Hydrogeology of Sierra Leone

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Sierra Leone's geography, including its dense tropical forest, influenced settlement and migration patterns from other areas in Africa. From the 15th century, European traders arrived, dealing primarily in slaves. By the 18th century Islam, spreading from the north and east, became widely adopted. In the late 18th century, Freetown was established as a settlement for freed slaves on land held by the British Sierra Leone company, but there was little interaction with local peoples in the interior. In the early 19th century more freed slaves were sold to the original freed slaves in what was called the 'apprenticeship' system. This ethnic mix created the Krio identity and language, which still dominates in Freetown. In the late 19th century the British divided Sierra Leone into a coastal colony and an inland protectorate, governing them separately until the country gained independence in 1961.

After independence Sierra Leone initially had a democratic government, but in the late 1960s increasing political authoritarianism and military coups were followed what was effectively a one-party state until 1991, with periods of military and civil unrest. A civil war began in 1991, linked to war in Liberia, which became a complex conflict between several sides. In 2002 the end of the civil war was followed by elections and a period of disarmament, justice and reconstruction. In 2014-16 Sierra Leone was severely affected by the Ebola epidemic.

The economy is dependent on mining, especially diamonds but also many other minerals and precious metals, which account for most export earnings. The proceeds of diamond mining were an incentive for the civil war and helped funded it. However, the livelihoods of most of the population rely on subsistence agriculture, with rice a key crop. Even before the civil war, mismanagement had led to economic decline, and the national economy and infrastructure was decimated by the 11 years of war. Post war reconstruction and development was set back during the Ebola outbreak.

Sierra Leone has relatively abundant water resources, but access to improved water supplies remains low. Rainfall is high although seasonal, and there are a number of major perennial rivers. However, river flow is also seasonal in response to rainfall, and surface water resources are under increasing pressure from pollution and increasing water demand. In the dry season, rural populations rely largely on groundwater.

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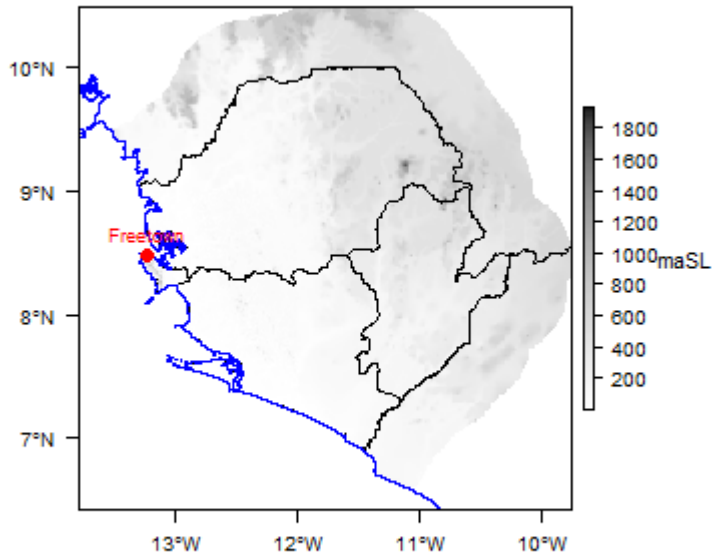
Terms and conditions

Geographical Setting

A coastal strip approximately 50 km in width extends over about 15% of the country. Inland are plains and plateaus. The lower plains, covering 43% of the country, rise from 40 m elevation in the west to 200 m elevation in the east. Swampy depressions in the west are known as bolilands. In the northeast and southeast, the plateaus range from 300 m to 700 m altitude, covering 22% of the

country. Hills and mountains in the east reach a maximum elevation of nearly 2,000 m at Mount Bintumani in the Loma Mountains, while the hills formed by the Freetown Complex reach 800 m height around Sierra Leone's capital (Lapworth et al. 2015).



Sierra Leone. Map developed from USGS GTOPOPO30; GADM global administrative areas; and UN Revision of World Urbanization Prospects. For more information on the map development and datasets see the geography resource page.

General

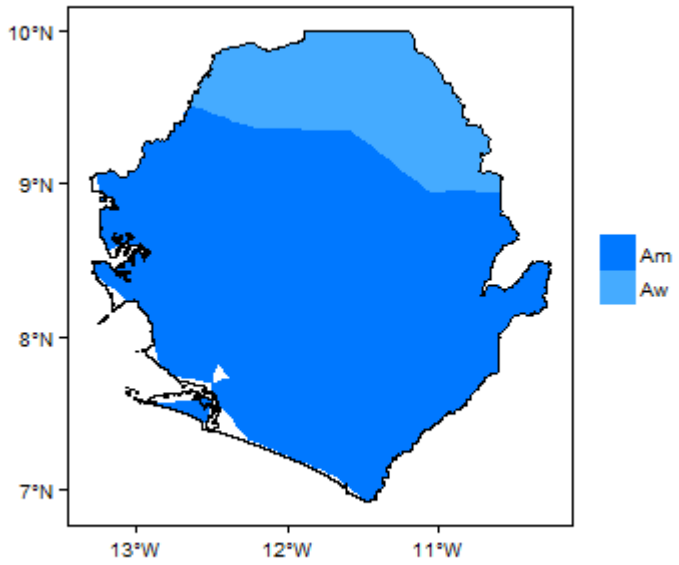
Capital city	Freetown
Region	Western Africa
Border countries	Guinea, Liberia
Total surface area*	km^2 (19,671,000 ha)
Total population (2015)*	15,129,000
Rural population (2015)*	8,585,000 (56%)
Urban population (2015)*	6,544,000 (44%)
UN Human Development Index (HDI) [highest = 1] (2014)*	0.4659

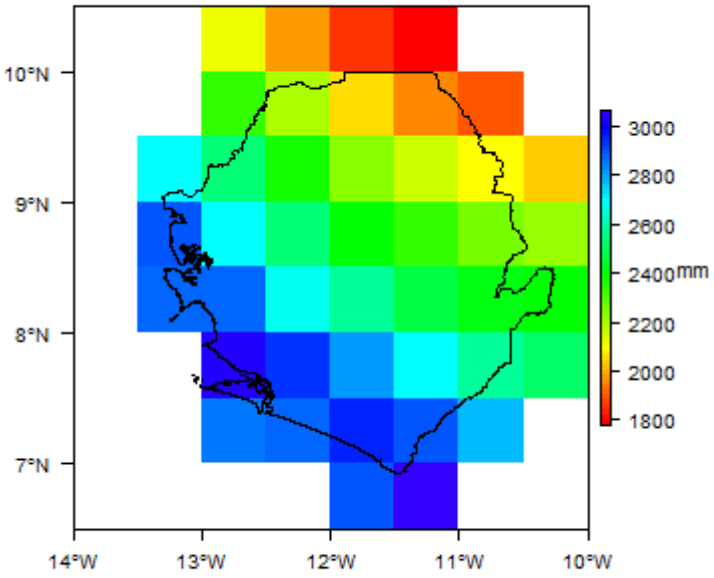
* Source: FAO Aquastat

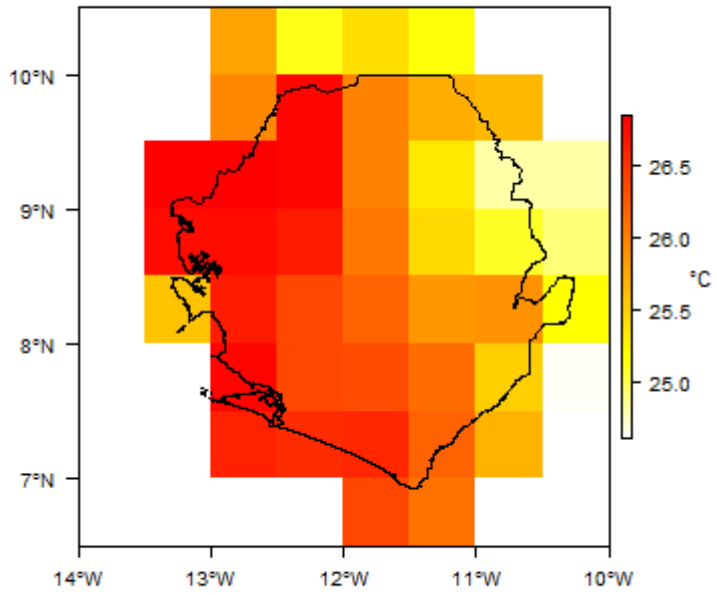
Climate

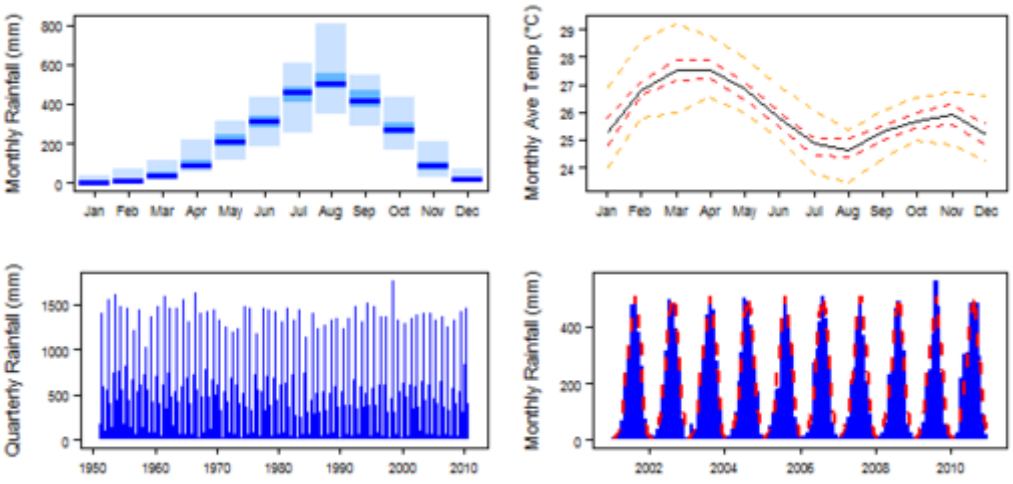
Sierra Leone has a humid tropical climate. Average annual rainfall is approximately twice the average annual potential evapotranspiration. Rainfall is highly seasonal, with a peak in August and a dry season from December to March. Inter-annual variation in rainfall is generally small, but there are some extreme rainfall events.

Temperatures are relatively uniform throughout the year, ranging from 24 to 28 degrees C. Lowest temperatures are from July to September, in the middle of the rainy season, and highest temperatures are in February and March, near the in end of the dry season (Lapworth et al. 2015).









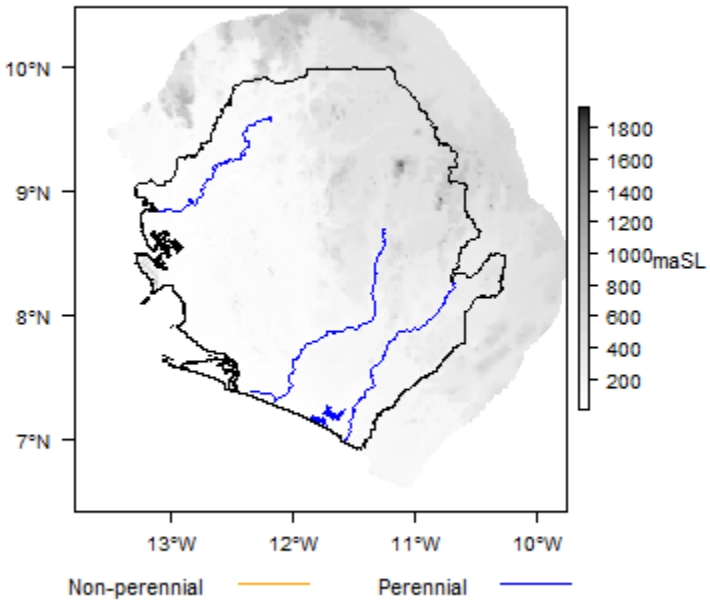
More information on average rainfall and temperature for each of the climate zones in Sierra Leone can be seen at the Sierra Leone climate page.

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

Five main rivers flow from northeast to southwest across Sierra Leone: the Little Scarcies, Rokel, Jong, Sewa and Moa rivers. Between them, they drain most of the land surface of the country. In addition, there are six smaller drainage basins: the Great Scarcies, Lokko, Rokel Estuary, Western, Robbi/Thauka and Sherbro Water Resources Areas. River runoff is highly seasonal, reflecting the seasonal distribution of rainfall. In the Rokel river, discharge increases from May, peaks in September and decreases to near-zero by March (Lapworth et al. 2015).

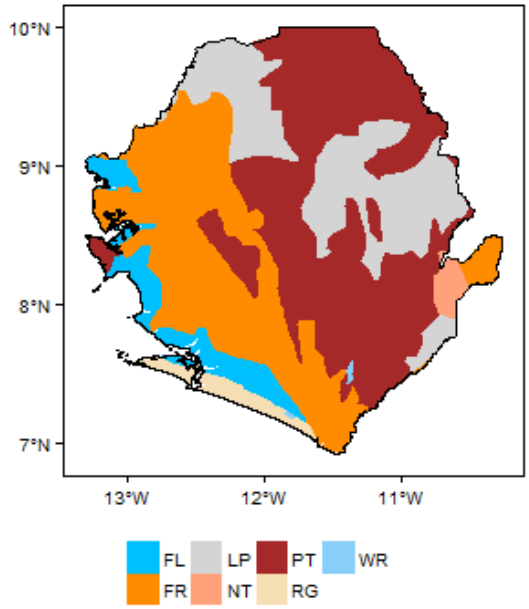
The Salone Water Security website includes data on surface waters in Sierra Leone, including maps of river basins and some monitoring data on surface water flows and levels.



Major surface water features of Sierra Leone. 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 datasets see the surface water resource page.

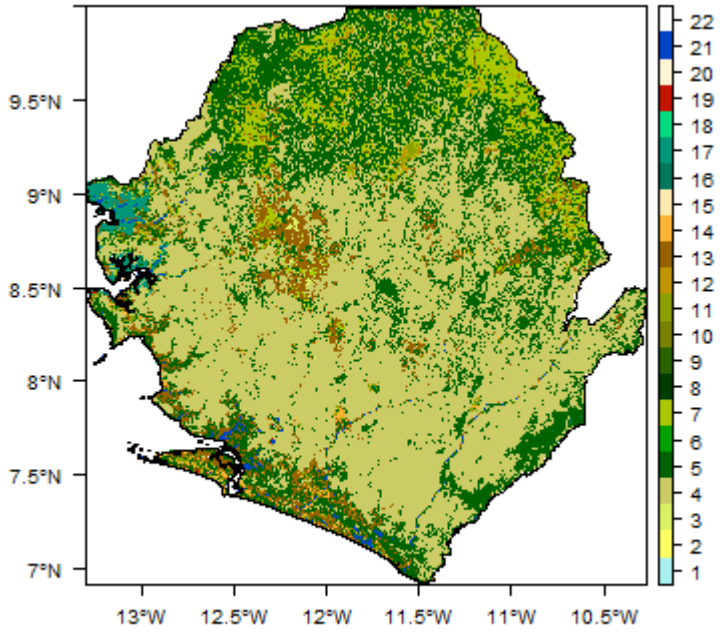
Soil

There is extensively weathered tropical soil, including distinctive duricrust development. The lowland area in the west of Sierra Leone is dominated by strongly weathered ferrasols with low nutrient levels. The upland area in the east has a partial cover of pisoplinthic plinthosols - soils with accumulations of iron that harden irreversibly when exposed to air and sunlight. Toward the coast these become yellow in colour. Elsewhere there are lithic leptosols - shallow soils over hard rock with bedrock close to the surface. In many cases, iron rich tropical soils contain openings and macropores which permit rapid infiltration and flow of water (Lapworth et al. 2015).



Soil Map of Sierra Leone, 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 Sierra Leone, from the European Space Agency GlobCover 2.3, 2009. For more information on the map see the land cover resource page.

Water statistics

	2002	2014	2015
Rural population with access to safe drinking water (%)			67.3
Urban population with access to safe drinking water (%)			92.9
Population affected by water related disease	No data	No data	No data
Total internal renewable water resources (cubic metres/inhabitant/year)		1,705	
Total exploitable water resources (Million cubic metres/year)	No data	No data	No data
Freshwater withdrawal as % of total renewable water resources	5.699		
Total renewable groundwater (Million cubic metres/year)		25,000	
Exploitable: Regular renewable groundwater (Million cubic metres/year)	No data	No data	No data
Groundwater produced internally (Million cubic metres/year)		3,500	
Fresh groundwater withdrawal (primary and secondary) (Million cubic metres/year)	No data	No data	No data
Groundwater: entering the country (total) (Million cubic metres/year)	No data	No data	No data
Groundwater: leaving the country to other countries (total) (Million cubic metres/year)	No data	No data	No data
Industrial water withdrawal (all water sources) (Million cubic metres/year)	58		
Municipal water withdrawal (all water sources) (Million cubic metres/year)	98		
Agricultural water withdrawal (all water sources) (Million cubic metres/year)	2,065		

Irrigation water withdrawal (all water sources) [1] (Million cubic metres/year)	No data	No data	No data
Irrigation water requirement (all water sources) [1] (Million cubic metres/year)	949.4		
Area of permanent crops (ha)		68,000	
Cultivated land (arable and permanent crops) (ha)		3,268,000	
Total area of country cultivated (%)		16.61	
Area equipped for irrigation by groundwater (ha)	10,000		
Area equipped for irrigation by mixed surface water and groundwater (ha)	No data	No data	No data

These statistics are sourced from FAO Aquastat. They are the most recent available information in the Aquastat database. 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

The geology map shows a simplified overview of the geology at a national scale (see the Geology resource page for more details).

Download a GIS shapefile of the Sierra Leone geology and hydrogeology map.

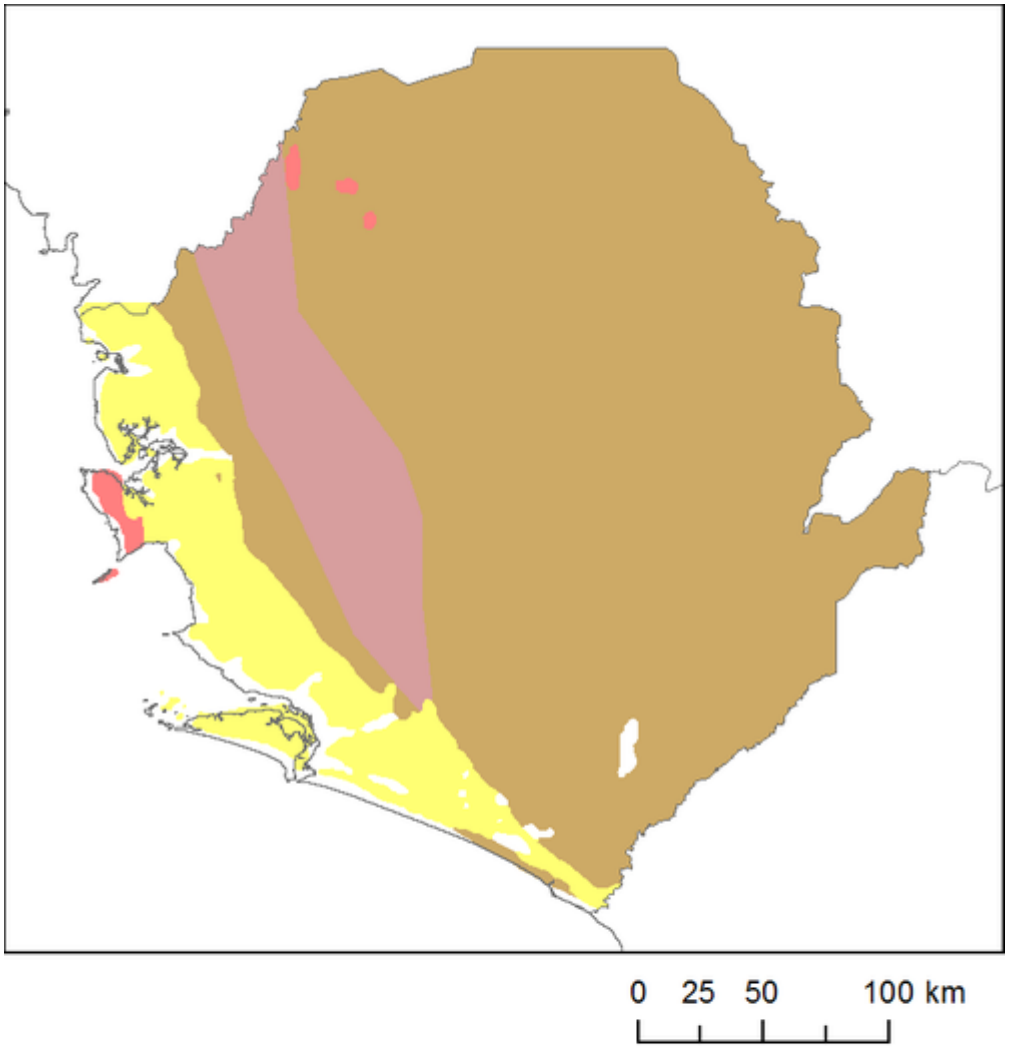
More information is available in the report UN (1988) (see References section, below).

Summary

Most of Sierra Leone is underlain by Precambrian cratonic rocks of the Archaean Basement Complex (Lapworth et al. 2015). A major belt of late Precambrian (Upper Proterozoic) to Lower Palaeozoic age metasedimentary rocks, with some (meta)volcanic rocks, occurs in the western part of the country (Camus and Cukor 2012, Lapworth et al. 2015). These are often capped by a weathered zone of unconsolidated material, where the Precambrian basement rocks have been weathered in-situ to sand, gravel and clay. They are also often capped by a layer of laterite or ferricrete.

There are outcrops of intrusive igneous rocks across the country, which are generally of granitic composition(Camus and Cukor 2012, Lapworth et al. 2015).

Across the country, in river valleys there are often unconsolidated alluvial deposits laid down by rivers. Along the coastal belt are extensive outcrops of coastal, marine and estuarine unconsolidated deposits.



Geology of Sierra Leone at 1:5 million scale. Based on map described by Persits et al. 2002/Furon and Lombard 1964. For more information on the map development and datasets see the geology resource page. Download a GIS shapefile of the Sierra Leone geology and hydrogeology map.

		Geological Environments
Key Formations	Period	Description
		Unconsolidated sediments
Bullem Group	Tertiary to Quaternary	Poorly consolidated marine and estuarine sediments, largely sands, gravels and kaolinitic clays with some lignite (Lapworth et al. 2015).
		Igneous intrusive
Freetown Peninsula Complex and other intrusions	Mostly Mesozoic	

Consolidated (meta)sedimentary rocks; some volcanic rocks		
Saionya Scarp and Rokel River groups	Upper Proterozoic to Lower Palaeozoic	Shales, schists, metaconglomerates and quartzites, metacherts and banded iron formations (BIF), with volcanic bands (Camus and Cukor 2012, Lapworth et al. 2015).
Basement Complex		
Marampa and Kasila groups	Precambrian (Archaean)	Crystalline granitic gneisses with supracrustal metamorphosed volcanic and sedimentary belts. The Marampa Group is dominated by metasedimentary and volcanic rocks; the Kasila Group is dominated by granulites, basement granites, gneisses and migmatites, volcanic greenstone, amphibolite and gneiss. The granitic basement has a well-developed fracture network (Lapworth et al. 2015).

Hydrogeology

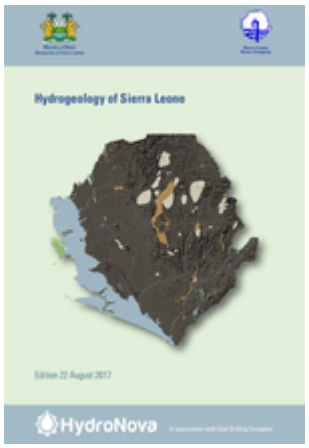
The hydrogeology map below shows a simplified overview of the type and productivity of the main aquifers at a national scale (see the Hydrogeology map resource page for more details).

Download a GIS shapefile of the Sierra Leone geology and hydrogeology map.

A comprehensive report on the **Hydrogeology of Sierra Leone** was published in 2017.

Maps, data and more information on groundwater in Sierra Leone are also available through **SALGRID** - the Salone Groundwater Resources Database portal, the official data portal and repository of hydrogeological information of the Government of Sierra Leone.

Other sources with information on the hydrogeology of Sierra Leone are listed in the References section, below.



Report cover of Hydrogeology of Sierra Leone (2017)

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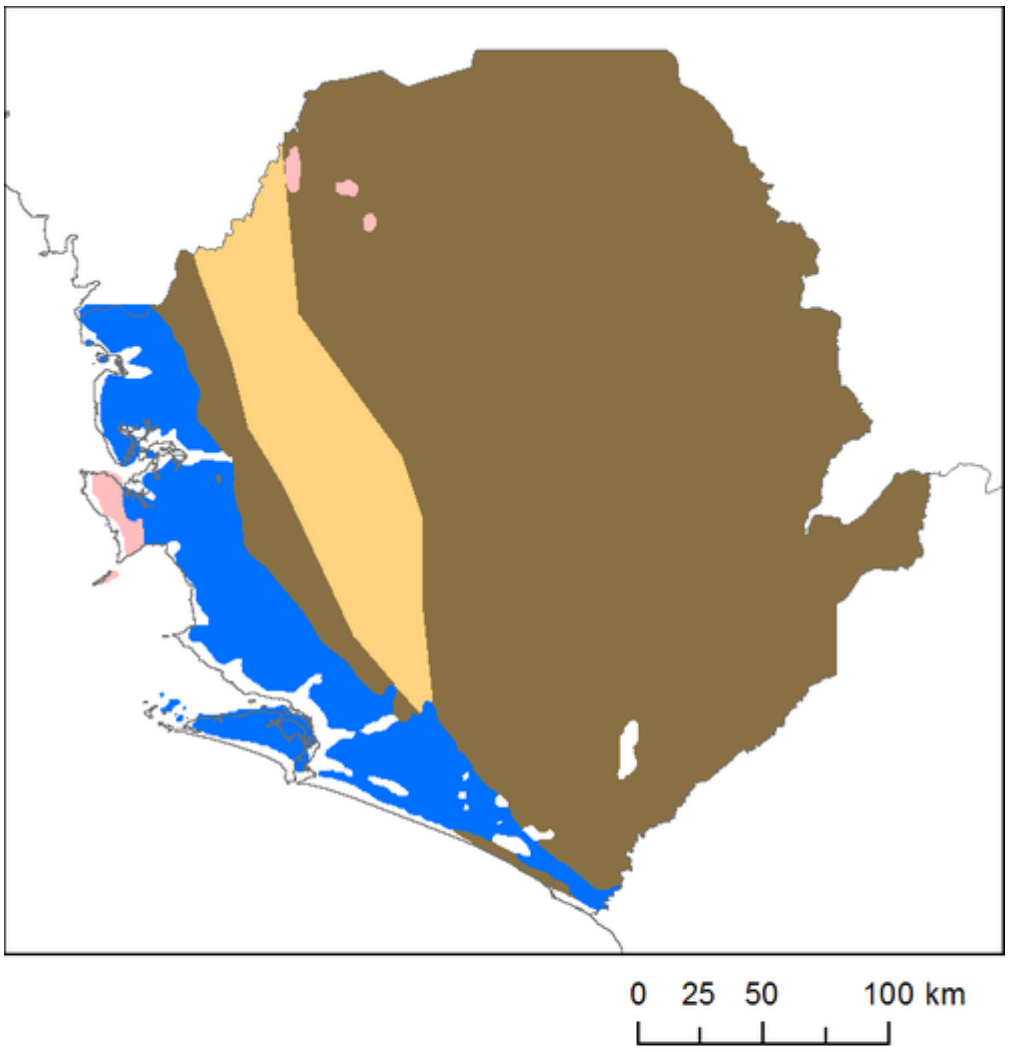

Hydrogeology of Sierra Leone at 1:5 million scale. For more information on how the map was developed see the Hydrogeology map resource page. Download a GIS shapefile of the Sierra Leone geology and hydrogeology map.

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Summary

The main hydrogeological distinction in Sierra Leone is between the relatively low permeability and productivity aquifers formed by the crystalline Precambrian Basement Complex, consolidated metasedimentary rocks and igneous intrusions; and the higher permeability and storage of the Bullom Group unconsolidated sand aquifer in the coastal zone. The weathered basement rocks form the most widespread and important aquifer across most of Sierra Leone.

Unconsolidated Sedimentary

Named Aquifers	General Description
Alluvial (valley fill) deposits	Sands, gravels and clays that overlying the basement rocks, usually up to 15 m thick. They can have high permeability. Groundwater storage and flow is entirely intergranular. There is little data on borehole yields, but it is likely that yields of between 0.3 and 5 litres/second (l/s) will be possible (Lapworth et al. 2015).
Bullom Group	Unconsolidated sands and clays (inland alluvial & coastal), usually 10 to 20 m thick, can form a moderately productive aquifer with potential borehole yields up to 3 l/s. Groundwater flow is intergranular and storage capacity can be high. Fracture flow is less common (Lapworth et al. 2015). Below this are interbedded sands and clays which are typically 30 to 80 m thick. Boreholes can often abstract up 6 l/s (Lapworth et al. 2015).

Consolidated (meta)Sedimentary - Fracture Flow

Named Aquifers	General Description
Saionya Scarp / Rokel River groups	There is a near-surface weathered (regolith) layer that is often dominated by clay. Below this are ancient conosolidated (meta)sedimentary rocks, with very little intergranular porosity. Groundwater storage and flow occurs within fractures in the rock, which are often along old bedding plains, although there is little information on potential borehole yields (Lapworth et al. 2015).

Igneous

Named Aquifers	General Description
Granites, gabbros, dolerites	Fractured gabbros are thought not to typically develop a thick weathered zone. Groundwater is likely to flow through the igneous rocks largely in fractures, although thin weathered zones may also contribute. There is little information on borehole yields (Lapworth et al. 2015).

Basement Complex

Named Aquifers	General Description

There is typically a layer of highly weathered rock (regolith) overlying the unweathered bedrock, which has often transformed to a thick tropical soil. This is generally up to 20 m thick, although up to 37 m thick has been seen. The upper section of this weathered zone often has relatively little clay - the clay minerals have often been leached out, leaving metal oxides. These metal oxides are often in the form of indurated or gravelly layers, which can be highly permeable, and can allow rapid horizontal groundwater flow. Towards the bottom of the weathered zone, the weathered rock is often dominated by clays, and therefore has much lower permeability. Yields from shallow boreholes abstracting from this zone are typically in the range 0.3 to 1.5 l/s. This shallow aquifer tends to dry up rapidly when the rains stop and groundwater drains rapidly away through the permeable material. It is vulnerable to contamination, because of limited attenuation potential in the subsurface and rapid horizontal and vertical groundwater flow pathways for seasonal rainfall recharge (Lapworth et al. 2015).
At the base of the weathered zone, the underlying crystalline bedrock is often extensively fractured and not clay rich, and can store and transmit groundwater through fractures. There can also be deeper fracture zones associated with faults. The average thickness of the fractured aquifer zone is 35 m, but it can be as much as 60 m. Borehole yields are typically between 0.3 and 1.5 l/s. Groundwater flowpaths are usually longer than in the shallow weathered aquifer, and groundwater flow can be rapid over distances of tens of metres. This deeper, fractured aquifer zone is typically a more sustainable groundwater source than the upper weathered zone. It also has more potential for the natural attenuation of contaminants, because of the overlying clay zone and the longer flowpaths (Lapworth et al. 2015).

Groundwater management

Information on groundwater sources (water points) is collected in certain districts, but there is no central national database of groundwater sources. Borehole logs with geological information are not readily available.

The Salone Water Security website is the focal point for Sierra Leone's national policies, strategies, legislation and regulation on water resources, water management and water security. It is also a repository for hydrological (rainfall, surface water and groundwater) data. The Ministry of Water Resources collates, quality controls, archives and publishes hydrometric data from gauging station networks across Sierra Leone.

The Salone Water Security website includes some groundwater level data for hand-dug wells and boreholes which were monitored during the Water Security Project from November 2012 onwards.

There is no national groundwater monitoring network, but the Salone Water Security website shows a map of a proposed groundwater monitoring network.

Transboundary aquifers

For further information about transboundary aquifers, please see the Transboundary aquifers resources page

References

The following reports provide more information on the geology and hydrogeology of Sierra Leone. Some, and others, can be accessed through the Africa Groundwater Literature Archive

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