



**REPUBLIC OF SIERRA LEONE**

**MINISTRY OF ENERGY AND WATER RESOURCES**

**FEASIBILITY STUDY FOR MANUAL DRILLING**

**MAPPING OF FAVOURABLE ZONES**

**PRACTICA**  
FOUNDATION

  
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## ***Introduction***

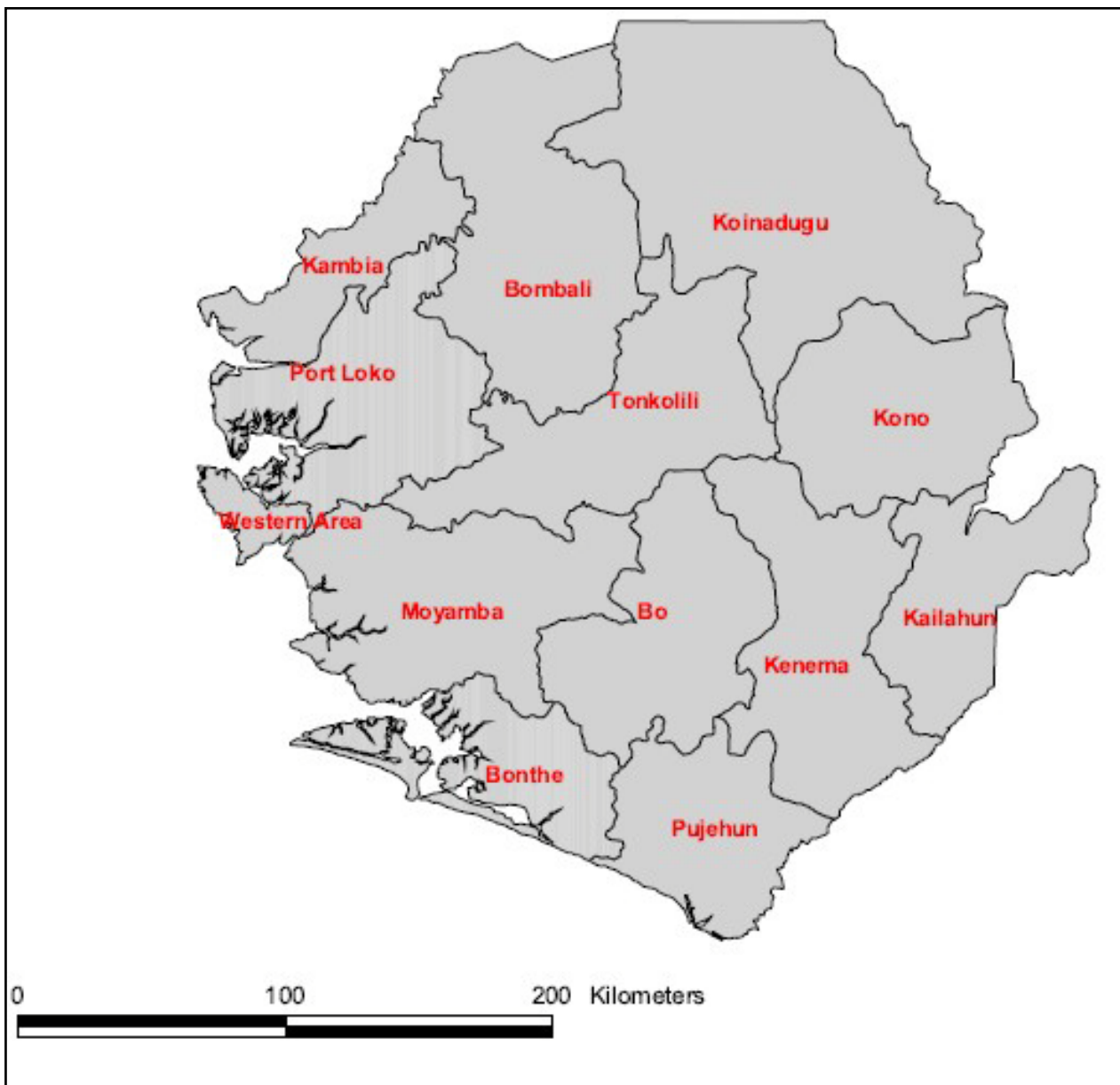
In the framework of its programme focused in supporting the application of low cost techniques of manual drilling in Africa, UNICEF promoted a study having as main purpose the analysis of the existing information at national level for in order to have an initial knowledge of areas where environmental and hydrogeological situation could make hand drilling techniques a potentially suitable low cost and sustainable solution to increase the availability of water for the population. The study has been carried out through the analysis with support of GIS systems of a set of data collected from public source of data (mainly web) and the collection of data available in different institutions at national level by a local consultant.

The present study aims to give a general idea and it is extend to the whole country; the results of this study must be used to target specific areas where more detailed analysis are required in order to have a detailed idea of the best strategy and location to support manual drilling

## General context

### Geography

Sierra Leone has an area of 72.000 Km<sup>2</sup>, with a coastline of about 400 Km on the Atlantic and shares boundaries with Guinea and Liberia. It is boarded on the north-east by mountain ranges rising to a peak of about 1950 m.



*District divisions*

## **Climate**

The country lies in the hot humid area of West Africa with wet and dry seasons

- The mean annual temperature is 26°C ranging from a minimum of 22°C in August to a maximum of 35°C in February. Mean
- Annual rainfall is a high 5.000 mm in the Freetown peninsular to 1800 mm in the north east. The dry season is from November to April. About 5-20% of the annual rainfall occurs during this season. The wet season occurs during the months from May to October.

## **Hydrography**

The country is drained by nine major rivers. These are the Rokel/Seli, Pampana/Jong, Sewa, Waanje and the Coastal Streams and Creeks which originate inside the country. The rest are the Great and Little Scarcies and Moa Rivers which originate from the Fouta Jallon Plateau in the Republic of Guinea, and the Mano River which originates from the Republic of Liberia. These rivers range in length from 160 km for the Great Scarcies to 430 km for the Sewa River and in area from 2,530 km<sup>2</sup> for the coastal streams and creeks to 14,140 km<sup>2</sup> for the Sewa River.

## **Hydrogeology**

Most of the country is underlain by Precambrian crystalline formations which have no primary porosity. Groundwater accumulation therefore occurs in fractures, joints and fissures. The aquifers are therefore discontinuous.

## **Population and drinking water coverage**

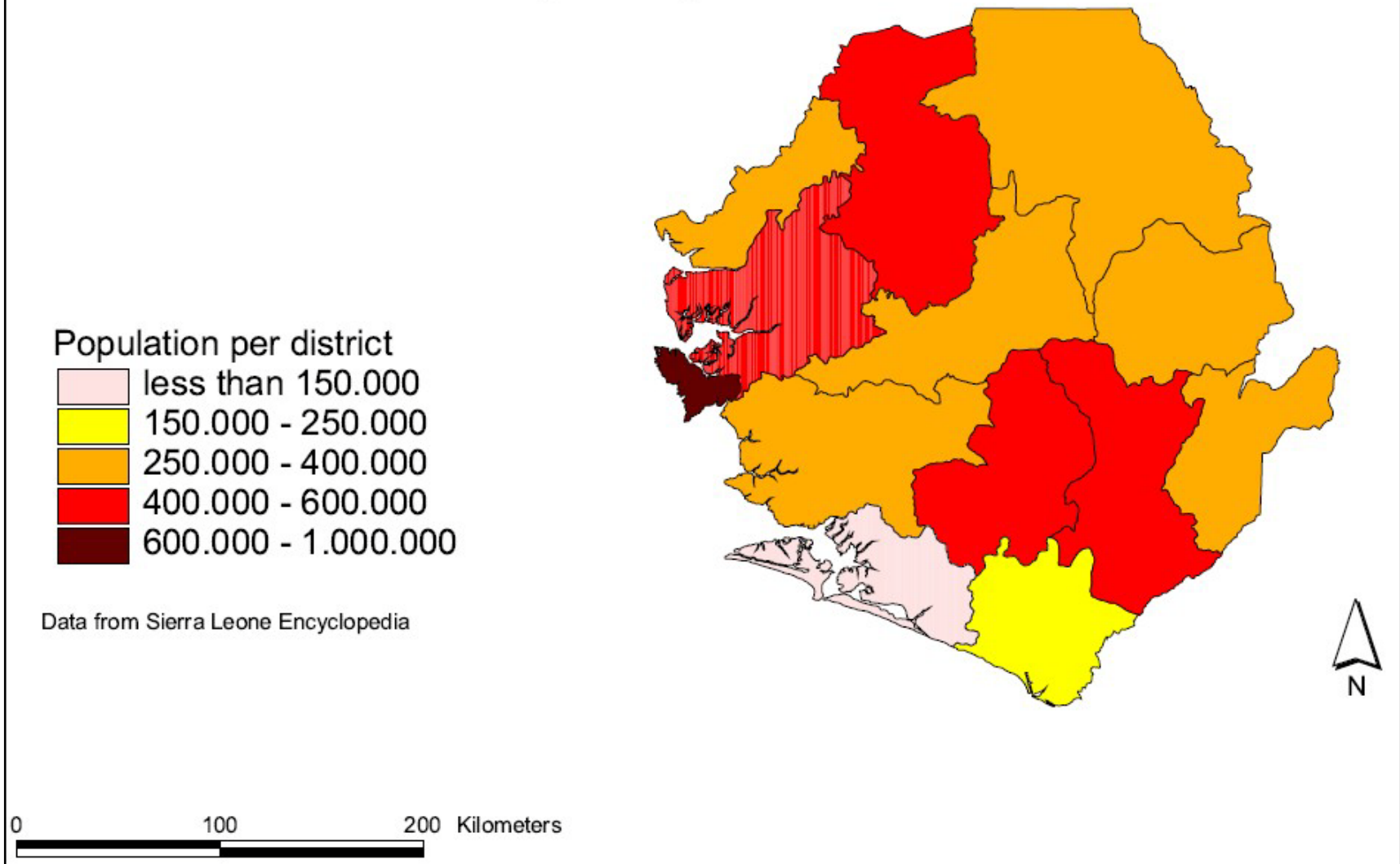
Despite these vast resources, the country currently faces severe constraints in the availability of water for domestic and agricultural purposes. National and District coverage of water and sanitation are presented in Table. The national average water supply coverage is 22% and ranged from 14% for Kailahun to 46% for the Western Area, while sanitation ranged from 6% in Kailahun to 15% in the Western Area. The present national coverage of 22% for water supply compares unfavourably with 35% achieved at the end of the IDWSSD in 1990.

Item No.	DISTRICT	WATER COVERAGE (%)
1	KAILAHUN	14
2	KENEMA	22
3	KONO	15
4	BO	25
5	PUJEHUN	20
6	MOYAMBA	25
7	BONTHE	15
8	TONKOLILI	20
9	BOMBALI	17
10	KOINADUGU	21
11	PORT LOKO	20
12	KAMBIA	25
13	WESTERN AREA	46
	<b>AVERAGE</b>	22

**Water Supply coverage (2003)**

Sierra Leone is endowed with vast water resources consisting of both surface and groundwater resources. However, these resources are unevenly distributed in space and time and in the dry season in particular, they are inadequate to meet the country's needs. The resources are also threatened with rapid population growth, increased industrial activities, environmental degradation causing soil erosion, drainage of wetlands and pollution of rivers. Also knowledge about the resource is inadequate.

## Sierra Leone - Population per district

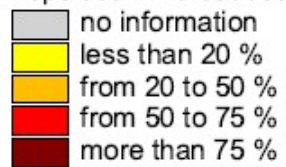


*Map of population per district*

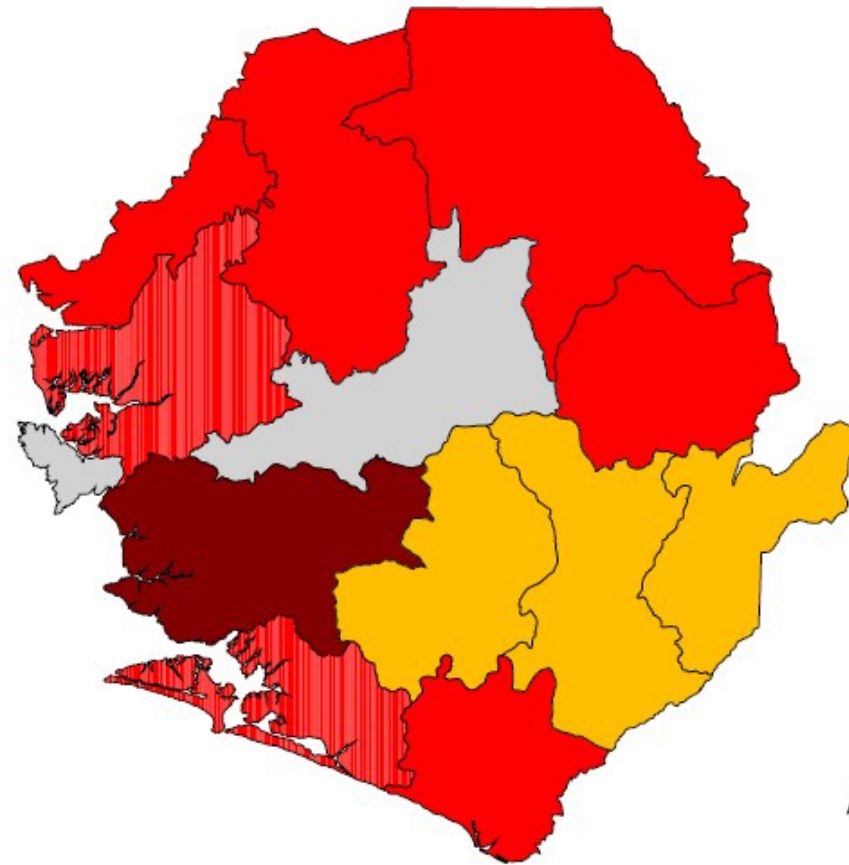


## Sierra Leone - Population without access to safe water

Population without access to safe water



Data from Sierra Leone Encyclopedia



*Map of population without access to safe water*

## ***Methodology for the estimation of suitability for manual drilling***

To estimate the suitability for manual drilling and identify those areas having the best potential we have adopted a methodology based on a cross analysis of the following criteria

- Geological suitability
- Suitability according to water level
- Morphological suitability

### **Geological suitability**

It means identifying the areas where geological formations have hardness and permeability conditions favorable for manual drilling, or identify areas of hard rock where there is likely to exist a weathered unconsolidated layer on top of the main hard rock. These weathered layers are not shown in the geological map, and their existence must be estimated on the basis of other sources of information such as:

- not systematized information based on the direct experience of local technicians who know the context of different regions of the country; their perception allows to estimate the probability that a geological formation in a selected zone was covered by exploitable weathered layer
- borehole logs, giving detailed information about shallow layers covering the main rock aquifer
- database of water points: the existence of a large number of wells dug by hand in areas characterized by hard geological formations may indicate the presence of soft surface layers not marked on the map

### **Sources of information**

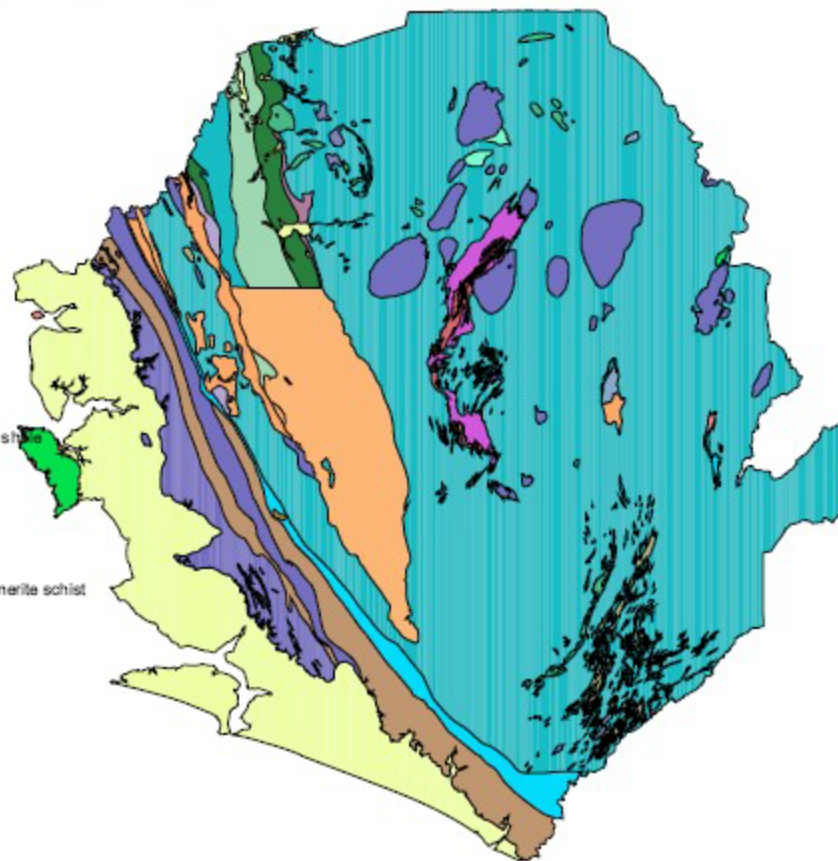
Main sources of information used are:

- 1: 250,000 geological map, it was available only in hard copy. Therefore it was required to scan the map, georeference it and finally digitized as a polygon layer
- Database of water points; this layer of information is still incomplete, and there are information only for 421 water points (291 water points approximately with coordinates, 90 water points without coordinates but with the name of the chiefdom, and 40 water points without sufficient geographic definition), scattered in different departments but mainly covering the central part of the country.

# Sierra Leone - Lithology of geological units

Geological Map 1:250000

- alluvium, beach sand, etc.
- Amphibolite
- Amphibolite, coronite
- Amphibolite, hornblende schist, pyroxene gneiss, ultramafic intrusions
- Amphibolite, hornblende schist, tremolite-actinolite schist, serpentine schist; ultramafic intrusive rocks
- Amphibolite, quartzite, banded ironstone
- Amphibolite, ultrabasic schist
- Andesitic lava, spillic basalt, dacite, dacitic tuff
- Anorthosite, metagabbro
- banded ironstone
- Basic intrusive
- Biotite granite, porphyroblastic granite, granitoid
- Diorite gneiss
- Dolerite
- Dunite, gabbro, troctolite, olivine gabbro, leucogabbro, anorthosite
- Garnet-cornwallite schist, banded ironstone, quartzite
- Gray shale interbedded with quartzite, arkose, subarkose
- Gray shale interbedded with quartzite, arkose, subarkose, conglomerate
- Grey mudstone and shale, occasional beds of grey clayey siltstone, fine-grained sandstone, laminated silty shale
- Hyperstene gneiss with feldspathic bands, olivine-bearing metagabbro
- Laminated argillite with rhythmites
- mafic granulite
- Massive and banded meta-andesite, ultrabasic lava, pillow lava
- Massive and banded metabasic and ultramafic lava and pillow lava
- Massive and banded metamafic and ultramafic lava and pillow lava
- Mica-quartzgneiss, grunerite-magnetite schist quartzite, banded ironstone
- Micaceous quartzite, mica-quartz gneiss, banded ironstone, cordierite gneiss, biotite gneiss, schist and grunerite schist
- migmatites, hybrid rocks
- Migmatitic gneiss and granitoid
- mylonite
- Nepheline syenite, syenite, alkali granite
- Pellic and Semipellic sediments
- Porphyroblastic banded gneiss, pyroxene augen gneiss, migmatitic gneiss, granitoid
- Psammitic and pellic metasediments
- Purple and gray shale with interbedded quartzwacke bands
- quartzite, ferruginous quartzite, banded ironstone
- Quartzo-feldspathic gneiss, coarse amphibolite, garnetiferous gneiss, lava
- sand, clay, clay sand, lignite, etc.
- sand, clay, clay sand, lignite, etc. + alluvium, beach sand, etc.
- schistose massive amphibolite, phyllite, pellic schist
- Semi-pellic schist, massive amphibolite
- Shale, arkosic sandstone, conglomerate
- Variegated shale, laminate siltstone, orthoquartzite, subarkose, arkose
- Variegated shale, laminate siltstone, orthoquartzite, subarkose, arkose; Grey mudstone and shale.....



0 100 200 Kilometers

*Lithology of geological formations*

### **Method of interpretation**

For each geological formation in the vector geological map (the result of digitizing the original paper map) the following parameters were estimated:

- The main lithology
- The expected resistance to drilling
- The expected intensity of weathering in the surface layer
- The expected permeability of the weathered zone

Expected resistance, weathering and permeability of weathered layer were given on the basis of the following assumption:

- Only soft lithological formations are fully favorable to manual drilling
- In case of hard or moderately hard lithological formation, it is possible to find a surface weathered layer with low resistance to drilling; in case this layer is thick enough, it could be a suitable aquifer for manual boreholes supplying water to small group of people.
- Drilling in weathered layers could produce manual drilled wells with low yield because of the low permeability of the sediments; therefore it is also important to estimate the degree of permeability of the weathered zone

Considering the lack of hydrogeological study in Sierra Leone and the unavailability of a sufficient and homogeneously distributed database of water points, the existence and characteristics of the weathered layer has been done mainly on the basis of the following assumption:

- Degree of weathering decrease moving from mafic intrusive to felsic and quartzitic rocks
- Rocks with mixed mineralogical composition and different size of components are likely to have deeper weathering than massive and homogeneous rocks
- Porphyroblastic and coarse-grained rocks are likely to be more weathered; furthermore the weathered layer will be more permeable.
- Degree of weathering in metamorphic rocks is similar or less than the corresponding intrusive or effusive rock

Combining the parameters of hardness and permeability of the main rock, together with the existence and nature of weathered layer, a classification of geological suitability organized in 6 classes has been defined

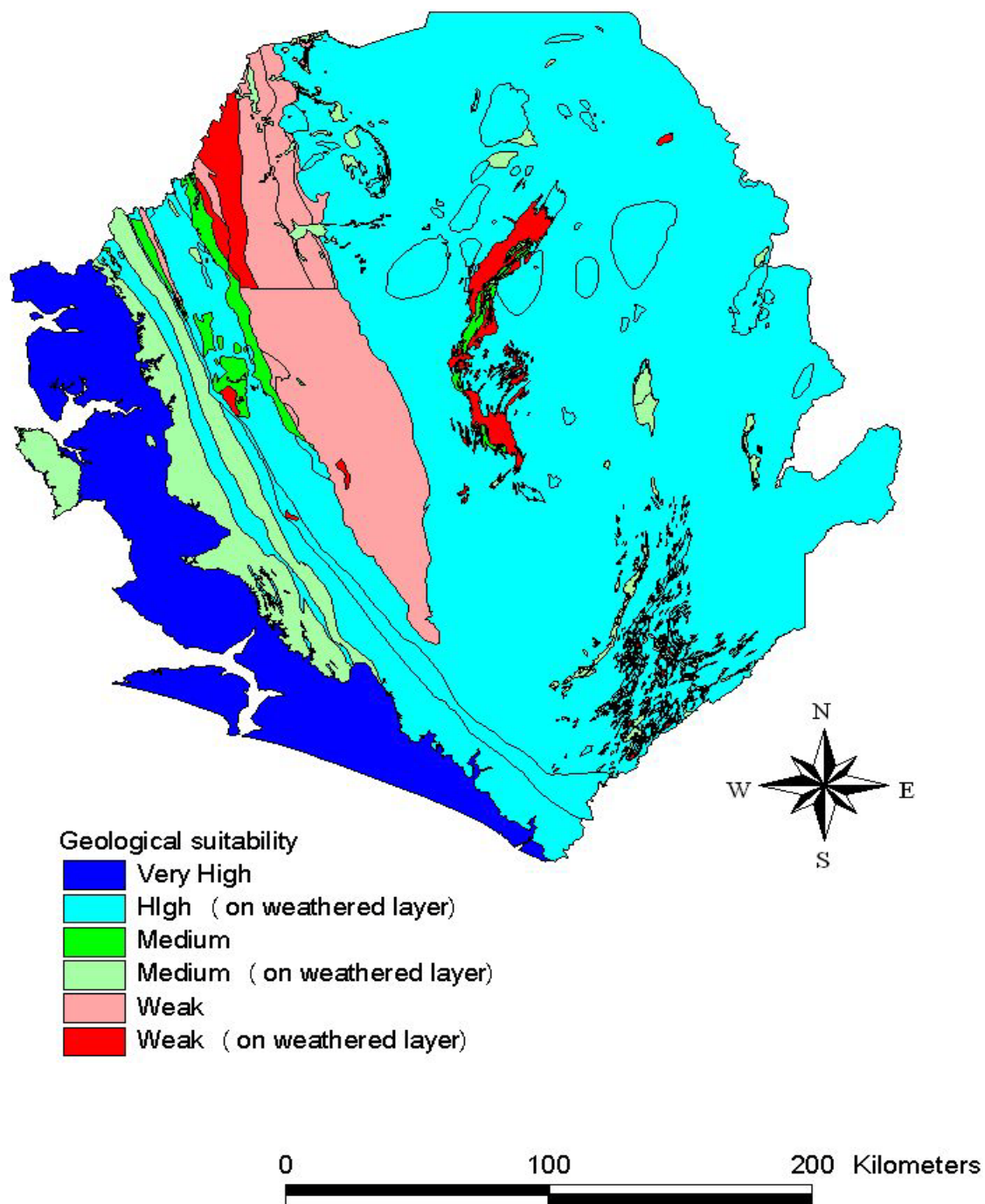
- Very high: it is associated with unconsolidated sediments with good permeability
- High (on weathered layer): associated with hard crystalline rocks with strong attitude to develop important weathered layers with good permeability
- Moderate: associated with unconsolidated sediments (or soft rock) with moderate permeability or partially resistant that could make more complex to drill

- Moderate (on weathered layer) associated with hard crystalline rocks with moderate attitude to develop important weathered layers, or developing thick weathered layers with moderate permeability
- Weak: associated with unconsolidated sediment (or soft rocks) of low permeability and not easy to perforate
- Low (on weathered layer): associated with hard rocks with low tendency to develop important weathered layers, or they develop weathered layer with low permeability

As we can observe in the map, most of the territory of Sierra Leone shows favorable or partially favorable geological conditions to manual drilling.

All the eastern part is covered by crystalline basement with good potential to develop exploitable aquifers, particularly in the eastern part where high fracturing of the rocks is indicated in the original geological map

# Geological suitability



*Map of geological suitability*

## **Suitability according to depth of water**

It means estimating the average depth in each zone where it is possible to find exploitable water. While in unconfined water table, this correspond to the static water level, in case we are in a confined aquifer the real water intake could be deeper than the static water level. Since static water level is generally the only parameter regarding water level that is registered in the water point database.

Once the average and most likely depth of water is determined, it must be classified taking into consideration that manual drilling has to be considered not feasible for ore than 35-40 metres in optimal condition; therefore it is considered not favorable an area having water level deeper than 25 m (considering that the difference between water level and total depth is required to maintain in good condition the pump and not to get dry.

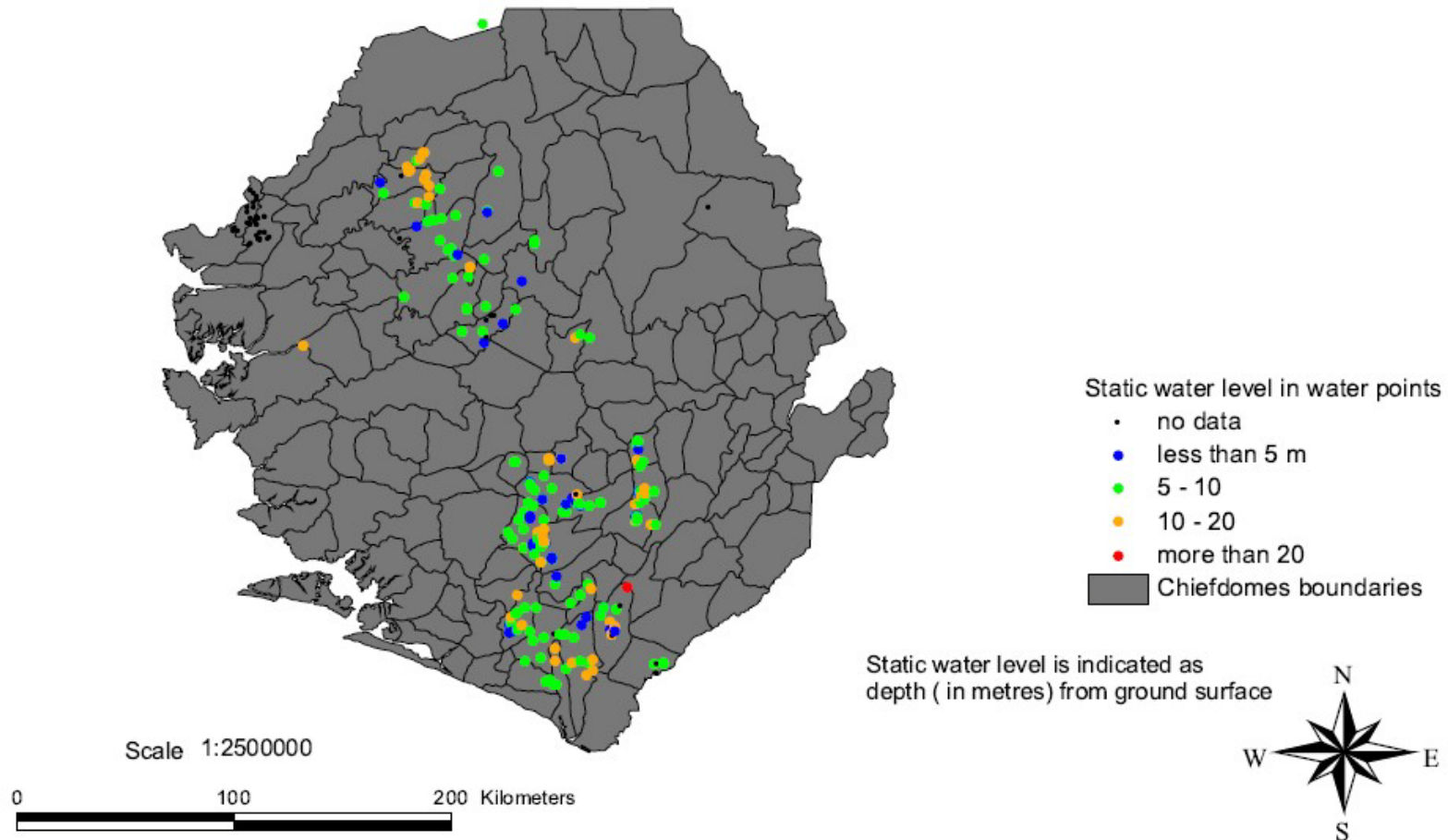
Water point's data don't cover all the country; therefore it results difficult to estimate the static water level on the basis of these data for the different zones. However, we can see that almost everywhere static water level is quite shallow. For this reason it is likely that in the whole country water can be found and exploited with manual drilling at a suitable depth (probably selecting the proper position according to the topography).

It is also important that boreholes and wells recorded in the database are generally less deep than 30 m, and the static water level indicated corresponds to quite shallow water table that can be exploited with manual drilling (in other words, it is not referred to deep and confined aquifers)

Although the interpretation is based only on a limited set of water points, we consider that water is generally shallow enough for manual drilling, and no specific areas with limitation for this reason can be defined



# Static water level in boreholes and wells



*Map of static water level in boreholes and wells*



## Morphological suitability

Morphological suitability search for those zones where morphological aspect facilitate the accumulation of unconsolidated weathered sediments (as a consequence of depositional process and transport of surface water) and shallow groundwater level. These zones are generally associated with depressed areas (bottom of valley) and partially flat areas.

To carry out this analysis the digital elevation model available internet and delivered by SRTM programme was used (90 m pixel resolution, obtained from radar images).

This DTM was processed, obtaining a slope map; later the TPI (Topographic Position Index) extension available in Arcview was used; this algorithm compare the position of each pixel with the surrounding area, and determine if the pixel is in lower position, higher position, or in a slope gradient. Finally comparing the relative position of the pixel with the surrounding area and the absolute slope, it calculates a slope position classification; the study area is divided in the following classes:

- Bottom areas
- Flat or gentle slope
- Steep slope
- Elevated areas

Crossing the results of the automatic procedure of slope position classification and slope maps, the territory was divided in 4 classes of morphological suitability

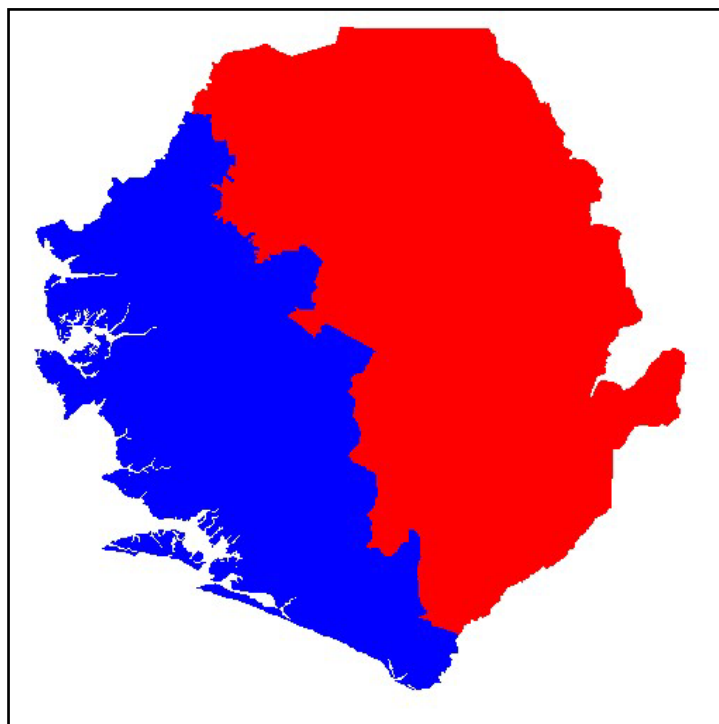
- Favorable: Bottom areas, with slope < 5 degrees
- Moderately favorable: gentle slope with slope less than 5 degrees
- Little favorable: bottom areas with slope > 5 degrees
- Not favorable: all areas with slope > 5 degrees or classified as “elevated areas” in slope position classification)

## Final aptitude

Sierra Leone can be divided in two zones, with different morphological characteristics:

- The western part is mainly flat or small hills
- The eastern part is more undulated, with some mountainous areas

The influence of morphology in defining the probability of accumulation of unconsolidated sediments (and therefore potentially suitable layers) cannot be estimated with the same criteria in the two zones; for this reason the cross analysis of hydrogeological aptitude and morphological aptitude has been done with different procedure for each zone:



**Morphological zones**

(blue = flat area; red = undulated/mountainous area)

In the western flat region it has been assumed that final aptitude is defined only by hydrogeological conditions, and local variations in morphology are not relevant

Geological Aptitude	Final Aptitude
High	Very good
High (on weathered layer)	Good (weath)
Medium	Moderate
Medium (on weathered layer)	Moderate
Weak	Low
Weak (on weatherd layer)	Low

**Classification of final suitability in the western flat area**  
(depending only on geological aptitude)

On the other hand, in the eastern undulated area the final aptitude derives form a cross analysis of geological aptitude and morphological aptitude, as topography can influence locally the processes of weathering /sedimentation / erosion

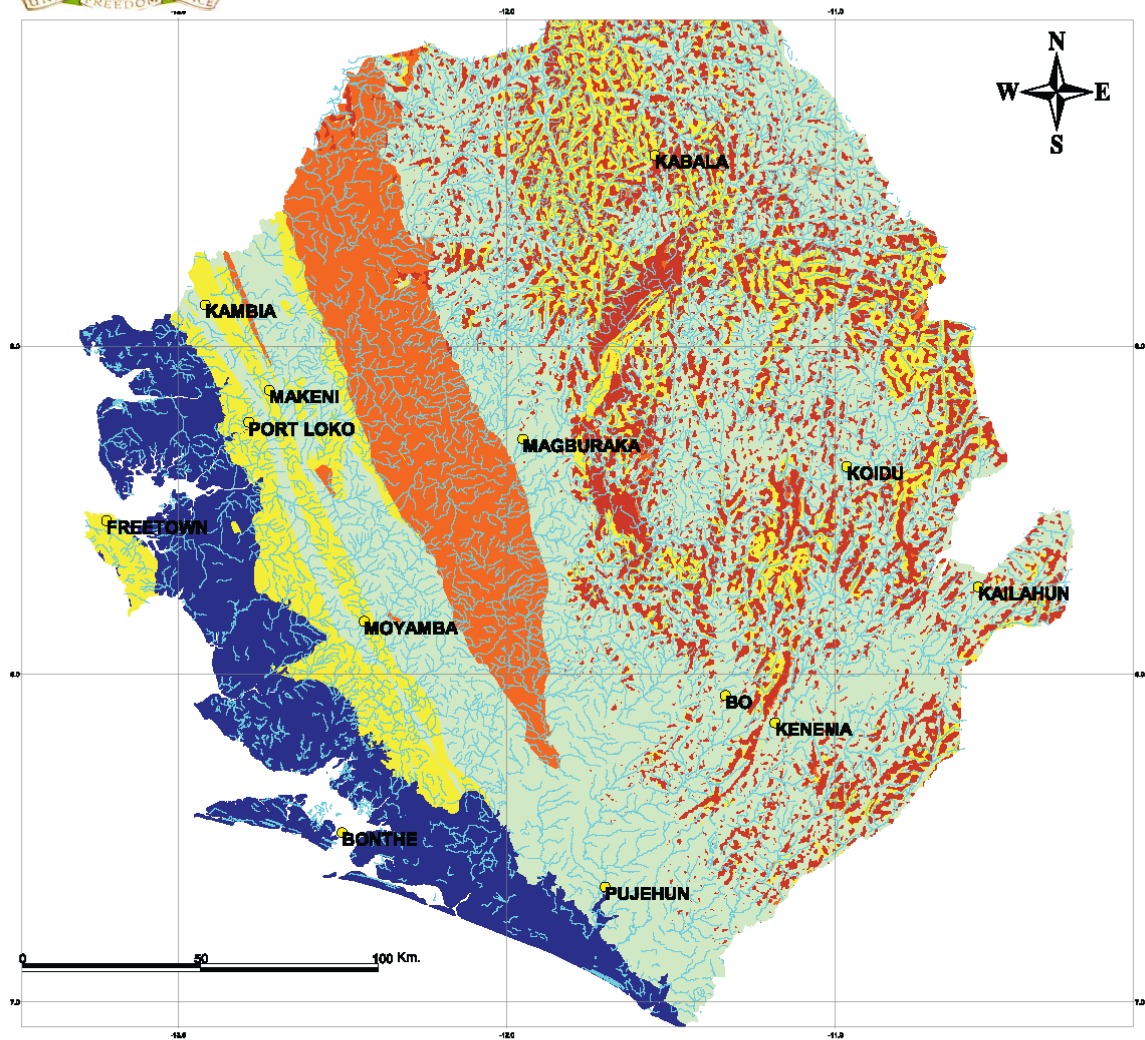
Geological Aptitude	Morphological Aptitude			
	Favorable	Moderately favorable	Little favorable	Not favorable
High	Very good	Very good	Very good	Very good
High (on weathered layer)	Good (weath)	Good (weath)	Moderate	Unsuitable
Medium	Moderate	Moderate	Moderate	Moderate
Medium (on weathered layer)	Good (weath)	Moderate	Low	Unsuitable
Weak	Low	Low	Low	Low
Weak (on weatherd layer)	Low	Low	Unsuitable	Unsuitable
<b>FINAL SUITABILITY TO MANUAL DRILLING</b>				

**Cross analysis and final suitability classification in the eastern part (ondulated/nountaineous area)**








The final result is the map of suitability to manual drilling; in this map the same classification is adopted in the whole country, but the procedure to assign to each area a specific value of suitability is different in western or eastern area, as explained above



### FEASIBILITY STUDY ON MANUAL DRILLINGS TECHNIQUES FAVORABLE ZONES MAP - REPUBLIC OF SIERRA LEONE



#### Legend

-  Main cities
-  Hydrography
- Class of suitability to manual drilling**
-  Very good suitability
-  Good suitability on weathered layer
-  Moderate suitability
-  Low suitability
-  Unsuitable

*Map of suitability to manual drilling*

# Legend

 Main cities

 Hydrography

Class of suitability to manual drilling

 Very good suitability

 Good suitability on weathered layer

 Moderate suitability

 Low suitability

 Unsuitable

*Legend of map of suitability to manual drilling*

## ***Conclusion and recommendations***

Sierra Leone has wide zones suitable to this technique, and manual drilling can be implemented and support the increase of water coverage, particularly in rural areas.

At the moment a quantitative estimate of the number of people who can be supported with manual drilling can't be complete, since it seems important to have more information regarding the type of water sources used in those areas where we have limited data about existing wells and boreholes.

However we can observe that we can estimate a good level of suitability in some districts where the present safe drinking water coverage is quite low. For example the north and northeastern part of the country (Bombali, Koinadugu and Kono districts) has more than 50% of population without access to safe water, and is considered generally suitable to manual drilling.

The interpretation and classification of geological data has been done with general criteria that must be cross-checked with the evidence of distribution of hand dug well and manual drilling in the country, as well as the local context of water supply in each zone.

Furthermore, a more precise zonification of the potential presence of weathered layers must be done observing the relation that this factor has with topography and drainage pattern. Due to the lack of systematized information and previous study, it is recommended to carry out a field survey in the areas potentially more favorable, in order to observe directly the water points and discuss with local technicians and population about the characteristics and eventual problems they face to use the present water points.