Republic of Sierra Leone

Ministry of Water Resources

Strategy for Water Security Planning

Volume 1 of a three-volume set

March 2015

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A simulated stakeholder negotiation undertaken by participants in a Water Security training course, December 2013.

The three volumes produced through the Sierra Leone Water Security Project (Box 2) were drafted by a team drawn from the Ministry of Water Resources and Adam Smith International. The team members were (in alphabetical order) Richard Carter, St John Day (Lead Author), Peter Dumble, Mohammed Juana, Ishmail Kamara and Abubakarr Mansaray. The three volumes have benefitted from additional comments from members of the Ministry of Water Resources and Bumbuna Watershed Management Authority, as well as inputs from local Government. This volume should be cited as ***Ministry of Water Resources (2015) Strategy for Water Security Planning. Volume 1 of 3. Government of Sierra Leone.*** It may be downloaded in electronic form from www.salonewatersecurity.com. The other two volumes are: *Volume 2 Water resources monitoring in Sierra Leone*, and *Volume 3 Data and hydrological understanding generated in the Water Security Project*. For further information contact Mohammed Juana (msejuana@yahoo.co.uk), cc'ing Richard Carter (richard@richard-carter.org), St John Day (stjohn.day@adamsmithinternational.com), and Peter Dumble (Peter.Dumble@PDHydrogeology.com).

Contents

List of Maps

List of Boxes

Abbreviations

AfDB	African Development Bank
ASI	Adam Smith International
ASL	Above sea level
BWMA	Bumbuna Watershed Management Authority
DFID	Department for International Development
EPA	Sierra Leone Environmental Protection Agency
GoSL	Government of Sierra Leone
MDA	Multilateral Development Agency
MEWR	Ministry of Energy and Water Resources
MW	Megawatts
MWR	Ministry of Water Resources
NWRMA	National Water Resources Management Agency
UNICEF	United Nations Children's Fund
WASH	Water, Sanitation and Hygiene
WSP	Water and Sanitation Program (World Bank)

Definitions

Community-based	Referring to activities undertaken by, or with the participation of, local communities.
Data, information and knowledge	Data are raw numbers derived from measurement or regular monitoring. When data is processed and interpreted, it becomes information. When that information is assimilated and used by individuals and organisations, it becomes knowledge.
Groundwater	Groundwater refers to water below ground, held in saturated bodies of rock or earth material. It can provide water to wells and boreholes. If the water table intersects the earth's surface, groundwater discharges naturally as spring flow and river base flow.
Hydrology	Hydrology is the study, measurement and understanding of surface water flows. Groundwater hydrology is the corresponding study of underground water.
Hydrometeorology	The study, measurement and understanding of surface and groundwater hydrology, together with the meteorology on which water resources depend.
Improved / unimproved water source	Improved water sources are those which are engineered and protected in such a way as to provide safe water, ie water free of, or low in, disease-causing pathogens. Unimproved sources are unprotected from faecal contamination and so pose a risk to human health.
Meteorology	Meteorology is the study, measurement and understanding of weather.
National monitoring networks	Networks of rain gauges, river flow stations and groundwater data points designed to inform a nation of the spatial and temporal distribution of its water resources.
Water resources	Water resources are the streams, rivers, surface water bodies and groundwater stores which by their natural discharges support wetland ecosystems, and which can be exploited for water supply for many purposes.
Water security	Water security means different things to different water users. However, the common feature for all is the assurance of sufficient quantity and quality of water for all the uses to which water is put. This, combined with low risk from water-related hazards (floods and droughts) constitutes water security.
Water security planning	Water security planning is a structured participative process involving risk assessment, focused monitoring and action planning. It is an extension of the more narrowly focused approach known as water safety planning.
Water supply	Water supply is the act of harnessing, engineering and managing the delivery of water to water users, for domestic, agricultural and industrial (including electricity generation) uses.

Ministerial Foreword

Sound monitoring and management of water resources are essential in all countries which are striving to achieve water security for their people and economies. This strategy document sets out our vision and commitment for starting this lengthy process.

Prior to our nation's destructive civil war (1991-2002), Sierra Leone had extensive hydrometeorological monitoring networks and published annual water resources yearbooks. In the years that followed virtually no water resources management activities have taken place. We want to address this oversight by (re-)establishing systems for monitoring and managing water resources, strengthening our institutions and helping to promote sound stewardship of water and land resources at local, national and transboundary levels.

With increased understanding of water quality and quantity, coupled with the introduction of new legislation and the formation of a new regulating agency, we have the possibility to develop our water resources in a safe and sustainable manner. The time and cost involved in introducing water security measures will be far outweighed by the social, economic and environmental damage that will be experienced if we do not act now.

The more our population grows and industries working in Sierra Leone expand, the greater the impacts on our water and land resources. We must also overcome the difficulties of water security planning by coordinating and guiding the growing number of donors and implementing agencies that plan to undertake some form of water resources monitoring and management activities. Everyone agrees the challenge is to build institutional capability so that we can ensure water availability is consistent with growing demand. In particular we need to understand collective water demands on dry season river flows. If we can become better at building on models of success, ensure that good ideas don't get lost and adopt them more quickly and efficiently across the country, then we can build national and transboundary water security plans from local level initiatives.

I am committed to achieving the ambitions contained within this strategy document, as I believe they can be a catalyst for the change Sierra Leone needs to make. We are all increasingly aware of the importance of sound stewardship of water and land resources. But we will only achieve our ambitions through clear commitment and leadership from Government, working alongside our international donors, industry, communities, water utilities and implementing partners.

I would like to thank everyone who has contributed to this strategy, especially those who have been directly involved in the Sierra Leone Water Security Project, who have taken the time to share learning and evidence generated from this project.

Honourable Minister Momodu Maligi III
Ministry of Water Resources, Sierra Leone

Executive Summary

Water is essential for health, agriculture, industry and for future economic growth. All nations need to have a clear vision and strategy if they are to manage their water and land resources efficiently. This is no small undertaking because water resources management is a difficult and time-consuming process. Sound water resources management requires near continuous assessments of water availability, with well-resourced national and local Government institutions that have ability to monitor, collate, analyse and publish data. In turn the outcomes of hydrometeorological monitoring must solve real water management issues, enforced through sound water resources legislation and regulation. Subsequent improvements in water storage and supply infrastructure must also be undertaken. This is particularly challenging in Sierra Leone, because we must overcome the ever-present obstacles of limited institutional capability, inadequate recurrent finance, a lack of water resources and water supply infrastructure, and high inter-annual seasonality.

A recurring theme of this strategy is the need to re-establish monitoring activities as pressures on Sierra Leone's water resources increase. Water resources are limited in their regional and seasonal availability and collective demands on dry season availability needs to be determined. Good forecasting and planning will be essential.

Sierra Leone is primarily concerned with transitions - the change from one (inferior) situation, where virtually no monitoring or management of water resources has taken place, to a much better one. This strategy document sets out how some of these transitions can be achieved. It describes the reasons why water security planning is important and points the way forward drawing on evidence and experiences from the Sierra Leone Water Security Project (Box 2). Positive examples of the steps already being taken include the (re-)establishment of hydrological monitoring, participatory monitoring involving schools and communities, the design of national monitoring networks, building institutional capability as well as the passage of new water resources legislation.

Over the past twenty years the Integrated Water Resources Management model has dominated mainstream water resources management approaches. Although well intentioned, such approaches may not always be tailored to national and local contexts if they are driven externally and from the top down. Instead, as this strategy explains, we must adopt an approach of *learning by doing*. We must adopt flexible approaches and where possible we should avoid overly complex approaches if they prove to be too costly and cumbersome. We must ensure our goals and targets are realistic and achievable.

The evidence from the Water Security project is that cleaner and simpler solutions are much needed. National and transboundary water security plans must be developed from local (grassroots) initiatives. Furthermore, evidence and experience from our fieldwork must continue to inform national strategy and policy. To that end we will:

- Encourage donors and organisations to contribute to (re-)establishing our preferred national monitoring networks;
- Work closely with international donors so institutional capacity can be developed incrementally for the foreseeable future;

- Encourage the water and sanitation sector to engage in monitoring of water resources, so that functionality and seasonality of water points are addressed;
- Remind industry and major water abstractors of their responsibilities to establish effective environmental controls and safeguards;
- Promote the importance of managing water locally with active participation from communities and schools.

This strategy document aims to promote the importance of sound water resources management and provide direction as to how progress can be achieved in the immediate and short term. It is by no means the last word on water security planning in Sierra Leone, but if it demonstrates some practical and realistic steps that can be undertaken now by government institutions, donors, implementing agencies, major water abstractors and local communities then it will have served its purpose.

Box 1 Sierra Leone's river basins

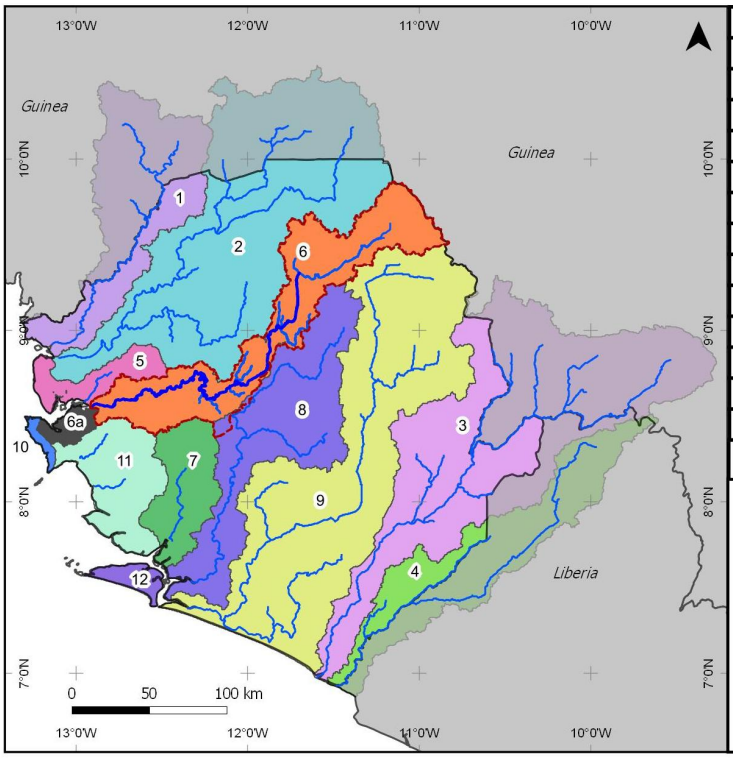
Between ten and thirteen main river basins and water resource areas (WRAs) have been identified in Sierra Leone following those shown in a 1988 map in Ndohamina and Kabia 2004. Map 1 is updated from the 1988 map using the same numbering system but with boundaries generated by USGS HydroSHEDS (http://hydrosheds.cr.usgs.gov/index.php). This map provides a more accurate representation of boundaries between basins than previously available and includes the full extent of those which cross international borders into neighbouring Guinea and Liberia. There is a 2% difference in the total HydroSHEDS river basin areas compared to the officially published country area for Sierra Leone of 71,740 km^2. This is due to different methods of calculation.

USGS HydroSHEDS catchment boundaries are generated automatically and should be considered to be first order approximations. Boundaries are computed from 15 arc second (~450 m) Shuttle Radar Topography Mission data (SRTM). Although SRTM data is currently the best digital elevation data available for Sierra Leone, the automated methods, together with vegetation artefacts and other noise sources in elevation data can lead to errors in boundary positions. In order to improve the accuracy of the Rokel-Seli catchment boundary, the HydroSHEDS generated boundary was validated and corrected using contours derived from the more detailed SRTM DEM 3 second data (~90 m). Further validation and correction was then undertaken against other data sources such as Bing and Landsat satellite images. The revised boundary is shown in red in Map 1 and is in fact slightly larger than the HydroSHEDS calculated basin area. It is this area that is used in the maps and other details of this report.

Ultimately all Sierra Leone catchments should be validated in this manner. Improved validation is now possible following the release in October 2014 of SRTM 1 arc second (~30 m) elevation data.

Maps

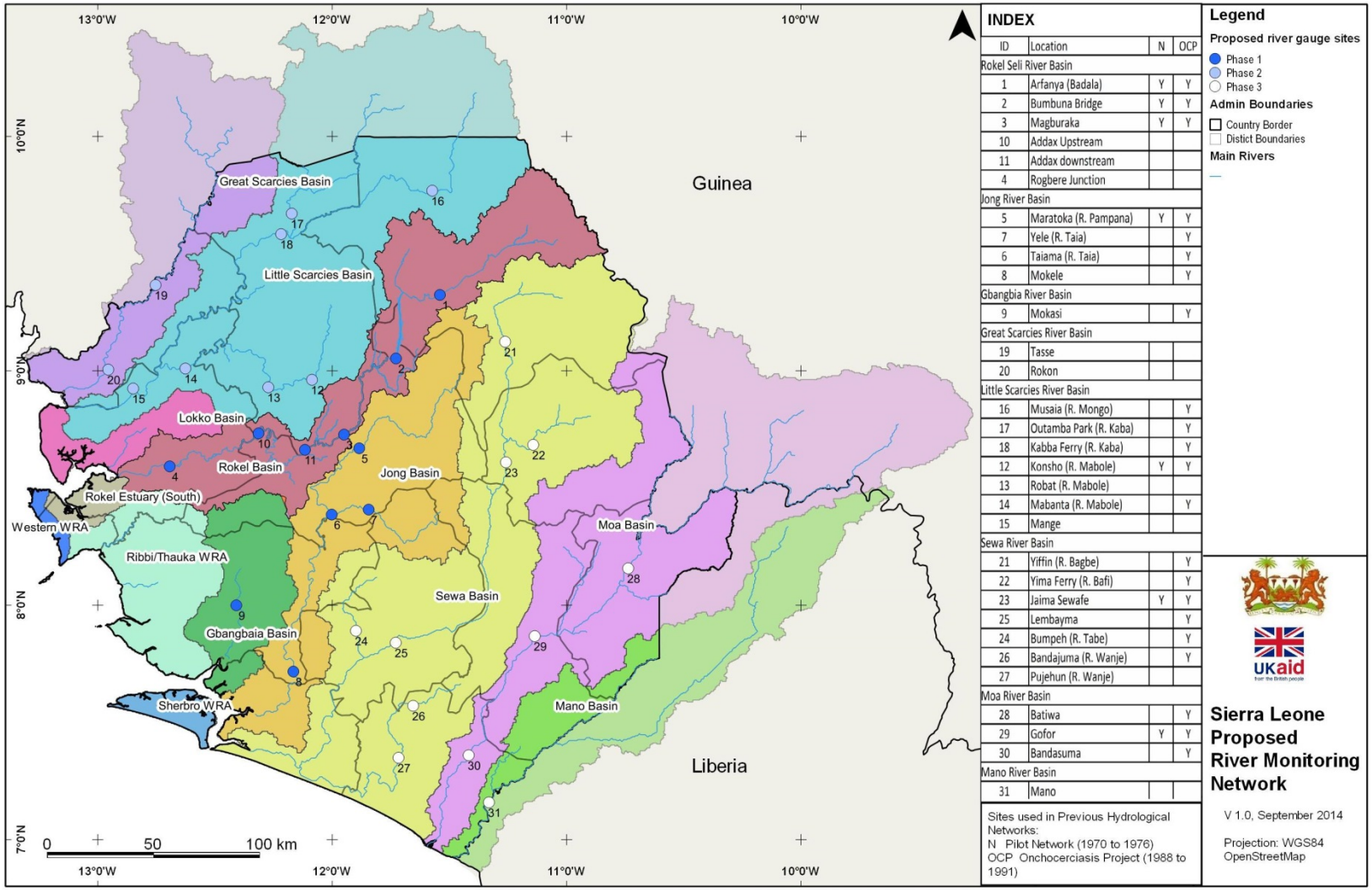
Map 1 Sierra Leone river basins



Basin	Name	Country Area	Total Area
B 1	Great Scarcies Basin	2979	8303
B 2	Little Scarcies Basin	13383	18955
B 3	Moa Basin	9583	19835
B 4	Mano Basin	1959	7776
B 5	Lokko Basin	1565	1565
B 6	Rokel Basin	8236	8236
B 6a	Rokel Estuary (South)	579	579
B 7	Gbangbaia Basin	3121	3121
B 8	Jong Basin	8288	8288
B 9	Sewa Basin	19022	19022
B 10	Western WRA	223	223
B 11	Ribbi/Thauka WRA	3670	3670
B 12	Sherbro WRA	612	612
	Totals	**73220**	**100185**

Notes:
* Source HydroSHED catchment boundaries http://hydrosheds.cr.usgs.gov/index.php
* Rokel basin area has been modified after manually digitising the Rokel boundary (Red line)
* All areas are in square kilometres
* WRA - Water Resources Area
* "Country Area" is basin area inside Sierra Leone
* "Total Area" is total basin area
* Basin 6a is part of the Rokel River management area shown in GOSL documents. It is subdivided here for clarity

Map 2 Sierra Leone river basins and proposed river monitoring network



INDEX

ID	Location	N	OCP
Rokel Seli River Basin			
1	Arfanya (Badala)	Y	Y
2	Bumbuna Bridge	Y	Y
3	Magburaka	Y	Y
10	Addax Upstream		
11	Addax downstream		
4	Rogbere Junction		
Jong River Basin			
5	Maratoka (R. Pampana)	Y	Y
7	Yele (R. Taia)		Y
6	Taiama (R. Taia)		Y
8	Mokele		Y
Gbangbia River Basin			
9	Mokasi		Y
Great Scarcies River Basin			
19	Tasse		
20	Rokon		
Little Scarcies River Basin			
16	Musaia (R. Mongo)		Y
17	Outamba Park (R. Kaba)		Y
18	Kabba Ferry (R. Kaba)		Y
12	Konsho (R. Mabole)	Y	Y
13	Robat (R. Mabole)		
14	Mabanta (R. Mabole)		Y
15	Mange		
Sewa River Basin			
21	Yiffin (R. Bagbe)		Y
22	Yima Ferry (R. Bafi)		Y
23	Jaima Sewafe	Y	Y
25	Lembayma		Y
24	Bumpeh (R. Tabe)		Y
26	Bandajuma (R. Wanje)		Y
27	Pujehun (R. Wanje)		
Moa River Basin			
28	Batiwa		Y
29	Gofor	Y	Y
30	Bandasuma		Y
Mano River Basin			
31	Mano		

Sites used in Previous Hydrological Networks:
N Pilot Network (1970 to 1976)
OCP Onchocerciasis Project (1988 to 1991)

Legend

Proposed river gauge sites
- Phase 1
- Phase 2
- Phase 3

Admin Boundaries
- Country Border
- Distict Boundaries

Main Rivers

UKaid from the British people

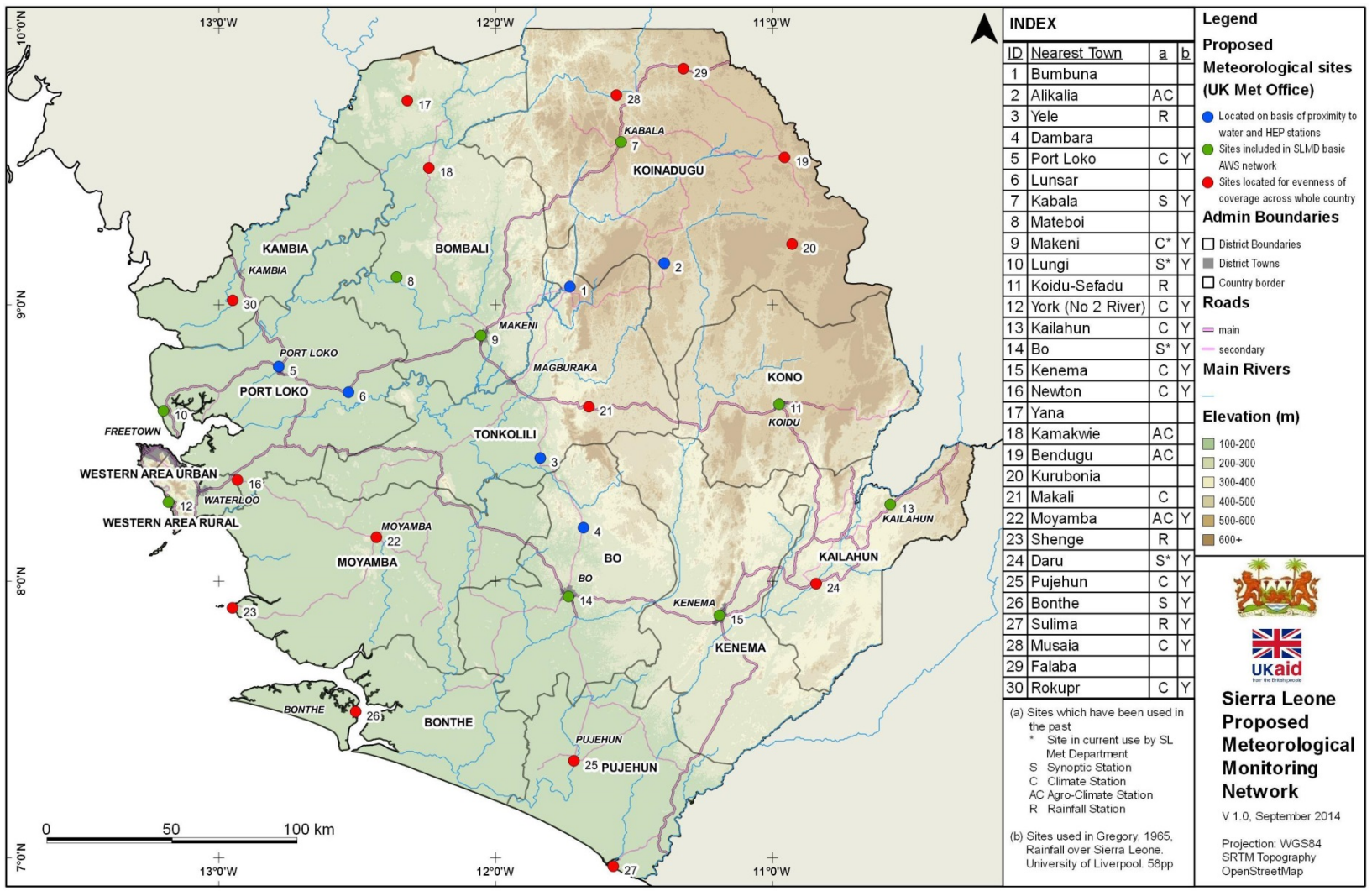
Sierra Leone Proposed River Monitoring Network

V 1.0, September 2014

Projection: WGS84
OpenStreetMap

For details and locations of historical river gauging stations, see Volume 1, Appendix C.

Map 3 Sierra Leone topography and proposed meteorological monitoring network



INDEX			
ID	Nearest Town	a	b
1	Bumbuna		
2	Alikalia	AC	
3	Yele	R	
4	Dambara		
5	Port Loko	C	Y
6	Lunsar		
7	Kabala	S	Y
8	Mateboi		
9	Makeni	C*	Y
10	Lungi	S*	Y
11	Koidu-Sefadu	R	
12	York (No 2 River)	C	Y
13	Kailahun	C	Y
14	Bo	S*	Y
15	Kenema	C	Y
16	Newton	C	Y
17	Yana		
18	Kamakwie	AC	
19	Bendugu	AC	
20	Kurubonia		
21	Makali	C	
22	Moyamba	AC	Y
23	Shenge	R	
24	Daru	S*	Y
25	Pujehun	C	Y
26	Bonthe	S	Y
27	Sulima	R	Y
28	Musaia	C	Y
29	Falaba		
30	Rokupr	C	Y

(a) Sites which have been used in the past
* Site in current use by SL Met Department
S Synoptic Station
C Climate Station
AC Agro-Climate Station
R Rainfall Station

(b) Sites used in Gregory, 1965, Rainfall over Sierra Leone. University of Liverpool. 58pp

Legend

Proposed Meteorological sites (UK Met Office)

- Located on basis of proximity to water and HEP stations
- Sites included in SLMD basic AWS network
- Sites located for evenness of coverage across whole country

Admin Boundaries

- District Boundaries
- District Towns
- Country border

Roads

- main
- secondary

Main Rivers

Elevation (m)

- 100-200
- 200-300
- 300-400
- 400-500
- 500-600
- 600+

UKaid

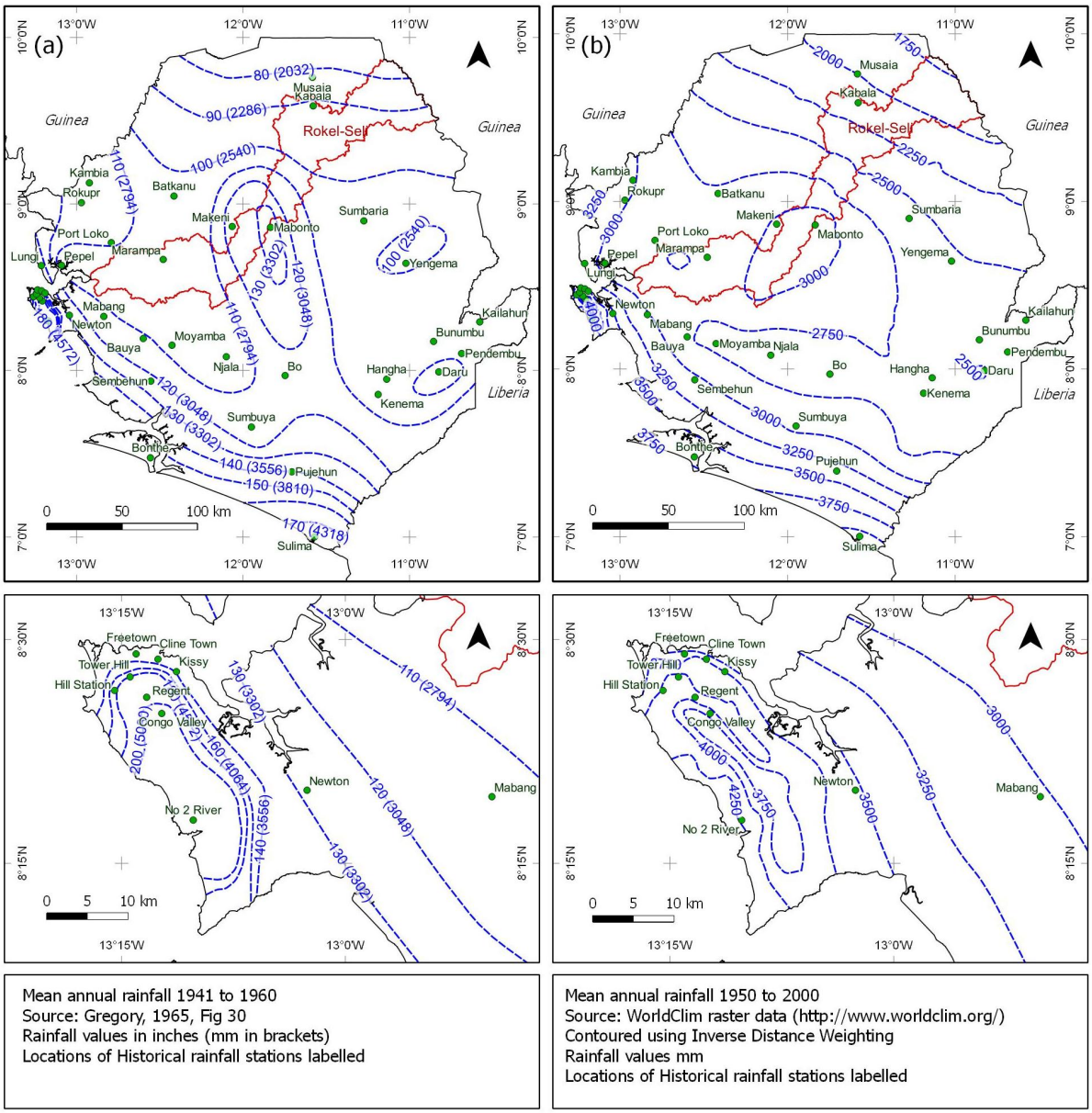
Sierra Leone Proposed Meteorological Monitoring Network

V 1.0, September 2014

Projection: WGS84
SRTM Topography
OpenStreetMap

For details and locations of historical Meteorological and Rainfall stations, see Volume 1, Appendix B.

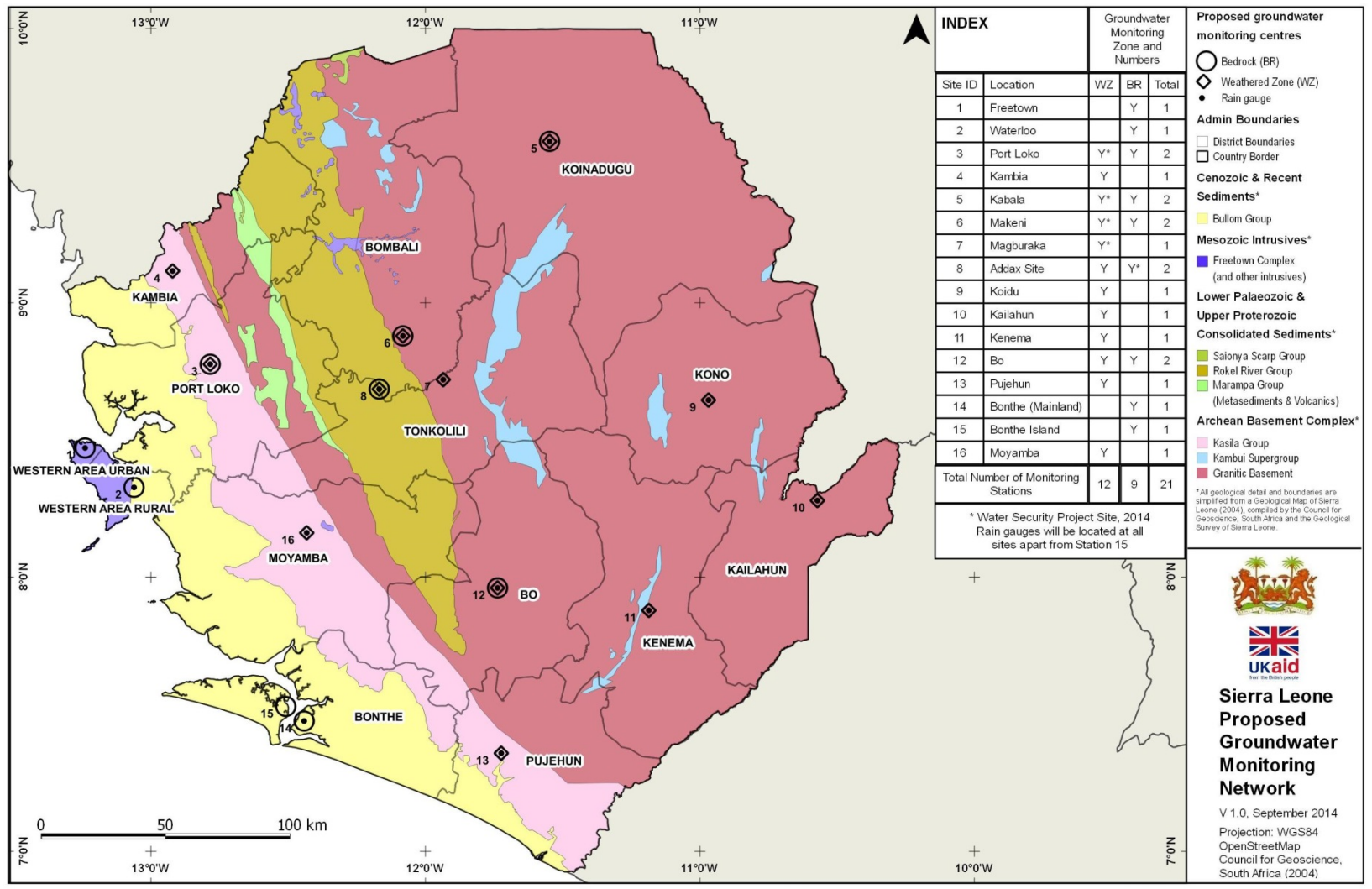
Map 4 Sierra Leone mean annual rainfall



Mean annual rainfall 1941 to 1960
Source: Gregory, 1965, Fig 30
Rainfall values in inches (mm in brackets)
Locations of Historical rainfall stations labelled

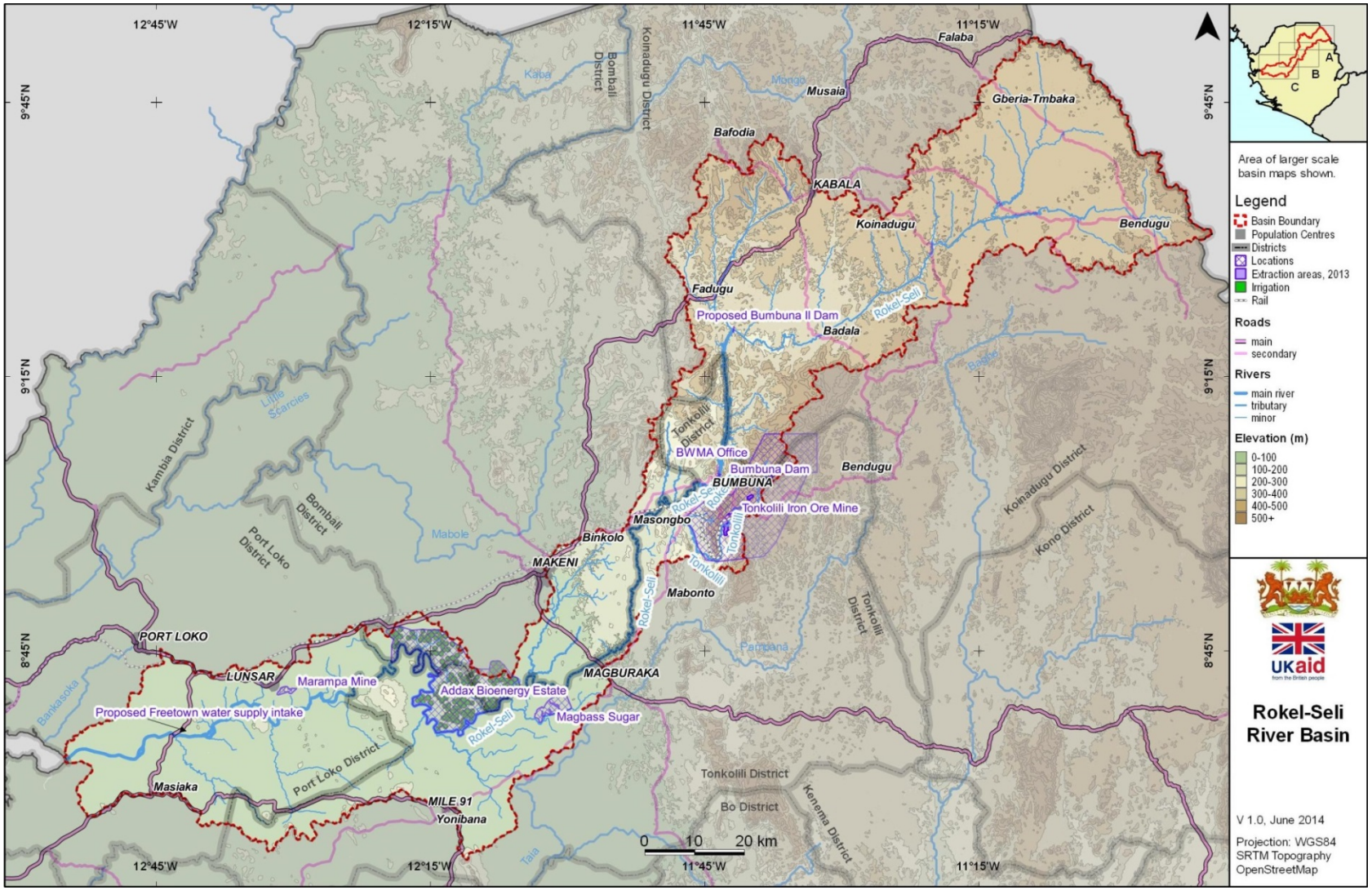
Mean annual rainfall 1950 to 2000
Source: WorldClim raster data (http://www.worldclim.org/)
Contoured using Inverse Distance Weighting
Rainfall values mm
Locations of Historical rainfall stations labelled

Map 5 Sierra Leone geology and proposed groundwater monitoring network

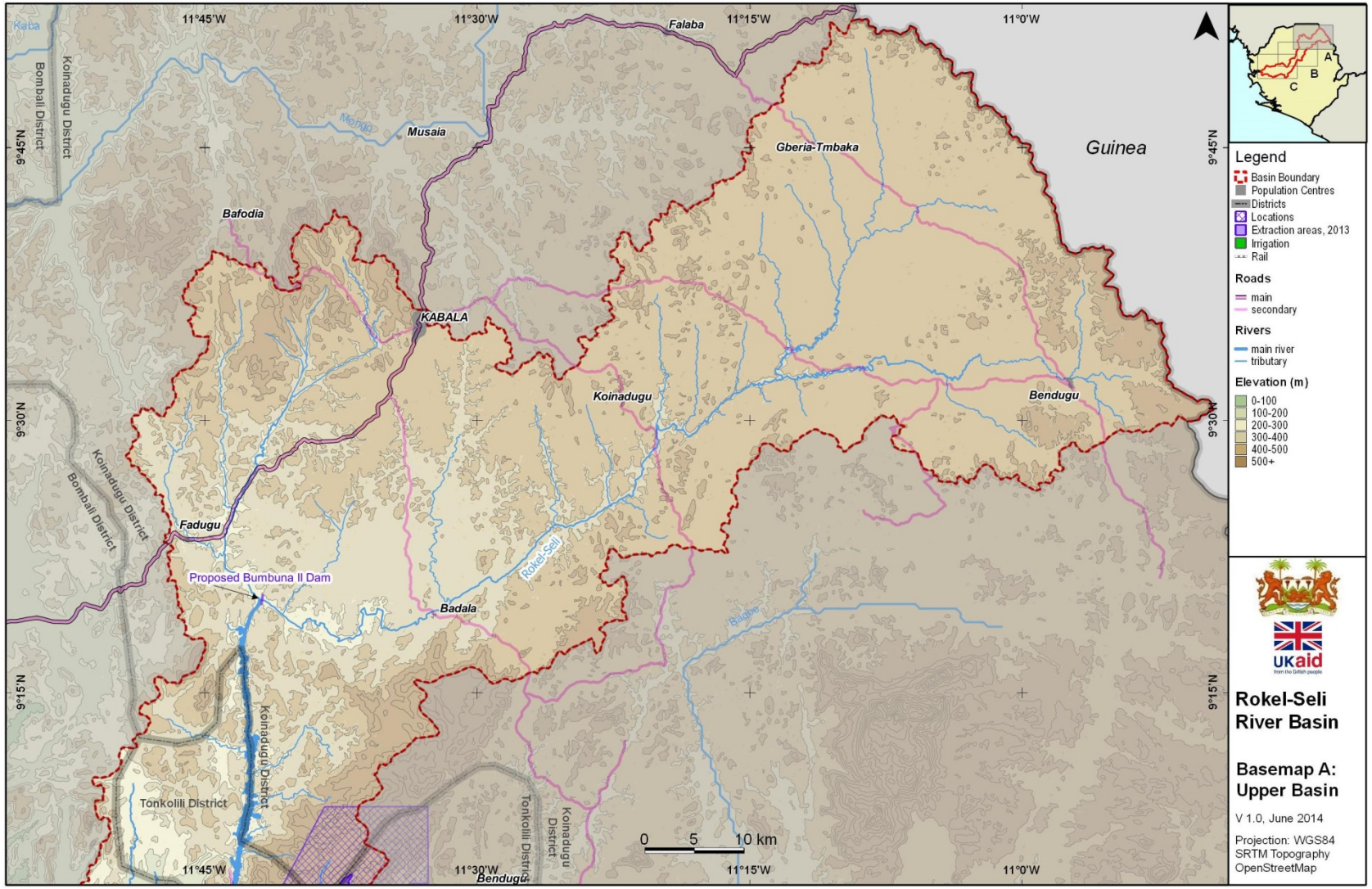


For a photographic reproduction of a more detailed Map from the Geological Survey of Sierra Leone (2004) see Koidu Holdings web site (*http://www.koiduholdings.com/images/kkp_geology_fig1_large.jpg*)

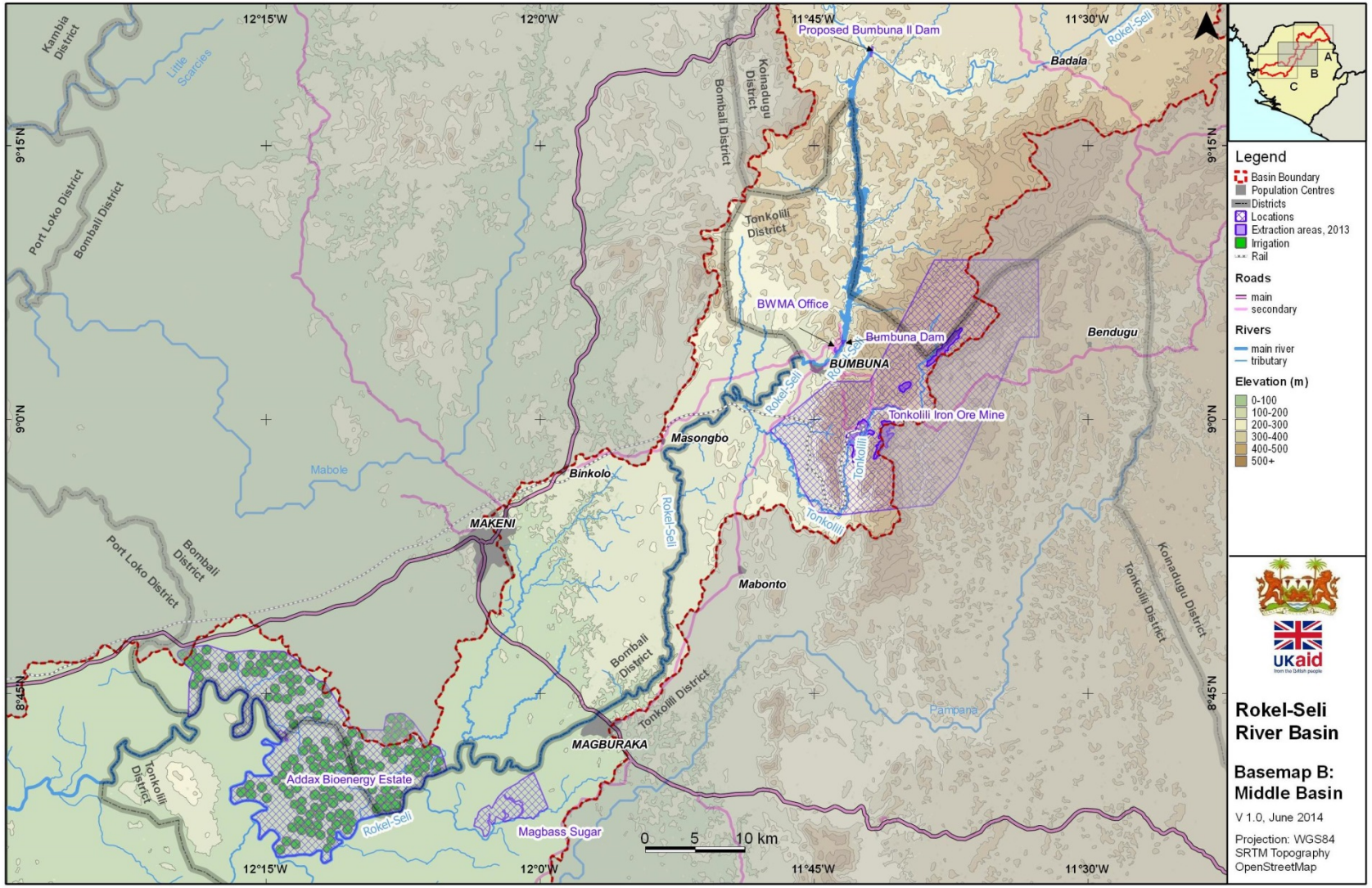
Map 6 Rokel-Seli River Basin



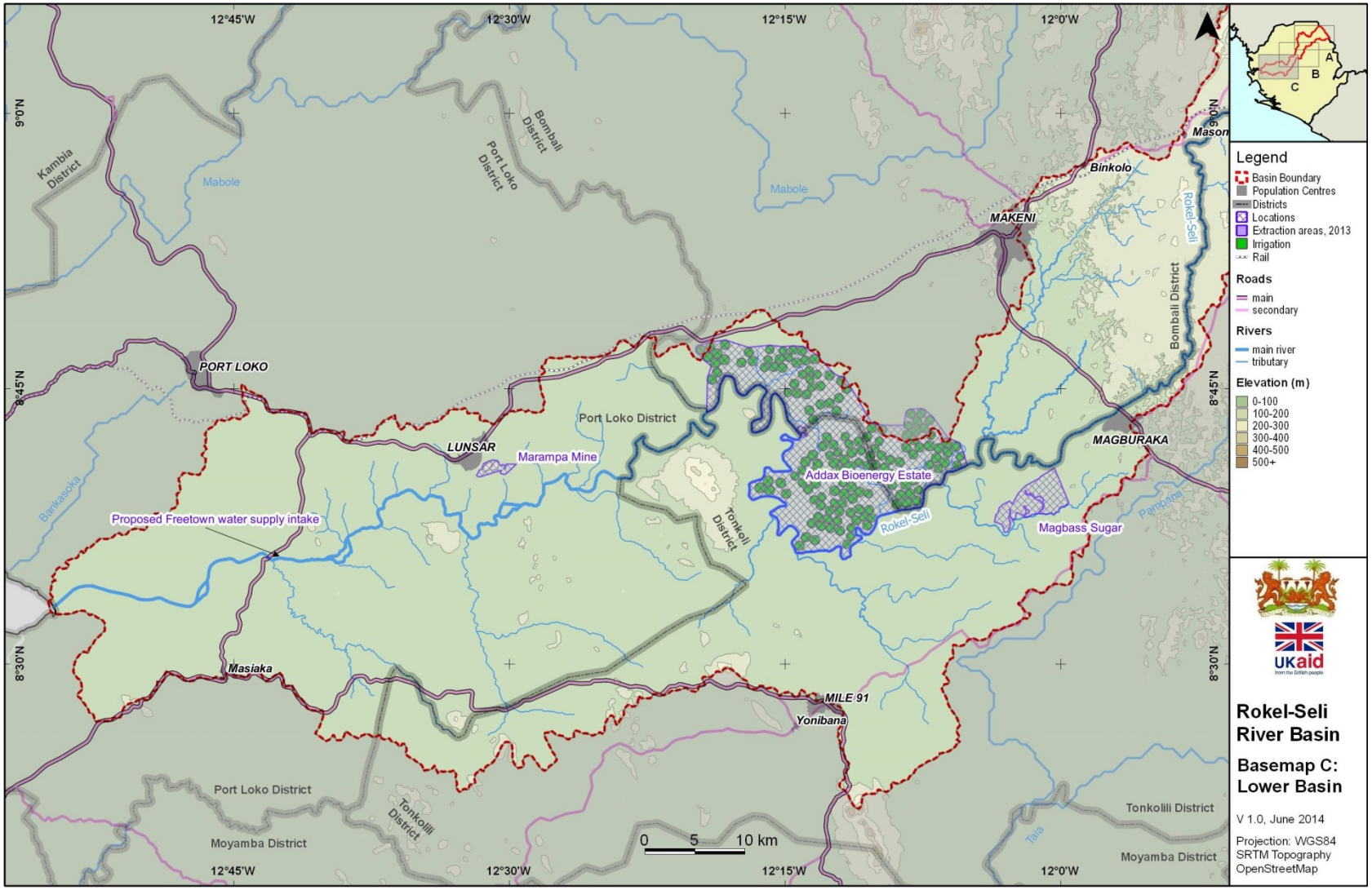
Map 7 Rokel-Seli River Basin – Upper Basin



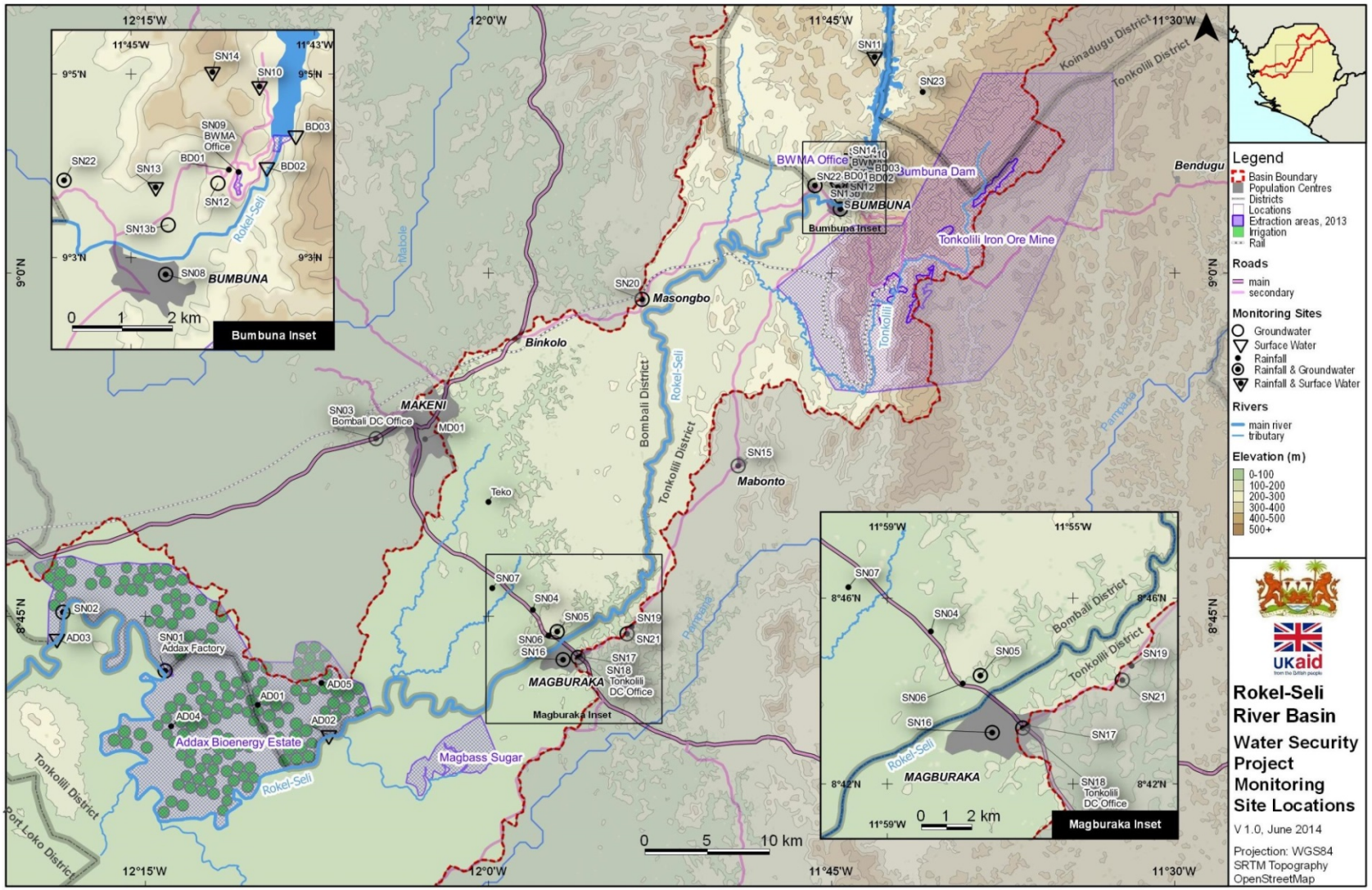
Map 8 Rokel-Seli River Basin –Middle Basin



Map 9 Rokel-Seli River Basin –Lower Basin



Map 10 Rokel-Seli River Basin – Pilot Area and Water Security Project Monitoring Sites



Box 2 The Sierra Leone Water Security Project

The Sierra Leone Water Security Project consists of two work streams, both funded by DFID through its national WASH Facility. The two work streams together facilitate collaboration on water security between the Ministry of Water Resources, the Ministry of Energy (specifically the Bumbuna Watershed Management Authority), a team of specialist consultants from Adam Smith International, and a large number of local and national stakeholders. The two work streams began in late 2012 and early 2013, and completed their initial phases in 2015. The two work streams are considered jointly in these Volumes.

The Water Security Project has the overall aim of '*putting in place the foundations for water security in Sierra Leone*'. Water security means different things to different water users. However, the common feature for all is the assurance of sufficient quantity and quality of water for all the uses to which water is put. This, combined with low risk from water-related hazards (floods and droughts) constitutes water security.

The Water Security Project has been working in the middle reaches of the Rokel-Seli River Basin, the largest and arguably one of the most strategic river basins in Sierra Leone. The Rokel-Seli River Basin contains a microcosm of the water management and water security issues which occur in Sierra Leone. Large-scale hydroelectric power production, mining, urban water supply and irrigated agriculture compete for surface water, while rural and small town populations depend heavily on spring flows, small streams, wells and boreholes for their domestic water supply.

Overall, the Water Security Project has been addressing the following main issues:

- how to begin to re-establish water resources monitoring in Sierra Leone;
- how to most usefully analyse, interpret and present hydrometeorological data;
- how to involve all stakeholders in decision-making over water management;
- how to guide Government as it considers its policies and procedures for national-scale water resources management.

The main written outputs of the Water Security Project are the three volumes, of which this is Volume 1.

Box 3 The Rokel-Seli River Basin, Sierra Leone

The Rokel-Seli River Basin rises in the highlands of the Sierra Leone – Guinea border, in the north-east of Sierra Leone, at an elevation of about 900masl. It runs a total distance of about 390km, discharging into the Atlantic Ocean north of Freetown. The catchment area is estimated as 8236km^2. The mean annual river flow at Bumbuna (measured over the period 1971-78) was 112.9m^3/s or 3,560Mm^3/a. The flow is highly seasonal with mean monthly discharge in September of 330.5m^3/s and in March only 6.1m^3/s.

The Bumbuna hydroelectric power dam is located 2.5km upstream of the Bumbuna falls. It was commissioned in November 2009, although construction had originally commenced in the 1990s. Construction was abandoned in 1997 when the dam was 85% complete, as a consequence of the war. The dam has been operational since 2009. It is a run-of-river scheme, having relatively little reservoir storage despite its 88m high dam and 30km long reservoir. The power plant is rated at 50MW (through two turbines), but it has rarely operated at this level to date. A second dam, Bumbuna II, is under detailed design at the time of writing. It is to be located 28km upstream of Bumbuna I at Yiben, and it will significantly add to the power output of the Rokel-Seli River.

Other major water users / potential polluters in the upper catchment include the iron ore mine operated by African Minerals at Tonkolili and the Magbass irrigation scheme developed in the 1980s.

Further down the catchment Addax Bioenergy abstracts water from the Rokel-Seli River for irrigation of sugar cane, while a number of other mining concessions exist too (including Marampa, near Lunsar, operated by London Mining since 2011).

There are current plans / intentions to extend Freetown's water supply, based on abstraction from the Rokel-Seli River at Makeni Ferry Bridge about 24km upstream of Freetown.

The Rokel-Seli River Basin flows through parts of Koinadugu, Tonkolili, Bombali and Port Loko Districts. Within these districts, rural and small town water supply is needed for domestic use, and the demands for clean water are likely to go on increasing as population grows.

In short, the Rokel-Seli River Basin is a microcosm of all the competing demands for water from rural and urban domestic users, industry, energy and agriculture, together with the risks of water pollution which accompany all these uses. In the absence of well-informed decision-making, water security in the Rokel-Seli River Basin, as elsewhere in Sierra Leone, is at risk.

Introduction

On-going efforts to extend water supply coverage and improve energy and food security in Sierra Leone can only be sustained if water and land resources are understood and managed well. The purpose of the Ministry of Water Resources (MWR) is to lay the foundations so this can be achieved.

Historically it has been perceived that Sierra Leone is exceptionally well watered and future development will not be constrained by water resources limitations. Consequently water resources management has sometimes been afforded low priority compared to the construction of new water supply systems. Over time we have realised we must not be complacent and we need to monitor and manage our water resources in a responsible manner.

Today our groundwater and surface water resources face increased pressures and constant change. Driving this change are supply and demand side pressures that include a growing population and expanding industry. In confronting these changes it is imperative that activities related to monitoring and managing water resources are (re-)established, supported and scaled up in the near future.

This strategy for Water Security Planning is Volume 1 of 3. It describes Sierra Leone's current vision for achieving water security at local, national and transboundary levels. It does not seek to address every aspect of water resources management, rather it paves the way for better water security planning. It describes how we must undertake a transitional approach for water management that will enable government institutions and regulating agencies to build experience and expertise in an incremental manner. It is complemented by two further documents entitled: "Water resources monitoring in Sierra Leone" and "Data and hydrological understanding generated in the Water Security Project". Together these documents form Volumes II and III respectively.

The single overarching message of this document is:

Water supply systems, energy security and food security can only be sustained if water resources are measured, understood and managed appropriately. Sierra Leone recognises that many institutions, from those at community level, all the way through to those involved in international (trans-boundary) water management, have a role in the stewardship of water resources. Sierra Leone will ensure a process of evidenced transition is undertaken, to enable communities, local and central Government as well as regulating agencies to play their part responsibly.

At the heart of this document is our approach for the achievement of the National Water and Sanitation Policy (NWSP) goals related to water resources management. The principles and approaches described in this document draw on practical field experiences and learning generated from the Sierra Leone Water Security Project in the Rokel-Seli River Basin, as well as elsewhere.

This document is of direct interest to Ministries, Departments and Agencies (MDAs) and will provide guidance to regulating agencies, local government, donor partners and implementing agencies (such as Non-Governmental Organisations). This document sits alongside other strategies produced by the MWR that include Rural Water Supply, Small Towns and Urban Water Supply.

Our national policy goals

Sierra Leone has set itself a number of ambitious policy goals for water management to be achieved by 2015. The specific policy targets related to water resources management include the following:

- To revise out-dated legislation and enact a new National Water Resources Law.
- To (re-)establish hydrological monitoring activities leading to the national monitoring networks for precipitation, surface water and groundwater.
- To develop a website and repository for collating hydrometeorological data.
- To establish a regulator for water resources management, termed the National Water Resources Management Agency (NWRMA).
- To develop sustainable and integrated plans for water resources development.
- To ensure water resources are better understood and used efficiently.
- To promote regional and international cooperation on utilisation of trans-boundary water resources.
- To increase utilisation of groundwater resources in a responsible manner.
- To promote sustainable service delivery so that water supply systems (infrastructure) continue to function indefinitely.

The Agenda For Prosperity (A4P), which was officially approved and launched in 2013, similarly recognises the importance of water and land resources management. Together these collective policy targets represent a substantial undertaking. Sierra Leone has commendable ambitions to improve water security for its people, which are evidenced by the creation of a distinct Ministry of Water Resources in 2013, the drafting of a National Water Resources Law and the (re) establishment of hydrological monitoring in 2012. It is vital that a phased transition is now undertaken so that each stage of development builds on and enhances the previous one.

The importance of obtaining accurate and reliable data (information) for improved knowledge and decision-making is frequently overlooked. This oversight needs to be corrected and it should be borne in mind that water availability, in adequate quantity and quality, relative to need should not be taken for granted, even in a country perceived as well watered as Sierra Leone. The following section briefly examines the Hydrology of Sierra Leone.

Water resources and water management

Rainfall

The quantity of water available in Sierra Leone varies significantly from place-to-place and season-to-season. Average annual rainfall (Map 4) varies from less than 2000mm in the drier areas of the north-east of the country to about 2500mm in the southeast and more than 4000mm in the Freetown Peninsula. However a substantial amount of Sierra Leone's rainfall (around half) is lost by evapotranspiration, and the numerous rivers discharge water directly to the sea in the absence of significant abstractions. Today, no one knows with absolute certainty how much internal renewable freshwater resource there are in Sierra Leone. This is because there has been a lack of published monitoring data, and similarly there is limited information on the quantity of surface water and groundwater that is currently abstracted.

This strategy encourages us all to think about the components of the natural water cycle – rainfall, direct runoff, infiltration, evapotranspiration, groundwater recharge and discharge - and our impacts on both the quantities and quality of these components.

The practical steps we will take now include the re-establishment of raingauge monitoring networks combined with improved data collection, validation, analysis and publication to improve understanding, decision-making and appropriate follow up action. This will require substantial resources because the relationships between rainfall, runoff and surface and groundwater resources are complex.

Surface Water

Although Sierra Leone receives high annual rainfall the vast majority of river flows discharge to the Atlantic Ocean unused. This is because Sierra Leone has limited surface water storage (such as dams and reservoirs), no major groundwater aquifers, and relatively small abstractions to date.

Good surface water management will involve the re-establishment of river gauging stations on all major national rivers. There are 12 River Basins and Water Resources Areas in Sierra Leone (Map 1). River Basin areas have recently been redrawn and recalculated using HydroSHEDS software. Three of the River Basins (Great Scarcies, Little Scarcies and Moa) originate in Guinea, while the Mano River Basin originates in Liberia. Sierra Leone is a member of The Mano River Basin Union (along with Liberia, Guinea and Ivory Coast).

A deeper understanding of river flows in both wet and dry seasons is necessary if we are to ensure water availability is consistent with demand. Fieldwork undertaken as part of the Sierra Leone Water Security Project (Box 2) has shown that information contained in some industry Environmental Impact Assessments (EIAs) is not accurate for future planning and design. In some cases it is even misleading. In future, river flow monitoring and a thorough understanding of abstraction regimes will serve to guide forthcoming national development and management.

Our vision for the future includes more flexible abstraction regimes, with enforcement and regulation, so domestic water supplies for rural and urban communities are not threatened by over-abstraction or pollution.

A further requirement for Sierra Leone will be to establish Catchment Abstraction Management Strategies (CAMS) so we can identify how much internal renewable freshwater resources is readily available, how much the natural environment needs, how much is already licensed for abstraction and how much is potentially available for abstraction.

At an international level Sierra Leone is also committed to supporting the principles of transboundary water management through the work of The Mano River Basin Union. As part of our initial contribution we will publish hydrological data and information and provide training and support to build on the success of our initial work on the Sierra Leone Water Security Project.

Groundwater

Groundwater is a vital element of the natural water cycle helping to sustain river levels and inland valley swamps in the dry season. Groundwater is the main source of drinking water for rural communities. However, a water point mapping survey conducted in 2012 identified that water point seasonality is a major problem in Sierra Leone, due in part to the fact that groundwater storage is limited.

Nearly 80% of Sierra Leone sits on geological formations collectively referred to as *Basement Complex* or *crystalline basement* (Map 5). Basement aquifers of significant extent occur across much of sub-Saharan Africa and they are of particular importance because they are characterised typically as having low yield and limited storage. In Sierra Leone development of groundwater sources today is mostly from low yielding hand-dug wells equipped with handpumps.

In future Sierra Leone will need to understand the volume of groundwater abstracted particularly during the dry season months. This will require the establishment of a groundwater-monitoring network and routine groundwater monitoring in water, sanitation and hygiene (WASH) programmes. This requires a small number of monitoring wells to be established in each district, so enabling Sierra Leone to establish and regulate a sustainable groundwater abstraction regime.

Water Quality

The quality of water in our streams, rivers and estuaries is of crucial importance and it is an indicator of how well we look after the environment. Much remains to be done to establish a routine water quality monitoring programme. Furthermore we still have significant water quality problems to address.

Sources of pollution include widespread open defecation evidenced by the fact that sanitation coverage rates remain disappointingly low, only 22% and 7% for urban and rural areas respectively according to JMP 2014 statistics; and no functioning sewage treatment works exist in Sierra Leone. Water resources are at risk from pollution as a result of mining activities and the use of pesticides in commercial agriculture. Physical changes to land and watercourses as a result of farming or artisanal mining also have an adverse impact. Over-abstraction of river flows can also concentrate pollutant loadings.

To address these gaps Sierra Leone will look to establish a national surface water and groundwater quality monitoring programme, focusing on key water quality parameters that Sierra Leone can address. In the long term our goal must also be to reduce the amount of pollution entering the

environment from open defecation, illegal discharge of sludge tankers, and from major industries that are not taking the necessary safeguards to prevent discharges and pollution from their operating sites. The Government will enforce new water resource management laws and make the case for effective regulation. Charges for pollution will be introduced to cover the costs of recurrent monitoring and any necessary treatment. Both the National Water Resources Management Agency and Environmental Protection Agency will work with companies to address these issues.

The challenge

The achievement of sound water resources management is difficult, requiring substantial resources and expertise. This is especially true in Sierra Leone because we need to overcome the pervasive obstacles of limited finance, weak government institutions, inadequate water infrastructure and high inter-annual seasonality.

Much of Sierra Leone's water supply and water resources monitoring infrastructure was destroyed during the decade long civil war (1991 – 2002). Before the war significant networks existed for the collection of meteorological and hydrological data (Annexes A and B). Institutional knowledge and historical data were lost, and over the past decade consideration for groundwater and surface water resources has lagged behind efforts to extend water supply coverage. Sierra Leone is now promoting the importance of both *resources* and *service delivery* aspects if sustainable water supply systems are to be delivered and sustained.

We must also debunk a past misconception that Sierra Leone's future development will not be constrained by water resources limitations. We can expose this misunderstanding by considering the following: The United Nations Food and Agriculture Organisation (FAO) has previously estimated Sierra Leone's internal renewable freshwater resources as 160km^3/a. This is almost certainly a gross over-estimate (given that the mean annual rainfall of 2,526mm amounts to 181km^3/a, and the difference, 21km^3/a, would be a serious under-estimate of evapotranspiration). The true figure for renewable freshwater resources is probably in the range 60-100km^3/a. Matching our constantly improving understanding of the quantity and quality of water resources to the demands for water and the pollution pressures on the resource is the key to sustainable development.

Our changing environment

There are five main environmental problems taking place in Sierra Leone: -

Population Growth: First, the rate of population growth and urbanisation in Sierra Leone is not insignificant. Today the national population is estimated at around 6 Million with an annual growth rate of 2.33%. This implies that Sierra Leone's population is doubling every 42 years. Within these figures there are some clear trends, such as an increase in the rate of urbanisation, increased water demands and continued encroachment on catchment areas. Population growth increases pressures on food, energy, water and shelter and can potentially lead to competing water demands between different water users, such as domestic users, farmers, commercial agriculture and mining companies. In the absence of adequate sanitation facilities and sewage systems it will also lead to widespread pollution of the environment including land water and soils.

Land Degradation: The second evident impact of a growing population is the resultant impact on land and soil resources. More people need more space and more natural resources. Pollution and contamination from industry is also increasing. Iron ore mining activities result in deforestation, loss of vegetation, soil erosion and contamination of surface water resources. Artisanal gold- and diamond-mining along riverbanks also creates similar issues albeit on a different scale. This has an adverse impact on neighbouring communities, particularly those that are engaged in farming. On a

national scale Sierra Leone needs to substantially increase its exports and energy production, but we also have to deal with the environmental impacts of human activity.

Energy Security: Sierra Leone's Hydro-Electric Power (HEP) potential remains largely untapped. Of a total estimated capacity from large rivers of 1500 MW[1], less than 25 MW is generated at present and the Bumbuna Hydro Electric Power (HEP) Plant has failed to reach its 50MW capacity. A lack of published river flow data also poses a genuine risk to Sierra Leone's water and energy security. For example, the planned Bumbuna II HEP Plant has recently downgraded its energy projections because of a lack of river flow data. Today 80% of energy produced is consumed by the industrial and mining sub sectors with energy costs remaining prohibitively high for the poorest households and communities.

Commercial agriculture systems, such as Addax Bioenergy[2] (see Map 10), provide an alternative source of power in the dry season months, but the production of sugar cane requires substantial amounts of water for irrigation especially in the dry season when river flows are at their lowest. In Sierra Leone today the challenges of sustainable development are still water-based, but more complex due in particular to energy demands for big businesses (agriculture and mining) and urban population growth. Responding to these challenges the MWR will work closely with the Ministry of Energy to ensure individual energy projects are coordinated so they minimise impact on river flows and water security.

Water Demands: Next, water is in growing demand as a result of population growth and expanding industry. A critical issue, evidenced by fieldwork in the Rokel-Seli River Basin, is to understand the collective water demands on dry season river flows and groundwater resources. The MWR recognises that some of the current abstraction licences have been agreed based on a rudimentary understanding of average river flows, which inadvertently masks the impacts of dry season water demands. This approach is unhelpful and will be addressed.

Seasonality of groundwater levels is also evident across Sierra Leone, as demonstrated in the 2012 waterpoint mapping survey (WSP, 2012). Water point seasonality leads to communities collecting water from distant unprotected surface water sources. Some rivers, such as the Tonkolili, have also suffered increasing levels of water pollution and may cease to flow in the future unless substantial safeguards are put in place. Coastal waters may also be put at risk from continued uncontrolled discharges to rivers. To improve this situation the MWR has worked hard over the past 18 months to foster greater collaboration with our important industry partners.

Climatic Variability: Finally, Sierra Leone experiences high seasonal climatic variability, with the majority of rain falling between the months of May and November. Mean annual rainfall is thought to have decreased since 1960 but it is unknown whether this is part of a long-term trend or regional variability (McSweeney et al, 2012). The key challenge for the nation is to manage dry season water demands (December - April) in the absence of significant surface water storage or major aquifers.

Climate change exacerbates these difficulties further, particularly in the sense of increased climatic variability between rainy and dry seasons. However, climate change, whether it is anthropogenic

[1] http://www.smolpawa.com/current-projects/sierra-leone

[2] The Addax Bioenergy plant aims to produce 32MW power once production commences fully in November 2014 with 17MW being supplied to the national grid.

(man-made) or natural climatic variability, should not be viewed as a "stand-alone" risk. Rather it should be viewed as one of multiple risks to water resources.

The most fruitful approach for Sierra Leone is to build resilience to floods and droughts and ensure water supply infrastructure continues to serve rural and urban populations continuously without interruption. The 2012 mapping of water points revealed that 51% of improved water points provide water on a seasonal basis only. Such shortcomings cannot be attributed to climate change but instead are a reflection of weaknesses in implementation in the water supply and sanitation sector. Sound monitoring and management of water resources will only serve to strengthen resilience to climate change (and other) risk factors. They will also ensure that Sierra Leone has intelligent, analysed information for better decision-making.

When designing water resources projects, it is important that organisations address real problems, rather than coming with pre-determined solutions. "Blueprint" solutions or "best practices" designed elsewhere may not be fit-for-purpose and fit-for-context in Sierra Leone. The design of solutions must begin with a rigorous analysis of the problem and the context, so that the result addresses a real need in a realistic manner.

Consequences

Looking ahead it is evident that Sierra Leone's water resources face constant and growing pressures. Water demands between competing water users will increase and rivers, streams and groundwater will remain highly seasonal and vulnerable to pollution. Efforts will be needed to understand collective demands on water resources (particularly dry season flows) and points of pollution will need to be identified and addressed through robust legislation and regulation.

The Rokel-Seli River Basin (Box 3) represents a microcosm of water issues in Sierra Leone and provides a good lookout for the challenges that will need to be addressed in future. It is clear that none of us should be complacent over water security in Sierra Leone and we must ensure that monitoring and management of water resources solves real water management problems on the ground. Sierra Leone is committed to ensuring that environmental considerations are brought into the centre of decision-making.

The response

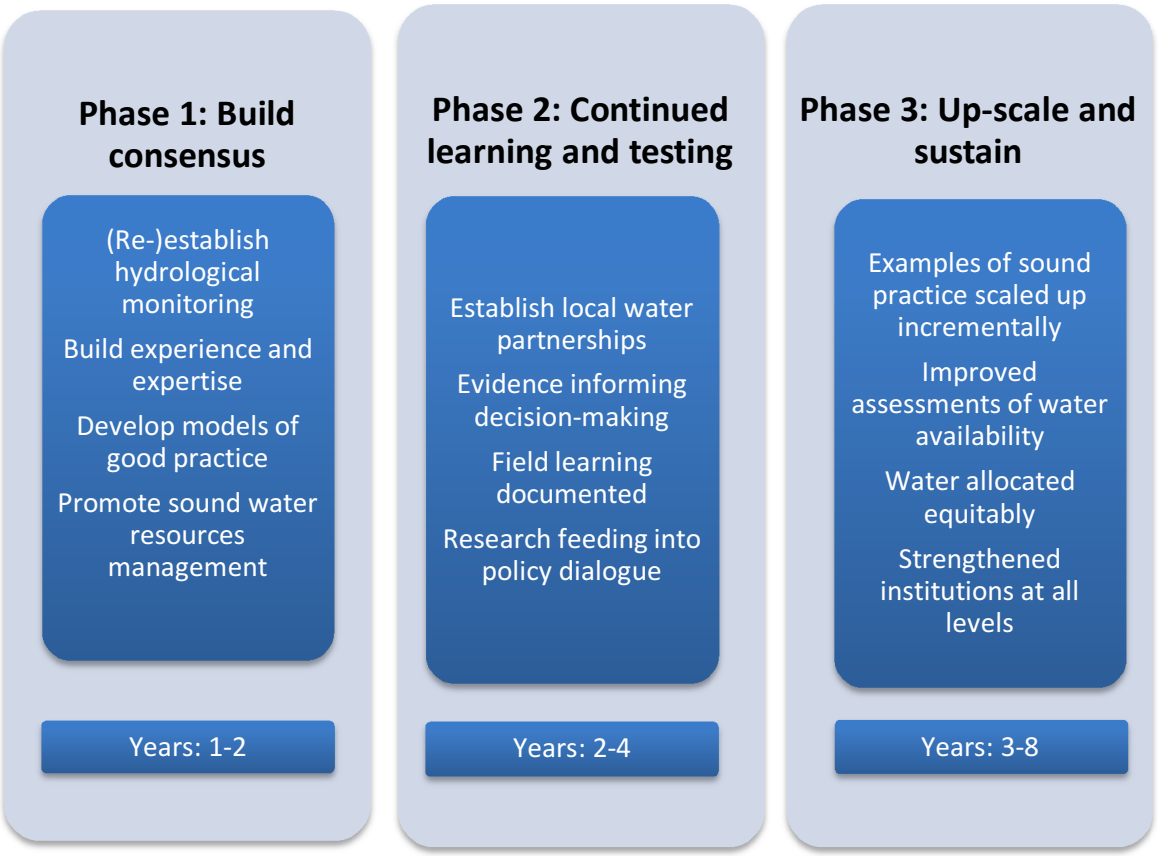
Since 2011 Sierra Leone has worked hard to build bridges between water resources policy, law and practice. These important components are each discussed in turn below.

National policy

Our national policy targets represent a significant undertaking, and our commitment to bring about water, food and energy security for the people of Sierra Leone. We have undertaken in-depth analysis to identify how our overarching policy targets can be applied in practice. This revolves around a shared perception of the need for sound water resources monitoring and management, carrying out extensive research on the current state of water resources management in Sierra Leone and developing the evidence that will inform future actions of government and regulators. Since 2012 our work to date has focused on building consensus, testing and learning. In the coming months and years our aim is to scale up and refine these initial approaches across the nation.

The approach we are promoting is set out in Figure 1. Our philosophy is to start small and build experience and expertise of government institutions in an incremental manner. The approach initially adopted allows for a process of examination and (re-)examination and has been proposed in favour of an exclusively top down approach that is reliant on foreign "blueprints" for water resources management.

Figure 1: A phased approach to national water security



Phase 1: focuses on (re-)establishing hydrological monitoring and laying the foundations for sound water resources management. It revolves around developing models of sound practice that can be replicated and scaled up incrementally. In practical terms this has meant establishing the Sierra Leone Water Security Project within the Rokel-Seli River Basin starting in October 2012. At the end of Phase 1 the aim is to share learning experiences and provide guidance to other organisations that plan to undertake some form of water resources monitoring and management. MWR recognises the importance of using evidence to inform strategy and guidance.

Phase 2: revolves around continued learning and documenting experiences to scale up water resources monitoring and management activities. It also aims to address issues and challenges that will inevitably be encountered. These include ensuring monitoring data is routinely collected, analysed and published, reducing the recurrent costs of monitoring and establishing local water partnerships, termed Catchment Management Committees and River Basin Boards. Our continued learning and testing will also be supported by the enactment of the water resources law and laying the foundations for the establishment of the NWRMA.

Phase 3: in this phase the aim is to ensure continued and sustained improvements for water resources management. Scale should emerge through incremental improvements, evidenced learning, strengthened institutional capacity and continued and assured funding. The MWR will be the driving force behind this process and will be responsible for ensuring sustained improvements at local, national and transboundary scales. We will identify the necessary finance and delivery mechanisms to achieve water security at national and transboundary levels so that management committees can play their roles effectively.

The timeline envisaged for these separate but inter-linked phases reflects the challenging nature of this work and Sierra Leone's broader desire to bring about water security for all communities and households across the country.

Water resources legislation

In 2011 – 2012 the then Ministry of Energy and Water Resources worked in partnership with other MDA's to redraft out-dated water resources legislation. A working partnership was established with a number of organisations that included the Environmental Protection Agency (EPA), Ministry of Local Government and Rural Development and Ministry of Agriculture, Farms and Food Security. A law working group was formed, a water management issues paper was published and five public presentations at national and regional levels were organised. This important work has been continued by the MWR and at the time of writing the revised water resources law is set before Parliament awaiting final approval.

New water resources legislation will pave the way for the establishment of a new regulatory body, the National Water Resources Management Agency, that will have oversight of the nation's water resources. In turn it will support the creation of River Basin Boards at national scale and smaller scale Catchment Management Committees that enable river basins to be divided into smaller management units. This is important because it enables water issues to be resolved locally. New legislation and regulation will also encourage the collation, analysis and publishing of a large body of

scientific hydrometeorological data that will support future planning and decision-making. This information will be housed here: www.salonewatersecurity.com

Practical application

In relation to the practical application of water resources management the MWR has identified a number of overarching principles that must be applied. These principles (described below) are flexible and can be adapted to local context. However, they set out a number of important elements that need to be recognised and addressed within all water resources management programmes. Collectively they will ensure water resources are monitored and managed at the lowest most appropriate level in accordance with the principle of subsidiarity. The approach identified also encourages schools and communities to become "observers," "monitors" and "stewards" of water resources across Sierra Leone.

Practical field level activities began in the Rokel-Seli River Basin in October 2012. Fieldwork has contributed to the (re-)establishment of hydrological monitoring in Sierra Leone, albeit in a limited geographical area so far, and has assisted in building institutional capacity at local and central Government levels. The approach adopted has deliberately been one of "learning by doing" to innovate and adapt water resources management actions and equipment based on local contexts and experiences. This approach differs to conventional water, sanitation and hygiene (WASH) projects that are often bounded by quantitative output construction targets. This distinction is important because it is unlikely the outcome of any water security project will be known from the outset. Consequently a flexible approach is required that allows the impact of activities to be continuously examined.

This fieldwork and the learning generated represents the beginning of our ambition to promote the importance of sound water security planning. We must do this by demonstrating our leadership nationally. As part of this process the MWR identified a number of overarching principles that are considered important to the achievement of water security.

Overarching principles

In our experience successful water resources management requires a number of mutually compatible factors to be in place(Figure 2). Together they summarise a number of important factors, which are evidenced in the literature, and which are reviewed in the following parts. The guiding principles are built around the logic that if these important factors are addressed there is a much better likelihood of programme success. The following section describes these principles and sets out how they can translate into some practical action on the ground.

Figure 2 Water security principles

Principle 1: Participatory monitoring

The first essential element is that the quantity and quality of the resource are known and this information is accessible. The availability (quantity) and condition (quality) of groundwater and surface water resources can only be determined if water resources are monitored (measured). Volume 2 describes how this work can be undertaken. The assessment of water availability is normally based on historical data and on site technical investigation. However, in the context of Sierra Leone many historical monitoring records have been lost, and water resources monitoring infrastructure was destroyed during the civil war (1991-2002). In response to these challenges the MWR has worked hard to rediscover[3], document and publish historical monitoring records. Another immediate priority for the MWR has been to (re-)establish hydrological monitoring and rebuild capacity to undertake monitoring. This work has already commenced in the Rokel-Seli River Basin and over time, and with experience, central and local level institutions will have the ability to assess the resource and identify what institutional measures it would take to safeguard water resources in terms of quality and quantity (Volume 3).

[3] The Sierra Leone Hydrological Year Book (1970 – 1976) was recently discovered by the MWR.

Many institutions have a role to play in monitoring and managing water resources. These include communities and schools, major water abstractors (such as farmers, commercial agriculture and mining companies), local councils, central Government authorities, implementing agencies (NGOs) and those organisations engaged in transboundary water resources management. Fieldwork conducted in the Rokel-Seli River Basin from 2012-2013 has shown that communities and schools can play their part responsibly and collect hydrological monitoring data with reasonable degrees of accuracy. Furthermore monitoring equipment does not need to be overly complex involving the use of telemetric or automated monitoring systems.

The MWR will work with other organisations to identify and pursue interests in hydrometeorological monitoring. It should be borne in mind that WASH organisations can and should engage in some form of local level hydrological monitoring. This is almost always a missing component of conventional WASH programmes. In future it is important that the following hydrological parameters are measured:

- Rainfall
- Groundwater levels
- Stream flows
- River flows
- Abstraction rates for submersible and mechanised pumps
- Water quality including discharges to surface water and groundwater resources

Principle 2: Institutionalise monitoring

The MWR and Sierra Leone Meteorological Department are providing clear leadership to help ensure the process of monitoring is institutionalised. A learning forum held in December 2013, devoted to coordinating monitoring activities in Sierra Leone, revealed that a commitment to undertake hydrometeorological monitoring is not sufficient unless the process of monitoring is systematised. This means that monitoring data needs to be collected, cleaned, validated, analysed and published so that it serves a real purpose. To that end the installation of monitoring devices must translate into published monitoring data, improved decision making and appropriate follow up action.

The learning forum, organised by the MWR, drew attention to the current focus of many funding proposals for monitoring programmes on instrumentation and technology. There is often much less consideration for how monitoring equipment will be maintained and institutionalised so that monitoring data serves a real purpose. In future the MWR and Sierra Leone Meteorological Department will provide the platform to ensure these issues are addressed. We will continue to play a clear role by outlining four important considerations. First, the recurrent costs of surveying, installing, retrieving, cleaning, analysing and publishing monitoring data need to be calculated and understood with hard-headed reality. This is an obligation of both the donor and implementing agency. Second provision must be made for the logistical and equipment resources required and these must be proportional to the amount of monitoring equipment to be installed. Third, continued training and institutional support is required to ensure data collection, verification and analysis becomes routine. Fourth, the outcomes of published monitoring data must lead to

improved decision-making and appropriate follow up action. Government, donors and implementing agencies must all take responsibility for ensuring these issues are addressed from the outset of any investment in improved water resources monitoring.

Principle 3: Manage water locally

Principle 3 recognises that water matters need to be resolved locally through a process of local monitoring, collaboration and dialogue. Our commitment to this approach is evidenced in the revised water resources law that proposes the establishment of smaller management units in the knowledge that river basins across Sierra Leone are large and complex. The MWR recognises that water and its management have important local dimensions and water challenges need to be resolved by local stakeholders with effective external support from local and central Government.

National and regional water security plans should be developed from local level (grassroots) initiatives. Sierra Leone is developing a "bottom up" approach and this methodology is important because it also enables government institutions and agencies to build capacity in an incremental manner based on evidence and field experience. Water resources management should not be undertaken for its own sake - it is vital that real water management issues are addressed through locally available information and through dialogue between local stakeholders.

Principle 4: Establish water partnerships

Water partnerships need to be formed involving all interested and relevant local stakeholders. Such partnerships can be used to understand and mitigate risk to water security. They should directly involve a diverse range of participants including community members, paramount chiefs, farmers, major water abstractors, local utilities, dam operators, local and central government agencies. Extensive effort is required to ensure water partnerships are balanced, and their formation should be facilitated through training and technical advice. Understanding the priorities and water security requirements of each stakeholder is an important prerequisite to build trust and reach consensus on how water should be allocated and managed. Local meetings must lay the foundations for all stakeholders to jointly plan and ensure appropriate action that leads to sound water resources management plans. Decisions must be informed by an improved understanding of local hydrology as a result of effective monitoring. To that end "evidence" should precede "decision-making".

In Sierra Leone local water partnerships at catchment, river basin and national level also serve as a vehicle for enacting the National Water Resources Management Act 2014. Partnerships can serve as a platform for jointly analysing and discussing monitoring data and for resolving water disputes. The existence of multiple water partnerships will also serve to promote interaction and dialogue between stakeholders, as well as acting as a structure for coordination, training and decision-making. This important process has already begun in the Rokel-Seli River Basin and includes direct discussions with Koinadugu, Tonkolili, Bombali and Port Loko Local Councils, as well as representatives from industry and local communities.

Principle 5: Negotiate water allocations

One of the main purposes of forming local water partnerships is to ensure there are agreed arrangements in place for sharing (allocating) water between different users. Experiences from the Rokel-Seli catchment highlight three particularly important considerations that need to be addressed when undertaking water allocation negotiations. The first is that a robust understanding of local hydrology is required. In particular, dry season river flows and groundwater levels need to be assessed against collective demands. Second, dry season river flows give cause for concern. Assessments of water demands against average annual flows are not particularly useful and mask the natural seasonal variability in flows. In future, critical demands need to be assessed in relation to varying water availability. The third important consideration is that domestic water supplies for urban and rural populations must be prioritised. Government must also ensure that local communities have a *seat at the table* where the bargaining process takes place.

Principle 6: Establish water laws and byelaws

Sierra Leone's water resources are experiencing increasing demands and pressures, yet at the time of writing, no effective water resources laws and regulation exists in Sierra Leone. The MWR is addressing this issue as a matter of national importance.

Water laws and byelaws define the "rules of the game" for water management. Once the new water resources law has been passed the MWR is committed to ensuring the law can be translated into day-to-day operational practice for the allocation, distribution and protection of water resources. The law will provide the enabling environment for establishing a regulatory agency as well as smaller management units at river basin and catchment scale. The MWR is mindful that multiple stakeholders have a role to play in applying laws and policing water usage on a daily basis. Government will therefore support the creation of local water management byelaws so that the laws and rules for daily water management can be applied locally.

Principle 7: Establish a regulatory agency

The National Water and Sanitation Policy (2011) and Water Resources Act (2014) both define the need for a single independent regulatory authority to maintain oversight of water resources in Sierra Leone. The role of the regulator is to establish regulations to safeguard surface and groundwater resources. Examples include: registering abstraction points, issuing water permits, defining water rights and imposing fines for over abstraction and pollution.

However even with the best of intentions it will take some time for the agency to become fully established. An immediate priority will be to ensure the new regulator can perform essential functions consistently. Effective regulation will therefore only be possible in the short to medium term through self-regulation (policing) with support from local stakeholders. This will require local water partnerships to establish water resources management plans, which involve local stakeholders. These localised management plans will focus on minimising over abstraction of surface water and groundwater resources (particularly in the dry season months) and reducing overt pollution. The agency will be responsible for reviewing and approving these management plans and

providing continuing external support and guidance. In the short term the NWRMA will prioritise site inspections and engagement with major water abstractors and polluters.

Principle 8 Improve water supply

The achievement of water security for all requires a strong link between water resources and the services provided by those resources. In order to safeguard water resources, water supply systems must supply water efficiently and water must be managed in the various components of the water cycle. The MWR will continue to foster close collaboration with sector partners who are engaged in delivering water supply services. To that end we will work with water utilities and water plant operators to undertake effective water security planning. This will require water utilities to complete assessments of future water demands that include future projections for water usage. In time we will also develop catchment management plans that include options for increased retention of surface runoff, coupled with assessments of water availability. It is also clear that much more needs to be done to ensure water can be supplied efficiently so losses and non-revenue water can be minimised.

There is also a requirement to increase engagement with the WASH sector. To date the water supply and sanitation sector has engaged relatively little in water resources management. This is largely because it is assumed that domestic water supplies (boreholes and piped water supply systems) are not constrained by water resources limitations. Many NGOs and UN agencies implement water supply programmes on a limited scale. But their involvement in water resources management in Sierra Leone is important for two reasons: first, community water supplies will come under threat if there is no consideration for the groundwater or surface water resources that sustain them. Second, given the challenges faced by government institutions the recurrent costs of monitoring and managing water resources can be reduced significantly if implementing NGOs play their part in monitoring and managing risks to water resources.

What will this mean for you?

This section addresses the question of how this strategy and the Ministry's early field experiences are relevant to other organisations that plan to undertake some form of water resources monitoring and management.

For donors

You will have an opportunity to invest in new water security programmes that will help (re-)establish national monitoring networks and develop national water security plans. To that end we encourage:

- Long term support for water resources monitoring and management activities;
- Support for institutional capacity building;
- Flexible approaches that recognise water resources management projects need to examine and (re-)examine what does and does not work;
- A better balance between the capital and recurrent investments associated with (re-) establishing national monitoring networks;
- Programmes that recognise multiple pressures on water resources in addition to climate change;

For NGOs and UN agencies

You will be able to play an active role in innovation and research by engaging in water resources management activities. GoSL recognises that NGOs and UN agencies can make a significant contribution to local and central level water management activities. Some examples are highlighted below:

- Monitoring groundwater levels and rainfall in selected parts of your working areas in partnership with Local Councils;
- Understanding how groundwater seasonality varies spatially;
- Measuring spring and stream flows before and after the construction of spring boxes;
- Recognising that sustainable community water supplies are dependent on sound stewardship of water resources. Water quantity (availability) needs to be considered alongside water quality;
- Preventing water pollution by promoting safe sanitation and ensuring all components of a sanitation system are considered including the collection, removal, transportation, treatment, disposal and reuse of human sludge;
- Ensuring people's concerns over water security are addressed through robust analysis of water resources, effective siting of water points and good quality water supply infrastructure.

For water utilities

You will be supported and empowered to undertake the following:

- Thorough risk assessments of pressures and future demands that affect water supply operations. This includes factors such as encroachment on catchment areas and levels of pollution;
- 5-year cyclical projections of water demands and abstractions. These detailed assessments will need to be submitted to the National Water Resources Management Agency for approval;

- Collect evidence (through monitoring) to ensure that abstraction and discharge licenses are being adhered to;
- Commit to ensuring water supplies are delivered efficiently with reduced leakage and wastage and increased revenue generation.

For industry

You will be able to operate in a much more professional working environment that encourages sound stewardship of water and land resources for the benefit of all. In future government will work with industry in a collaborative manner to ensure that:

- All major water abstractions and discharges are monitored and all reasonable efforts are made to adhere to agreed environmental standards;
- Any necessary corrective action is undertaken within agreed timeframes;
- A culture of openness and transparency is established for sharing hydrometeorological data in agreed formats;
- National environmental and monitoring standards are adhered to;
- Where abstraction rates have been erroneously assessed these will be revised accordingly, particularly for assessing impacts on low river flows;
- Current and future water abstraction demands will need to be submitted well in advance of the onset of the dry season.

For local councils

The Ministry of Water Resources will work closely with the Sierra Leone Meteorological Department and all MDAs and local councils in delivering our vision for improved water security planning. In 2015 MWR will establish an Inter Ministerial Committee to coordinate activities that impact on land and water resources. We will work with international donors to ensure that local councils have the resources and equipment to engage in practical monitoring and management activities, building on the water security training delivered in 2013 and 2014.

For communities

We recognise the importance of meaningful engagement with community-based institutions (such as farmers and growers) and schools in monitoring and managing water resources. Our experiences in the Rokel-Seli River Basin have already demonstrated that communities and schools can play an active and participatory role in collecting rainfall data. We will encourage continued participation by interested community based institutions, while at the same time ensuring that sound water resources management leads to subsequent improvements in people's livelihoods and community water supplies.

Action

The MWR has selected eight priorities or minimum commitments considered fundamental to ensure that water security is achieved for the people of Sierra Leone. The MWR will work in partnership with all local and central Government departments and regulatory agencies to ensure these commitments are applied in practice over the coming months and years.

Our eight minimum commitments
1. Provide sector Leadership
2. (Re-)establish and institutionalise national hydrometeorological monitoring networks
3. Review current abstraction licences and improve water allocation
4. Enact the National Water Resources Law
5. Increase funding for monitoring and managing water resources
6. Establish a National Water Resources Management Agency
7. Improve water resources and water supply infrastructure
8. Document field experiences and scale up

Each of these important components are discussed in turn:

Provide sector leadership

The Ministry of Water Resources, in collaboration with other MDAs, will: -

- Clarify roles and responsibilities for water resources management in Sierra Leone;
- At national level the MWR will establish collaborative working partnerships with other key MDAs whose activities impact on water resources. This includes the Sierra Leone Meteorological Department and EPA.
- Commit to a decentralised approach for water security planning that applies the principle of subsidiarity – solving water issues at the lowest most appropriate level. At local level MWR will set up water partnerships that are designed to generate interest and a shared commitment to collective water security across key stakeholders (such as industry, local government, farmers and local communities).
- Advocate for increased and assured funding for water resources management and in particular for local council budgets to have funds set aside for activities that directly support monitoring and management of water resources.
- Promote the importance of water security planning by publishing strategy documents and guidelines that are informed by field evidence and experiences.
- Create the enabling environment for water security planning in Sierra Leone by engaging with international donors and sector partners to generate interest and willingness to engage in water resources monitoring and management activities.
- Form collaborative working partnerships with industry.

(Re-)establish and institutionalise national monitoring networks

Our approach to (re-)establishing hydrological monitoring is built on the premise that monitoring must lead to the publication of analysed data, increased knowledge for decision making and appropriate follow up action. A great deal of time and effort can be expended on procuring, programming, installing, retrieving and cleaning monitoring data. However, unless the analysed data is used it will serve little purpose. On the issue of hydrological monitoring the MWR will: -

- Coordinate the establishment of national hydrometeorological monitoring networks, working alongside the Sierra Leone Meteorological Department. See Maps 2, 3 and 5 in this document for current proposals for river gauging, meteorological and groundwater monitoring networks.
- Require all funding organisations to quantify and establish the responsibility for the recurrent costs associated with hydrometeorological monitoring.
- Develop standards for hydrological monitoring in Sierra Leone.
- Ensure instrumentation and technology choices are proportional to institutional budgets and capacities (Volume 2).
- Encourage monitoring "gap filling" to be undertaken. If particular information or studies are required, for example for the design of water supply systems (such as the Rokel Water Supply Project or small towns water supply systems).
- Encourage WASH organisations to engage in some form of hydrological monitoring (such as rainfall and groundwater levels). This information is important because it will contribute to efforts to map national groundwater resources and it will encourage implementing agencies to address water security issues within conventional WASH programmes.

Review current abstraction licenses and improve water allocation

In the past water abstraction licenses have been granted without a robust understanding of water availability. To ensure water allocation is equitable the MWR will:

- Form collaborative working relationships with all major water abstractors.
- Ensure Environmental Impact Assessments and water abstraction agreements are based on a thorough understanding of dry season river flows and groundwater levels.
- Take active measures to ensure major water users monitor abstraction rates and discharges.
- Where water availability (quantity and quality) information is missing we will work to ensure monitoring information is captured and abstraction rates do not exceed water availability.
- Ensure appropriate institutional arrangements are put in place to maintain water availability for all water users, with domestic water supplies and water for small-scale farming being prioritised.
- Strongly encourage all major water abstractors to share collected data so it leads to better decision-making.

Enact the National Water Resources Law

To enact the National Water Resources Law the MWR will ensure that:

- All attempts are made to brief MDAs, industry, local Government, farmers and local communities to increase knowledge and awareness of the new water resources law.
- Best practices are applied to improve stewardship of water and land resources across Sierra Leone.
- Systems for issuing abstraction permits and discharge licenses are established and functioning.

- Catchment Management Committees and River Basin Boards are established in the major River Basins across Sierra Leone.
- Local magistrates have knowledge and understanding how to apply the new water law.
- Revenues generated through abstraction licenses and fines are handled in a transparent and accountable manner.
- The NWRMA is adequately equipped, staffed and resourced so that water resources law is meaningfully applied.
- Effective arrangements are put in place to ensure the law is applied and enforced through effective regulation that holds water polluters and over abstractors to account.

Increase funding for monitoring and managing water resources

To attract increased and assured funding for water security planning MWR will: -

- Coordinate development partners to avoid duplication of activities and to encourage organisations to work to the MWR vision and strategy.
- Encourage donors to support recurrent monitoring costs.
- Advocate for increased budgets for water resources monitoring and management activities.
- Support local councils to receive finances in a timely manner for local level water resources management.
- Attract new investment for water security planning from international donors.

Establish a National Water Resources Management Agency

In establishing a national regulator for water resources the MWR will ensure that: -

- A regulator is established, equipped and resources so that it can perform basic functions consistently by the end of 2016.
- A large body of scientific data is collated that will support decision-making by the NWRMA.
- Systems are established that will support issuing of water permits and discharge licenses.
- Standards for the use of water resources are established by 2015 that comply with international best practice.
- The regulator works directly with River Basin Boards, Catchment Management Committees and local communities so that regulatory and self-regulation approaches can be effectively applied.
- River basin and catchment management plans are in place for two major river basins by the end of 2015.

Improve water resources and water supply infrastructure

MWR recognises the importance of linking water resources management with subsequent improvements in water supply infrastructure. In relation to improving the efficiency and sustainability of water supply services MWR will ensure that: -

- Thorough river flow and feasibility assessments are conducted for the Rokel Water Supply Project.
- A hydrogeological assessment is undertaken for the Western Area of Freetown.
- Improvements in community water supply and sanitation services are undertaken for those schools and communities which are engaged in some form of hydrological monitoring.

- Ensure best practices are followed by the WASH sector to deliver rural water supplies in an efficient and sustainable manner.
- Catchment protection plans are developed by water utilities for piped water supply systems, serving small towns, regional capitals and Freetown.
- River flow data is collated and published in a timely manner.

Document field experiences and scale up

The MWR is adopting a "learning by doing" approach to water resources management. In relation to sector learning therefore the MWR will ensure that: -

- Periodic studies are undertaken to identify what approaches work for monitoring and managing water resources.
- Studies are documented and published widely and active measures are taken to engage interested stakeholders in debate and reflection.
- Important studies contribute to sharing experiences on the Sector Learning website.
- Research findings are presented at national and international conferences and engage others in debate, reflection and learning.

Implementation

In this strategy we have set out a number of priority actions. Delivering on them will be vital to achieving our vision of water security for all.

As Government is committed to strengthening water security planning we will take proactive measures to engage with industry, implementing agencies, local councils and other MDAs.

The MWR will set up an Inter-Ministerial Committee and will appoint two key individuals to foster partnerships with other MDAs. The composition of the Inter-Ministerial Committee will be worked up during the first quarter of 2015 ready for full commissioning of water security activities in 2015.

This strategy document will be launched in Quarter 1 of 2015 alongside Volumes 2 and 3. To make sure the implementation is as strong as the ambition, we will roll out learning from the Sierra Leone Water Security project across the country. The publications will also be made widely available. To enable the public and interested groups to access information we will also launch a website (www.salonewatersecurity.com) that will serve as a source of information and a data repository. In time it will transition to form the public website for the NWRMA.

In support of the regulating agency we must succeed in (re-)establishing national hydrometeorological monitoring networks and translate raw data into intelligent, analysed information that is published, communicated and applied. It is also imperative therefore for us to create the environment where there is an appropriate balance between capital and recurrent investments. We want all donors and implementing agencies to ensure their programmes are proportional to the levels of institutional capacity and professionalism that exist. This principle will be pursued, as we create national monitoring networks.

Finally, in 2015 we will engage with as many stakeholders as possible to listen and understand what water security concerns people have. We need to ensure engagement with industry, major water abstractors, communities and water sector professionals so we can plan and revise our strategy and guidelines accordingly over time.

Measuring Progress

Key to making progress on water security matters is to set some clear milestones for progress over the next 12 months, while at the same time establishing a robust and flexible approach.

In relation to setting realistic targets the Ministry of Water Resources will: -

- Ensure roles and responsibilities for water resources management are understood and adhered too.
- Require all implementing agencies and donors to coordinate their activities with the national hydrometeorological monitoring networks proposed for precipitation, surface water and groundwater.
- Ensure that additional monitoring fills gaps in knowledge that currently exist, based on river basin priorities.
- Insist that all actors understand the recurrent monitoring costs that will be incurred and make appropriate arrangements to ensure government institutions have adequate capacity.
- Publish hydrological monitoring data annually so assessments of water availability are widely known.
- Review current water abstraction agreements, as necessary, based on an improved understanding of local hydrology.
- Ensure the enactment of the water resources management law is documented.
- Identify opportunities to improve and upgrade water resources management infrastructure (such as ensuring efficient service delivery).
- Encourage all WASH sector actors to contribute to national water security planning by engaging in monitoring and management activities.
- Commit to working in a collaborative manner with industry.
- Document field learning and publish the outcomes of discussions held at local water partnership meetings.
- Ensure that adequate financial, technical and logistical support is provided to establish the National Water Resources Agency.
- Ensure the NWRMA can perform essential functions routinely.

References

Akiwumi F. (1994) reducing costs of monitoring networks in developing countries by collation and analysis of pre-existing hydrogeological data. Future Groundwater Resources at Risk (Proceedings of the Helsinki Conference. June 1994). IAHS Publication 222. 481-490.

Geological Survey of Sierra Leone (2004) Geological Map of Sierra Leone. Map reproduced from Koidu Holdings web site. http://www.koiduholdings.com/images/kkp_geology_fig1_large.jpg (photographed image)...accessed on 1 March 2014.

Government of Sierra Leone (2012) The Agenda for Prosperity, road to middle-income status http://www.sierra-leone.org/Agenda%204%20Prosperity.pdf last accessed 9th February 2015.

Gregory, S (1965) Rainfall over Sierra Leone. Research Paper, Department of Geography, University of Liverpool. The Acorn Press, Liverpool. 58pp.

HydroSHEDS GIS web site: http://hydrosheds.cr.usgs.gov/index.php. accessed in March 2014

McSweeney, C, New, M, Lizcano, G, (2012) UNDP Climate Change Country Profiles, Sierra Leone. http://www.country-profiles.geog.ox.ac.uk last accessed 9th February 2015.

WSP (2012) Sierra Leone Waterpoint Report. Review Version – 26th June 2012. http://www.sl-wash.org/uploads/Sierra_Leone_-_Waterpoint_Baseline_Report.pdf

Annexes

Annex A Hydrological monitoring - extracts from a presentation by Francis Moijue

Source of Information

The following extracts are taken from a presentation by Francis Moijue (undated). They summarise the state of Hydrological Monitoring in Sierra Leone up to the early 1990s.

UNDP SUPPORTED HYDROLOGICAL STATIONS BY 1976

Name	Catchment Area km²	Max flow m³/s	Min. flow m³/s	Average runoff
Moa	17150	2942	9.6	788
Sewa	6870	730	4.8	909
Palima	361	160	0.24	1431
Dodo	57	16.7	0.07	1383
Pampana	2407	511	0.50	1410
Badala	2525	503	1.2	702
Bumbuna	3990	1164	1.5	898
Mador	9.5			
Magburaka	4710			
Marmpa				
Mabole				
Mange	17230			

ONCHOCERCIASIS (WHO) HYDROLOGICAL STATIONS

- **Established 24 hydrological stations**

Station	River	Date Installed	Nr. Of gaugings	Remarks
Outamba	Kaba	June 1988	15	
Kaba Ferry	Kaba	April 1988	13	
Musaia	Mongo	April 1988	16	
Kunshu	Mabole	April 1988	26	Earlier network as Mabole
Mabanta	Mabole	April 1988	10	
Arfania	Seli	April 1988	15	Earlier network as Badala
Bumbuna	Seli	April 1988	18	In earlier network
Magburaka	Seli	May 1988	28	
Marampa	Seli	May 1988	16	
Matotoka	Pampana	April 1988	20	In earlier network as Pampana
Yifin	Bagbe	April 1988	13	
Yima Ferry	Bafi	April 1988	11	

ONCHOCERCIASIS (WHO) HYDROLOGICAL STATIONS

Station	River	Date Installed	Nr. Of gaugings	Remarks
Njaiama	Sewa	April 1988	18	
Yele	Taia	May 1990	8	
Taiama	Taia	April 1990	8	
Mokasi	Gbangbaia	April 1990	5	
Mokele	Jong	April 1990	6	
Bumpe	Tabe	April 1990	10	
Lembema	Sewa	April 1990	4	
Bandajuma	Waanje	April 1990	6	
Bandasuma	Moa	May 1990	3	
Gofor	Moa	May 1990	7	
Masahun	Male	May 1990	4	
Batiwa	Moa	May 1990	5	


HYDROMETEOROLOGICAL MAP OF SIERRA LEONE
GUINEA
GUINEA
LIBERIA

Annex B 1991 list of historical meteorological monitoring sites

Sources of Information

The following lists have been primarily derived from Table 3.2 and Appendices D and E of the following consultancy report.

Mott MacDonald International et al, 1991. Sub-Saharan Africa. Hydrological Assessment. West African Countries: Sierra Leone. The World Bank, UNDP, African Development Bank. Draft Report. October 1991.

In total 118 meteorological monitoring sites are listed which have been in use for periods ranging from less than 1 year to several decades spanning the period 1910 to 1991. Sites have been cross-referenced in Table B2 against 38 rainfall sites listed in the following technical report.

Gregory S, 1965. Rainfall over Sierra Leone. Department of Geography, University of Liverpool Research paper No 2. The Acorn press, Liverpool. 58pp

National Meteorological Network 1991

The following details are drawn from the Mott Macdonald report.

Table B1 is a list of all synoptic, climatological and agro-climatological stations from which data has been gathered at some time between 1910 and 1991. In total these include seven synoptic and forty-two climate stations which were managed by the Meteorological Service, Ministry of Transport. A total of thirteen agro-climatological sites were established and managed by the Land and Water Development Division (LWDD) of the Ministry of Agriculture and Natural Resources from 1978 onwards including the adoption of one of the synoptic stations (Njala) and four of the climate stations (Kailahun, Kenema Farm, Makali and Musaia).

Figure B1 shows the meteorological network as it existed in 1991.

The **national meteorological network in 1991** comprised:

- **7 synoptic station**s and a weather radar system (at Tower Hill) operated by the Meteorological Service.
- **10 agro-climatological stations** established in 1978 and operated by the LWDD. These data were not copied to the Meteorological Service.
- **13 rain gauges and a climate station** operated by the Guma Valley Water Authority. Some of these data were passed on to the Meteorological Service. These sites were not specifically identified in the Mott MacDonald report and it is not known if they are included in the following lists.

Synoptic stations in 1991 were manned by observers employed by the Meteorological Service. At that time the frequency of observations had been reduced from hourly to 3 hourly during daytime only. Two stations were temporarily closed: Bo, due to a fire and Falconbridge (Freetown) due to

difficulty in replacing the observer who had been taken ill. One Synoptic station (Njala) was adopted by the LWDD as part of the 1978 Agro-Climatological Network.

Climatological stations in 1991. Few (if any) of these stations were operational or reporting to the Meteorological Service. Four Climate stations (Kailahun, Kenema Farm, Makali and Musaia) were adopted by the LWDD as part of the 1978 Agro-Climatological Network.

Agro-Climatological Stations (established 1978). These stations were established in the context of project AG:DP/SIL/73/002, "Agro-ecological Atlas of Sierra Leone" which ended in 1982.Data for these was held on file in the LWDD offices. None was sent to the Meteorological Service.

Rainfall Stations 1991

A total of 108 monitoring stations are listed within Appendix D of the Mott Macdonald report from which rainfall records have been provided at some time. These stations are included below in Table B2 and combined with those from Table B1 to produce a single list of sites from which rainfall data have been gathered in the past.

Data were normally recorded on a daily basis except in the case of autographic gauges at the synoptic stations where hourly figures were tabulated on monthly returns. Most sites were not in operation in 1991.

Figure B2 shows the network of rainfall stations as it was in 1969, the last year for which a year book was published.

Data Records 1991

Before the service was transferred from the airport at Lungi to Freetown (date unspecified), a fire destroyed some records.

None of the data had been entered into a computerised database. The Meteorological Service did not have an inventory of stations in 1991, nor did it have grid references for these. Monthly rainfall values were entered in ledgers for all stations up to 1989. The daily observations on the forms used for their original returns were available for inspection and copying in 1991.

Data were all stored either in the form of monthly summaries or as original report forms at the head office of the Meteorological Service in Freetown where it was possible to hand copy or photocopy.

Much of the synoptic and climatological data held by the Meteorological Service was put on microfilm by the DARE project (Data Acquisition and Rescue Project, International Data Co-ordination Centre, Brussels), presumably in 1991. Not all data were recorded due to time constraints. Records held by LWDD were not copied by the DARE project team and there were some communication issues reported in the copying of data at the Meteorological Service office.

Table B1 List of synoptic, agro-climatological and climate stations (as of 1991)

(based on Table 3.2, Mott MacDonald et al, 1991 (Consultancy Report)

	Station Name	Latitude		Longitude (West)		Period of operation		Used in Gregory, 1965	In Operation 1991	In Operation 2014	Comments
		deg	*mins*	*deg*	*mins*	*Earliest*	*Latest*				
Synoptic Network (SL Meteorological Service)											
1	Bo	7	58	11	45	1937	1986	√		√ ?	
2	Bonthe	7	32	12	32	1941	1984	√		√ ?	
3	Daru	7	59	10	52	1944	1984	√		√ ?	
4	Falconbridge (Freetown)	8	30	13	14	1930	1985	√			
5	Kabala	9	35	11	33	1933	1986	√		√ ?	
6	Lungi	8	37	13	12	1945	1991	√	√	√	International Airport
Synoptic Station shared with Agro-Climatological Network from 1978.											
7	Njala	8	6	12	5	1933	1991	√	√	√ ?	Joint agro-climatic station
Agro-Climatological Network established in 1978 (Data collected and held by LWDD, Ministry of Agriculture and Natural Resources)											
1	Alkalia	9	19	11	23	1978	1991		√		
2	Kailahun	8	17	10	35	1978	1991		√		
3	Katonga	8	50	12	56	1978	1991		√		Rainfall and temperature only
4	Kenema	7	52	11	11	1978	1991		√		
5	Makali	8	38	11	40	1978	1991		√		
6	Mattru Jong	7	38	12	10	1978	1991		√		
7	Moyamba	8	10	12	25	1978	1991		√		
8	Musaia	9	46	11	33	1978	1991		√		
9	Potoru	7	32	11	29	1978	1991		√		
10	Roloku	8	52	12	8	1978	1991		√		
11	Bendugu	9	31	10	58	1978	1980				Short term - observer problems
12	Kamakwie	9	30	12	45	1978	1980				Short term - observer problems
Climate Stations shared with Agro Climatological Network from 1978 but with Historical Data Records held by SL Meteorological Service											
1	Kailahun	8	11	10	35	1952	1961				
2	Kenema Farm	7	53	11	11	1951	1973	√			
3	Makali	8	38	11	40	1950	1955				
4	Musaia	9	46	11	33	1939	1975	√			
Other Climate Stations (SL Meteorological Service)											
5	Batkanu	9	4	12	25	1933	1961	√			Appx D shows operation from 1913 to 1971
6	Bunumbu	8	10	10	52	1949	1976	√			
7	Fourah Bay College	8	28	13	13	1955	1985				
8	Gambia	7	23	12	11	1972	1982				
9	Gbangbama	7	43	12	18	1957	1970				
10	Gbangba	7	29	12	12	1956	1957				
11	Guma Dam	8	22	13	13	1974	1985				
12	Hanga	7	56	11	9	1950	1964	√			
13	Njaiama	8	33	11	6	1933	1939				
14	Kissy	8	28	13	11	1939	1954	√			
15	WAFRI Kissy Dockyard	8	29	13	11	1953	1959				
16	Kontobi	8	14	12	10	1975	1984				
17	Koyeima	8	15	11	42	1933	1977				No record 38-44 and 60-76
18	Kbwable					1959	1977				
19	Lumley	8	28	13	16	1954	1984				
20	Magburaka	8	43	11	57	1954	1959				
21	Makeni	8	53	12	3	1941	1983	√		√	
22	Marampa	8	41	12	31	1939	1975	√			
23	New England	8	28	13	14	1959	1984				
24	Newton	8	20	13	0	1938	1978	√			
25	No 2 River	8	21	13	12	1948	1978	√			
26	Port Loko	8	47	12	47	1954	1984	√			No record 71-79
27	Pendemba Farm	8	5	10	41	1962	1977	√			
28	Pepel	8	35	13	4	1939	1974	√			*Co-ordinates corrected (Offshore otherwise)*
29	Pujehan	7	21	11	43	1953	1977	√			
30	Rokupr	9	1	12	57	1935	1985	√			
31	Segbwema	7	59	10	58	1933	1946				
32	Sembehun	7	56	12	32	1942	1947	√			
33	Solon					1954	1968				
34	Tongo					1980	1982				
35	Tonkolili					1957	1962				
36	Torma Bum	7	25	12	1	1972	1980				
37	Waterloo Town	8	20	13	4	1939	1952				No record 44-49
38	Wellington	8	27	13	10	1974	1985				No record 77-78
39	Wilberforce	8	28	13	16	1957	1961				
40	Wordu	8	27	10	57	1961	1976				
41	Yengema	8	37	11	18	1938	1983	√			
42	Yongibana	8	26	12	13	1953	1961				

Sources

Mott MacDonald International et al, 1991. Sub-Saharan Africa. Hydrological Assessment. West African Counries: Sierra Leone. The World Bank, UNDP, African Devopment Bank. Draft Report. October 1991.

Gregory S, 1965. Rainfall over Sierra Leone. Deartment of Geography, University of Liverpool Research paper No 2. The Acorn press, Liverpool. 58pp

Personal Communication, 2014. Sierra Leone Meteorological Department.

Figure B1 Locations of synoptic and agro-climatological Stations, 1991
(Source: Figure 3.2, Mott MacDonald et al, 1991 Consultancy Report)

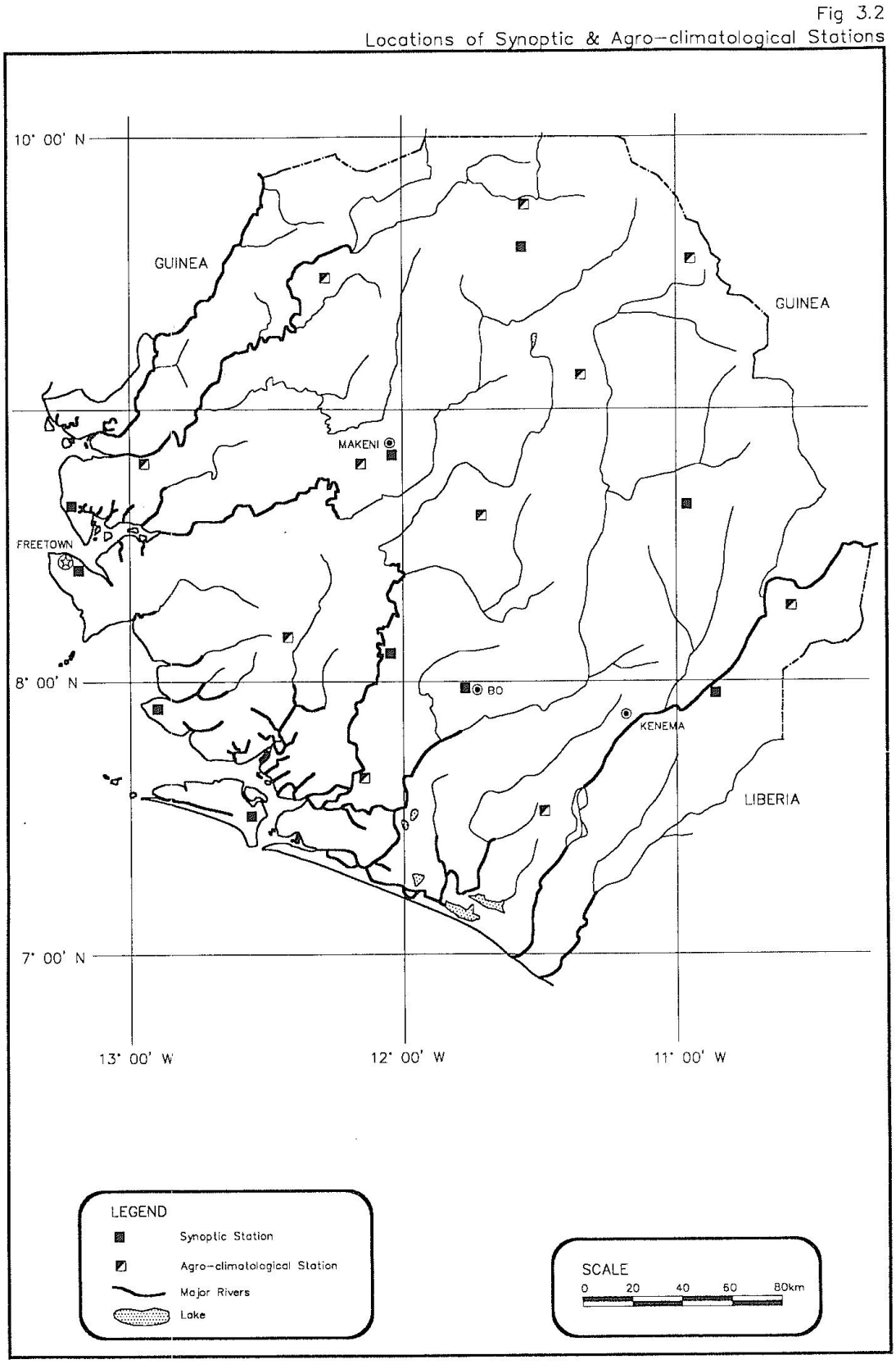


Table B2 Alphabetical list of rainfall stations including climate, synoptic and agro-climatological stations (1991)

(based on Appendix D, Appendix E and Table 3.2, Mott MacDonald et al, 1991 Consultancy Report)

	Station Name	Period of operation as Rainfall Station[1] (from Appendix D)			Max No of Consecutive Years with Continuous Rainfall Record[2]							Station Type[3] (from Table 3.2 and Appendix D)				Period of operation as Synoptic or Climate Station (from Table 3.2)				Used in Gregory, 1965	In Operation 1991	In Operation 2014 ?	Comments
		Earliest	*Latest*	*Span*	*<5*	*<10*	*<20*	*<30*	*<40*	*<50*	*>50*					*Earliest*	*Latest*	*Span*					
1	Alkalia	n/a	n/a										AC			1978	1991	14			√		Not in Appendix D
2	Bafodia	1953	1975	23	√							R											
3	Bagla Hill	1975	1975	1	√							R											
4	Batkanu	1913	1971	59						√		R		C		1933	1961	29		√			
5	Bauyu	1940	1956	17			√					R								√			
6	Bendugu	n/a	n/a										AC			1978	1980	3					Not in Appendix D
7	Belebu (nr Kenema)	1980	1980	1	√							R											
8	Blama	1941	1977	37	√							R											
9	Bo	1913	1983	71						√		R			S	1937	1986	50		√		√	
10	Bonthe	n/a	n/a												S	1941	1984	44		√		√	Not in Appendix D
11	Bunumbu	1932	1976	45		√						R		C		1949	1976	28		√			
12	Cape Sierra leone	1941	1946	6	√							R											
13	Cline Town	1941	1969	29				√				R								√			
14	Daru	1913	1990	78						√		R			S	1944	1984	41		√		√	
15	Falasa	1962	1964	3	√							R											
16	Falconbridge (Freetown)	1939	1990	52						√		R			S	1930	1985	56		√			
17	Fourah Bay College - Mt Auriol	1953	1983	31					√			R		C		1955	1985	31					
18	Gambia / Gambia Oil Palm	1971	1983	13		√						R		C		1972	1982	11					
19	Gandorhun	1955	1981	27	√							R											
20	Gbangba	n/a	n/a											C		1956	1957	2					Same Site?
21	Gbangba (nr Torma Bum)	1964	1967	4	√							R											
22	Gbangbama	1956	1971	16		√						R		C		1957	1970	14					
23	Gbap	1946	1959	14	√							R											
24	Gberia Timbako	1957	1973	17		√						R											
25	Gola North	1963	1965	3	√							R											

Continued on next page

Table B2 continued

	Station Name	Period of operation as Rainfall Station[1] (from Appendix D)			Max No of Consecutive Years with Continuous Rainfall Record[2]							Station Type[3] (from Table 3.2 and Appendix D)				Period of operation as Synoptic or Climate Station (from Table 3.2)				Used in Gregory, 1965	In Operation 1991	In Operation 2014 ?	Comments
		Earliest	*Latest*	*Span*	*<5*	*<10*	*<20*	*<30*	*<40*	*<50*	*>50*					*Earliest*	*Latest*	*Span*					
26	Guma Valley / Guma Dam	1974	1990	17			√					R		C		1974	1985	12					
27	Hanga	1939	1972	34				√				R		C		1950	1964	15		√			
28	Hastings Airfield	1941	1944	4	√							R											
29	Hill Station	1917	1983	67					√			R								√			
30	Jaima Nimikoro	1932	1947	16	√							R											
31	Kabala	1922	1989	68							√	R			S	1933	1986	54		√		√	Data exists from 1921 to at least 1948
32	Kailahun	1932	1962	31	√							R	AC	C		1952	1961	10		√	√		
33	Kamakwe	1953	1979	27	√							R											
34	Kamakwie	n/a	n/a										AC			1978	1980	3					Not in Appendix D
35	Kambia - Rokupr	1933	1962	30			√					R								√			
36	Kambia (by Makeni)	1973	1976	4	√							R											
37	Kangama	1953	1972	20	√							R											
38	Kasewe	1952	1984	33		√						R											
39	Katonga	1956	1967	12	√							R	AC			1978	1991	14			√		
40	Kbwable	n/a	n/a											C		1959	1977	19					Not in Appendix D
41	Kenema (Dispensary)	1932	1963	32			√					R											
42	Kenema Forest Quarters	1964	1968	5	√							R											
43	Kenema Farm	1949	1974	26			√					R	AC	C		1951	1973	23		√	√		
44	Kenema Works	1951	1967	17	√							R											
45	Kent	1977	1978	2	√							R											
46	Kissy	n/a	n/a											C		1939	1954	16		√			Same site as Kissy Mental Hospital?
47	Kissy Dockyard (WAFRI)	1953	1961	9	√							R		C		1953	1959	7					
48	Kissy Mental Hospital	1913	1961	49					√			R											Same site as Kissy?
49	Koidu	1941	1956	16			√					R											
50	Kongo Valley	1942	1983	42					√			R								√			

Continued on next page

Table B2 continued

	Station Name	Period of operation as Rainfall Station[1] (from Appendix D)			Max No of Consecutive Years with Continuous Rainfall Record[2]							Station Type[3] (from Table 3.2 and Appendix D)				Period of operation as Synoptic or Climate Station (from Table 3.2)				Used in Gregory, 1965	In Operation 1991	In Operation 2014 ?	Comments
		Earliest	*Latest*	*Span*	*<5*	*<10*	*<20*	*<30*	*<40*	*<50*	*>50*					*Earliest*	*Latest*	*Span*					
51	Kontobi	1956	1983	28	√							R		C		1975	1984	10					
52	Koyeima	1931	1977	47		√						R		C		1933	1977	45					
53	Kpuaba	1959	1978	20	√							R											
54	Lumley	1953	1983	31			√					R		C		1954	1984	31					
55	Lungi	1948	1989	42						√		R			S	1945	1991	47		√	√	√	Site operational in 2014
56	Mabang / Mabong	1941	1962	22			√					R								√			
57	Mabonto	1935	1963	29			√					R								√			
58	Macumray (by Makeni)	1972	1974	3	√							R											
59	Magbars	1977	1980	4	√							R											
60	Magburaka	1954	1960	7	√							R		C		1954	1959	6					
61	Makali	1950	1955	6	√							R	AC	C		1950	1955	6			√		
62	Makeni	1933	1989	57							√	R		C		1941	1983	43		√		√	Site operational in 2014
63	Makeni (Makump)	1923	1932	10		√						R											
64	Makoi	1965	1985	21		√						R											
65	Mambolo	1955	1970	16	√							R											
66	Mapotolon	1951	1955	5	√							R											
67	Marampa	1933	1981	49				√				R		C		1939	1975	37		√			
68	Massory (by Makeni)	1973	1973	1	√							R											
69	Maswari	1945	1972	28			√					R											
70	Matru	1956	1970	15	√							R											
71	Mattru Jong	n/a	n/a									R	AC			1978	1991	14			√		
72	Mokanji-Sieromco	1981	1982	2	√							R											
73	Monga Bendugo	1958	1970	13	√							R											
74	Moyamba	1913	1980	68				√				R	AC			1978	1991	14		√	√		
75	Musaia	1948	1979	32			√					R	AC	C		1939	1975	37		√	√		

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Table B2 continued

	Station Name	Period of operation as Rainfall Station[1] (from Appendix D)			Max No of Consecutive Years with Continuous Rainfall Record[2]							Station Type[3] (from Table 3.2 and Appendix D)				Period of operation as Synoptic or Climate Station (from Table 3.2)				Used in Gregory, 1965	In Operation 1991	In Operation 2014 ?	Comments
		Earliest	*Latest*	*Span*	*<5*	*<10*	*<20*	*<30*	*<40*	*<50*	*>50*					*Earliest*	*Latest*	*Span*					
76	New England	1959	1984	26			√					R		C		1959	1984	26					
77	Newton	1931	1980	50					√			R		C		1938	1978	41		√			
78	Nimini South	1964	1971	8	√							R											
79	Njaiama	n/a	n/a											C		1933	1939	7					Not in Appendix D
80	Njala	1925	1990	66						√		R	AC		S	1933	1991	59		√	√	√	
81	No 2 River	1943	1988	46			√					R		C		1948	1978	31		√			
82	Nyeama	1954	1982	29		√						R											
83	Panguma	1941	1967	27		√						R											
84	Pendembu Farm	1965	1980	16	√							R		C		1962	1977	16		√			
85	Pendembu Hospital	1941	1967	27		√						R											
86	Pepel	1934	1976	43		√						R		C		1939	1974	36		√			
87	Port Loko	1937	1983	47			√					R		C		1954	1984	31		√			
88	Potoru	n/a	n/a										AC			1978	1991	14			√		Not in Appendix D
89	Pujehan / Pejeben	1923	1978	56		√						R		C		1953	1977	25		√			
90	Regent	1939	1984	46					√			R								√			
91	Rokupr	1933	1988	56					√			R		C		1935	1985	51		√			
92	Roloku	n/a	n/a										AC			1978	1991	14			√		Not in Appendix D
93	Safadu	1984	1988	5	√							R											
94	Segbwema	1933	1947	15		√						R		C		1933	1946	14					
95	Sembehun	1943	1968	26			√					R		C		1942	1947	6		√			
96	Senehun	1960	1971	12	√							R											
97	Shenge	1988	1988	1	√							R											
98	Solon	1953	1969	17		√						R		C		1954	1968	15					
99	Sulima	1940	1982	43		√						R								√			
100	Sumbaria	1947	1984	38			√					R								√			

Continued on next page

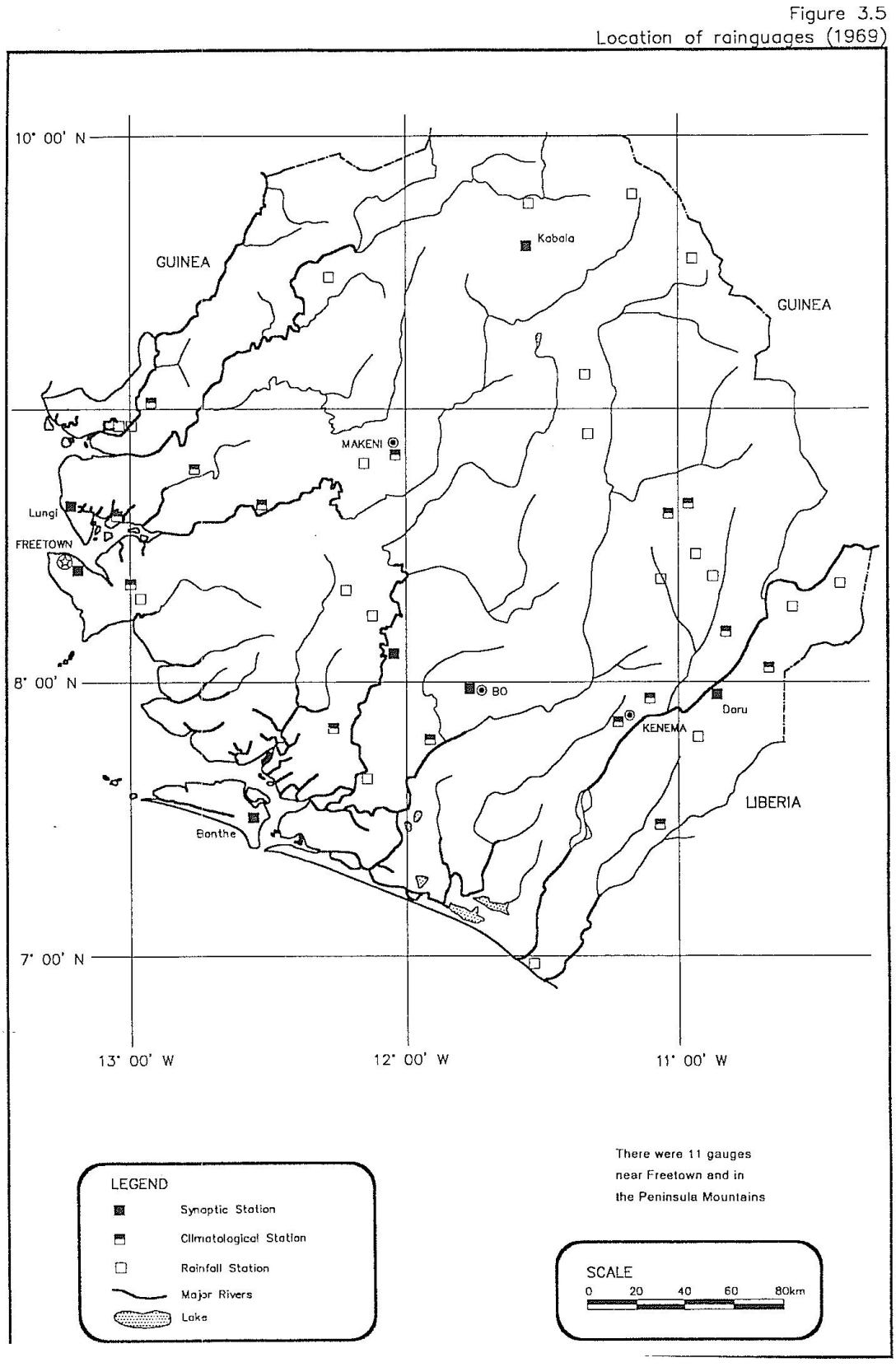
Table B2 continued

	Station Name	Period of operation as Rainfall Station[1] (from Appendix D)			Max No of Consecutive Years with Continuous Rainfall Record[2]							Station Type[3] (from Table 3.2 and Appendix D)				Period of operation as Synoptic or Climate Station (from Table 3.2)				Used in Gregory, 1965	In Operation 1991	In Operation 2014 ?	Comments
		Earliest	*Latest*	*Span*	*<5*	*<10*	*<20*	*<30*	*<40*	*<50*	*>50*					*Earliest*	*Latest*	*Span*					
101	Sumbuyu	1952	1978	27			√					R								√			
102	Teko	1942	1985	44			√					R											
103	Tongo	1982	1985	4	√							R		C		1980	1982	3					
104	Tonkolili - Farangbaia	1957	1962	6	√							R		C		1957	1962	6					
105	Torma Bum	1957	1981	25		√						R		C		1972	1980	9					
106	Tower Hill (Freetown)	1911	1985	75				√				R								√			
107	Tuasa	1961	1962	2	√							R											
108	Waterloo Town	1939	1953	15	√							R		C		1939	1952	14					
109	Waterloo Airfield	1943	1946	4	√							R											
110	Waterloo - WAIFOR	1953	1962	10		√						R											
111	Wellington Industry	1974	1985	12		√						R		C		1974	1985	12					
112	Wilberforce (MGSH)	1957	1961	5								R		C		1957	1961	5					
113	Wordu	1961	1976	16	√							R		C		1961	1976	16					
114	Yele	1982	1987	6	√							R											
115	Yengema	1936	1990	55					√			R		C		1938	1983	46		√			Replaced by Sefadu
116	Yongibana / Yoniba	1951	1967	17		√						R		C		1953	1961	9					
117	Zimmi Farm	1962	1967	6	√							R											
118	Zimmi Forest	1965	1965	1	√							R											
	TOTALS				**47**	**20**	**18**	**5**	**8**	**6**	**2**	**108**	**13**	**42**	**7**					**38**	**12**	**7**	

Notes	
1	Earliest and latest dates are read from a horizontal bar chart extending over a period of 80 years. It is difficult to read the exact start and end year, so either of these may be 1 year in error.
2	Individual rainfall records span many years, often with signifcant breaks. These colums provide an indication of which records have been maintained for the longest continuous period without breaks.
3	Station Types: R: Rainfall; AC: Agro-climatological; C: Climate; S: Synoptic
4	**Sites in operation 2014?** Lungi and Makeni were definitely operational. No certainty regarding any of the other locations.

Figure B2 Location of rain gauges (1969)

(Figure 3.5, Mott MacDonald et al, 1991 Consultancy Report)



Annex C 1991 list of historical hydrological monitoring sites

Sources of information

The lists of sites in this Annex have been derived from Table 4.1, Table 4.2 and Appendix F of the following consultancy report.

Mott MacDonald International et al, 1991. Sub-Saharan Africa. Hydrological Assessment. West African Countries: Sierra Leone. The World Bank, UNDP, African Development Bank. Draft Report. October 1991.

In total 30 river gauging stations are listed which were in use spanning the period 1970 to 1991. The information in this report coincides with that in Francis Moijue's presentation (Annex A)

Statistical data in the Mott Macdonald report is derived from summary pages within the 1976 Hydrological Year Book, data from which has been digitised and is available on the water security project website www.salonewatersecurity.com.

Hydrological Year Book of Sierra Leone (1 May 1970 - 31 March 1976). UNDP / MEP (Water Supply Division) SIL/72/007.

Hydrological Unit - hydrometric network 1970 to 1976

The following detail is drawn from the Mott Macdonald report.

SLEC network (1969 to 1975)

Twelve gauging stations were established under the auspices of two UNDP projects in 1969 and 1972 (SIL/69/509 and SIL/72/007) and were maintained by the Sierra Leone Electricity Corporation (SLEC) until January 1975 when responsibility was transferred to the Hydrological Unit of the Ministry of Energy and Power.

Data from these stations were compiled into the 1976 Hydrological Year Book. Locations are identified in Figure C1 and Table C1 which also includes a summary of catchment sizes and flow data. Grid references are provided in Table C2.

Some of these stations continued to operate for a few years after 1976 but a hydro-electric study in 1982 for the Manu River Union felt the data were of unknown accuracy and used only the published data (i.e. those in the 1976 Year book).

In 1991 the original 3 monthly recorder charts were stored in the Water Supply Division offices (44 charts) including most of the charts for Bumbuna.

Onchocerciasis (River Blindness) Project (1988)

Twenty-four hydrological stations were established between 1988 and 1990 in the context of the WHO Onchocerciasis control programme (OCP) with an objective to eradicate blackfly. Eight of these were based at sites used by the earlier network.

All twenty four of the gauging stations are identified in Table C2 and Figure C2 based on information in Appendix F and Table 4.2 of the Mott MacDonald Report .

Staff gauges were installed by external hydrologists from Office de Recherche Scientifique Technique Outre Mer, France (ORSTOM). All installation data was managed by ORSTOM with project records and gauging records transferred to Odienne (Côte d'Ivoire). Equipment repairs were carried out in either Bamako (Mali) or Ouagadougou (Burkina Faso). Gauging data were processed by ORSTEM staff in Odienne using the HYDROM computer programme, though no rating curves have ever been published from these.

Routine (weekly, sometimes less frequently) staff gauge readings were carried out by staff of the WSD and by a United Nations volunteer who remained in country until June 1991. These data were sent to the head office of OCP in Ouagadougou with copies held in the WSD field office in Makeni.

Data Quality and Availability

There is no inventory of data or any organised filing system.

A comparison of actual flow data for the gauging site on the Sewa at Njaiama for the period 1989 to 1991 is plotted in Figure C3 of the Mott MacDonald report to compare with the published rating curve from 1976 Year Book. There is a difference in datum, though the gauging data at low and medium flows are close to the rating curve. The highest actual flow measurement (at a gauge height of approx. 3.8m is significantly higher than that of the rating curve (430 m^3/s compared with 350 m^3/s) .

Other hydrological data sources

Guma Valley Authority (1946 onwards)

Before the start of construction of the Guma Valley dam in 1961 a hydrological station was operated from March 1946 to January 1956. Equipment consisted of an automatic water recorder and a weir was constructed. Monthly values of flow and some statistics were held in the offices of the company in Freetown. It is possible more complete archives are held by their consultants, Howard Humphreys and Partners (UK).

The Guma Valley Authority has also kept regular records of the water level in the reservoir along with pan evaporation, rainfall, seepage and draw-off. All these data represent the longest set of hydrological data in the country, though none has been collated or published.

Mano River Gauging (1956 onwards)

A gauging station was established on 29 August 1958 on the Mano River at Mano Mines (also named Kavilahun) at a point where the river forms part of the boundary with Liberia. The gauge was read intermittently from 1959 to 1969 and data contained anomalies. In January 1970 an automatic recorder was fitted. A rating curve was established and flows published (monthly means) for the period November 1958 to December 1961; January 1970 to April 1971 and September 1975 to December 1979. These are reported to be included in the following document.

Mano River Union 1981. Mano River Basin Development Project Feasibility Study. Volume 3: Topography and Hydrology. Mano River Union. Sofrelec, March 1981.

Other River Flow Measurements

Two unseen documents with possible river flow records are referenced by Mott MacDonald:

Hammelberg J, 1981. Freetown Peninsula road studies (stream flow velocity measurements).

Helmish F and Thirugnanasambanthar S (undated). Dry season stream flows in selected areas of Sierra Leone.

Table C1 Hydrological stations with data summary (1970 to 1976)

(based on Table 4.1, Mott MacDonald et al, 1991 Consultancy Report)

Number[1]	River Basin	River	Station Name[2]	Catchment Area	Maximum Flood	Minimum Flow	Average Runoff	Auto Recorder?	Rating Curve Quality
				km^2	m^3/s	m^3/s	mm		
4	Little Scarcies	Mabole	Mabole (Kunshu)	n/a	n/a	n/a	n/a	n/a	None
R2	Little Scarcies	Kaba	Mange	17230	n/a	n/a	n/a	n/a	None
R6/6	Rokel	Seli	Badala (Arfania)	2525	503	1.2	702	Yes	Approximate
R6-1	Rokel	Seli (Tributary)	Mador	9.5	n/a	n/a	n/a	n/a	None
7	Rokel	Seli	Bumbuna	3990	1164	1.5	898	Yes	Approximate
8	Rokel	Seli	Magburaka	4710	n/a	n/a	n/a	n/a	None
9	Rokel	Seli	Marampa	n/a	n/a	n/a	n/a	n/a	None
R9/10	Jong	Pampana	Pampana (Matotoka)	2407	511	0.5	1410	No	Unknown
R13/13	Sewa	Sewa	Sewa (Njaiama-Sewafe)	6870	730	4.8	909	No	Fair
R15	Sewa	Bundoye	Palima	361	160	0.24	1431	No	Unknown
R16	Sewa	Moboa	Dod	57	16.7	0.07	1383	No	Good
R17/22	Moa	Moa	Moa (Gofor)	17150	2942	9.6	788	Yes	Good

1	Numbers used are those in Mott MacDonald 1991, Appendix F
2	Names in brackets are those used for the OCP Network (see Mott MacDonald 1991, Appendix F)
3	Catchment and statistical data is from the Hydrological Year Book, 1976

Figure C1 Location of river gauging stations (1976)

(Figure 4.2, Mott MacDonald et al, 1991 (Consultancy Report)

Table C2 Hydrometric station inventory (as of 1991)

(based on Appendix F and Table 4.2, Mott MacDonald et al, 1991 Consultancy Report)

Number	River Basin	River	Station Name	Latitude		Longitude (West)		Period of operation		SLEC Network 1970's	OCP Network from 1988	Date OCP Stations Installed	No of Gaugings (to 1991)	Data Gaps (up to Jan 1991)	Comments
				deg	*mins*	*deg*	*mins*	*Opened*	*Closed*						
1	Little Scarcies or Kaba	Kaba	Outamba	9	35	12	10	1988			√	Jun 1988	15		Rating curve in preparation
2	Little Scarcies or Kaba	Kaba	Kaba Ferry	9	35	12	13	1988			√	Apr 1988	13		Rating curve in preparation
R2	Little Scarcies or Kaba	Kaba	Mange	8	55	12	49	1972	1976	√					No rating curve due to tidal effects
3	Little Scarcies or Kaba	Mongo	Musaia	9	46	11	36	1975			√	Apr 1988	16		Rating curve in preparation
4	Little Scarcies or Kaba	Mabole	Kunshu (Mabole)	8	58	12	6	1975		√	√	Apr 1988	26	Apr76-Mar88	in 1975 there was an automatic recorder. No rating curve
5	Little Scarcies or Kaba	Mabole	Mabanta	9	1	12	37	1988			√	Apr 1988	10		
R6/6	Rokel	Seli	Arfania (Badala)	9	19	11	32	1970		√	√	Apr 1988	15	Apr76-Jan88	1970 to 76 there was an automatic recorder and provisional rating curve
7	Rokel	Seli	Bumbuna	9	2	11	45	1970		√	√	Apr 1988	18	Apr76-Mar88	
8	Rokel	Seli	Magburaka	8	44	11	57	1988		√	√	May 1988	28		A few levels were recorded at a staff gauge in 1975/6
9	Rokel	Seli	Marampa	8	40	12	27	1988		√	√	May 1988	16		Data unreliable. Never published.
R6-1	Rokel	Seli	Mador	9	3	11	43	1975	1976	√					Station operated for 1 year only.
11	Sewa	Bagbe	Yifin	9	7	11	15	1988			√	Apr 1988	13		
12	Sewa	Bafi	Yima Ferry	8	41	11	9	1988			√	Apr 1988	11		
R13/13	Sewa	Sewa	Njaiama-Sewafe (Sewa)	8	34	11	16	1971		√	√	Apr 1988	18	Apr76-Mar88	1970 to 76 there was an automatic recorder and provisional rating curve
R16	Sewa	Moboa	Doda	8	9	11	9	1972	1976	√					Mini hydro scheme built between Doda and Palima stations
R15	Sewa	Bundoye	Palima	8	6	11	19	1972	1976	√					Mini hydro scheme built between Doda and Palima stations
19	Sewa	Sewa	Lembema	7	50	11	45	1990			√	Apr 1990	4		
18	Sewa	Tabe	Bumbe	7	52	11	53	1990			√	Apr 1990	10		
R9/10	Pampana or Jong	Pampana	Matotoka (Pampana)	8	40	11	52	1971		√	√	Apr 1988	20	Apr76-Apr88	1970 to 76 data are based on a staff gauge
14	Pampana or Jong	Teye	Yele	8	24	11	51	1988			√	May 1990	8		
17	Pampana or Jong	Jong	Mokele	7	43	12	10	1990			√	Apr 1990	6		
15	Pampana or Jong	Jong / Taia	Taiama	8	12	12	4	1990			√	Apr 1990	8		
R17/22	Moa	Moa	Gofor (Moa)	7	49	11	10	1971		√	√	May 1990	7	Sep75-Apr90	1970 to 76 there was an automatic recorder and a good rating curve
23	Moa	Male	Masahun	8	3	10	58	1990			√	May 1990	4		
24	Moa	Moa	Batiwa	8	9	10	44	1990			√	May 1990	5		
21	Moa	Moa	Bandasuma	7	23	11	25	1990			√	May 1990	3		
16	Gbangbaia	Gbangbaia	Mokasi	8	0	12	25	1990			√	Apr 1990	5		
20	Waanje	Waanje	Bandajuma	7	34	11	38	1990			√	Apr 1990	6		
	Totals							**28**	**4**	**12**	**24**				

Figure C2 Location of river gauging stations (1991)
(Figure 4.3, Mott MacDonald et al, 1991 Consultancy Report)

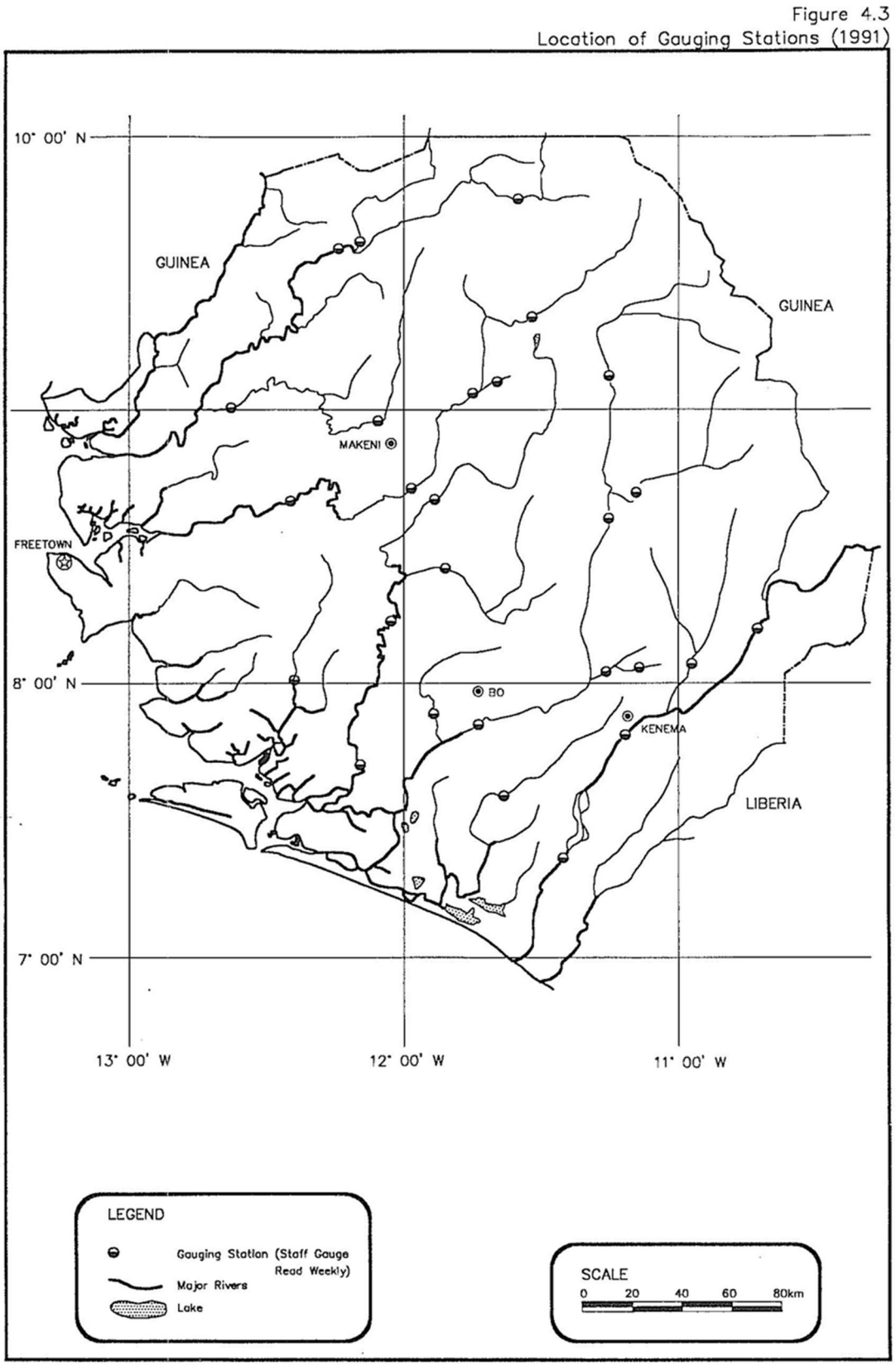


Figure C3 Stability of rating relationship – River Sewa at Njaiama
(Figure 4.5, Mott MacDonald et al, 1991 Consultancy Report)