
# Africa Groundwater Atlas

Making African groundwater information more available

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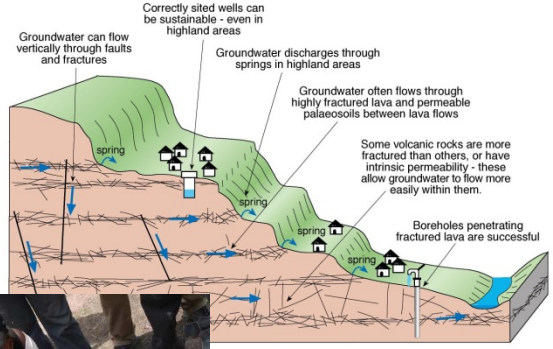
*British Geological Survey*

# Why is the Atlas important?

A lack of robust groundwater information constrains safe, sustainable groundwater development in Africa.

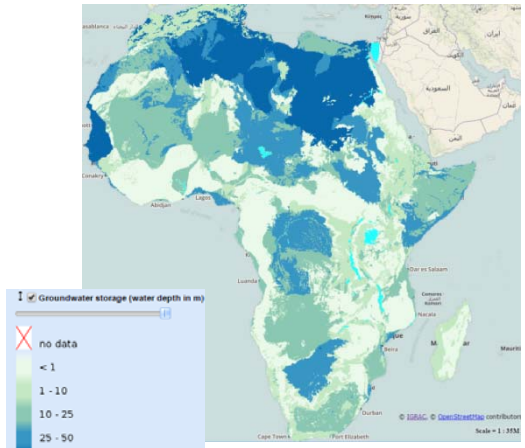


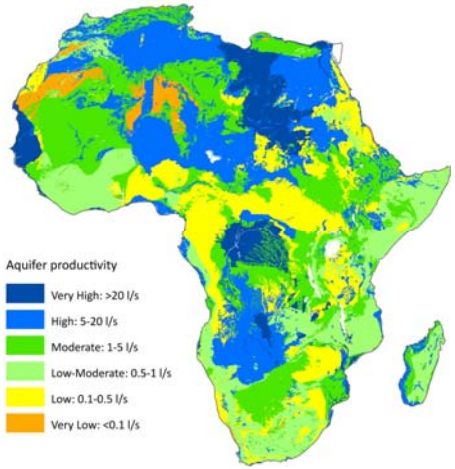

**BUT** – lots of good information is out there – just not easily **available** & **accessible**

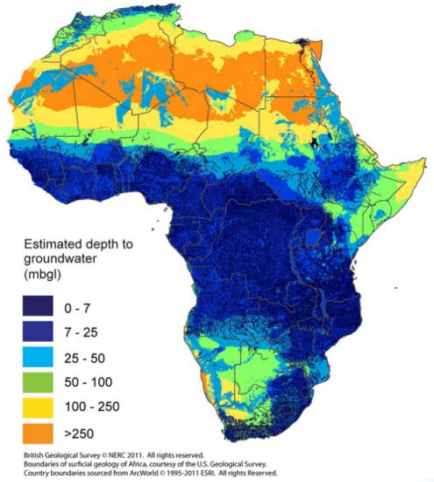
# Quantitative groundwater maps of Africa

New maps of **aquifer productivity**, **groundwater storage** & **depth to groundwater** *(ERL 2012)* provided a continental-scale summary – enthusiastically received.

Downloadable from BGS as digital GIS-enabled files



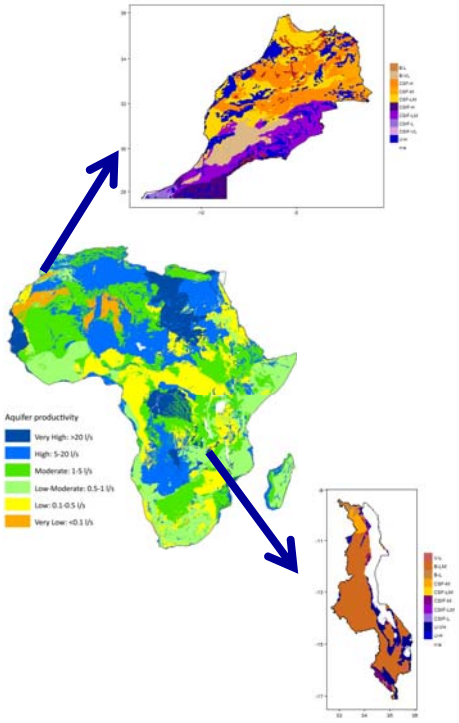




Now also available in IGRAC's *Groundwater Resources in Africa* viewer

Consequent demand to increase resolution of groundwater information to **country scale –** development of the online

## Africa Groundwater Atlas


Including the Africa Groundwater Literature Archive

# What's in the Africa Groundwater Atlas?

## Hydrogeology of Burkina Faso

Africa Groundwater Atlas >> Hydrogeology by country >> Hydrogeology of Burkina Faso

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### Authors [edit]


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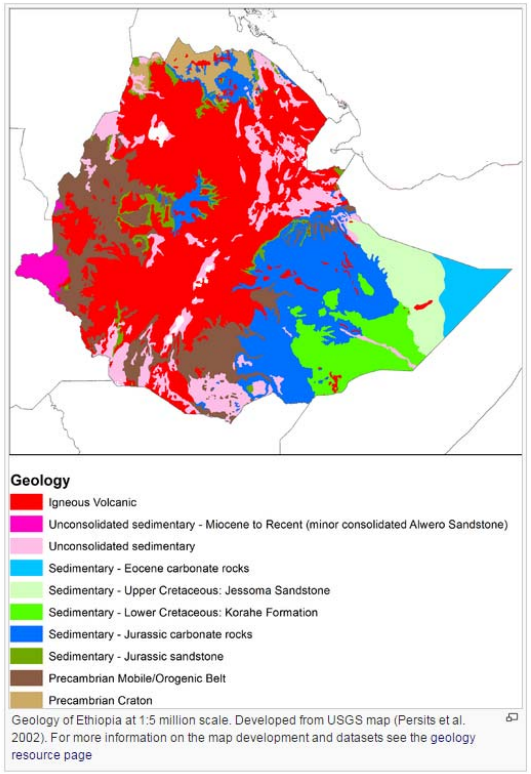
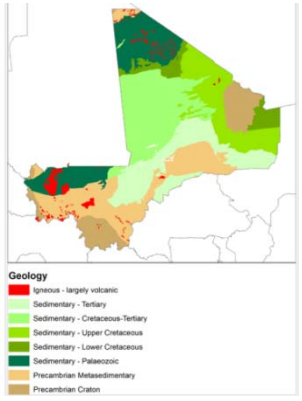
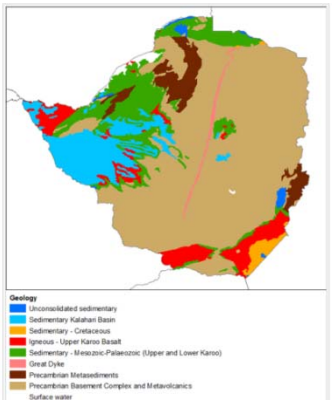
- A consistent overview of groundwater resources, key aquifers & their hydrogeology, groundwater status and management
- 51 countries
- Co-written with more than 50 hydrogeologists from across Africa

# New country-scale geological maps




Geology of Ethiopia at 1:5 million scale. Developed from USGS map (Persits et al. 2002). For more information on the map development and datasets see the geology resource page



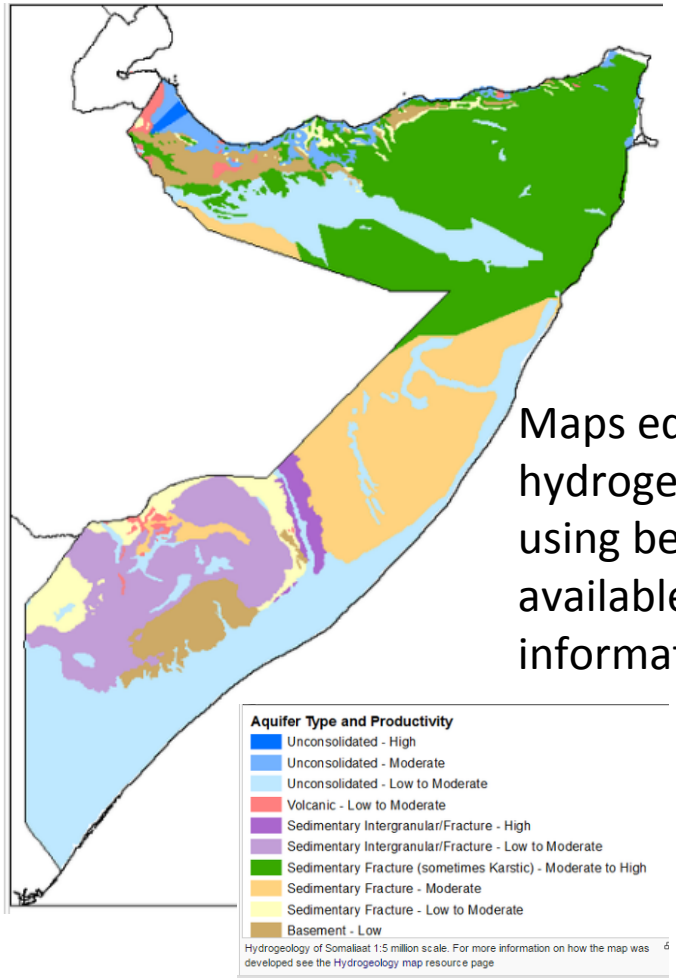

Maps edited using best available information

**Geological Environments**

| Key Formations | Period | Lithology | Structure |
|---|---|---|---|
| | | **Igneous - volcanic** | |
| Lesotho Formation (Drakensberg Group) | Jurassic | Massive basalts which overlie the sedimentary rocks of the Karoo Group. | Reaches thickness of 1600m at Mount-aux-Sources in the north of Lesotho (Schmitz and Rooyani 1987). |
| | | **Igneous - intrusive** | |
| Dolerite intrusions | Jurassic | Numerous dykes cross the country in two dominant directions: NW-SE and NNE-SSW. Most dykes are near vertical, plate-like bodies, but some dip as shallowly as60° (Schmitz and Rooyani 1987). Some dykes cut across all geological formations and others die out within the basalts. Sills (plate-like, near-horizontal intrusions) occur in older Karoo sedimentary strata, especially in the southwest of Lesotho. | |
| | | **Sedimentary – Karoo** | |
| Clarens Formation (Cave Sandstone) (Stormberg Group) | Late Triassic to Early Jurassic | This is the youngest sedimentary formation underlying the basalts of the Jurassic Lesotho Formation. It occurs across the central and eastern parts of Lesotho, but crops out only in central Lesotho and in major valleys within the Lesotho Formation. The sandstones are of aeolian origin. Generally pale white and cream coloured, although darker beds occur. The formation can be subdivided into three zones:<br>1. Zone I: thickly to very thickly bedded, light brown and light red, very fine grained sandstone, silty sandstone and sandy siltstone.<br>2. Zone II: alternating beds of massive and cross-bedded sandstone.<br>3. Zone III: massive to very thickly bedded, very fine grained sandstone to massive silty sandstone, sandy siltstone and siltstone. | Thickness from 15 to 250m. Outcrops in the form of plateaux in the lower foothills and as cliffs overlooking the lowlands. |
| Elliot Formation (Red Beds) (Stormberg Group) | Late Triassic to Early Jurassic | Underlies the Clarens Formation and characterised dominantly by red and purple mudstones and shales and medium to fine grained sandstones.<br>The strong red and purplish coloration differentiates it from the underlying Molteno Formation and from the white and cream coloured overlying Clarens Formation. The transition from the underlying Molteno Formation to the Elliot Formation is gradual, indicating continuous sedimentation. | Thins from a maximum of 250m in the south to 15m in the north. |
| Molteno Formation (Stormberg Group) | Late Triassic to Early Jurassic | White arkosic grits and gritty sandstones, mainly pebbly, with occasional thin shaly sandstones and bluish mudstone (Schmitz and Rooyani 1987). The Molteno Formation underlies the whole of Lesotho and outcrops in the lowlands, where it comprises up to 50m of massive, coarse sandstone. | Thins out northwards (Schmitz 1984): from 35m in the north to 150m in the south. |
| Burgersdorp Formation (Beufort Group) | Mid Permian to Lower Triassic | Green, purple and red shales and mudstones with some buff sandstone; occasional carbonaceous shales with thin coal seams; some ferruginous concretion beds. Only the uppermost part of this formation is exposed in Lesotho, with its maximum exposed thickness in the Mohokare (Caledon) River Valley in the extreme western part of Lesotho (UNDP 1984). | Maximum exposed thickness of 200 to 250m |

Consistent summaries of main geological formations

# New country-scale hydrogeological maps




Maps edited by hydrogeologists using best available information

**Igneous** [edit]

| Named aquifers | General description | Water quantity issues | Water quality issues | Recharge |
|---|---|---|---|---|
| | Igneous aquifers exist in Zaccae, Djudjura, Collo and l'Edough in the east, and in Hoggar. Groundwater flows through fractures and altered horizons, and discharges naturally through springs. In Hoggar, borehole drilling has shown that groundwater is encountered at between 20 and 50 m depth. The aquifers generally have low productivity. | | Average total dissolved solids in Hoggar are 500 mg/l | Important recharge occurs in northern igneous aquifers.* |

**Sedimentary - intergranular and fracture flow** [edit]

| Named aquifers | General description | Water quantity issues | Water quality issues | Recharge |
|---|---|---|---|---|
| Cenozoic sandstones and limestones | Semi-consolidated marine sedimentary rocks with relatively high porosity in which groundwater is stored and flows through both intergranular matrix and fractures. | | | |
| Jurassic and Cretaceous limestones - Northern (Atlas) domain | Consolidated marine sedimentary rocks with relatively high karstic porosity, in which groundwater is stored and flows dominantly through fractures and karst conduits. This is often a highly productive aquifer. Yields of more than 100 l/s are seen from the Zibans karst; and greater than this from the Neritic formation of Constantine (900 l/s at Hamma springs; 400 l/s at Fourchi; 650 l/s at Boumerzoug).<br>In some parts there is extensive groundwater discharge via springs, e.g. at Zaccar (Miliana sources), Djurdura, and its extension to Bejaia. | | Thermal waters. The groundwaters are generally of calcium bicarbonate or calcium sulphate type. | Direct recharge, mostly occurring during periods of exceptionally heavy rain. Some recharge by horizontal flow from other aquifers. |
| Complexe Terminal (Late Cretaceous to Cenozoic) and Continental Intercalaire (Palaeozoic to Late Cretaceous) | These two aquifers together form part of the transboundary Northern Saharan Aquifer System (SASS), also known as the North-west Sahara Aquifer System (NWSAS) (see section on Transboundary aquifers, below). These are largely deeply buried, and can be at least 2000 m thick. Much of the aquifer is siliclastic sandstone; some parts are karstic; and there are some evaporates. This is often a highly productive aquifer. Analysis of pumping tests in the Continental Intercalaire in the Adrar region suggests hydraulic conductivity values of between 3 x $10^{-4}$ and 3 x $10^{-5}$ m/s. | The groundwater resource is generally considered to be 'fossil' - many thousands of years old - and in areas is known to be overexploited, with | Water quality ranges from good, with relatively low levels of mineralisation, to poor. In some areas, groundwater in the Complexe Terminal has salinity levels between 4 and 9 g/l (FAO, 2009). Groundwater from the | Recharge is minimal, due to the generally deep burial of the aquifers and the arid climate. Small amounts of recharge occur from episodic rainfall where the |

Consistent summaries of key aquifers

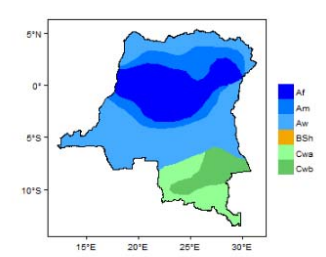
# Country-scale maps & graphical overviews of **climate**, **surface water**, **topography**, **soil** and **land cover**

**Climate** [edit]

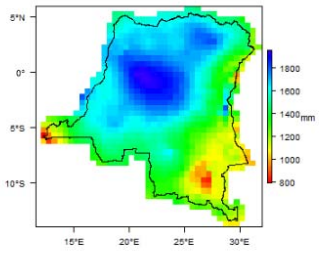
The Democratic Republic of the Congo lies on the equator. Average temperatures across much of the country are around 25 degrees C, except in the eastern mountains where average temperatures are around 20 degrees C. There is much cloud cover over much of the year, with the maximum sunshine in the dry season.

Average annual rainfall for the whole country is over 1,200 mm, rising to more than 2,000 mm in the central basin, and falling to a minimum of around 850 mm at the western coast. There is a single rainy season, from September to June in the south and from February to November in the north; and a single dry season, in June and July in the south and December and January in the north.

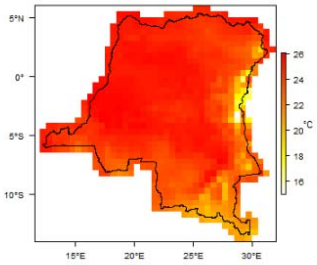
These maps and graphs were developed from the CRU TS 3.21 dataset produced by the Climatic Research Unit at the University of East Anglia, UK. For more information see the climat resource page.



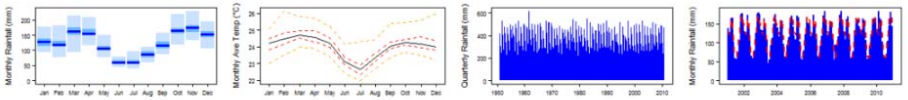

Koppen Geiger Climate Zones



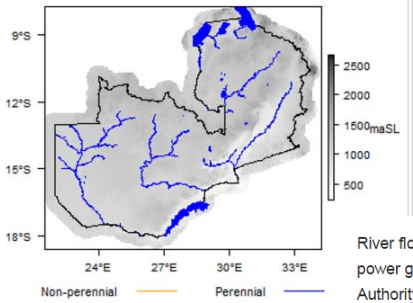

Average Annual Precipitation




Average Temperature



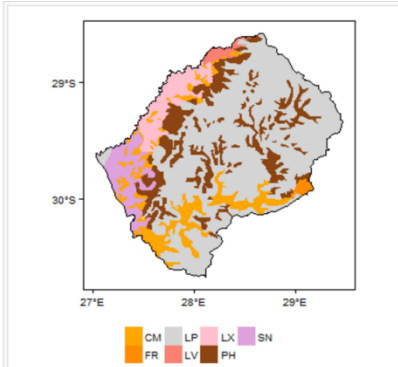
**Surface water** [edit]




Major surface water features of Zambia. Map developed from World Wildlife Fund HydroSHEDS; Digital Chart of the World drainage; and FAO Inland Water Bodies. For more information on the map development and datase resource page.

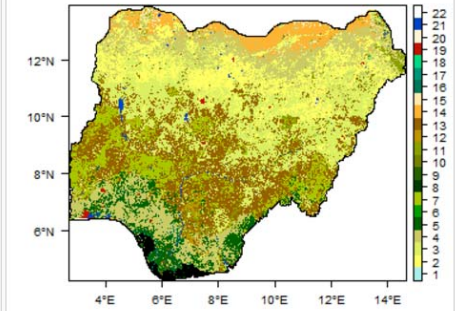
River flow gauging is undertaken by Zesco, Zambia's power generating company, and the Zambezi River Authority (ZRA). Zesco's gauging stations are mainly on the Kafue River, while the ZRA gauges the Zambezi and stretches of the Kafue.

**Soil** [edit]




Soil Map of Lesotho, from the European Commission Joint Research Centre: European Soil Portal. For more information on the map see the soil resource page.

**Land cover** [edit]




Land Cover Map of Nigeria, from the European Space Agency GlobCover 2.3, 2009. For more information on the map see the land cover resource page.

- Derived from 3rd party data
- Consistently presented

# An overview of groundwater status, use & management in each country

## Groundwater Status [edit]

### Groundwater quantity [edit]

The recent FAO/SWALIM study (2012) considered that in the northern provinces of Somaliland and Puntland, where there is no perennial surface water, "total annually recl groundwater (although not necessarily available for abstraction) in the major aquifer systems is theoretically equal to some 4.3 x $10^9$ m³. Although this amount of water, eq of 139 m³/s looks very promising, the large area of these two regions - more than than 289 000 km² - means that groundwater water is still scarce. Estimated specific grour less than 0.5 l/s/km², which classifies northern Somalia as having extremely poor groundwater reserves.

Most drilled boreholes provide yields in the range 1 to 5 l/s, but there are many with lower or higher yields. In some cases, boreholes can't sustain high pumping rates, but aquifer could yield more groundwater if higher capacity pumps or pipe diameters were installed to increase borehole capacity.

The highest known aquifer potential is illustrated by the most productive well known in northern Somalia, in the Auradu karstic limestone aquifer in Ceerigabo, which is 15 had a test yield of 50 l/s for a drawdown of only 2.43 m (Faillace and Faillace 1986). Another known high productivity aquifer is the terrace and alluvial sediments of Geed are used for the water supply of Hargeysa (the capital of Somaliland). Average boreholes yields are 15 l/s with drawdown not larger than 5-10 m.

### Groundwater quality [edit]

Groundwater quality is a major issue in many parts of Somalia. The natural quality of groundwater depends in part on aquifer lithology and the soluble products of weather aspects such as seasonal recharge, so that groundwater quality can vary from season to season. Many boreholes are abandoned because of poor water quality. The qualit in individual aquifers is summarised in the relevant tables above.

A FAO/SWALIM survey in 2012 showed that in the northern Somaliland and Puntland regions, across all aquifers, only 30% of groundwater samples were below the safe S limit of 1500 microS/cm, with 29 % of the samples in the range 1500 to 3000 microS/cm and 41 % of the samples above 3000 microS/cm.

### Recharge [edit]

Recharge occurs only if the rainfall regime is favourable. In areas with scarce and uneven rainfall, infiltration may occur only along stream beds and floodable depressions. Short duration thunderstorms covering small areas usually occur in the northern regions and generate spate flows in *toggas* (wadis or seasonally dry streambeds), which lasti from a couple of hours to a couple of days (Faillace and Faillace 1986).

### Groundwater dependent ecosystems [edit]

There are numerous springs in the north of Somalia in the study area of the FAO/SWALIM programme. A total of 287 springs were registered, which tend to be more common in fractured and/or karstic aquifers. They are of crucial for local ecosystems.

## Groundwater use and management [edit]

### Groundwater use [edit]

Given the lack of perennial streams and the arid climate in much of Somalia, groundwater is the sole water resource in most of the coun Juba and Shabelle. Approximately 95% of the population use groundwater for drinking water. Most groundwater is used for drinking, anc also a significant groundwater use. Irrigation is not widely developed, except along the two major perennial rivers. There are no large gr industrial sector.

The most productive groundwater sources are boreholes drilling into unconsolidated alluvial terrace aquifers and karstic aquifers. Boreho alluvium in *toggas* (wadis), to a few hundred meters in Eocene karstic aquifers or the Nubian (Yessoma) sandstone aquifer. Submersible hand pumps are used to tap water from shallow aquifers.

Due to limited reserves related to very low effective rainfall; a very deep groundwater table in many areas; and/or increased water salinit limited access to it in most of the country. The water supply situation in many parts of Somalia is therefore exceptionally severe. A large access to safe, sufficient groundwater. Several deep drilling projects have been undertaken with the aim of developing groundwater resc hydrogeological knowledge, the success rate of groundwater development has been very low.

Fourteen water utilities serve major towns and settlements in the Somaliland and Puntland regions, with a total around 2,544,000 inhab Somalia. However, not more than 25% of this population is connected to water distribution systems and pipelines (FAO/SWALIM 2012). is in Sheikh, at 4%, but most problematic is Hargeysa where over 750,000 of residents, mostly in suburban areas, have no proper acces

### Groundwater management [edit]

Key groundwater institutions include:

The Ministry of Water Resources in Mogadishu

The Ministry of Water Resources in Somaliland

The Puntland State Agency for Water, Energy and Natural Resources

After the end of the former government of Somalia there was no legal framework for groundwater management in the country. However, Somaliland and Puntland have made significant steps towards re-establishment of the water regulatory framework. In Somaliland a Wate 2013, and put into use, with the Ministry of Water Resources issuing permits for groundwater drilling. The capacity of the water authoriti strengthened for the laws and policies to be fully implemented.

### Groundwater monitoring [edit]

#### Groundwater level monitoring [edit]

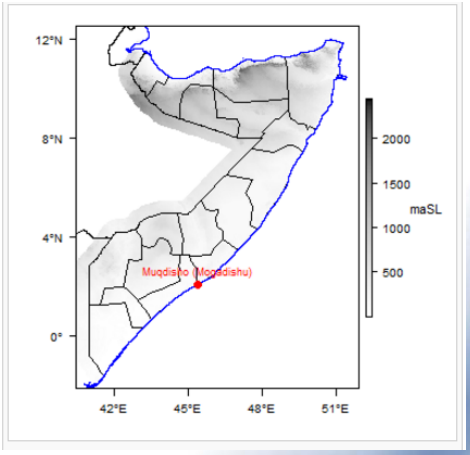
FAO/SWALIM established an initial groundwater monitoring network in the northern provinces Somaliland and Puntland in 2012, installe 8 groundwater level loggers are installed in Hargeisa, Borama, Berbera and Burco in Somaliland; and Garoowe, Boosaaso, Gaalkacyo a

Data from this network will help to prevent future depletion of aquifers due to the high risk of groundwater over-exploitation in major tow water for domestic use and watering livestock.

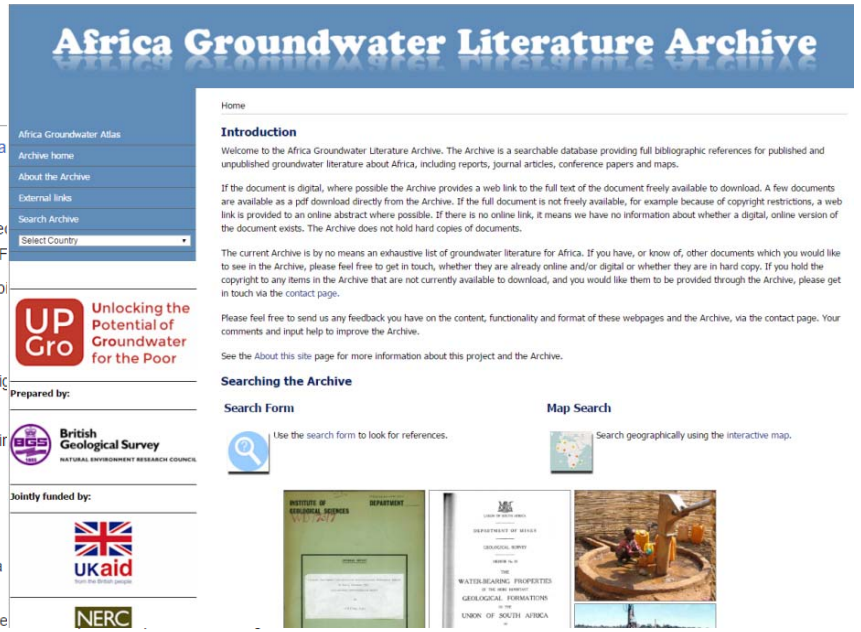
#### Groundwater quality monitoring [edit]

No systematic groundwater quality monitoring is done. Local water utilities sporadically control water quality in their areas.

Somalia



# Key geological & hydrogeological references for more detailed country-scale information




## References [edit]

Many of the references below, and others relating to the hydrogeology of Nigeria, can be accessed through the Africa

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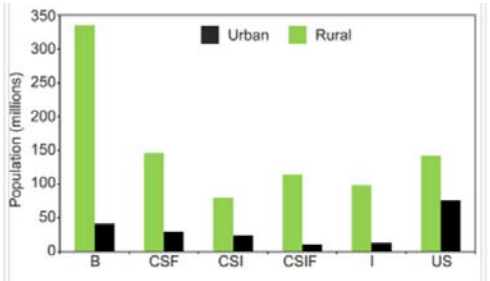
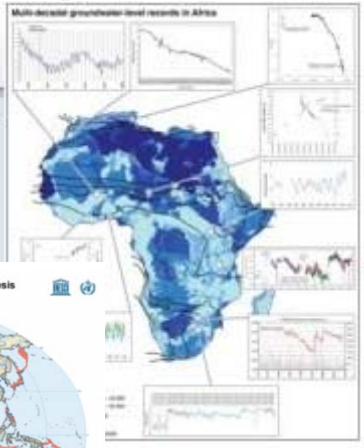
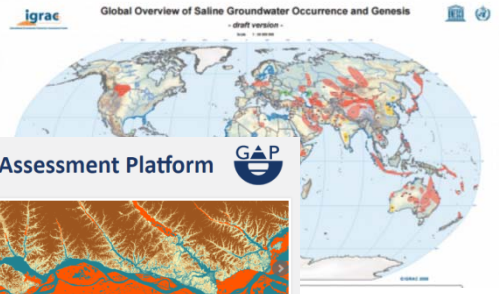
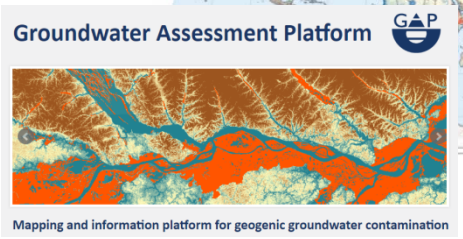
- **Resource Pages**: background information, technical explanations & links to external resources
- Key issues like groundwater use & quality; recharge estimation; sustainable groundwater development & management

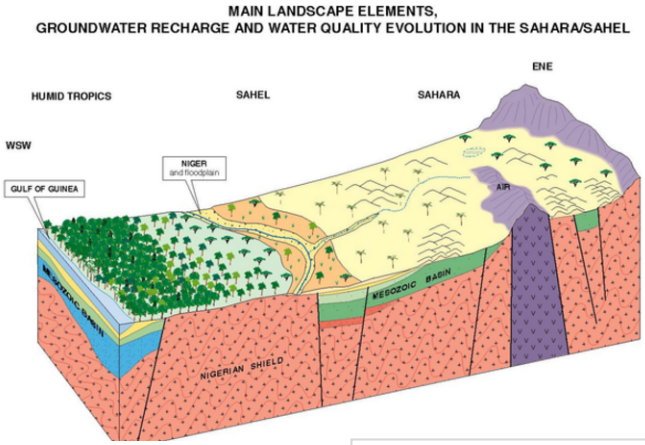



Urban and rural population living on: basement rocks (B); consolidated sedimentary rocks in which fracture flow (CSF), intergranular flow (CSI), and fracture and intergranular flow ( dominate; igneous rocks (I); and unconsolidated sedimentary






**Groundwater Governance** [edit]

The Groundwater Governance project aims to influenc management in averting the impending water crisis.

**RWSN** [edit]

The Rural Water Supply Network (RWSN) produces ma development:

Furey, S G, and Danert, K. 2014. Sustainable Groundv Gallen.

**Africa Groundwater Network** [edit]

The Africa Groundwater Network (AGW-Net) has produ English and French. The manual is designed to suppor range of other activities relating to its key aims of incre sector in Africa. AGW-Net promotes communication

**UPGro** [edit]

The UPGro programme (Unlocking the Potential of Groundwater for the

**IGRAC** [edit]

The UN International Groundwater Resources Assessment Centre (IGRA groundwater resources development and management, and produces a n

Tuinhof, A, Foster, S, van Steenbergen, F, Talbi, A, and Wishart, M. 201 climatic variability. Strategic Overview Series, No. 5, GW-MATE/World

**WaterAid** [edit]

WaterAid produces information on managing water resources, including g of communities to water stress. Other WaterAid publications can be foun

**International Association of Hydrogeologists** [edit]

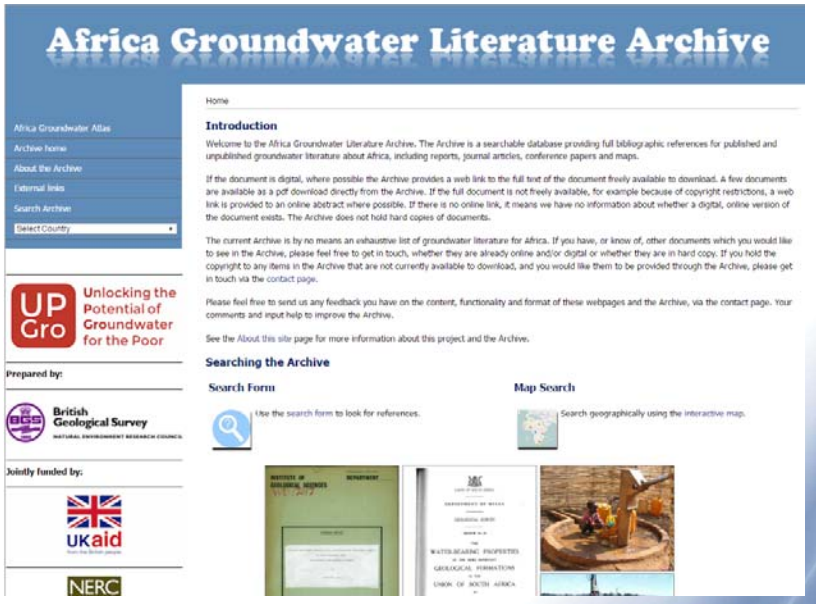
The International Association of Hydrogeologists (IAH) works to raise aw groundwater. IAH publishes academic research through the Hydrogeology

**IUCN** [edit]

The IUCN publish the handbook Spring: managing groundwater sustaina

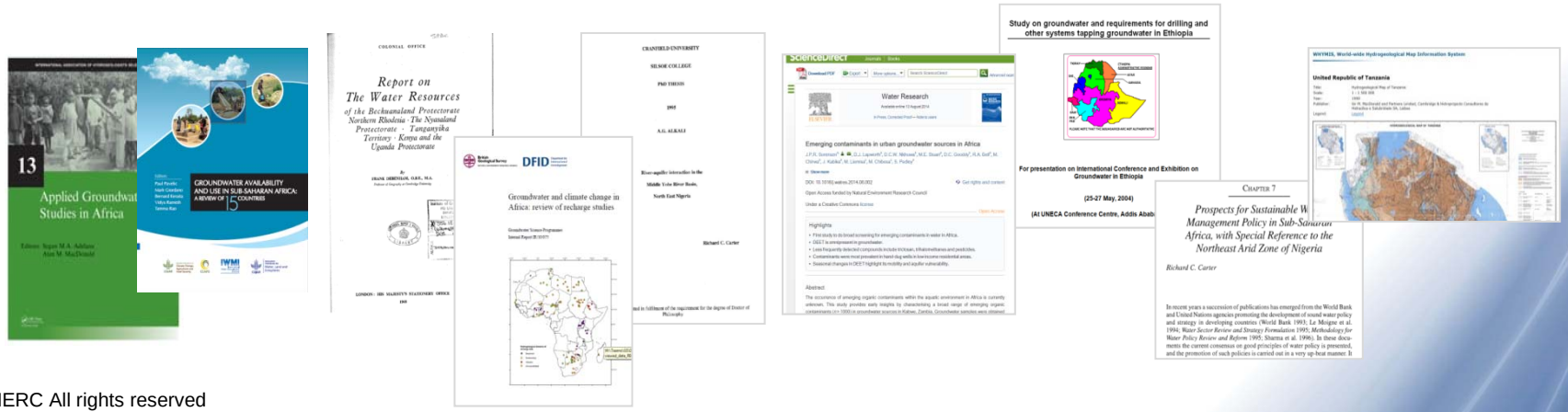
# Africa Groundwater Literature Archive

- The most comprehensive yet index of African groundwater literature
- ~7000 entries (so far)
- Full text download if available; or for copyrighted documents, link to online abstract if available
- Full bibliographic references
- Complements other literature archives: e.g. by WRC; IRD; SADC/BGS Grey Literature Archive



# What's in the Archive?

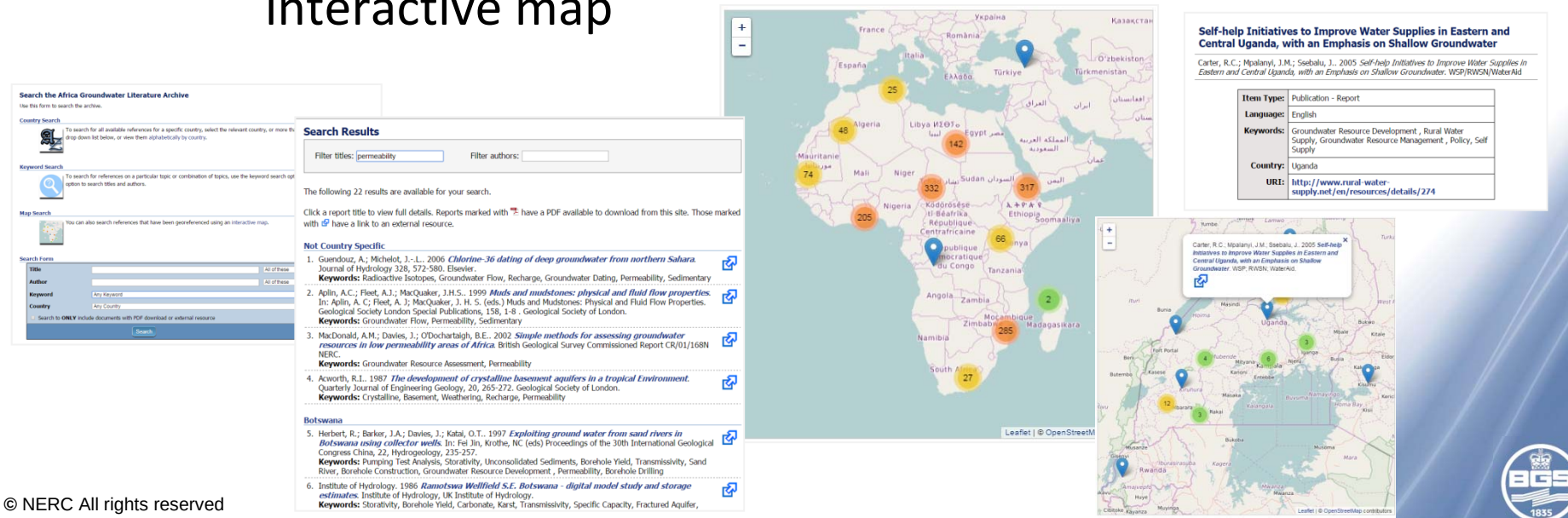
- Unpublished reports (full texts), 1897-2014 (e.g. by geological surveys; governments; development organisations)
- Journal articles, 1927-2014 (URL to online article &/or abstract)
- Conference papers, academic theses, books & book sections (URL to online text if available)
- Hydrogeological maps (pdf or image files; or URL to online file)



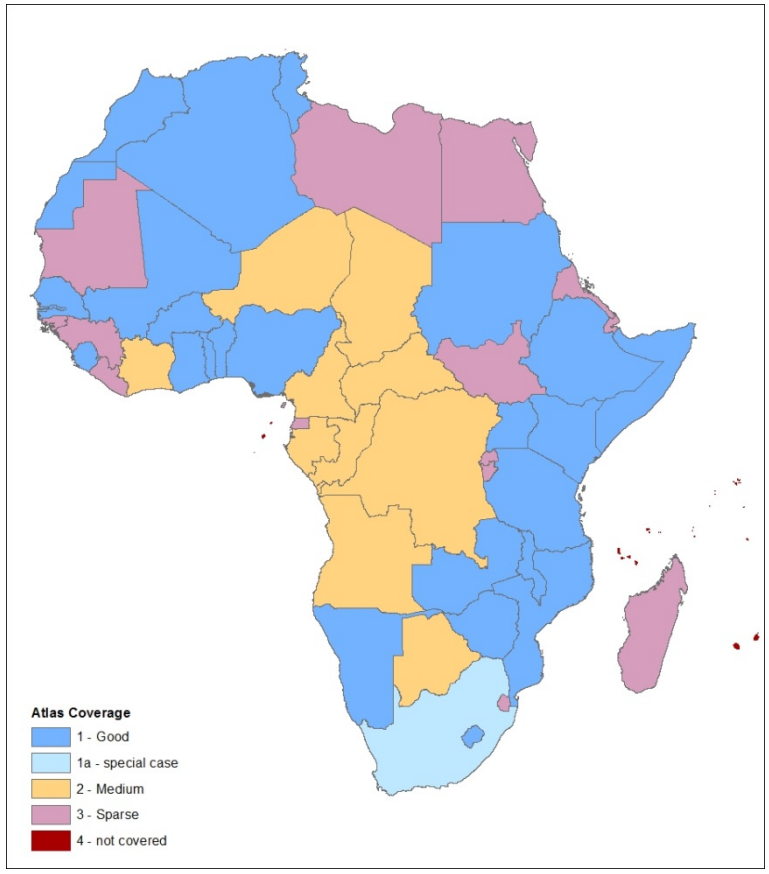
# Using the Archive

Powerful search options:

- **Thematic keyword**: >200 hydrogeological keywords
- **Free text**: Search or Filter Results by Title and Authors
- **Geographically**:
  - Every relevant reference tagged by **country**
  - As many as possible **georeferenced** & searchable on interactive map



# What's next for the Atlas and Archive?




- Improve level of detail for countries currently with only sparse information
- Include GIS-enabled downloads of hydrogeology and geology maps
- Offline Atlas version
- Update Archive with more hard-to-access groundwater reports & other documents

**What do you want to see?**

# Available online now!


**http://www.bgs.ac.uk/africagroundwateratlas**