thick). Weathered basins typically thin towards outcropping inselbergs. Yields are generally 0.25 to 0.5 l/s but can reach 2.0 l/s. Hydraulic conductivity is generally 0.5 to 15 m/d. Transmissivity is generally 5 to 35 m²/d. Storage coefficient is typically 10⁻³ to 10⁻². The basement aquifers are typically unconfined. Water table depths are generally 5 to 15 m below ground level, but can be deeper (up to 30 m below ground level). Seasonal water table fluctuations are thought to be between 1 and 5 m. Boreholes are typically drilled to depths of 45 to 60 m.</p>	Boreholes are usually fitted with hand pumps, and therefore abstraction rates are typically low.	<p>Total dissolved solids (TDS) is generally less than 1000 mg/l and usually around 500 mg/l. pH is usually neutral to slightly basic. High salinity is occasionally reported. The weathered basement is vulnerable to nitrate contamination from agricultural sources and latrines.</p>	Recharge is not well quantified.
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Groundwater status

Low yields from basement aquifers, which cover most of Benin, lead to difficulties with fresh water availability in medium to large cities.

Potable water supply is also an issue in parts of the coastal basin, where the saturated thickness of the shallow aquifers is not sufficient for large supplies. Where the shallow deposits are unable to sustain sufficient yields, boreholes are drilled deeper into the weathered basement below.

Groundwater in shallow aquifers is often of poor quality due to contamination. Saline intrusion is a particular problem in the coastal aquifers. In the capital, Cotonou, groundwater is extensively abstracted, but studies have found that groundwater in the urban area contains levels of many contaminants above WHO guidelines, including lead, chromium, cadmium, zinc, coliforms and E.coli (Erah and Akukieze 2002, [https://www.researchgate.net/publication/280839085_Groundwater_pollution_and_the_safe_water_supply_challenge_in_Cotonou_town_Benin_West_Africa Totin et al 2013]).

The Oueme River loses water to the permeable coastal sedimentary aquifer, and river flow depletion is therefore an issue in this river downstream of the contact between the Precambrian basement aquifer and the coastal sedimentary aquifer.

The surface water coastal lagoons around Godomey in central-south Benin often dry up due to intensive pumping from the adjacent Godomey well field.

Groundwater use and management

Groundwater use

The main uses of groundwater in Benin are domestic supply (both urban and rural), agriculture, livestock and fish farming, tourism, industry and transport.

Groundwater sources vary from boreholes with electric pumps, hand pumps and foot pumps, modern and traditional wells, and traditional and improved springs.

Groundwater development and drilling

In 2009 the cost of water borehole drilling in Benin was estimated at an average of 5000 FCFA per metre (about 9 USD per metre) ([Bartel et al 2009](#)).

Groundwater management

The key groundwater institutions in Benin are:

- National Company of Urban Water Supply (SONEB) - responsible for groundwater supply in urban areas.
- General Directorate of Water (DG-Eau) - responsible for groundwater supply in rural areas.

The "Code of Water in Benin" is the key piece of legislation related to groundwater management. Permits are required for drilling and groundwater abstraction. These are issued by the government through the Ministry of Justice and the Ministry of Water.

Groundwater protection is very difficult, particularly in more densely populated areas, because the disposal of waste is largely uncontrolled.

A water point database exists, with information about more than 15 000 boreholes and wells across the country, although no geological logs are available.

Groundwater monitoring

Groundwater monitoring is carried out by the National Company of Urban Water Supply (SONEB), the General Directorate of Water (DG-Eau) and the National Institute of Water.

The Laboratory of Climatology carries out work to look at climate change impacts on groundwater.

Transboundary aquifers

In the coastal region the Quaternary and Continental Terminal aquifers are shared with Nigeria, Benin, Togo and Ghana.

The aquifers of the Iullemeden Basin are shared with Niger, Mali and Nigeria.

For further general information about transboundary aquifers, please see the [Transboundary aquifers resource page](#)

References

The following references provide more information on the geology and hydrogeology of Benin.

These, and others, can be accessed through the [Africa Groundwater Literature Archive](#)

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