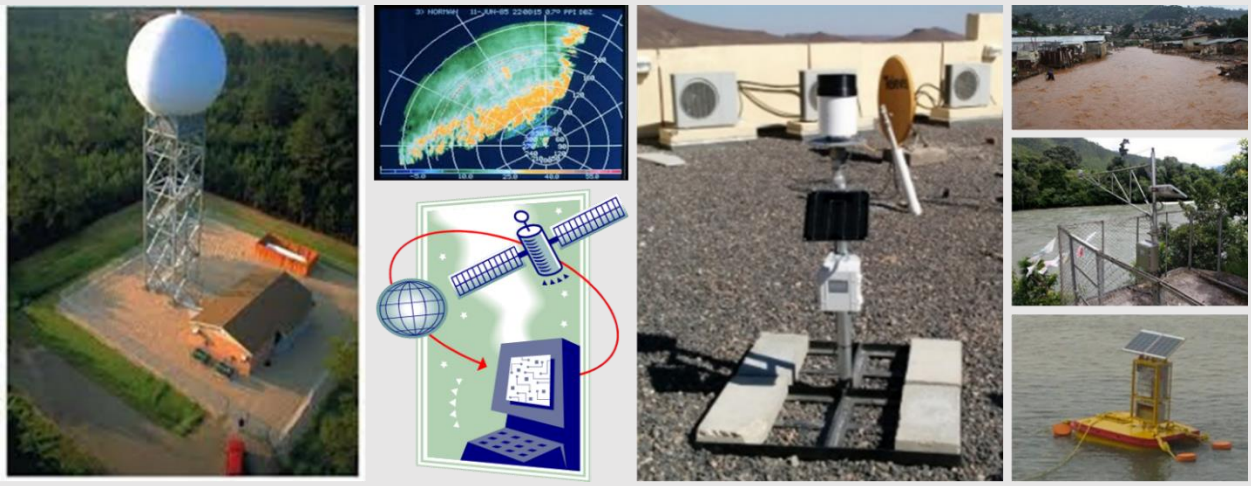


Enhancing Climate Information Systems for Resilient Development in Sierra Leone

PRE-FEASIBILITY ASSESSMENT , June 2023

Enhancing Climate Information Systems for Resilient Development in Sierra Leone

Pre-Feasibility Assessment

A report prepared by the Government of Sierra Leone, with technical support from the African Development Bank.

Executive Summary

Sierra Leone is prone to natural hazards such as floods, landslides, tropical storms, coastal erosion, and droughts that cause severe economic damage and loss of lives with disproportionate effects on the poorest and most vulnerable[1]. Climate change and underlying socioeconomic factors—such as the increase in urban population exposed to disasters, poverty, and low levels of economic development—will aggravate the impact of adverse natural events in the future (World Bank, 2017)[2].

The IPCC notes that "strengthening communication systems for anticipating and responding to climate risks" is an important tool to improve adaptive capacity for climate change. Yet climate information services in Sierra Leone are inadequate in the provision of timely, relevant information that can help the population to make decisions that improve their livelihoods – from seasonal forecasts to information on coming storms, to warnings from upstream communities about downstream flooding.

This feasibility study provides the basis for the Green Climate Fund (GCF) proposed program on "Enhancing Climate Information Systems for Resilient Development under the Freetown WASH and Aquatic Environment Revamping Program. The project builds on key early experiences and proposes an approach that scales the most effective solutions to commonly encountered barriers to the uptake of climate information, advisories and warnings. This study examines the latest science on climate impacts in Sierra Leone; reviews the current state of early warning systems; identifies gaps in current information provision; and reviews existing projects under implementation. Recommendations are provided to increase the resilience of the most vulnerable people and communities. In summary the study makes the following conclusions:

Pilots to create and/or improve early warning systems have been conducted successfully but remain geographically limited. Community based early warning systems have been successful by disseminating information to downstream communities, using local communication methods. Other international organizations, including the UNDP through its Least Developed Country Fund- have focused on building forecasting infrastructure and piloting technology, such as the use of Information and Communications Technology (ICT) in information dissemination. All of these projects demonstrate potential for scaling

This study recommends the strengthening of resilience through s: (i) tailored products and services, including ICT to disseminate early warnings and climate information to communities, including farmers (these products should be demand-based and stimulate private markets for information services) (ii) improving the information available for monitoring and forecasting floods and water resources (iii) scaling up of community-based early warning systems to provide "last-mile" access to information and improve disaster preparedness (iv) additional weather and climate infrastructure to underpin information dissemination and (v) training for first responders at the district and community level in technology and information dissemination to improve disaster preparedness and response. The interventions respond to climate risks and hazards the affect key economic sectors of Sierra Leone's economy such as agriculture, health, fisheries, forestry, water and sanitation, energy, among others. The interventions will ensure effective generation and coordination of climate information and services to support informed decision-making processes in public and private sectors.

[1] For more information on Sierra Leone's Hazard Profile and Risk Assessments, see HARPIS-SL (Hazard and Risk Profile Information System – Sierra Leone, by INTEGEMS and UNDP): http://www.harpis-sl.website/index.php/hazard-profiles/sierra-leone-hazardprofile.

[2] World Bank. (2017). Rapid Damage and Loss Assessment of August 14, 2017 – Landslides and Floods in the Western Area. Washington DC: World Bank.

List of Acronyms

AfDB	African Development Bank
AR5	Fifth Assessment Report of the IPCC
AR6	Sixth Assessment Report of the IPCC
CCCAP	Coastal Climate Change Adaptation Plan
CSO	Civil society organizations
DMA	Disaster Management Agency
DMD	Disaster Management Department
DRR	Disaster risk reduction
EPA	Environment Protection Agency
GCF	Green Climate Fund
GEF	Global Environment Facility
GCM	General circulation model
GoSL	Government of Sierra Leone
IC	Inter-ministerial Committee (for NAP process)
ICT	Information and communications technology
ICZMP	Integrated Coastal Zone Management Plan
INC	Initial National Communication, IPCC Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
LCCRDS	Low-Carbon Climate-Resilient Development Strategy
LDC	Least Developed Country
MAF	Ministry of Agriculture and Forestry
MoE	Ministry of Energy
MoWR	Ministry of Water Resources
MTA	Ministry of Transport and Aviation
MTNDP	Medium-Term National Development Plan (2019-2023)
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NCCPF	National Climate Change Policy Framework
NCCSAP	National Climate Change Strategy and Action Plan
NDC	Nationally Determined Contribution
NEAP	National Environmental Action Plan
NFCS	National Framework for Climate Services
NMHS	National Meterorological and Hydrological Services Agencies
NWRMA	National Water Resources Management agency
ODSS	Operational Decision Support Systems
PA	Protected Areas
PRSP	Poverty Reduction Strategy Paper
PSC	Project Steering Committee
RCRCCC	Red Cross Red Crescent Climate Centre
SDG	Sustainable development goals
SFDRR	Sendai Framework for Disaster Risk Reduction
SL-MET	Sierra Leone Meteorological Agency
SLRCS	Sierra Leone Red Cross Society
SNC	Second National Communication (to the UNFCCC)
SWOT	Strengths, weaknesses, opportunities, threats
TNC	Third National Communication (to the UNFCCC)
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
V&A	Vulnerability and adaptation

WMO	World Meteorological Organization
WSS	Water Supply and Sanitation

Table of Contents

List of Figures

List of Tables

1. CLIMATE RISK PROFILE OF SIERRA LEONE

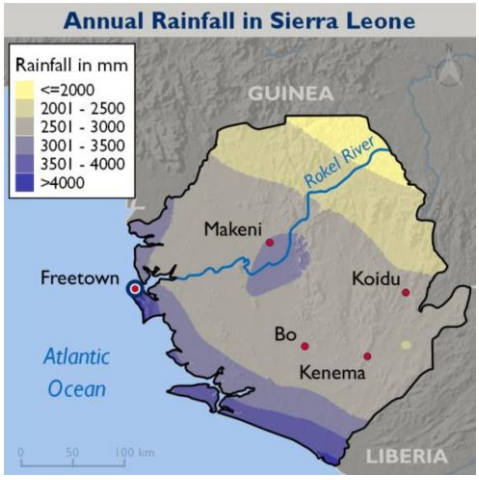
1.1. General Overview of Sierra Leone

The Fifth Assessment Report (AR5) of the IPCC indicates that Sierra Leone is among the most vulnerable African countries to the increasing frequency of climate change impacts and has been ranked third most vulnerable after Bangladesh and Guinea Bissau. (GoSL, 2015). According to the Notre Dame Global Adaptation Index, Sierra Leone is 158th most vulnerable to climate change out of 182 nations . The nation has a significant mortality risk from a variety of dangers, with 13% of its geographical area and more than 35% of its population at risk.

Sierra Leone is vulnerable to the increasing frequency and severity of droughts, floods and severe storms and their impacts on sectors such as agriculture, fisheries, as well as infrastructure and hydroelectric power production. Such climate-related hazards are having increasingly adverse effects on the country, and future climate change will exacerbate the situation. A large proportion of the population has an exceptionally low capacity to adapt to climate change. Climate change impacts are likely to impact Sierra Leone's rural population due to their high dependence on rain-fed agriculture and natural resource-based livelihoods

Sierra Leone has a hot and humid tropical climate that shows a distinct coast-interior gradient, a function of the country's varied topography (Figure 1). The wet season, from May to October, has an average rainfall of 3000 mm, with coastal and southern areas receiving up to 5000 mm annually and inland areas between 2000–2500 mm. The dry season, November to April, is prone to dusty and hot Harmattan winds and drought conditions. Average temperatures range from 25–27°C, with lower temperatures (22–25°C) during the wet season. Climate change threatens food security and the livelihoods of most of the population. Changes in precipitation patterns and rising temperature, increase in risks of droughts, floods, and increase in sea level affect the country's agriculture, water, energy, infrastructure and coastal areas (SL NC3, 2018).

Figure 1: Map of Sierra Leone (USAID, 2016)



A larger percentage of Sierra Leone's 7.9 million inhabitants, (80-90%), reside in rural areas and most of the population derives their income from agriculture. According to the 2015 Population and Housing Census, the population was about 7.09 million (59% rural; 41% urban), of which 53.1% under the age of 19. Sierra Leone is divided into 5 administrative regions (Eastern, Northern, North-western, Southern and Western areas), which are further subdivided into 16 districts. Most of the population lives below poverty line and the vast majority of people are malnourished partly due to the 10 years civil conflict, Ebola outbreak and natural disasters including flooding and landslides. The country's infant mortality is among the highest in the world and life expectancy at birth is estimated at less than 40 years.

1.2. Urbanisation and population growth

In recent years, Sierra Leone's urban population has grown at a slower pace than regional peers and the regional average, although population projections show that urban population will more than double by 2050, with about 8 million people living in urban area. Urban population is primarily located in the capital

Freetown, with about 1.1 million inhabitants that are expected to become 1.8 million by 2035. Kenema is the second largest city but has less than a fifth the population of Freetown showcasing[3].

the concentration of the population in the capital city and its surrounding areas

Figure 2: Projected Urbanization in Sierra Leone (Source: Authors with data from UN DESA)

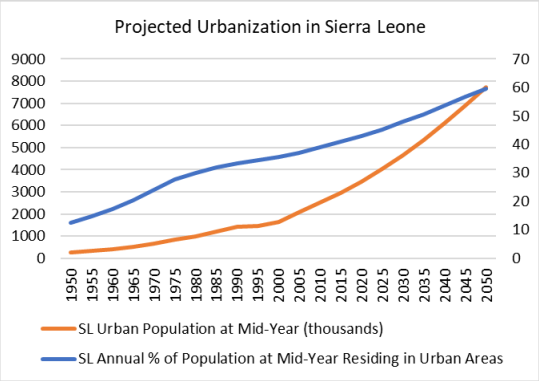
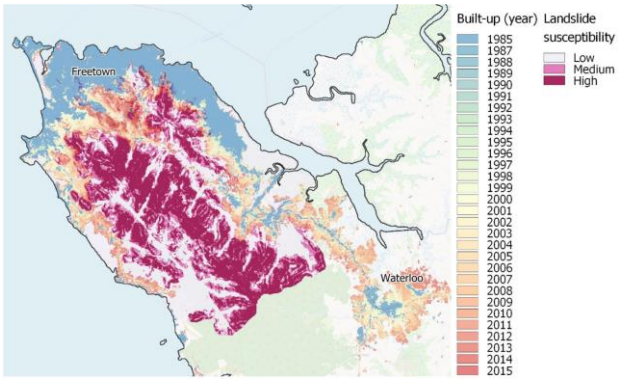


Figure 3: Urbanization in Freetown (1985–2015) (Source: World Bank with data from DLR and ARUP



Uncontrolled urban expansion and the lack of affordable housing has also led to inefficient land allocation in Freetown, characterized by the proliferation of slums near the city center, concentrated in flood plains and next to waste dumps. This results in the poorest and vulnerable people of the city being exposed to regular flooding during the rainy season in overcrowded coastal areas. This also entails significant health risks when flooding is combined with solid and liquid waste issues (World Bank, 2018)[4].

1.3. Environmental structure

1.3.1. Biodiversity

High dependence on agriculture and natural resources, coupled with high rates of poverty, unemployment and environmental degradation, leave Sierra Leone vulnerable to climate change impacts[5]. Sierra Leone's natural landscape includes lowland rainforest, mountain forest, freshwater swamps, mangrove/coastal ecosystems, and marine habitats. Arable fields make up almost 75% of Sierra Leone's total land area (CEP, 2006). Although Sierra Leone has an extremely rich biodiversity, overexploitation of the country's terrestrial and marine biodiversity has grown over time. In total, Sierra Leone has 48 forest reserves and conservation areas, or around 4% (180,250 ha) of its total geographical area. Only two of these areas, Tiwai Wildlife Sanctuary (TWS) and Outamba Kilimi National Park (OKNP), have been given the IUCN designations of national park and wildlife sanctuary, respectively. Gola woods, Western Area Forest Reserve, Outamba-Kilimi National Park, Loma Mountains, Tingi Hills, Tiwai Island Wildlife Sanctuary, and Kangari Hills are a few of the important protected areas. The main threats to biodiversity are indiscriminate farming methods, deforestation, overfishing, the generation of energy, mining, and logging, as well as climate change. The country is home to about 500 bird species, 9 bat species, 18 antelope and duiker species, and 15 species of primates. Six bird species face extinction, according to

[3] Ishizawa, Oscar A.; Bonnafous, Luc; Gaspari, Maria; Giron Gordillo, Alex; Muñoz Díaz, Joaquín; Pomonis, Antonios; Wandel, Nathalie. 2020. Sierra Leone Disaster Risk Management Diagnostic Note. World Bank, Washington, DC. © World Bank.

[4] World Bank. (2018a). Freetown Urban Sector Review: Options for Growth and Resilience (English). Washington, D.C.: World Bank Group.

[5] World Bank. n.d. Data: Sierra Leone.

experts. The 15 primates are all considered to be fragile or endangered. Two of the 18 antelopes are extinct, while 16 are under danger of going extinct.

Agriculture accounts for 31% of the country's GDP and 60% of its people. The use of biodiversity has significant consequences for Sierra Leone's efforts to reduce poverty and ensure food security as a result of this. One of the country's biggest issues is the loss of biodiversity. The National Biodiversity Strategy and Action Plan (NBSAP), a document created and adopted by the government of Sierra Leone in 2003, described the state of the country's various ecosystems and biological resources, outlined the threats to their survival and functionality, and offered action steps (including the means) for resolving these impending threats. These action steps short-, medium-, and long-term efforts have the potential to prevent the complete collapse of Sierra Leone's biodiversity (as well as other environmental and ecological products and services) and to permanently preserve the integrity of vital biological systems.

The understanding of how climate change will impact biodiversity in Sierra Leone is still growing. According to projections, the temperature appropriateness of 91% of amphibian, 40% of bird, and 50% of mammal species across the protected area network of the region will have decreased by the years 2070 to 2099. By 2070–2099, only three bird species, one mammal species, and no amphibian species are predicted to have "very likely" enhanced climate suitability in the area. The biodiversity is significantly threatened by habitat loss and hunting and the expected effects of climate change pose a serious threat. Belle et al. (2016) have identified the locations where climate change could have the biggest effects on Protected Areas (Pas). Where species are at risk of extinction, action must be done to identify potential refugia, ensure their protection, and increase connectivity across locations to allow for range shifts.

1.3.2. Water Quality, Resources and Use

Surface and Groundwater resources. Climate variability and change pose challenges to the availability and quality of Sierra Leone's extensive water resources, which comprise surface waters connected through a network of river basins. An estimated 80% of the country's rural population obtains its water from these sources. Seasonal variations in river flows are significant, with minimal discharges occurring during the dry season, affecting water availability: an estimated 40% of the country's protected water points suffer water shortages in the dry season. Increased intensity of rainfall events increases runoff and sediment loads in rivers, affecting water quality. Increased temperatures can also negatively affect water quality by increasing algal growth and providing more conducive breeding grounds for disease vectors[6].

In Sierra Leone,12% of the population get drinking water from surface water sources and only 21% have access to piped water supply systems in 2020[7]. SLMet only 13% have access to safely managed water services in urban centers like Freetown. The urban water supply systems including the capital Freetown, are of poor quality. The threat to the nation's supply of clean and fresh water is the most significant of the challenges that Sierra Leone is currently facing.

Sewerage and sanitation. Sierra Leone's metropolitan regions lack sewerage systems. Basic sanitation coverage only increased marginally from 15% (2015) to 17% (2020). An estimated 6% of the population with improved sanitation facilities use Septic tanks and 48% use pit latrines, according to the latest

[6] Oates, N., et al. 2014. Adaptation to Climate Change in Water Sanitation and Hygiene.
[7] Progress on drinking water, sanitation and hygiene in Africa 2000-2020: Five years into the SDGs. New York: United Nations Children's Fund (UNICEF) and World Health Organization (WHO), 2022

estimates from the World Health Organisation and UNICEF[8]. The excessive reliance on pit latrines combined with the overcrowding and congestion of urban areas, particularly Freetown, has increased the incidence of water-borne infections. Streams and rivers are used as outlets for the discharge of sewage and solid waste. The expansion of water supply and sanitation services will be one of the major issues in the upcoming years. Excreta from humans, animals, and solid and liquid wastes all contribute to the contamination of groundwater resources. Rural dwellers are faced with more challenges finding potable water due to siltation in lake and riverbeds brought on by mining operations.

Wetlands. Sierra Leone's coastal and marine biodiversity faces many threats ranging from habitat destruction, climate change (coastal erosion, flooding and droughts), hunting, collection of sea turtle eggs, to land use change as a result of agriculture and settlement and fish stock overexploitation[9]. A total of 4,837.8 km^2 of Sierra Leone is covered in wetlands, with the predominant types of vegetation being mangroves, riparian areas, and freshwater swamp forests. Seasonal wetlands known as bolilands serve as crucial habitats for a variety of migrating waterfowl species, water-dependent amphibian and mammal species, and buffalo and waterbuck grazing grounds. However, the conversion of these bolilands to rice farming poses a hazard, and during the dry season, anthropogenic bush fires frequently occur. Additionally threatened are the lake ecosystems of Lake Mape, Lake Mabesi, and Lake Sonfon, which provide great habitat for a variety of waterfowl, waders, and game animals.

1.3.3. Coastal and Marine Environment

Around 560 kilometres make up Sierra Leone's coastline. It contains four coastal islands as well as the estuaries of three sizable river networks (Sierra Leone, Scarcies, and Shrebo). The marine fisheries as well as crabs, shrimp, lobsters, turtles, cuttlefish, squids, and other sea life are all abundant in Sierra Leone. The nation's economy benefits from the solid and valued foundation provided by the coastal and marine resources. Mangroves, sandy beaches, a number of river estuaries and freshwater bodies, cliffs, wildlife, cultural and historical sites, and landscape are other coastal resources. Around 825 kilometers of shoreline in Sierra Leone's estuaries, including the Scarcies Rivers (34,234 ha), Yawri Bay (24,505 ha), and Sherbro River (99,854 ha), are covered in about 172 000 hectares of mangroves (World Bank, 1994). The mangrove ecosystem reduces coastal and river erosion, providing home for a wide variety of species, and providing wood for building, fuel, and charcoal. Thousands of migratory and shorebirds are supported by it, and many types of prawns and marine fish can breed and grow there (CCSL, 1993). The mangrove root system purifies water by filtering out heavy metals and organic waste while erecting land by storing silt and organic debris. Due to farming, fuelwood collecting for fish smoking, home development, and urban sprawl, these mangroves along the coastal waterways have experienced significant deforestation.

In some areas of the Sierra Leone beaches, signs of environmental deterioration and a loss in the richness of natural resources are becoming visible. This is due to population growth that is occurring quickly, poverty, and an increase in land-based activities and pollution sources like industrial1 and agricultural activities. The key issues among these are: (i) Declining harvests of marine and coastal living resources (ii) Loss of coastal and Marine biodiversity (iii) Coastal pollution and (iv) Beach (coastal) erosion. For the management of coastal areas, there are currently no specific projects. Statistics on the degree of

[8] Ibid

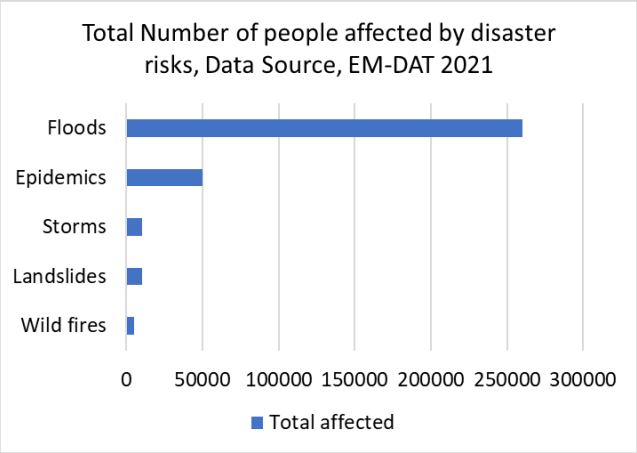
[9] https://www.wetlands.org/publications/pilot-project-for-sustainable-coastal-management-in-sierra-leone/

mangrove destruction and land use trends are inadequate. Therefore, the creation of an integrated coastal zone management plan is urgently required for the preservation of coastal and marine resources.

1.4. Climate Change Impacts, Risks and Vulnerability Assessment

With 13% of its area and more than 35% of the population at risk, the country is considered to be at a high mortality risk from multiple hazards. Sierra Leone's historic disaster records are limited (see Figure 4 for summary statistics), but they suggest that the 2017 mudslide near Freetown was the worst adverse natural event experienced in recent decades, while the Ebola Virus Disease (EVD) outbreak in 2014–16 represents the most adverse health related crisis in the country until 2019.

Figure 4: Summary Statistics of Historical Disasters in Sierra Leone (1975–2020)

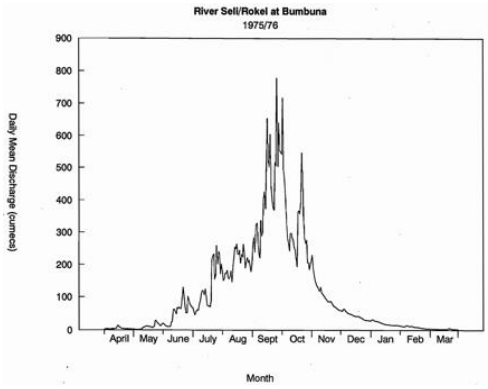


In the last 20 years, Sierra Leone has experienced four major floods that affected over 220,000 people, causing severe economic damage in addition to loss of lives. Exposure to natural disasters is likely to worsen in the coming years, given the low capacity to cope with extreme events, as well as Sierra Leone's vulnerability to the adverse effects of climate variability. The Second National Communication on Climate Change notes that more than 2.3 million people, many on the Freetown peninsula, live in areas that would be inundated by a 1-meter rise in sea levels, which is expected by 2100. Many more could be threatened due to contamination of fresh water sources by sea water

1.4.1. Hydrological variability

With an extended rainy season lasting from May to November and a tropical monsoon climate, Sierra Leone experiences severe downpours totalling over 4,000 mm. The rainy season is variable. Some observations imply that single rainfall events occur frequently and with greater intensity[10]. Current water levels along the Freetown peninsula range from a Lowest Astronomical Tide of (+0.00m); Mean Sea Level (+1.77m); and Highest Astronomical Tide (+3.5m), according to data from the Environment Protection Agency from 2015[11]. There is a significant decline in annual precipitation, and if this trend persists, it will negatively affect the environment and have a synergistic effect with rising temperatures and the clearing of the steep hill sides that are characteristic of the region (Figures 5 and 6).

Figure 5: Discharge of the Rokel River at Bumbuna

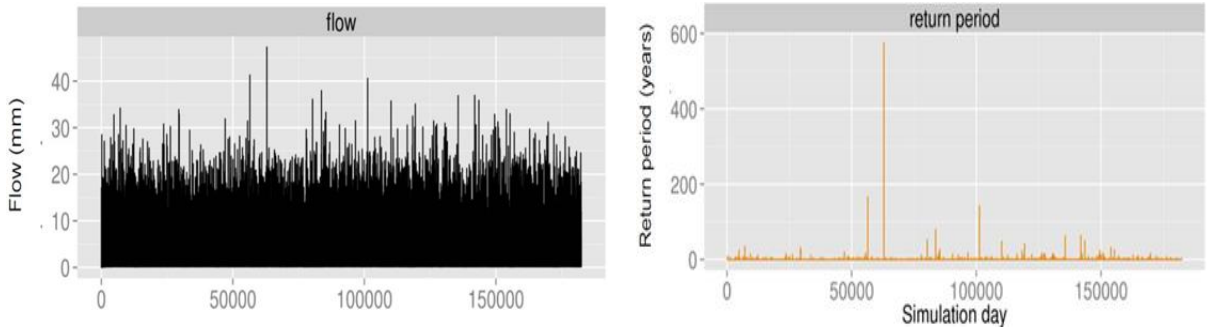


[10] Republic of Sierra Leone. 2012. Second National; Communication on Climate Change.

[11] Sea-level rise projections are based on the Atmosphere-Ocean General Circulation Models (AOGCM) as part of the Intergovernmental Panel on Climate Change (IPCC) Fifth assessment report (AR5

This will result in reservoir silting, landslides, the drying up of springs, and other issues. Given the limited ability to adapt to extreme events and the inadequate climate, weather, and hydrological monitoring infrastructure (mostly damaged during the decade-long Civil War (1991-2002)), exposure to natural catastrophes is anticipated to worsen in the coming years. During the civil wars, all observing stations and facilities were obliterated. Through the UNDP and IFAD, new ones are being created with the assistance of the GEF. Makeni currently has a manual synoptic station running continuously with hourly observations. The information gathered from this station is kept in Makeni and sent to Freetown every month12. Over 250,000 people were affected by floods between 1996 and 2019, and an estimated 183 people died (EMDAT, 2020). The Freetown peninsula is vulnerable to landslides and floods because of its topography. According to the World Bank (2018)[13], annual average losses from flood damage might reach US$ 2.5 million. According to statistics, 90% of all those impacted by disasters in Sierra Leone during the past 30 years were victims of flooding-related catastrophes (UNDP, 2012).

Figure 6: Translation between the river flow time series (top) to a return period time series (Ibid).



1.4.2. Flood Risks

The multicity hazard and risk assessment (World Bank, 2018) provides information on the probable damages to buildings and infrastructure from flood events[14]. The assessment focuses on fluvial and pluvial flood, landslide, and coastal flood and sea level rise risk in the cities of Freetown (which accounts for 15.5% of the national population), Makeni (1.7% of the national population), and Bo (2.4% of the national population)[15]. Increased rainfall intensity, fast population growth, and the concentration of the underprivileged in low-lying coastal elevation zones all contribute to flooding. Over $30 million was predicted to be the event's economic impact (Ibid). A third of the built-up area has grown in high- or medium-risk zones, or about 38%(World Bank ,2018)[16].

The exceedance probability curve is presented in Figure 7, suggesting that flood risk is concentrated in the capital Freetown where a flood causing at least $32 million in losses has a 5% probability of happening any given year[17]. Examining the exceedance probability curve (Figure 8) reveals a saturation of losses starting from a 50-year return period at $123.6 million.

---

[12] https://alliancehydromet.org/wp-content/uploads/2021/07/Sierra-Leone-report.pdf

[13] World Bank (2018). Sierra Leone Multi-City Hazard Review and Risk Assessment: Freetown City and Hazard Risk Assessment

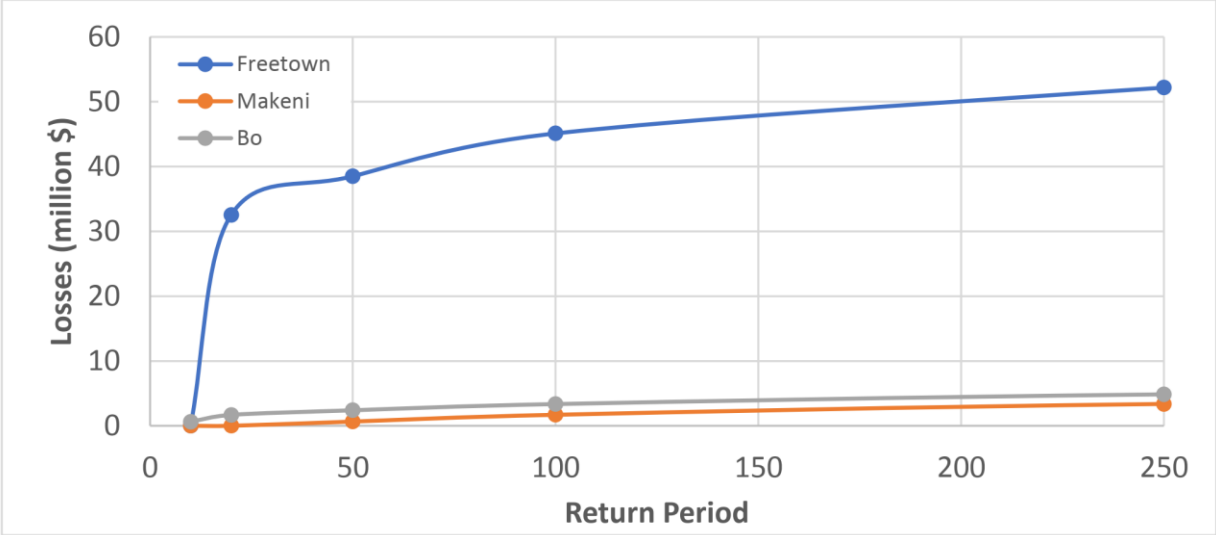
[14] Model accounts for educational, government, healthcare, utility and industrial facilities, formal and informal residential buildings, and road infrastructure

[15] Ibid

[16] The World Bank Sierra Leone Multi-City Hazard Review and Risk Assessment Final Report (Volume 5 of 5): Map Volume. 2018.

[17] Ishizawa, Oscar A.; Bonnafous, Luc; Gaspari, Maria; Giron Gordillo, Alex; Muñoz Díaz, Joaquín; Pomonis, Antonios; Wandel, Nathalie. 2020. Sierra Leone Disaster Risk Management Diagnostic Note. World Bank, Washington, DC. © World Bank.

Figure 7: Exceedance Probability Curve of Flood Risk for Freetown, Makeni, and Bo ARUP. World Bank (2018)



In Sierra Leone a in general and Freetown in particular, riverine floods (Figures 9 and 10) make up the majority of floods. Furthermore, in low-lying coastal locations, flooding tainted by wastewater can pose a health danger. Floods that coincide with storm events or high tides also have the potential to spread widely. Extreme weather events are likely to occur frequently, and this, along with changes in land use and land cover, increase the frequency of flood events.

Figure 8: Exceedance Probability Curve of Flood Risk for Sierra Leone (national level) UNDRR (2017).

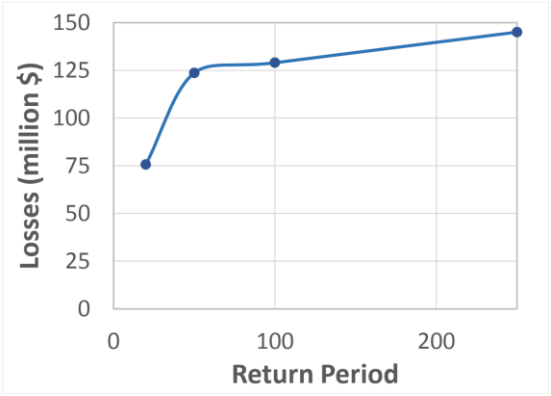


Figure 9: GAR's 100-Year Return Period Riverine Flood Hazard Map UNDRR (2017).

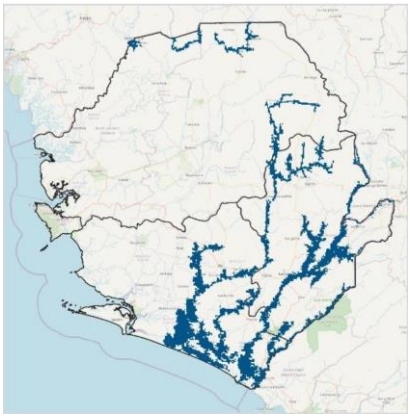
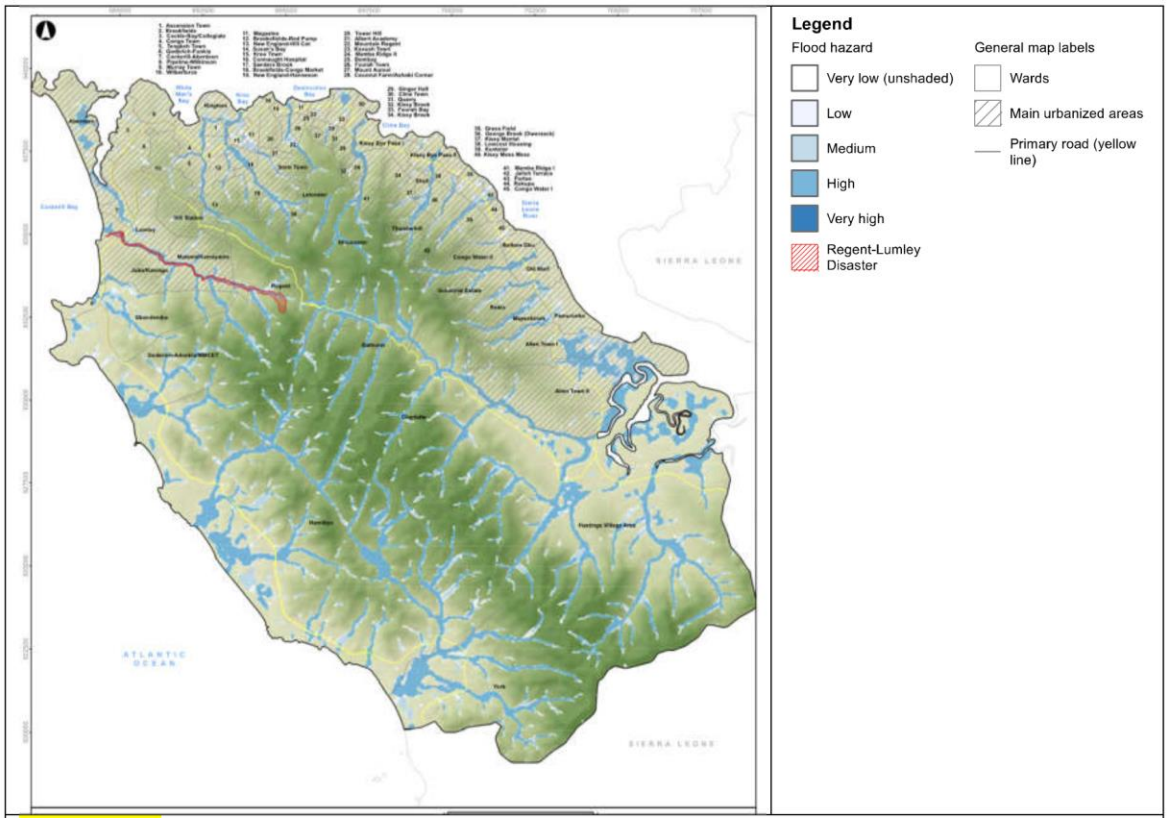


Figure 10: Qualitative flood hazard assessment in Freetown[18]



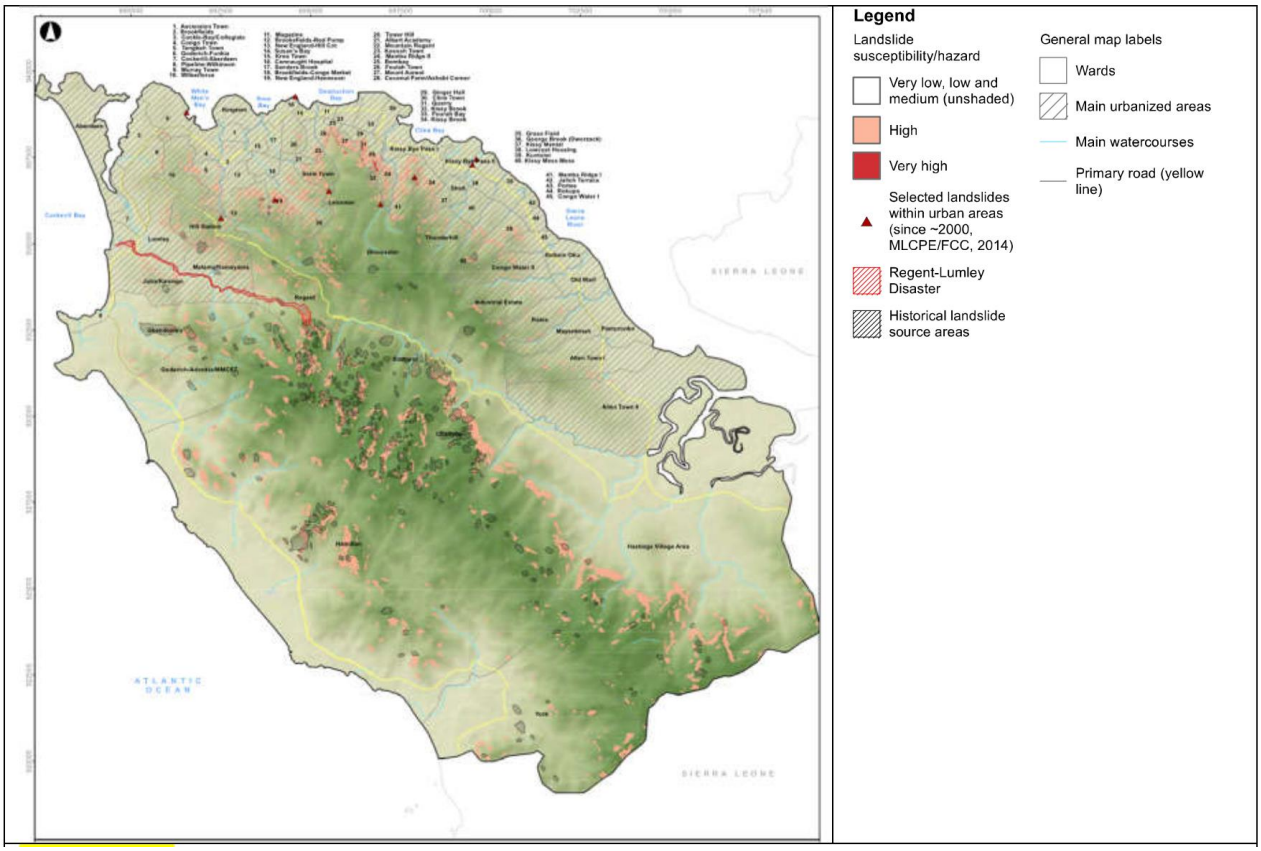
1.4.3. Landslides Risks

With the expansion of settlements, people will be exposed to these disasters to a greater extent (Figure 11). A significant landslide occurred on August 14, 2017, between the Regent and Lumley neighborhoods completely destroyed the area. A 7km flow caused by the landslide debris and flooding devastated and destroyed everything in its path, including vital infrastructure and a large number of residential buildings. A rapid Damage and Loss Assessment (World Bank, 2017) was conducted following the events, assessing the total cost of the event at $31.7 million, of which 53% correspond to damages (suffered by the housing sector) and 47% correspond to losses (primarily experienced by the social protection and health sectors)[19]. Although the Regent landslide was unprecedent in size and magnitude, the large damages and losses suffered reveal the potential for large-magnitude landslide events in the region, with costs well above the above-presented Annual Average Loss (AAL).

[18] Each qualitative hazard assessment is a general appraisal of the likelihood of the given area to experience a particular hazard. Qualitative flood hazard was assessed based on the spatial extent of the modelled flood hazard levels and return periods which have been produced for the quantitative flood hazard assessment.

[19] Ishizawa, Oscar A.; Bonnafous, Luc; Gaspari, Maria; Giron Gordillo, Alex; Muñoz Díaz, Joaquín; Pomonis, Antonios; Wandel, Nathalie. 2020. Sierra Leone Disaster Risk Management Diagnostic Note. World Bank, Washington, DC. © World Bank.

Figure 11: Qualitative landslide hazard assessment in Freetown[20]



This catastrophe directly affected more than 5,000 people. Hence the requirement for an early warning system and impact-based forecasting[21].The vulnerability, particularly to floods, is increased in metropolitan areas by improper drainage systems. Because urban drainage infrastructure is created based on past rainfall intensities, it might not be able to manage higher future intensities.

Flash floods are particularly difficult because they overwhelm drainage systems, impede urban transportation, and have negative effects on health and the environment because of untreated sewage. The 2017 landslide and floods in Freetown, where precipitation levels were 300% greater than normal, had a disastrous effect and left over 1,000 persons unaccounted for.

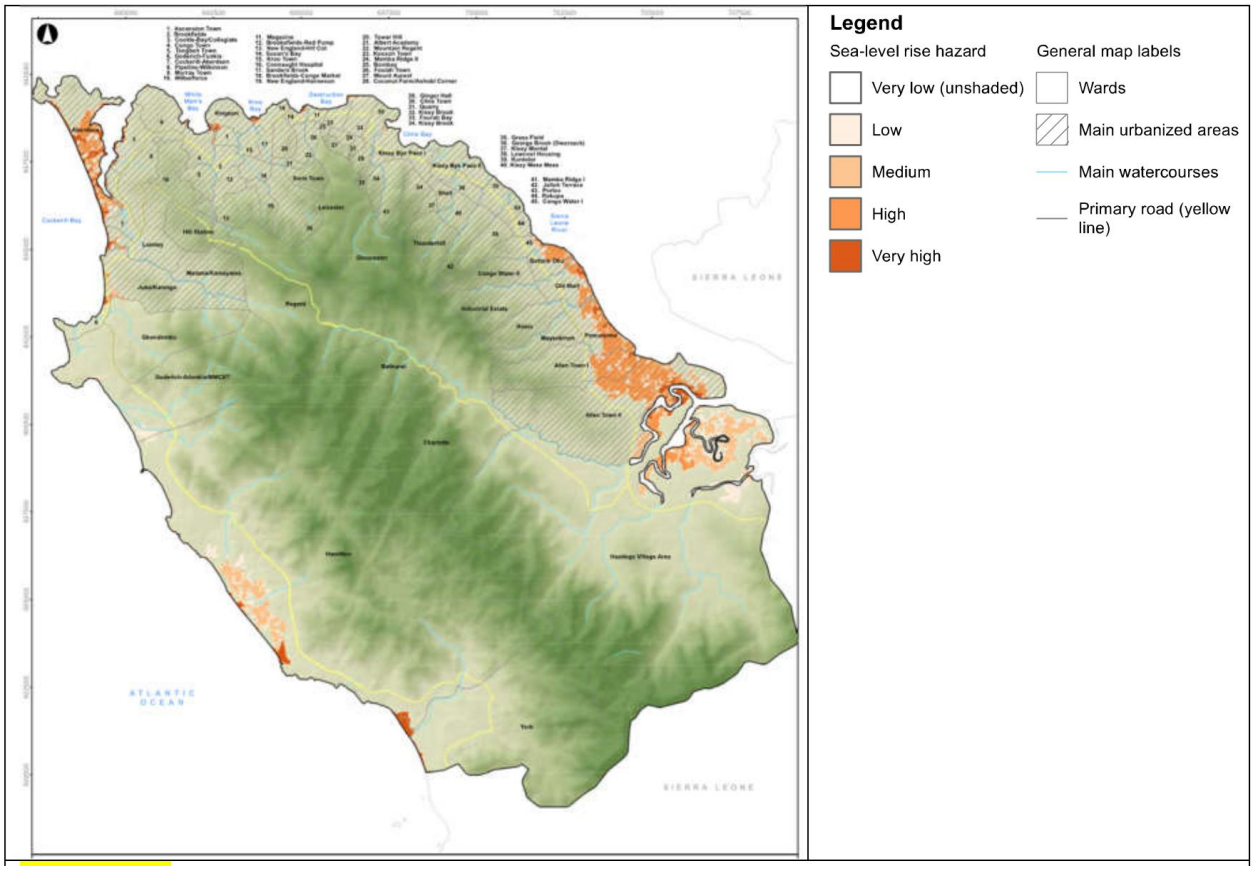
1.4.4. Sea level rise

Sierra Leone's coastal areas are increasingly vulnerable to the impacts of global climate change (Figure 12). The combined effects of sea level rise and environmentally unsustainable practices such as mangrove deforestation and sand mining are expected to result in accelerated rates of coastal recession and destruction of infrastructure. This puts coastal communities' lives and way of life under danger. Over 2 million people along coastal areas in Sierra Leone are expected to be at risk from predicted sea level rise. In addition to loss of properties and beaches, the consequences of sea level rise include population

[20] Qualitative landslide hazard was assessed using a weighted scoring system, which classified and then combined slope angle and a built environment density factor with a weighting of 75:25.
[21] World Bank (2017). Rapid Damage and Loss Assessment of August 14th, 2017, landslides and floods in the Western Area

displacements, flooding and saline intrusion, and threats to coastal aquifers, freshwater resources and agricultural water resources, undermining subsistence of local communities[22]. The qualitative assessment for sea level rise in freetown is shown ion Figure 10. Storm Surges and Changes in Ocean Dynamics also impact on fisheries resources and undermine subsistence of local communities.

Figure 12: Qualitative Sea level rise hazard assessment in Freetown[23]



1.4.5. Estimated Range of Annual Disaster Costs

Climate-related shocks cause heavy casualties and economic losses, underlining the importance of investing in adaptation for infrastructure to reduce vulnerability. Based on historical events and disaster risk information, an approximate value of annual costs of disaster and climate-related shocks in Sierra Leone has been estimated, including asset losses as well as response costs to support communities[24]. Table 1 below presents a range of the estimated cost per peril or item based on risk estimates and information from historical events from various sources. Damages to building and infrastructure assets from perils such as floods, landslides, windstorms, and fires are estimated to be worth about $5.7–10 million per year. The annual costs of responding to disasters and epidemics are estimated to be between

[22] UNDP (2017): Adapting to Climate Change Induced Coastal Risks in Sierra Leone

[23] The potential and frequency of sea-level inundation is assessed qualitatively by comparing the elevation of low- lying areas around the coastline with the potential effects of incremental increases in sea-level. This is based on expert judgement, but also on the basis that good practice in the UK dictates that properties should not be constructed at an elevation less than the level of the highest astronomical tide + some allowance for sea-level rise + an overtopping allowance + 0.3m

[24] Ishizawa, Oscar A.; Bonnafous, Luc; Gaspari, Maria; Giron Gordillo, Alex; Muñoz Díaz, Joaquín; Pomonis, Antonios; Wandel, Nathalie. 2020. Sierra Leone Disaster Risk Management Diagnostic Note. World Bank, Washington, DC. © World Bank.

$9–16.9 million. Due to limited information and high uncertainty on the available data, the estimates are rough values resulting from 'back-of-the-envelope' calculations (Ibid).

Table 1: Estimated annual aggregate costs of disasters in Sierra Leone (in million $)

Peril or Item	Amount		Comment
	Low	High	
Flood	3.60	6.00	Conservative rough estimates of building and infrastructure losses. Rough extrapolation of Freetown/Western Area AAL to country level (Freetown accounts for about 44% of the country's building stock; 24% of the 2.5 million Sierra Leoneans moderately exposed to landslide risk live in the Western Area—according to HARPIS-SL (n.d.) landslide risk assessment).
Landslide	0.90	1.50	
Windstorm	0.50	1.50	Similar magnitude as landslides.
Fire	0.70	1.00	Similar magnitude as landslides, based on comparison of limited historical events
Total Natural Perils Asset Losses	5.70	10.00	

1.5. Assessing Changes on Future Disaster and Climate-Related Risk

1.5.1. Climatology and historical climate of Sierra Leone

There is a need for long-term perspectives on the climate of Sierra Leone because the country is not immune to the effects of climate change. Utilizing historical climate records contributes to advancing our understanding of previous climate variability and conditions. Geographically, the quantity of mean annual total rainfall in Sierra Leone decreases from the coast to the north-eastern part of the country (Figure 13). The north-eastern region of the country has a climate that is colder (20 °C/year) and drier (2000 mm/year), whereas the south-western region has a climate that is wetter (>3000 mm/year) and warmer (>32 °C/year). The averages of three regional climate models reproduced the observed geographical differences in mean annual minimum and maximum temperatures, as well as, precipitation, with similar characteristics. The wet southeast with a steeper northward rainfall gradient, however, has more precipitation than the model estimates. The seasonal migration of the Inter-Tropical Discontinuity, which determines the spatiotemporal amount of moisture in the region, and the monsoon rainfall delivery, which accounts for over 70% of the rainfall in West Africa, are closely correlated with the observed and modelled gradients in precipitation and temperature (Hagos and Cook, 2007).

Figure 13. Climatological mean of annual total precipitation and surface maximum and minimum temperature in Sierra Leone for the period 1976-2005 from CRU[25] and three-member regional climate model ensemble means (RCM-ENS[26]).

[25] Harris, I. et al. (2020) 'Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset', Scientific data, 7(1), p. 109.

[26] The three regional climate models (RCMs) participate in the Coordinated Regional Climate Downscaling Experiment (CORDEX, Giorgi et al., 2009) framework and were retrieved from the ESGF portal. These RCMs consist of the Swedish Meteorological and Hydrological Institute, Rossby Centre (SMHI, Samuelsson et al., 2015), the Climate Limited-area Modelling Community (CCLM, Rockel, Will and Hense, 2008) and the Helmholtz-Zentrum Geesthacht, Climate Service Center, Max Planck Institute for Meteorology (REMO, Jacob et al., 2001). The RCMs were driven with initial and boundary conditions from the Max Planck's Earth Systems Model (Giorgetta et al., 2013) low resolution runs.

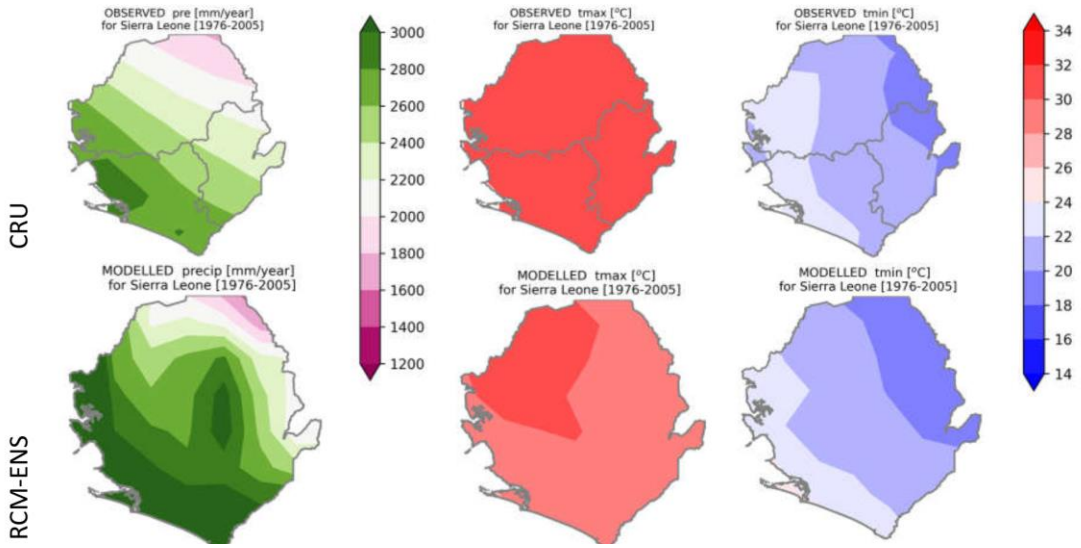
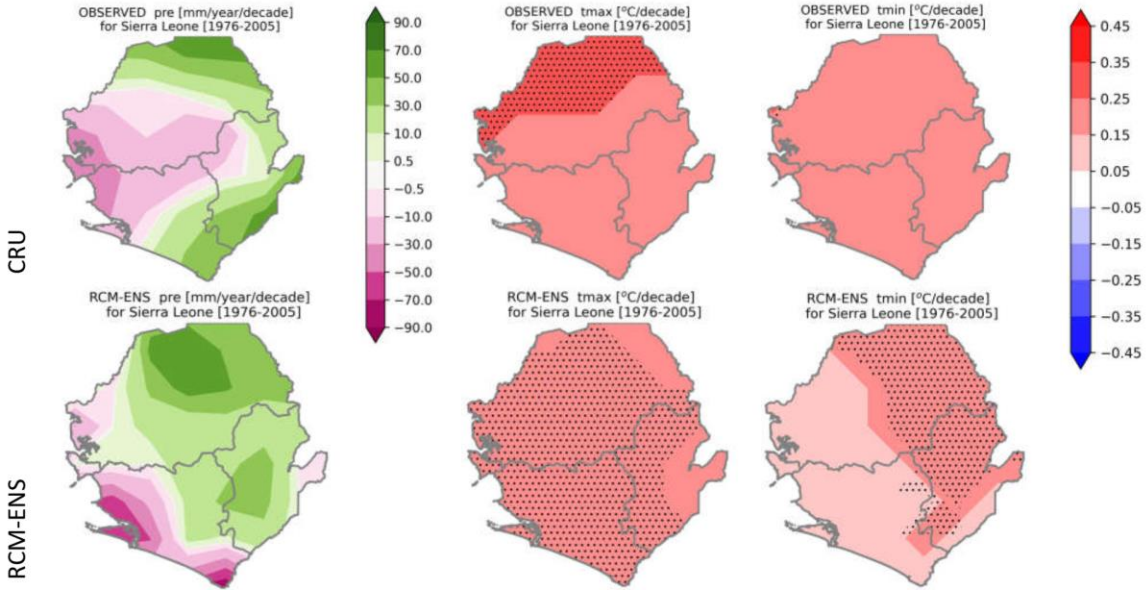


Figure 14 displays the spatial distribution of the trend in annual mean precipitation, maximum temperature, and minimum temperature for the current climate from observation and simulations.

Figure 14: Present-day trends in annual total precipitation and surface minimum and maximum temperature in Sierra Leone for the period 1976-2005 from CRU and three-member regional climate model ensemble means (RCM-ENS[27]).



In the western province, as well as the northwest and southwest of the northern and southern provinces, the rainfall trend is downward. Over the entire nation, a general rising trend in minimum and maximum temperatures is seen and modelled. The far northern regions show the fastest significant warming trend, with maximum and minimum temperatures increasing at rates of >0.35°C/year/decade and >0.15°C/year/decade, respectively. Although the model is capable of capturing the direction of the trends,

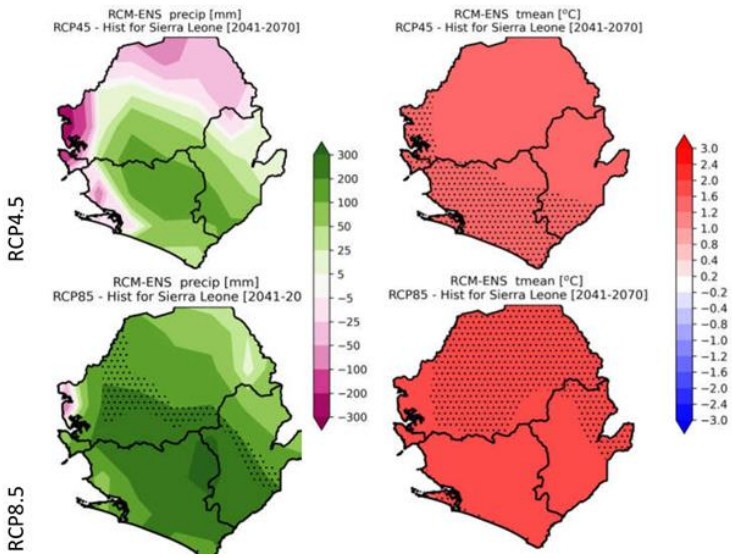
[27] The contours show values of the departure from the baseline (1976-2005). Dotted areas depict region where trends are statistically significant at 0.05 level

the magnitude is less but still significant across the nation. The extensive drying trend along the country's coastline and a SLMET area in the eastern province were both replicated by the model ensemble mean simulation. Additionally, the model predicted a notable trend in the country's maximum temperature as well as the minimum temperature in the eastern regions of the northern and eastern provinces.

1.5.2. Future Climate Projections

The ensemble means model's performance (Figure 15) demonstrate its applicability for projection studies despite the model's flaws and biases.

Figure 15: Projected change in annual total precipitation and surface minimum and maximum temperature in Sierra Leone for the period 2041-2070 from RCM-ENS under low-medium (RCP4.5) and high (RCP8.5) emission scenarios.



A few aspects of the observed climate are preserved by the model, though. With the help of these findings, we can use the ensemble mean model simulation to evaluate the predicted changes in mean and extreme climates over the coming years. According to the model, the northern region of the country could experience dryness under RCP4.5, but by RCP8.5, the country could suffer widespread wetness. The plotted values are departures from the baseline (1976-2005) while the dots marks areas where the change are statistically significant at 0.05 level.

Mid-century warming of more than 1.6 degrees Celsius is anticipated, particularly under the RCP8.5 scenario when values are projected to approach 2 degrees Celsius. The country's surface evaporation will increase due to the anticipated temperature increase, adding more moisture to the atmosphere and changing the amount of rainfall. Additionally, due to an increase in algae growth and the creation of favourable breeding grounds for disease vectors, the rapid warming may result in less water reaching streams, lakes, and reservoirs. This will have a detrimental impact on water quality. Furthermore, the anticipated rise in precipitation under RCP8.5 could lead to greater floods, which could result in fatalities and damage to the nation's physical assets.

1.6. Baseline Assessment and Situational Analysis/SWOT

Currently the National Meteorological and Hydrological Services (NMHS) agencies in Sierra Leone lack the capacity to fully meet the growing national needs and requirements for production of data and services. In particular (i) Data-gathering capacity and data quality are declining in absolute terms and (ii) There is a shortfall in on-line hydrometeorological observations. These constraints have emerged against a global background of improving longer-lead-time forecast modelling, which is necessary for mitigation of the impacts of natural hazards. The same constraints are evident also in relation to climate data. Climate-trend analysis is an increasingly important function to help address concerns of the NMHS about human-induced climate change and climate variability.

The lack of adequate financing stems primarily from several factors: the low visibility of the NMHSs, low appreciation for current services provided by NMHSs, good capacity of the current aviation sector providers of meteorological services, a lack of adequate legislation to Promote the capacity of the NMHSs, and low awareness among the Government and industry about potential hydrometeorological services which could be produced by better-equipped NMHSs. The financial shortfalls also partially result from the fact that NMHSs have not identified their customers and end-users, as well as a lack of public-private partnerships, and the low capacity of the NMHSs to cooperate internationally and to raise international funding (which is available from a large number of sources).

These constraints can be eliminated by strategies such as rapid and effective external financial support. Such support needs to be large enough to bring the NMHSs to adequate technical levels, to Promote adequate human resources, and to guarantee sustainable operation of investments made, for a number of years. It is critical to invest in internal training programmes for staff and management, in development programmes for the staff, and in international cooperation.

In order to get national support for strengthening the NMHSs, and to ensure their sustainable development, it is essential to demonstrate convincingly to the Governments, industry and the public that meteorological products and services contribute to different economic sectors and to sustainable socioeconomic development of the community.

It is critical to build a general awareness that sustainable development in the countries will only occur through incorporating weather and climate information in the national policies and strategic planning that cover crucial areas like risk and vulnerability assessment; preparedness and early warning systems for the mitigation of severe weather effects on the economies and communities; and development of the economic sectors in the countries, and in the region.

It is also critical for the NMHSs to recognize the modern structure of production of hydrometeorological services, to secure financing for such production, and to identify the current and potential customers and end users of their services. Furthermore, in order to expand the capital base of the NMHSs in Sierra Leone, it will be necessary to develop the national legislation and regulations so that the NMHSs can produce commercial services, and that they can use the revenue for investments. Tables 2 and 3 present a summary of a SWOT analysis of the SL-Met as the main institution for delivering the NFCS and the National Water Resources Management Agency, its role on sustainably managing and regulating the country's water resources for equitable use of the water resources and socio-economic development.

Table 2: SWOT analysis of capabilities within the SL-MET (source: SL-MET 2018)

Strengths	**Weaknesses**
• Being a member of the world meteorological organization enabling the Agency to participate in and benefit from international cooperation in meteorology, hydrology and related geosciences • The continued financial support by the government and development partners • The availability of land to establish observation stations • Two manned stations and 16 Automatic Weather Stations (AWS)) monitoring and collecting weather observations	• The observation network damaged during the conflict has not been re-established and the available stations are not adequate to provide information that represents weather and climate patterns and characteristics in Sierra Leone. • The staff is inadequate and does not have adequate skills. • Lack of staff with skills in meteorology, numerical weather prediction, modelling, agricultural meteorology, disaster management, marine, hydrometeorology, and expertise to develop

• A staff strength of 46 of which only two hold university degrees calling for more training • Availability of some historical data useful for research to develop user targeted products • Ability to work with other institutions to achieve the shared objectives; and • Having some computers and accessories to facilitate the operations of the Agency.	computer application tools for communicating weather and climate forecasts and early warnings • Inadequate technicians, and trainers in meteorology • Inadequate internet services to access observations, model products from advanced centres • Inadequate digitisation of hydrometeorological data and observations • Lack of Radiosondes to make upper air observations and Ocean buoys to make marine weather observations • Lack of infrastructure to collect, process data & observations to generate forecasts and early warnings • Lack of radar to support nowcasting and issuance of weather alert and warnings • Inadequate financial resources to enhance and modernize infrastructure for monitoring weather and climate, for collecting observations, and for processing observations to generate forecasts and early warnings • Inadequate awareness and visibility of the services provided by the Agency; and • Inadequate cost recovery from hydrometeorological services.
Opportunities	**Threats**
• Support efforts of the government, citizens, and institutions to achieve SDGs particularly as relates to ending poverty and hunger; ensuring healthy lives; ensuring availability and sustainable management of water and sanitation; ensuring access to affordable, reliable, sustainable and modern energy; achieving sustainable economic growth; building resilient infrastructure; making cities safe; combating climate change and its impacts; and sustainable management of forests • Support efforts of the government, institutions and individuals to reduce disaster risks as is expected of them under the Sendai Framework for Disaster Risk Reduction 2015-2030 • Support efforts of institutions and individuals to adapt to climate change by minimizing the risks and enhancing opportunities associated with severe weather and climate extreme events • Support government efforts , institutions and individuals to mitigate climate change. • Meet the needs of the projected increase in aviation traffic associated with expected increase in aviation passengers in parts of Africa.	• The services provided by the private providers, which despite inadequate skills, are easy to access • Inadequate budgetary provisions to re-establish and modernize infrastructure and train staff to provide services to meet the rapidly evolving needs of the public and institutions: • Inability to meet evolving and increasing demands from the public and institutions • Rapidly evolving models to provide services to the aviation sector and the associated demands from International Civil Aviation Organization (ICAO) • Inability to upgrade and modernize operational system to adapt to the rapidly evolving information and communication technology • Rapidly changing needs of users of weather and climate services; and • Expanding responsibility due to the needs of weather and climate information to address the ever-increasing demands from users.

Table 3: SWOT analysis of capabilities within the National Water Resources Management Agency[28]

Strengths	Weaknesses
• NWRMA Act 2017 exists • Staff appointed have experience in IWRM • Ability for sector coordination and implementation of IWRM activities • Clearly defined roles and responsibility of NWRMA • Availability of institutional knowledge • Availability of some hydrological equipment and data	• No regulations enacted • Inadequate coordination among IWRM actors • No technical standards for water resources management • Inadequate human and institutional capacity • Limited awareness of water resources management • No operational logistics and tools • Insufficient budget
Opportunities	**Threats**
• Strong political will at the highest level of government to ensure sustainable water resources management • More focused attention on water resources management issues • Donor commitment to support water resources management activities • Benchmarking opportunities both nationally and internationally	• Pressure for land leading to the destruction of critical watersheds and catchments • Increasing pressure on water resources from the growing population • Insufficient knowledge of water resources management among stakeholders • High level of vulnerability to climate change • Non-compliance with the rules and regulations by some stakeholders • Conflicting or overlap in mandates • Inadequate and untimely release of subvention (i.e., budgetary allocation) for projects

1.7. Policy landscape (NDC, NAPs, etc)

Sierra Leone has developed a National Framework for Climate Services and implementation plan which clearly describes strategies and action plans for the delivery of climate services in the country.

Climate change is a prioritized development challenge for Sierra Leone as noted in their Nationally Determined Contributions and the Government's new Medium-term National Development Plan (MTNDP) 2019–2023. In particular, the Government seeks to build resilience against the impact of climate change on agriculture, water resources and vector-borne diseases. However, there is still limited knowledge about the potential effects of climate change and increased variability.

Sierra Leone has developed a national strategy to combat climate change and adopted a framework for crisis response. Sierra Leone approved the first NDC in November 2016 and presented the updated version in 2021, which identified a broad range of sectors affected by climate change. It also envisions to achieve mitigation goals of reducing CO2 emissions by 5% before 2025, 10% before 2030, and 25% before 2050, and sets adaptation goals of reducing vulnerability by half by 2030.

Sierra Leone's updated NDC illustrates an ambitious estimate of climate-related spending needs at US$2.8 billion (66% of GDP in 2020) between 2021 and 2030, significantly revised upward from US$900 million in

[28] Sierra leone: National Water Resources Management Agency (NWRMA); Five-year Strategic Development Plan (2019 -2023)

the previous version (NDC, 2021). The estimated costs for mitigation and adaptation are US$1.7 billion and US$1.1 billion respectively, which implies an ambitious annual fiscal cost (of about US$276 million) at 6.6% of GDP or 43% of fiscal revenue in 2021. While the estimated mitigation and adaptation cost is high, it includes a large amount of spending for development purposes regardless of climate change

In 2021, Sierra Leone published the initial National Adaptation Plan (iNAP) to enable decisive and sustainable actions in adaptation identified in the updated NDC. It includes the four key blocks along the lines developed by UNFCCC, namely i) identifying climate impacts, vulnerabilities, and risks, ii) adaptation-related policies, plans and programs, iii) mainstreaming of adaptation, and iv) monitoring evaluation and reporting. The iNAP identified five categories of adaptation projects (investments, human capacity development, institutional strengthening, regulatory modifications, research) for each vulnerable sector. Together with the National Adaptation Plan of Action (NAPA) developed in 2007, the authorities have prioritized 24 adaptation projects with detailed rationales, project objectives, inputs, outputs, institutional arrangements, risk and barriers, monitoring, and cost estimates (Irish Aid, 2015). However, selection criteria to prioritize these programs and projects were missing in the iNAP and NAPA (IMF 2022).

The iNAP is consistent with the National Climate Change Policy, Strategy and Action Plan, and the Medium-Term National Development Plan (2019-2023) which includes a cluster on addressing vulnerabilities and building resilience. The iNAP covers five priority sectors of Agriculture and Food Security, Water Resources and Energy, Coastal Zone Management, Environment, and Disaster Management, and two identified cross cutting priorities of Gender Equality and Social Inclusion and, Hard and Soft Infrastructure

Sierra Leone has also endorsed several Conventions including: (i) the UFCCC, (iii) the UNCCD and (iv) the Convention on Wetlands of International Importance (Ramsar). Resilience to disaster and climate change risks is critical for achieving the SDGs and strengthening the coherent implementation of the SDGs, Sendai Framework for Disaster Risk Reduction and Paris Agreement on Climate Change.

The proposed project is consistent with attributes of climate action and disaster risk reduction as mentioned in SDG 13 for combating climate change and its impacts, Goal 11 for making cities inclusive, safe, resilient and sustainable and Goal 6 on ensuring access to water and sanitation for all. The project is aligned to the Paris Agreement, in particular, Article 7.1, on enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change and Article 8.1, on averting, minimising and addressing loss and damage associated with the adverse effects of climate change. It is consistent with paragraph 13 of the Sendai Framework for Disaster Risk Reduction, in particular addressing climate change as one of the drivers of disaster risk and represents an opportunity to reduce disaster risk in a coherent manner. The alignment of the project to national and international conventions and agreements is key to in reducing urban risks and increasing building resilience against flooding, landslides, coastal erosion and sea-level rise in Freetown.

The following general capacity development gaps and needs for the NFCS have been identified after a review of the existing architecture for providing climate services in Sierra Leone: insufficient infrastructure, particularly the observation network, which is currently insufficient for collecting data on the entire country; insufficient communication facilities, which hinder the quick exchange of meteorological data and products; diversified forecasting facilities. The nation's 11-year civil war, which significantly damaged meteorological services nationwide, made these shortcomings worse. The ability to observe, monitor, forecast, package, and convey information about the many climate conditions was hampered by the conflict.

2. PRE-FEASIBILITY ASSESSMENT

2.1. Purpose of Hydromet services and user needs

The main purpose of meteorological and hydrological services is to enable the public and economic sectors to make appropriate decisions when faced with weather, climate, and hydrological hazards. Regardless of the level of development, the NMHS and its partners need to be able to: (i) make meteorological and hydrological observations (ii) combine this information with products generated by the WMO community—generally in the form of gridded numerical products, which assimilate observations from everywhere into numerical weather prediction systems (iii) make accurate and timely forecasts and warnings relevant to their national users and (iv) disseminate this information, using diverse means to match different sectors of society. This information has to be useful to the users if it is to support appropriate behaviours, especially during extreme weather events

The value of hydrometeorological information for end users is more than just the total reduction of economic losses. Monitoring of the environment, together with climate and hydrometeorological forecasting, are a few of the management tools that can play an important role in decision-making and can increase both human safety and business efficiency and productivity.

However, improved scientific knowledge of hydrometeorology does not automatically increase the socio-economic value of the products provided by NMHSs. Even a correct forecast has no value if it is not disseminated to the end-user at the right time and in the right and understandable format.

2.2. Current status of the hydrological observing and forecasting systems

2.2.1. Meteorological observing systems

According to the Sierra Leone country hydromet diagnostics, report (2021), the SL-MET has the following operational surface stations: (i) 8 Agromet stations (but some stations have faulty sensors) (ii) 4 Marine weather stations (iii) 3 manual stations and (iv) 60 automatic rainfall stations. For data transmission all the rainfall stations use 3G cellular data to automatically transmit data to the on-premises server via ADCON Telemetry gateway. The data is obtained either as pdf or csv. However, none of the existing stations are registered with WIS and currently do not transmit data to the WMO Information System (WIS) / Global Telecommunication System (GTS) platforms.

Also added to the OMS and the rainfall monitoring stations the institution have Eight (8) agrometeorological station which are not linked to the head office on-premises server. Data from this agrometeorological station are manually obtained as print outs (hard copy).

Presently, there is no existing formal policy and practice for free and open sharing of observational data in SL-MET. International data reception is not readily available because of inadequate operational systems (workstations, telecommunication, and internet facilities).

The SL-MET has access to the European Centre for Medium-Range Weather Forecasts (ECMWF) forecasting products through the officially open channel but does not have any dedicated channel as a WMO member country. The ECMWF is a European global forecast seamless model. It is widely regarded as the best and most reliable model currently in existence. SLAM also have access to UK-MET office forecasting products. However, they presently do not have access to any satellite data either in a national, regional, or global context.

Nigeria provides daily forecast based on the Consortium for Small-scale Modeling (COSMO) COSMO-Model[29]. SL-MET makes use of model outputs from ECMWF and UK-MET office as some of their main sources of information for forecasting at different timescales. The agency also does not have the internal ability and capacity to run and maintain a fully functioning forecasting model of its own.

Although the SL-MET does their probability forecasts by ensemble forecasting using products from available models (ECMWF, UK-MET, and other forecasting centres that are available online), they do not perform data assimilation and forecast verification on their own.

With training for forecasters in the use and interpretation of Numerical Weather Prediction (NWP) models and products and the implementation of more robust operational forecast services, the maturity level could easily improve.

2.2.2. Oceanographic monitoring stations

Four (4) oceanographic monitoring stations (OMS) have been established at Tagrin, Government Wharf, Shenge and Bonthe and linked to an on-premises server at the SLMet head office in Freetown. All monitoring stations use 3G cellular data to automatically transmit data to the on-premises server via ADCON Telemetry gateway. The data is obtained either as pdf or csv.

2.2.3. Warning and advisory services

The aviation meteorology division of SL-MET operates as per WMO guidelines concerning the issuance of warning and advisory services. Also, services such as public weather forecasts and marine weather forecasts are available on a 24/7 basis through the Agency's mobile application SLMet official Facebook page and designated WhatsApp group. The Agency issues warning and advisory specifically for rainfall intensity, wind speed, and direction. Feedbacks are received and considered via Facebook, workshops, meetings, WhatsApp and emails.

The Agency is in the process of implementing the Common Alerting Protocol (CAP) and has undergone initial training on it. However, immediate assistance is required to assist SL-MET in receiving and disseminating NiMet produced TV weather bulletin and forecast. In order to manage the flow of risk information available in the country, both with regard to hazards (flood and landslides) and exposure of populations and infrastructure, there is need to have an inter-ministerial coordinating committee, with responsibility for addressing and communicating climate and weather-related emergencies.

2.2.4. Hydrological monitoring systems

The NWRMA have twenty-five (25) surface and ten (10) groundwater monitoring stations in different locations across the country. These automatic monitoring stations are linked to an on-premise server at the NWRMA head office in Freetown. The density of stations is inadequate for provision of hydrological services.

There are no standard products such as Quantitative Precipitation Estimate (QPE) and Quantitative Precipitation Forecasting (QPF) to meet the needs of the hydrological community in SL-MET. There is however a Standard Operating Procedure (SOP) for the exchange of information between SL-MET and

[29] The Consortium for Small-scale Modeling (COSMO) was formed in October 1998. Its general goal is to develop, improve and maintain a non-hydrostatic limited-area atmospheric model, that has been used both for operational and for research applications by the members of the consortium (details). Moreover, within a licence , the COSMO model has been used for operational and research applications by other national (hydro-)meteorological services, universities and research institutes.

hydrological communities. The country diagnostic noted the non-availability of real-time data for flood warnings, and no assessment of flood-related risks, determination of flood threshold levels, flood mapping, warning mechanism.

In uplifting the capacities of the NMHS, the Sierra Leone Country Hydromet Diagnostics report (2021), report notes that considerable effort should be made to improve the synergy between the SL-MET and Sierra Leone National Water Resources Management Agency (SL-NWRMA) and strengthening the NWRMA whose purview is to manage the hydrological activities for the country.

2.2.5. Hydrological modelling and data assimilation

The current hydrological monitoring and predictive capacity of the country remains low, and significant investment is required to uplift this capability. Any future project intervention should therefore strengthen data management and hydrological modelling capacity building and infrastructure. This should also include the integration of observations, development of modelling capabilities and forecasts, and flood hazard mapping for other basins. This will be specifically critical to the production of flood risk assessment maps and data. The generation of these maps requires well-calibrated hydraulic models (good quality flow observations and rating curves for each river), as well as accurate digital elevation models (DEMs) derived from satellite (e.g., SRTM) or aircraft LIDAR measurements

2.2.6. Operational priority funding for the establishment of a functioning network

This assessment has identified operational priorities for funding, which are needed to provide the basic system functions on which can be built increased capacity and further equipment/systems. These priorities include the following (note that many of these funding priorities also apply to the operations and maintenance of meteorological stations): (i) a minimum number of staff are required per district to undertake the work, but this minimum is not currently met (ii) Equipment for transportation, survey, safety, flow gauging, district offices and general maintenance at stations is recommended in order for the teams to operate effectively; (iii) Transport is a priority, and sufficient budget should be set aside for vehicle procurement as well as operation and maintenance (iv) the tools and goods required for everyday maintenance of stations such as gauge plates, angle irons, bolts and nuts, paint, cement, shovels, picks, wheel barrows, shifting spanners, spirit levels are needed for each district; (v) a project of station maintenance should then be started using the transport, survey equipment, station maintenance consumables and tools procured above; (vi) re-rate all the stations for low-flows is also required.

Once all the above issues have been addressed, it is recommended to begin refurbishing the high flow gauging equipment and network. A program of re-rating all the stations for high flows should then be undertaken so that the measurement of high flows can be at a high level of confidence.

2.3. Gaps, needs and processes and capacity needed to deliver priority requirements

A survey of government officials from Agriculture, Energy, Environment, Aviation, Maritime safety, Water Management and Disaster Risk Management sectors suggested that the level of services provided by the NMHSs requires to be improved.

The need for hydromet data and forecasting and other expert services in Sierra Leone is growing, as awareness of the options and possibilities of modern science and technology increases among end-users.

From the stakeholder consultations, the common needs of different customers and end-users of hydrometeorological services were identified as: (i) twenty four hour warnings of rainfall intensity (ii) sector-specific tailored products, based on a better understanding of the needs of end-users (ii) better

and more location-specific timely weather forecasts of different hydrometeorological parameters and air-quality, for shorter ("nowcasting") and longer (more than 7-10 days) periods (iii) seasonal and annual climate outlooks (iv) more real-time hydrometeorological and environmental data, including radar data (v) better and more location-specific analyses on climate variability and extremes (vi) local-scale studies on impacts of climate change (averages, extremes, variability) for different socioeconomic sectors in different time frames (vii) improved awareness of hydrometeorological applications and services (viii) better dialogue with the NMHSs (ix) public-private partnerships and (x) an integrated decision and information system to forecast severe hydrometeorological and environmental events, and to provide advance warnings to commercial, municipal and government organizations.

It is also clear that many of the sectors and individual companies would be willing to invest through public-private partnerships in strengthening the national observation network and hydrometeorological services if they could use on-line data for their own purposes and gain from tailored products.

2.3.1. Gaps in the meteorological observation network

There is a need to increase observations in catchment areas for all major rivers in the country– including smaller rivers that are at present not included in the observation network. In addition to the poor spatial coverage, existing stations noted in section 2.2, only partially function as a result of: i) vandalism; ii) limited spare parts; iii) inefficient maintenance; and iv) incorrect calibration. Furthermore, reporting of information from manual stations is frequently inaccurate or absent. This is as a result of inadequate diligence or technical capacity of personnel to collect and transmit readings via mobile phone, telephone and/or radio. Regarding AWSs and rainfall logging stations, data collection and transmission is hindered by limited airtime availability for GSM transmission and expired licenses for visualisation software.

In expansion and modernisation of the observation network the following need to be taken into consideration (i) the funding and the implementation of an operational maintenance plan for the hydromet monitoring network, the conventional stations and the automatic stations; (ii) the integration of redundancy in the monitoring network and the data communication network to enhance sustainability and Promote business continuity (iii) the establishment and funding of a reliable, secure data communication system (iv) the use of weather observers at the conventional stations at the highest possible level to provide a manual back-up for data from the automatic stations when needed (v) the redesign of AWS with the aim of redundancy of meteorological sensors in particular with regard to the power supplies, batteries, loggers and communication links and (vi) change in the job description requirements of the weather observers indicating their responsibility for the real time provision of the data from the weather stations assigned to them.

2.3.2. Gaps in infrastructure, products, capacity and communications

Hydrological monitoring stations: The density of hydrological stations needs to be improved. In addition, the NWRA needs to develop a decentralized system, whereby automated hydrological sensors are installed and disseminate water level information and messages to communities. This will allow warnings of rising flood levels to reach communities in a timelier manner and provide communities with more time to engage in evacuation and flood mitigation procedures.

Water products and services: There is a need to strengthen and update the national hydrological databases and data base management systems. This information (water levels, measured discharges, water quality, ground water levels, sediment load and weather/climate information) is essential and can be used by planners, policy makers, private sector and the public at large.

Automated Rain gauges. According to WMO standards each hydrological station requires a rain gauge in order to collect meteorological data that is used to understand runoff for flood forecasting and input to hydrological models. These rain gauges will need to be installed in districts across the river basins (particularly the proposed Scaling up districts, but also possibly to supplement LDCF-funded weather stations where coverage is limited).

Monitoring Equipment/Sea buoy. The seas have been adversely affected by climate change and other environmental factors e.g., siltation due to land use change on its periphery. Currently NMHSs have no scientific data to monitor environmental trends on the sea itself. The installation of buoys will enable the collection of a wide range of weather, climate and hydrological data, which will allow climate-related trends to be monitored and eventually disaggregated from other environmental processes.

2.3.3. Gaps/Needs for climate information dissemination

Current gaps include the translation of climate information into the language of the target audience – in most areas the majority of users of climate information understand the information better in their local language. The other gap is capacity building for those managing the climate centres and the entire chain that transmits the information, because the image that is currently downloadable is the global weather image, which demands knowledge of climate science and Meteorology to interpret. Targeted capacity building is therefore necessary. Linked to this, advisories linked to the weather forecast is an area that needs huge investment because users require a trusted source of information that advises them on what to do with that information. Should there be need for upscaling this initiative, space is not always easy to find. Some rooms in district councils have had to be renovated for the centre to find space.

2.3.4. Technological gaps in community-based flood early warning systems (CBEWS)

Over half of disasters experienced are weather-related, mostly floods and landslides, with floods claiming more lives and destroying more property. With climate change these extreme weather conditions are likely to increase in frequency and intensity. To mitigate the impact of flooding, CBEWS can be developed, in particular to ensure “last mile” access to information. Establishing this information and communications technology (ICT) enabled a flood early warning system that uses a flood sensor attached to a transmitter to detect rising water levels. When the water reaches a critical level, a signal is wirelessly transmitted to a receiver and the flood warning is disseminated via mobile phones to appropriate agencies and vulnerable communities downstream.

2.3.5. Human resource constraints

Given the need for tailored products across sectors, this will require building the human capacity to generate appropriate products, part of which will be undertaken by each sector in order to ensure weather/climate information is packaged correctly with other information sources. However, part of the work will also need to be undertaken to ensure that the weather/climate information is of the required scale and provided in a timely manner in useable formats for use by the different sectors: fisheries, agriculture and water. This will require developing human capacity at the NMHSs to utilize available hardware and software to i) visualize meteorological, environmental and oceanographic data; ii) analyze and properly use satellite-based data and information; iii) produce and issue < 1 day severe weather nowcasts, 1-10 day weather forecasts and 1-6 months seasonal forecasts; and iv) edit and package weather and climate data and information into a suitable format for user-agencies –and local community end-users such as farmers and fishers. This will include building capacity for generating accurate and timely forecast products including seasonal drought forecasts and drought alerts focused on assisting local

community preparedness for agricultural stresses. Severe weather alerts (advisories, watches and warnings) for winds need to be developed for assisting fishers.

2.4. Recent Projects to Build Upon

There are several ongoing climate adaptation projects, on which the GCF financed project could build upon (details are included in Appendix 1). These include: (i) the "Adapting to Climate Change Induced Coastal Risks Management in Sierra Leone" project financed by the GEF/Adaptation Fund (ii) the "Strengthening Climate Information and Early Warning Systems in Africa for Climate Resilient Development and Adaptation to Climate Change", financed by the GEF (iii) the "Building Resilience to Climate Change in the Water and Sanitation Sector", implemented effective 2014, financed by the GEF and co-financed by the AfDB which aims at building resilience to climate change in the water and sanitation sector and (iv) the "West Africa Biodiversity and Climate Change (WA BiCC) program", a five-year program funded by the United States Agency for International Development (USAID) that aims to improve conservation and climate-resilient, low-emissions growth across West Africa. Implementation of the project measures will contribute towards the updated NDC targets and support the paradigm shift towards a more climate resilient development pathway.

2.5. Recommendations for technical interventions, given gaps, current efforts, and scalability

Given the gaps and needs, and the ongoing initiatives that have the potential to be applied more widely, a dialogue was initiated with government and non-government stakeholders to identify the priority requirements for equipment, capacity building and tailored products/services that can use climate information. Based on these discussions, as well as discussions at the stakeholder consultation workshop and the preceding needs/gap analysis, products/services were identified. It is important to recognise that the starting point for these discussions was the potential tailored services/products which showed promise for scaling up and which allow the expanded EWS activities to reach the users of EWS messages and warnings.

2.5.1. Improving Community-based Early Warning Systems (CBEWS)

At times of disaster, impacts and losses can be reduced if authorities, individuals and communities in hazard-prone areas are well prepared and ready to act, and are equipped with the knowledge and capacities for effective disaster management. Disaster Risk Management Projects include improving the disaster risk management systems for the sectors and enhancing dissemination and use. Strengthening preparedness capacity and people-centered early warning systems are also key policy priorities under the recently developed initial National Adaptation Plan (NAP) , 2021). EWS must provide warnings that are timely and understandable to those at risk, consider the demographic, gender, cultural and livelihood characteristics of the target audiences, including guidance on how to act upon warnings, and support effective operations by disaster managers and other decision makers.

An EWS can be based in a community without being owned or driven by that community. The most lasting impact, however, occurs when a community has a strong understanding of the EWS; EWS are only as good as the actions they catalyze as triggered action is an essential part of any warning system. In designing a CBEWS, solutions must aid communities in both receiving urgent information and in acting upon it. Therefore, this study recommends scaling up the successful practices through 1) awareness raising 2) improved communication methods and 3) installation of sensors to provide early warnings. Efforts need to include local knowledge within any decision process and a starting point should be how currently the communities are warned and when they decide to react to any warnings.

2.5.2. Advisories and warnings for marine use

Existing warnings and information products for fishers at sea are currently limited. These communication channels, which have direct contact with fishers, and marine transporters, offer the potential for expansion and inclusion of warnings of extreme weather important to fishers and their safety – thunderstorms, squalls, extreme waves and winds. Collaborating partners will need to include Departments responsible for Meteorology and Climate Change, Disaster Risk and Management, Marine Police, and Safety of vessels (Marine Department). The following are examples of the types of technical messages which have been identified and could be developed through this project.

Early warning messages for the fishers, and marine transporters so that they are aware of the kind of weather expected for the next few days. This should help them to plan and do other business or income generating activities for their households. The processors can be informed about what type of weather lies ahead and how it will affect catches. Information flow of weather changes to the targeted stakeholders may be critical to inform their daily commercial routines.

2.5.3. Tailored agricultural products for managing risks

Tailored climate related products for managing agricultural risks, particularly for Smallholder farmers suffering food insecurity, are needed. Therefore, this assessment recommends extending the initial design work and evaluating its application in a wider set of districts, where farming systems may change, and other social and environmental concerns may come into play. The robustness of the products, their usefulness and delivery mechanism can be extended and assessed, through which a set of generalised products will be identified for different farming concerns, locations and crops/livestock.

2.5.4. Tailored climate related products for managing hydro-meteorologic risks

Tailored climate related products for managing hydro-meteorologic risks, are needed. There is need to collaborate with communities to jointly develop appropriate products (utilising both weather and seasonal forecast information), which can be used for decision-making. Tailored demand-based services/products, which demonstrate a high potential for scaling up, include the following identified interventions:

(i) Sub national and community level capacity development on disaster management. Tailored climate related products for managing agricultural risks, particularly for Smallholder farmers suffering food insecurity, are needed.

(ii) Advisories and warnings for fishers on the sea. Existing warnings and information products for fishers are currently limited. These communication channels, which have direct contact with fishers, and commuters offer the potential for expansion and inclusion of warnings of extreme weather important for maritime safety – thunderstorms, squalls, extreme waves and winds.

(iii) District level climate information centres. This study recommends that proposed interventions related to the climate information centres include climate information advisories, site specific weather information, and capacity building of the entire information sharing chain. Linking to rural radio stations also needs supporting, as in other districts this effort has been limited by budgets

(iv) Regular training of area civil protection committees. To address the gaps in disaster risk management, this study recommends that district and community-based disaster risk management services in

locations affected by landslides and floods be trained in emergency response and setting, running and management of district level emergency response protocols.

2.5.5. Observational equipment needed to service identified products

In order for these products and services to have access to the required information streams it will be necessary to upgrade some of the current equipment and monitoring/forecast processes in strategic locations where there are gaps. The study recommends focusing on installing the following equipment:

(i) AWS in key locations to service both the hydrological modelling (i.e., providing information on catchment rainfall for strengthened Operational Decision Support Systems (ODSS) and the need for localised weather data for developing sector specific advisories. A further use for weather data is that in the long term if can be used to de-bias satellite estimates which will help reduce dependence on weather stations and extend the ability to monitor to further regions.

(ii) Hydrological monitoring stations will be needed to provide information to the ODSS, which is used to tie the hydrological models to represent current conditions. This helps ensure that the hydrological models do not drift too far when estimating current and near future conditions. Installed stations.

(iii) Sea buoys, which measure the weather and wave conditions, will provide data and information not currently available. This will enable the prediction of inclement weather, which poses a danger to fishers, as well as improve their forecasts of the coastal region. It will further be able to provide weather/wave information, which will be used as the basis for developing warnings and services for marine activities.

The list of the proposed services and amount of monitoring equipment are presented in appendix 2. The exact locations will be determined in consultation with local communities and the operating departments, to ensure that there is sufficient access, security, data communications and support from local residents. Additionally, it is recommended that where regular observers exist, additional manual observing equipment (low-cost rain gauges and hydrological staff gauges) are installed, to provide checks for data transmitted automatically and as a fail-safe in situations where automatic telemetry fails and takes time to repair.

2.5.6. Approach and budget for operations and maintenance of additional equipment

Operation and maintenance (O&M) of the installed hydrometeorological infrastructure will need to be pursued through a wide range of approaches, including the leveraging of domestic resources, human and financial (planning) capacity building for sustained O&M and exploring private sector partnerships to operationalise and provide financial returns from the generation of early warnings and climate information.

Maintenance and service contracts (for 3 years) should be bundled in the procurement notices, beyond which O&M will be provided by the NMHS through their budget allocations, including the following domestic resources which have been discussed and agreed upon

It is proposed that the project supports capacity building of the relevant agencies as well as communities to ensure that the technical capabilities and human resources are sustained for O&M beyond the project lifetime. Specifically, the project should include the following: (i) training for staff from NMHS of the lake-based weather and wave buoys and to assimilate/combine these data with forecasts (ii) training for technicians at NMHS to operate & maintain the installed AWS and hydrological water level stations and associated telemetry systems and calibration of sensors (iii) the procurement agreement with suppliers

for supply of equipment for NMHS which should will include factory trainings by the supplier at their manufacturing sites, as well as on-site training at one or two selected sites in Sierra Leone. (to enhance technicians understanding on the O & M of the equipment being installed) (iv) where possible, after sales service contracts for the lifetime of the project will be negotiated, ensuring spare parts are available beyond the project lifetime and (v) training of trainers for the NMHS and community members on O&M of community based EWS equipment (including establishing community based responsible technicians) to provide basic maintenance and safety care of the AWS/hydro met stations

Table 3 indicates the resources that can be made available for O&M activities for the initial 4 years of the project based on committed domestic co-financing, and GCF funding. This would cover the expected lifetime of the equipment assuming it was installed in year 1. Where equipment is installed in years 2 and 3 the timeframe will shift accordingly (including bundled service and maintenance contracts), but still incorporate provision for purchasing spare parts before the project ends. Funds for years 1 & 2 will still be required to allow for site visits and planning of infrastructure rollout (including vehicle maintenance), as well as to purchase tools and equipment for maintenance etc.

Table 4: Indicative Costs for Operation and Maintenance

Equipment	Source of Finance	Year 1 USD	Year 2 USD	Year 3 USD	Year 4 USD	Year 5 USD
Automatic weather stations and hydrological stations						
Spare parts	GOSL				10000	10,000
	GCF		40000	40000	40000	
Procure and installation of Weather Radar (including training) and weather forecasting models	GCF		4,500,000			
Domestic Financing (Human Resources NMHSs)	GOSL					50,000
Training and O&M of AWS and hydrological equipment	GOSL		30,000	30,000	30,000	
	GCF		20,000	20,000	20,000	20,000
Operation of community based EWS						
Spare parts	GOSL				10000	10000
	GCF		20000	20000	20000	
Training of officers and community members on O&M of community-based equipment	GCF			20000	20000	20000
Lake-based buoys						
Spare parts	GOSL			5000	5000	5000
	GCF		15000	15000		
Training for O&M of lake based buoys	GCF	30000	30000	30000		
Human resources & travel (fuel and vehicle/boat maintenance)	GCF	20000	20000	20000	20000	20000
Development of strategy +contingency						
Development of long-term O&M strategy	GCF		50000	50000	50000	50000
Contingency		20000	20000	20000	20000	20000

2.5.7. Forecasting and analytical capacity needed to provide information for tailored products

This assessment recommends the development and application of an operational decision support system to catchments that have the potential to help better understand flooding risk and develop knowledge products. Once these aspects have been developed, applying the system will require less development and testing, though it will still need to be calibrated for different river systems and catchments, which will depend on the available hydrological, weather, satellite and other environmental data. This system when applied to catchments will help better understand flooding risk (increasing the lead times for flood warnings) and water resource availability, and dependence on upstream catchments which may not be prone to flooding. It therefore offers an opportunity to develop catchment wide knowledge products and not only focus on the highest flood risk areas. To do this will require installing hydrological and weather stations in related catchments, some of which may not demonstrate high flood risk.

2.5.8. Enhancing capacity of NMHS staff

Staff at the NMHS will require training both to operate and maintain the weather and climate forecasting infrastructure and to effectively utilize the produced data. This study therefore recommends the following capacity building activities:

(i) training staff on O&M for equipment, including AWS, hydrological water level stations, sea buoys, and calibration of sensors. Taking a training of trainor's approach will reduce reliance on external consultants in the long term, though initially it is recommended that new equipment is purchased with a minimum of 3-year service warranties to ensure that staff have the time to become familiar with equipment and the subtleties of O&M under field conditions

(ii) training trainers to teach community members basic maintenance of equipment and providing support when communities are unable to fix or maintain equipment; and

(iii) training staff in data analysis and visualization; forecast production (both for weather and seasonal prediction, downscaling e.g., for running numerical weather prediction models); development of other tailored products, such as drought alerts; and formatting to facilitate use of data by end-users, including communities and other agencies.

A key consideration highlighted in this assessment is that NMHS staff participate in co-production and co-analysis of data with communities and users of the information and products. This is essential if there is to be uptake of hydromet products.

It is also critical that NMHS staff engage in developing the products that will be distributed via mobile phone and other media, and that interactions with communities/users are approached from a learning perspective, where both the scientific and local knowledge/perspective are given equal consideration.

3. SPECIFIC INFORMATION ON THE PROJECT

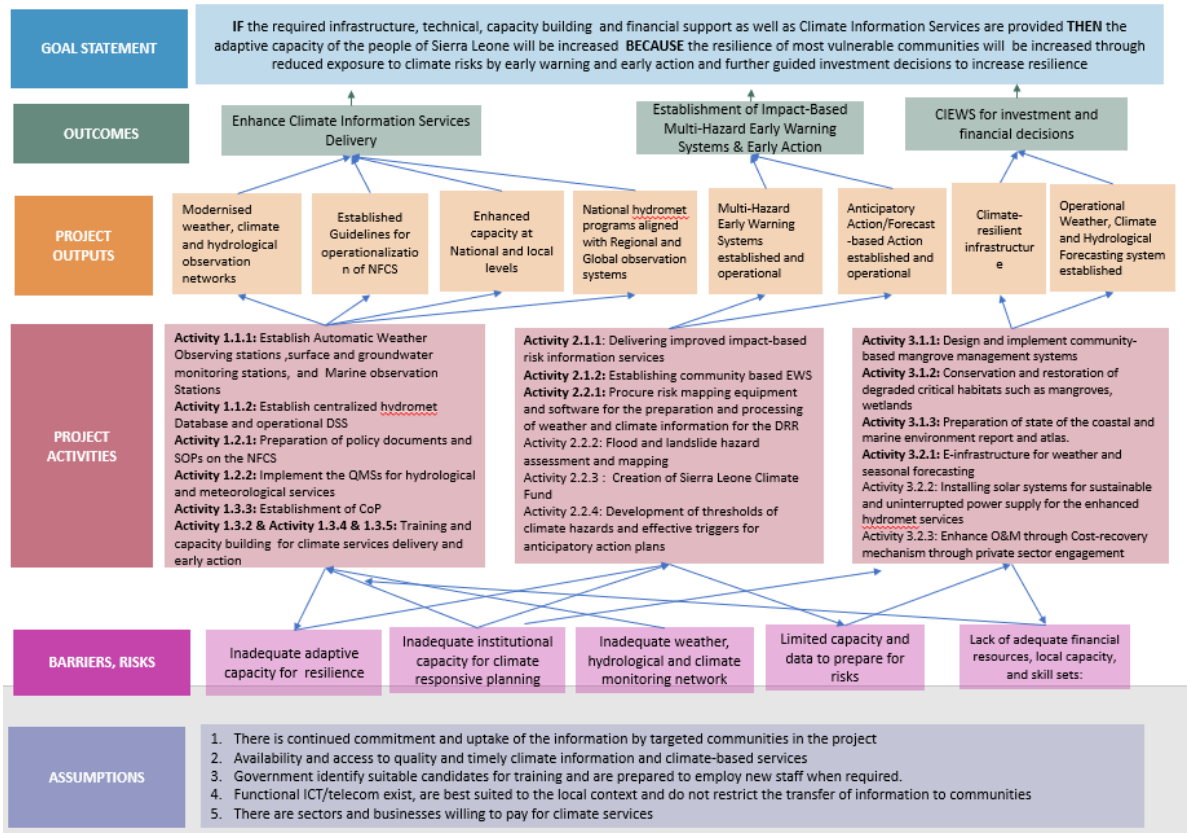
3.1. Theory of Change

Through GCF support, the proposed project will overcome key barriers to increasing the climate change resilience of communities by strengthening the hydromet services in Sierra Leone. Business-as usual Hydromet projects (Small-scale, without user-centered approaches) do not allow full resilience and risk informed sustainable development and economic growth. Without the leverage of the GCF, Sierra Leone will remain increasingly hampered by climate-related risks and changes; community livelihoods will be continuously threatened by changes in temperature and rainfall patterns, as well as the increased frequency and intensity of climate extremes, such as tropical cyclones.

To overcome the barriers to provide timely, accurate, reliable and user-friendly climate services, interventions with the most transformative impact on reducing disaster risk and will foster adaptation to climate change, have been identified based on country consultations. These interventions will support the strengthening of NMHSs to produce target impact-based forecasts (IBF), and the timely dissemination of accurate and high-quality CP-CS, including multi-hazard early warnings (MHEW).

The project is built around three components which include (i) Enhancing Climate Information Services Delivery (ii) Establishment of Impact-Based Multi-Hazard Early Warning Systems & Early Action (iii) implementing CIEWS for investment and financial decisions and (iv) Project Management

Figure 16: Theory of Change



3.2. Project Objective, the Logical Framework and Components

The objective of this sub-project is to improve access to and use of weather, water, and climate services in Sierra Leone by strengthening observing and monitoring capabilities, early warning and early action systems, and other environmental-related information systems while adopting a gender-responsive approach across this project. It seeks to drive a paradigm shift towards evidence-based climate-informed decision-making, planning, and response. The goal is to integrate green growth, environmental resilience, and adaptation into national development planning through effective climate information systems.

The project properly proposes to provide timely and relevant climate information to reduce the loss of lives and livelihood, which affects vulnerable population like women the value of physical assets, and environmental and social losses due to the impact of extreme climate-related disasters and climate change. This outcome will have direct and indirect positive impacts on the dwellers of the country, mostly on the vulnerable population of the country exposed to the adverse effects of climate change and variability. As a paradigm shift, the project will upscale the existing hydromet infrastructure provided in previous projects and strengthen institutional coordination for improved s gender-responsive service delivery in different priority sectors of the Sierra Leonean economy to facilitate

seamless integration of climate information in national planning. The socioeconomic and environmental benefits of the project are also significant to the creation of jobs, increase income, and improve health and living standards, especially among women.

Key indicators include (i) Increased lead time and accuracy of global and regional forecasts (ii) Improved data collection and transmission (iii) Drastic reduction of response time for requests of archived data (iv) Increased reliability of seasonal flow forecasts in the river basins (iv) Introduction of client satisfaction surveys in hydromet performance evaluation and (v) Development and government approval of a long-term hydromet strategy, which leads to a massive increase in government support to the agency.

Broadly, the project will (i) increase the resilience and enhance the livelihoods of vulnerable people in Sierra Leone (ii) increase resilience of health and, well-being, and food and water security and (iii) increase resilience of infrastructure and the built environment to climate change threats

The project will focus on different vulnerable groups, especially women and the youth. It will apply a gender lens to ensure that men and women benefit from activities aimed at increasing their resilience and capacity to adapt to climate threats. It will also pursue revenue generation for self-sustaining operations by providing climate information services for potential clients such as large-scale commercial farmers, aviation sector businesses. The project will deliver benefits both at the national and local levels.

Drawing from the needs assessment and the theory of change, the project components will comprise the following

Table 5: Project components and outputs

Components /Outputs	Activities
Component 1 : Enhance Climate Information Services Delivery	
1.1 Modernised weather, climate and hydrological observation networks	Activity 1.1.1 Modernised weather, climate and hydrological observation networks
	Activity 1.1.2 Establish centralized Meteorological, Climatological and Hydrological (MCH) Database and operational decision support system

Components /Outputs	Activities
1.2 Established Guidelines for operationalization of NFCS	Activity 1.2.1 Preparation of policy documents and Standard Operating Procedures (SOPs) on the National Framework for Climate Services (NFCS)
	Activity 1.2.2 Implement the Quality Management Systems (QMS) for hydrological and meteorological services
	Activity 1.2.3 Procure and installation of Weather Radar (including training) and weather forecasting models
1.3 Enhanced capacity at National and local levels	Activity 1.3.1: Enhance the capacity of MDA staff to produce, package and communicate user-targeted services by equipping them with adequate skills through education and training
	Activity 1.3.2: Conduct trainings for public and private sector actors to enhance awareness and market products for the delivery of climate services
	Activity 1.3.3: Establishment of Communities of Practice
	Activity 1.3.4: Community based actions and capacity building
	Activity 1.3.5: Specialised training for actors in climate information producers including SLMet, NWRMA and disaster risk management staff
1.4 National hydromet programs aligned with Regional and Global observation systems	Activity 1.4.1: Implement WMO Information Systems and Integrated Global Observation Systems
	Activity 1.4.2: Collaboration and study tours with regional organisations
Component 2: Establishment of Impact-Based Multi-Hazard Early Warning Systems & Early Action	
2.1Multi-Hazard Early Warning Systems established and operational	Activity 2.1.1 Delivering improved impact-based risk information services
	Activity 2.1.2: Establishing community based Early Warning Systems
	Activity 2.1.3: Support the Meteorological Agency of Sierra Leone in designing an extreme weather early warning system (EWS) for different sections of the coast
2.2Anticipatory Action, Forecast-based Action established and operational	Activity 2.2.1: Procure risk mapping equipment and software for the preparation and processing of weather and climate information for the DRR
	Activity 2.2.2: Flood and landslide hazard assessment and mapping for Improved Resilience in Sierra Leone
	Activity 2.2.3: Creation of Sierra Leone Climate Fund to facilitate climate risks management activities including the forecast-based action
	Activity 2.2.4: Development of thresholds of climate hazards and effective triggers for anticipatory action plans
Component 3: CIEWS for investment and financial decisions	
3.1 Climate-resilient ecosystem-based infrastructure	Activity 3.1.1: Climate services for enhanced ecosystem-based disaster risk reduction (Eco-DRR)
	Activity 3.1.2: Conservation and restoration of degraded critical habitats such as mangroves, wetlands
	Activity 3.1.3: Climate services for climate-resilient infrastructure and user-resilience
3.2 Operational Weather, Climate and Hydrological Forecasting system established	Activity 3.2.1: E-infrastructure for weather and seasonal forecasting with support system including ICT infrastructure procured and established
	Activity 3.2.2: Installing solar systems for sustainable and uninterrupted power supply for the enhanced hydromet services
	Activity 3.2.3: Enhance O&M through Cost-recovery mechanism through private sector engagement

Components /Outputs	Activities
Component 4: Project Management	
4.1: A Project Management *Technical Assistance*	Activity 4.1.1: Recruitment of Technical Assistants, Preparation of the Operational manual and Project supervision
4.2 Monitoring, Evaluation and Learning system is established	Activity 4.2.1: Monitoring, Evaluation and Learning System Activity 4.2.2: Impact evaluation

3.3. Environmental, Economic and Social Assessments

3.3.1. Environment and social analysis

This Project is assigned as Category C, as per the Bank Group and GCF policies, and does not require an Environmental and Social Impact Assessment (ESIA) or Environmental and Social Management Plan (ESMP). However, an indicative Environmental and Social Action Plan (ESAP) has been prepared *(Table 6).*

The safeguards risks are primarily associated with the installation of new meteorological equipment mounted on masts (e.g., new or rehabilitated automatic weather stations, AWS), in the case of the Doppler Radar units on SLMet Agency tower structures (also supplied will be workstations, computers, wiring, etc.), and installation of hydrological stations.

AWSs are typically installed within local government owned properties. A limited area is required for each weather station (some 100m^2) at sites of modified and semi-natural habitat, such as airfields or government research institutes. With the exception of river gauges, the equipment will be installed exclusively at existing stations where they can be protected from damage, being on secure premises and/or through secure fencing. Many stations have fallen into disuse and project meteorological equipment will be established on existing sites on government owned land; therefore, the project will not result in land acquisition and/or resettlement of local population.

Table 6: Environment and social action plan

Summary of risks	Mitigation measures	Risk significance	Responsible party/person	Schedule	Expected results
Noise pollution from machinery and equipment, increase in generation of solid wastes, and increase in dust emissions as a result of civil works during the installation of the AWSs especially in new sites.	Collection, reuse / disposal of solid wastes by the standards of environmental safeguards sediment and waste sites	Moderately likely	Executing Entity and the NMHS agency	During implementation and during operation of the hydromet stations	Reduced pollution risk to the riverine environment
Risk of water pollution from solid waste and unintentional spills of chemical waste during the Installation and O & M , of hydro-	Collection, reuse / disposal of solid wastes by the standards of environmental safeguards sediment and waste sites	Moderately likely	Executing Entity and the NMHS agency	During implementation and during operation of the hydromet stations	Reduced pollution risk to the riverine environment

Summary of risks	Mitigation measures	Risk significance	Responsible party/person	Schedule	Expected results
meteorological stations					
Risk of disturbance of sediment when installing equipment on land and or in the riverine environment Risk of deterioration of the water through run-off from spoils and other excavated materials	Spoil materials that are generated will be stockpiled and subsequently removed to appropriate government approved sites to minimize interruption. The company will provide community outreach programs to property owners and occupants	Moderately likely	Executing Entity and the NMHS agency	During installation and during operation of the hydromet stations	Reduced pollution risk to the riverine environment
Influx of workers, laborers and other unknown in the area looking for opportunities related to the project resulting in cases of criminality and violence.	Search the participation of local elected officials, heads of Base Organizations and other local leaders in the recruitment process	Moderately likely	Executing Entity and the NMHS agency	During installation of the hydromet stations	Reduced negative social impacts
Neighbourhood Disruption Impact on neighbourhood activities, businesses and utilities/facilities	Neighbourhood Compatibility Assessment will be conducted Coordinate and plan to ensure project activities are as compatible as possible with surrounding properties and neighbourhood.	Moderately likely	Executing Entity and the NMHS agency	During installation of the hydromet stations	Reduced negative environmental impacts
Vegetation loss from preparation activities such as land clearing	Limit clearing strictly to necessary areas so as to minimize the destruction of vegetation.	Moderately likely	Executing Entity and the NMHS agency	During installation of the hydromet stations	Reduced negative environmental impacts

Summary of risks	Mitigation measures	Risk significance	Responsible party/person	Schedule	Expected results
	Avoid removal of vegetation and trees to the degree feasible to ensure species are protected				
Trampling and hardening of soils by humans and machines	Nurture vegetation and prevent direct exposure of soils to weather elements Use vegetal waste as compost to aid rapid vegetal propagation	Moderately likely	Executing Entity and the NMHS agency	During installation of the hydromet stations	Reduced negative environmental impacts

Negative environmental and social impacts which would potentially occur from the installation works of AWSs include noise pollution from machinery and equipment, increase in generation of solid wastes, and increase in dust emissions as a result of excavation and civil works during the installation of the AWSs especially in new sites. These impacts will affect, albeit temporarily, occupational health and safety of workers to be involved during construction works and surrounding localities in close proximity to the selected local government owned properties.

Other impacts will be noticeably short term spatially limited impacts during the construction and installation of the EWS. For example, this may include the disturbance of sediment when installing equipment on land and or in the riverine environment. It is anticipated that any impacts will be remediated during installation. There will be extraordinarily little waste generated as all equipment will be purpose built prior to installation. Further, the systems placed within riverine environments will not result in any changes in hydrological conditions due to their size.

The environment and social assessment has examined all such potential impacts and suggests negligible potential impacts if basic codes of good health and safety practice are followed by contractors, including national and international regulations applicable in the countries including ILO conventions. The nature of the project is such that its potential physical impact and safeguards risk factor is necessarily limited. The new physical infrastructure element at any location will be very modest in size and dispersed in siting so cumulative issues are not a relevant consideration.

The project will ensure that all equipment to be purchased meets international environmental, safety and technical standards. Where there are alternative options in siting the proponent will seek the optimal location subject to approval of the national environmental authorities. An E&S safeguard monitoring and reporting component will constantly review and audit the implementation of the project including setting up of new and rehabilitated hydrometeorological stations to verify that safeguards are implemented.

Social impacts will be limited to the installation and maintenance of the EWS. Prior to installation, stakeholder consultation will be undertaken with potential landholders to ensure the location of any

infrastructure does not impact detrimentally on their livelihoods. When available, infrastructure should be placed on government land which will allow unlimited access during maintenance. Where this is not available, the EWS should be placed in a location that does not require GoSL staff to traverse across additional people's land to undertake maintenance. Where available, local people will be employed to undertake maintenance, thereby providing a social benefit to the community. No peoples or their property will be displaced as a result of the project

In summary, extremely limited negative risks are predicted to arise from the project and, when effectively implemented, the project will provide reliable climate-related data of importance for climate risk adaptation and enhancing the management of natural resources, mitigating vulnerability of exposed populations and assets to climate change. Some sites will benefit positively as buildings and station sites in poor condition are renovated resulting in positive direct and indirect impacts. The accompanying training in use of new project-supplied equipment will include health and safety in equipment and facility use.

The project will provide significant environmental benefits. By enabling better predictive management of droughts and floods and risk informed planning for, the project will yield benefits through strengthened ecosystem resilience and improved soil and water quality. Support to water resource use modelling will also enhance sustainable water resource planning and use including for integrated water resource management policies and plans, hydropower planning, and water supply and use yielding positive environmental benefits

3.3.2. Stakeholders Analysis and Engagement Plan

The results presented below is an analysis of stakeholders' interests, and expectations from, and potential contribution to the Sierra Leone climate information services. These results are not exhaustive. They are intended to inform partnerships with the stakeholders with a focus on improving meteorological services to meet their needs. The proposed stakeholder assessment is presented in Table 7.

Table 7: Stakeholder Assessments for the delivery of NMHS

Stakeholders	**Interests**	**Stakeholder Expectations from Sierra Leone Meteorological Services**	**Potential stakeholder contribution to National Meteorological and Hydrological Services SLMET**
World Meteorological Organization	International collaboration in meteorology that includes sharing observation, data, products and relevant skills.	Annual contributions and implementation of WMO projects	Enhancing human resources and infrastructure through international collaboration in meteorology.
International Civil Aviation Organization, International Air Transport Association and Sierra Leone Airport Authority	High-quality meteorological information for air transport	Ability to provide high quality meteorological information for air transport	Resources from cost recovery to invest in the improvement of services.
World Health Organisation	Weather and climate information, and early warnings to support decision-making in the delivery of services	Timely, reliable and accurate weather and climate information, and early warnings to support the management of disease outbreaks and delivery of services.	Advocacy on the value of weather and climate services to the management of health activities and partnerships to enhance the infrastructure for collecting, sharing, and processing observations and data to generate products for the sector

Stakeholders	Interests	Stakeholder Expectations from Sierra Leone Meteorological Services	Potential stakeholder contribution to National Meteorological and Hydrological Services SLMET
World Food Programme	Weather and climate information to monitor food security and to support Agrometeorological initiatives	Timely, reliable and accurate weather and climate information to support the monitoring of conditions that would influence food security.	Advocacy on the value of weather and climate services for food security and partnership in the improvement of services
World Bank and African Development Bank (AfDB) and the United Nations Development Programme (UNDP)	Partnerships in enhancing the ability of society to adapt to climate change.	Weather and climate information to support the design and implementations of initiatives to enhance resilience to climate change.	Partnerships in actions to revive meteorological services in Sierra Leone by providing resources to establish infrastructure and train human resources for providing weather and climate services
Environmental Protection Agency	Weather and climate information to support activities to protect the environment.	Timely, reliable and accurate weather and climate information to support activities to protect the environment	Advocacy on the value of weather and climate services for environmental protection and partnership in the improvement of services
Sierra Leone National Red Cross Society	Weather and climate information, and early warnings for disaster risk reduction	Timely, reliable, and accurate weather and climate information, and early warnings to support activities for disaster preparedness and for search and rescue activities	Advocacy and Partnerships in joint projects
University of Sierra Leone	Partnerships in education, training, and research	Weather and climate data for conducting research and students for training.	Developing human resources and Enhancing understanding of weather and climate processes.
Ministry of Lands, Mines & Energy, and Rural Renewable Energy Agency	Weather and Climate services to develop and operate infrastructure for power supply and investment in renewable energy, and to support safety in mining	Timely, reliable, and accurate weather and climate forecasts, and early warnings and long historical climate information to support their activities	Advocacy and Partnerships in the development and implantation of joint projects to improve services to the ministry and the Agency.
Ministry of Information, Culture & Tourism	Expected weather and climate conditions	Timely, reliable, and accurate weather and climate forecasts to support the planning and management of activities in the sectors	Advocacy on the value of weather and climate services to tourism, public safety and improving the wellbeing of citizens-and partnerships in establishing weather observing stations
Sierra Leone Hydrological Service	Weather and climate information to support the design, development, and management of infrastructure for water resource management	Historical climate data, and observations in water catchment areas	Partnerships in gathering and sharing meteorological and hydrological data
National Disaster Management Agency	Weather and climate information, and early warnings for disaster risk reduction.	Timely, reliable and accurate weather and climate information, and early warnings to support activities for disaster prevention, preparedness, and for search and rescue activities	Advocacy on the benefits of weather and climate information and early warnings for disaster risk reduction and partnership in establishing infrastructure and developing the services for the sector
Public Security Organs	Weather and climate information for maintaining the safety of the public and for	Weather and climate information to support public safety activities	Advocacy on the value of weather and climate services to public safety

Stakeholders	Interests	Stakeholder Expectations from Sierra Leone Meteorological Services	Potential stakeholder contribution to National Meteorological and Hydrological Services SLMET
	managing any threats to public safety		
Ministry of Fisheries and Marine Resources	Weather and climate information and early warning to support the safety of fisherman offshore and inland through informed decisions to prevent exposure to weather and climate-related risks	Timely, reliable, and accurate weather and climate forecasts, and early warnings to support inland and offshore fishing activities	Advocacy on the value of weather and climate services to the sector and partnerships in establishing weather observing stations and in developing sector specific products.
Communities	Enhanced service delivery and warnings to communities	Improved early warning and community preparedness, including: (i) strengthening "last mile" connectivity to ensure appropriate understanding and use of information, and (ii) mobilization and sensitization of community and establishing effective feedback mechanism for communities at risk	Advocacy on the value of weather and climate services to public safety

3.3.3. Project level grievance redress mechanism(s)

During the installation and implementation phases of the hydromet equipment, a person or group of people can be adversely affected, directly or indirectly due to the project activities. The grievances that may arise can be related to social issues such as disruption of services, and other social and cultural issues. Grievances could also be related to environmental issues such as dust generation, damages to infrastructure due to construction, noise etc.

Should such a situation arise, there must be a grievance redress mechanism through which affected parties can resolve such issues in a cordial manner with the project personnel in an efficient, unbiased, transparent, timely and cost-effective manner.

The project will allow those that have a complaint and/or feel aggrieved by the project to be able to communicate their concern, complaints and/or grievances through an appropriate process. The Complaints Register and Grievance Redress Mechanism set out in the Funding Proposal will be used as part of the project and will provide an accessible, rapid, fair and effective response to concerned stakeholders, especially any vulnerable group who often lack access to formal legal regimes.

While recognising that many complaints may be resolved immediately, the Complaints Register and Grievance Redress Mechanism will encourage mutually acceptable resolution of issues as they arise.

The Complaints Register and Grievance Redress Mechanism for this project will set out to among others (i) be a legitimate process that allows for trust to be built between stakeholder groups and assures stakeholders that their concerns will be assessed in a fair and transparent manner; (ii) allow simple and streamlined access to the Complaints Register and Grievance Redress Mechanism for all stakeholders and

provide adequate assistance for those that may have faced barriers in the past to be able to raise their concerns; (iii) provide clear and known procedures for each stage of the Grievance Redress Mechanism process, and provide clarity on the types of outcomes available to individuals and groups (iv) ensure equitable treatment to all concerned and aggrieved individuals and groups through a consistent, formal approach that, is fair, informed and respectful to a concern, complaints and/or grievances; (v) provide a transparent approach, by keeping any aggrieved individual/group informed of the progress of their complaint, the information that was used when assessing their complaint and information about the mechanisms that will be used to address it; and (vi) f. enable continuous learning and improvements to the Grievance Redress Mechanism. Through continued assessment, the learnings may reduce potential complaints and grievances.

3.4. Gender Assessment

Women are 51% of the population and suffer from gender inequality and discrimination. Sierra Leone stands historically in the bottom 10 of the Gender Development Index (UNDP, 2020). Inequalities are apparent in terms of literacy rates, per capita GDP, access to land, and legal protection. Increased poverty among women in Sierra Leone results from a combination of factors, including limited skills and knowledge, unfriendly market structures that concentrate women in lower-paying work and restrict their access to capital and credit, traditional family structures perpetuating gender inequality through patriarchal norms of property ownership and inheritance, discrimination in the public domain, and weak and unequal trade and economic patterns (USAID, 2019).

The legal status of women in Sierra Leone was enshrined in the 1991 Constitution which provides for the equal enjoyment of fundamental human rights and freedoms by men, women, girls and boys everywhere in Sierra Leone and at all times. Various laws have been enacted to ensure the protection and promotion of the rights of women and children including the Domestic Violence Act (2007), Registration of Customary Marriage and Divorce Act (2009), Devolution of Estates Act (2007); Child Rights Act (2007), and the Sexual Offences Act (2012) among others. These laws were intended to reduce gender inequalities, but they have not been fully implemented. Some of the laws provide for exceptions for customary practices like the Children's Rights Act does not prohibit female genital mutilation (FGM). The Devolution of Estate Act has a gap that allows the application of customary laws which inhibit women and girls from inheriting land. This has implications for the application of climate information in terms of women investing in land they do not own or will inherit.

There are huge disparities in the political participation of women and men. Sierra Leonean women are under-represented in parliament, political parties, Government, national and local committees as leaders. Women occupy less than 20% of elective positions in government despite being the majority of the population. Some of the constraints to women's participation in politics include high illiteracy, entrenched customs and traditions, political violence and reprisals and lack of financial resources. Gender inequality in the political participation rate will affect the application of climate information in political decision-making.

While women constitute the majority of the agricultural workforce, they have never had full access to or control of land or property. In many parts of the country, women can access land only through their husbands or other male family members and are vulnerable to losing their access to land in cases of divorce or widowhood. In addition, women have less access to training opportunities, modernised farm inputs, and credit thus affecting agricultural production and productivity and contributing to food insecurity.

Cultural beliefs, practices, and stereotypes are a major barrier to gender equality and fuel gender inequalities in the social, economic, and political participation of men and women, boys, and girls. The patriarchal nature of African society limits the role of women to being wives, mothers and caregivers under the dominion of men. Bride fees does not only give husbands and their families, limitless rights over wives but also determine their participation in household or family decision-making.

Gender based violence is widespread in Sierra Leone. It takes various forms including sexual, physical, psychological, economic, and structural violence and harmful traditions like female genital mutilation/cutting (FGM/C) and widowhood rites. The major drivers of GBV include economic hardships that create tensions and strains on families increasing the risk of SGBV and socio-cultural norms that promote dangerous practices. There is however a continued reluctance to use the judicial system on the part of both victims and law enforcement which has led to non-reporting of rape and domestic violence cases and contributed to women's and girls' silent suffering.

Women play a critical role in the use and management of natural resources due to their knowledge and experience in working closely with their environment. Women are responsible for collecting firewood, water, food, herbs for medicine and materials for weaving baskets and mats. Women therefore suffer more from the adverse effects of climate change and environmental degradation, and it is important that they receive information on potential climate hazards.

There are also gender inequalities in the access and use of ICT. For example, most women cannot afford radios, computers, television sets and mobile phones. According to the Sierra Leone Demographic Health Survey (2019), 43% of the women and 64% of the men had mobile phones. The main source of information for women was radio.

Healthcare delivery for women and girls is improving and the government is committed to making sure healthcare continues to improve. To increase access to reproductive and maternal health services, the Ministry of Health and Sanitation (MoHS) in 2010 introduced Free Health Care (FHC) to provide universal access to quality health care for vulnerable groups and targeted pregnant women, lactating mothers and children below the age of 5 years. The initiative contributed to more women accessing health facilities during and after pregnancy and led to a dramatic improvement in health outcomes.

The project will have focus on gender sensitive planning and implementation to ensure the highest gains in the fight for gender equity. Women are more exposed to climate risks such as heavy rains, drought, flooding, and landslides etc. They are also more vulnerable as they have limited access to land, education, and have lower incomes. However, due to the close link between their roles and natural resources, women can be empowered to adapt to climate change.

The project shall aim to reduce gender inequalities to maximise the project impact through: gender-sensitive consultations to ensure the needs and views of women and men, boys and girls are captured and incorporated in the design and implementation of the project; affirmative action for women and girls to enrol in climate science courses through sponsorship and career guidance, mainstreaming gender in all project activities, advocating for gender equality in access and control of resources, ensuring gender balance in participation and sharing of benefits, using modes of communication that are accessible to both men and women and other vulnerable groups, ensuring that the climate information sent out to the public is easily understood by men and women otherwise there is the risk of the information either not being used at all or not being fully understood by women. Therefore, the communication channels and

capacity building efforts will be developed with special attention to the needs of women in relation to the uptake and adoption of EWs and climate information. The project will have significant gender benefits.

A Gender Action Plan (GAP) has been prepared and will be attached to the Funding Proposal. It will form the basis for operationalising the results and recommendations of the Gender Assessment presented in the above sections. It contains specific gender-responsive elements to be considered in the Project design and during the implementation of Project activities, in order to maximise the development impact and co-benefits of the GCF investment. The GAP is closely aligned to the outputs of the Project logical framework and proposed activities. The GAP complements the Environment and Social Safeguards Report (Annex 6b), which identifies the Project to be categorised as Risk Category C.

3.5. Financing Options Description

The public goods nature of the proposed project entails no revenue-generation or cost-recovery. With GoSL seeking 100% grant resources for the proposed project, the financial market overview is not applicable. A grant-financing instrument is used for this project with the GOSL seeking maximum concessionality to undertake the proposed adaptation investments. Without grant resources, the proposed interventions would not be financially sustainable in the long term.

First, as a Least Developed Country and a Low-Income Economy, there is limited capacity in the country for concessional debt financing for its adaptation investments. Sierra Leone is actively pursuing reforms to mobilize more revenues (including through environmental taxes) and improve spending efficiency, but their scope is limited, and progress is slow. Using macroeconomic insurance products, such as climate funds and issuing state-contingent bonds, has so far also been difficult given large risk premiums (IMF 2020). Second, the project targets highly vulnerable populations, more than half of whom are women, living in disaster prone and food insecure districts dependent on climate sensitive and marginal livelihoods. Finally, the public good nature of the solution to address the current deficiencies in climate observation systems and dissemination platforms entails zero cost recovery from the proposed measures to save lives and livelihoods of vulnerable populations in the country.

Modernising the Sierra Leone NMHS services U including the acquisition and maintenance of radar and other conventional weather systems is expensive and very demanding in terms of human resources and supporting infrastructure. Private sector financing, including concessional financing, of these investments is challenging given that at present revenue generation potential is limited, as are cost-recovery opportunities. The public goods nature of these investments means that public financing is required to overcome several barriers that constrain the GOSL's ability to scale up the use of early warning systems and climate information. These barriers are detailed in section 1.5 and include limited availability of financial, technical and human capacity for hydro-meteorological services, limited availability of tailored, sector-specific climate information and early warning products, lack of access to and awareness of use of early warning and climate information by vulnerable populations, limited demand and markets for generation and use of climate information, and limited accessibility to early warnings and low capacity at community level to prepare for and respond to climate-related disasters

Current financing gaps in domestic financing are hampering the GOSL's ability to implement adaptation measures and overcome these barriers. Without GCF resources, Sierra Leone will continue to experience loss of lives and assets due to climate-related disasters. Therefore, the GOSL seeks to combine GCF grant-resources with co-financing from its budget allocations and from the Bank Group's Climate Action Window (CAW) to achieve the project objective by: (i0 Investing in meteorological and hydrological observation

network and capacities of hydromet agencies to ensure spatial coverage and accuracy covering vulnerable areas; (ii) Investing in packaging and use of tailored, demand-based climate information /products /services to enhance 'last-mile' access; and (iii) Investing in empowering the communities in preparedness and response to climate related disasters through participatory and decentralized early warning systems and disaster risk reduction measures.

3.6. Economic and Financial Viability

The project aims to strengthen the capacity of the country to measure and monitor climate data to be better prepared to deal with climate hazards. This covers (i) enhancement of climate information services, (ii) establishment of impact-based multi-hazard early warning systems and early action, (iii) CIEWS for investment and financial decisions, and (iv) project management. We assume a physical contingency rate of 12% and a financial contingency rate of 8%. 2% of the investment is allocated to operation and maintenance costs (O&M).

The project offers several benefits which can take many different forms. Some benefits are measurable whereas others are not although they affect positively human and eco-stem functionalities in the country. Better weather forecasting facilitates the anticipation of and anticipation for extreme climate-related events that can have detrimental economic and social consequences on economies and organizational structures. From a practical point of view, this facilitates the protection of persons, businesses, and assets (prevention) as well as the acceptance of emergency measures implemented by national authorities to mitigate and adapt to climate change.

For instance, farmers can decide to change their planting dates and/or the types of crops seeded if they know well in advance the intensity of rainfall and temperature that can be expected in the near future. Insurance companies can modify the way they set premiums and cover risks associated with climate hazards if information about potential climate change patterns is presented to them; people can adjust their behavior to match their current and future local conditions depending on the type of climate they are going to face.

Therefore, the avoided asset and human losses are often seen as the major benefits associated with investing in hydro and meteorological services. For a developing country like Sierra Leone, potential localized benefits may cover rural development, growth in the informal sectors, women empowerment, growth in children's enrolment to school given the time saved in labor farming, etc.

We work with the losses avoided due to the investment in hydrometeorological infrastructures. When investments are undertaken these go into the asset capital of the country. The annual cost of climate change was estimated with GDP used as a proxy. The cash flow captures the cumulative differences between the annual losses avoided and the costs invested after having integrated the contingency rates. Different discount rates are used to evaluate the sensitivity of the project to different idiosyncratic risks and identify the one that offers a positive net return given the described time period. Net present values are calculated for the duration of the project lifetime. The cash flows associated with various discount rates were estimated through a cost-benefit relationship. This provides us with an overview of the regions in which the project becomes viable given the set of institutional and operational constraints. The project is viable at a discount rate of 10% and 15% given the positive NPV associated with the investment when a length of more than 15 years is considered.

3.7. Exit Strategy and Sustainability

3.7.1. Cost-recovery services

Through the project, business plans will be developed for the transition of current business models that are not sustainable to new one following the principles and guidance in the WMO Guide to Aeronautical Meteorology Services Cost Recovery (WMO-No. 904)[30]. The new business models will be based on cost-recovery for the relevant sectors in Sierra Leone, e.g., aviation, shipping, insurance, tourism, energy, among others. In addition, successful partnerships will be sought and built up in agriculture/fisheries, tourism, water resource management sectors and other at-risk communities, and are a part of the strategy for ensuring long-term sustainability of the Project's objectives.

3.7.2. New markets for services

Developing hydromet services should be based on identification, segmentation, and prioritization of target user groups within and across sectors. It is important to understand the needs and requirements of the target users as they vary across the different user groups within a sectorial value chain (refer to Table 7 for the varying categories of stakeholders). Thus, the types of products and services may range from basic over-the-counter services (products that meet the needs and requirements of a variety of users) to tailored services. This will enhance uptake of hydromet services and sustainability.

3.7.3. Sustainability

The hydro-meteorological equipment established through the project will be managed, maintained, upgraded and replaced as needed by the GOSL during and after the project. This will be ensured in the long run by: i) transferring skills to the NMHS to ensure equipment operation, maintenance and renewal; ii) achieving cost-efficiencies through regional complementarities and synergies on monitoring, modelling, forecasting and service delivery; iii) demonstrating the value of the climate services among users and end users (demand-side); iv) where possible, promoting the commercialisation of these services; and v) exploring options for leveraging funds from the newly Global Basic Observing Network (GBON) Systematic Observations Financing Facility (SOFF) for the completion of the implementation of the network and O&M. This strategic approach will ensure that these stakeholders are able to continue co-producing and using climate services once the project funding ceases; and can maintain the required O&M of the hydro-meteorological equipment.

3.7.4. The human resources challenge

A constraint for the Sierra Leone and other African NMHSs is retaining highly skilled employees, such as forecasters and information technology personnel. Competition with the private sector is substantial as economies develop, and the capacity and flexibility to reward is much higher in the private sector. In addition, there is government resistance to higher remuneration for those with high qualifications—often technical workers are paid at the same level as unskilled workers. Thus, innovative ways need to be found for staffing NMHSs in these countries. Such methods may include: (i) Establishing special, higher remuneration categories of employment for technical posts (ii) Using contract personnel (iii) Providing incentives through specialized training and establishment of career paths (iv) Using public-private partnerships and (v) Outsourcing functions.

[30] https://library.wmo.int/doc_num.php?explnum_id=5298

3.8. Risk Summary

Risk factors associated with the project implementation include technical, operational, and institutional aspects, as equipment installation does not cause major social and environmental impacts from the project. The risks may affect information generation due to delays in procurement and installation of equipment, vandalism, or lack of maintenance.

Other risks may affect the delivery of information to end users including the risks that local ICT/telecom infrastructure restricts the delivery of information or delays timely dissemination of information to end users. Risk related to lack of commitment of communities or lack of capacity may affect the proper use of information and products disseminated.

Technological failure might lead to a risk in alert information not being generated or lack of coordination can hinder reach of that information to communities. There are also risks that private sector will resist in engaging with public sector activities related to weather/climate data. A key risk related to sustainability relates to the identification of viable business models, given weak private sector capacity in the country, which can support the demand for weather and climate services.

Other risks considered include financial risk in terms of sustainability of the systems put in place, institutional through the inadequate institutional capacity for climate responsive planning, challenges in coordination, political risk which includes lack of political will

The proposed project includes several mitigation measures to address these risks. Effective administration and planning can mitigate the risk of delays in establishment of infrastructure. Appropriate and proven technologies have been chosen to mitigate the risk of technical failure or constrained delivery due to local conditions and infrastructure (such as telecom). To address financial failures, the project includes enhanced O&M through Cost-recovery mechanism through private sector engagement, for institutional capacity, coordination mechanisms will be set up at national, sub-national and district levels, to increase political will, the project will include capacity building and advocacy to increase political will

Community awareness, participation, and training will help mitigate the risk of vandalism or low commitment and uptake of the disseminated early warnings and CI. Training based on the most up to date scientific and technical advances in the fields of hydrology and meteorology will mitigate the risk that relevant alerts/forecasts are not generated.

Data sharing mechanisms and protocols will be established to promote information flow and coordination among agencies and communication channels will be strengthened to ensure last-mile reach. To address the risks related to enabling demand-based model, the feasibility studies will also include willingness-to-pay and a broader scope of business actors including MSMEs, larger private sector actors, public sector institutions to identify market for weather and climate information, in particular for project supported, value-added products. Studies will also identify incentives and partnerships to enable private and public sectors to engage in climate information services.

3.9. Implementation arrangements

3.9.1. Implementation timeline

The interventions will be implemented across a period of 54 months, across four components as indicated in the table below.

Table 8: Indicative implementation schedule

COMPONENTS	2023		2024				2025				2026				2027			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Component 1																		
1.1 Modernising weather, climate and hydrological observation networks																		
1.2 Establishing Guidelines for operationalization of NFCS																		
1.3. Enhancing capacity at to generate climate-related data and forecast extreme events																		
1.4 Aligning National hydromet programs aligned with Regional and Global observation systems																		
Component 2:																		
2.1 Establishing and operationalising Multi-Hazard Early Warning Systems																		
2.2 Establishing and operationalising anticipatory Action /Forecast-based Action plans																		
Component 3																		
3.1 Implementing Climate-resilient ecosystem-based infrastructure																		
3.2 Establishing an operational Weather, Climate and Hydrological Forecasting system																		
Component 4																		
4.1: Project Management and coordination																		
4.2 Establishment and operationalising M & E and Learning system																		

3.9.2. Capacity Assessment and Due Diligence on the Executing Entities

Guma Valley Water Company (GVWC)

GVWC will be the Executing Entity for the project. GVWC is a parastatal utility company responsible for the provision of water supply services to the City of Freetown and the Western Area. It is the Execution Agency of the baseline project FTWASHAERP and as such coordinates all the activities of the project. The Company was established by the Guma Valley Water Company Ordinance 1961, which was repealed by the Guma Valley Water Company Act of 2017, published into Law on 17th August 2017.

The GVWC is governed by the Board of Directors which comprises of six (6) members nominated by the President of the Republic of Sierra Leone upon the recommendations of the National Commission for Privatization and approved by the Appointments Committee of Parliament. The basis for the appointment of the Board Members is presented in the Act under section (3) as follows: Ex-officio member; a representative of FCC; a Chartered Accountant and experienced administrative and legal practitioner; a representative of Sierra Leone Institution of Engineers and the Managing Director of the GVWC Company.

The role of the Board, among others, is to provide guidance to the Managing Director and the staff of the GVWC. The GVWC is headed by the Managing Director, who is a person with wide Engineering and environmental and management knowledge and is appointed by the President of the Republic of Sierra Leone upon the recommendation of the National Commission on Privatization. The GVWC Act further provides guidance on the appointment of the Company staff under Section 27.

The GVWC has experience in managing water supply projects in Freetown and the Western area but has limited experience with implementation of climate related interventions. GVWC is currently being supported and will be supported by the key Implementing Partners and Technical Assistants with varying expertise including CIEWS and climate change to effectively implement the Project. The Bank will also be offering oversight responsibilities in the Project implementation.

3.9.3. Implementation Arrangements and Governance of the Project

The AfDB through Climate Change and Green Growth Department (PECG) and the ClimDev-Africa Special Fund (CDSF) have vast experience in managing Climate Change projects. The Ministry of Finance (MoF) and the Guma Valley Water Company (GVWC) will be acting as the executing entities (EE) for the project. The Ministry of Finance is a ministerial department of the Government of Sierra Leone and in charge of managing the revenue and finances of the Sierra Leone government. The GVWC will execute the project activities. A tripartite agreement will therefore be signed between the Bank which is the AE, the MoF and the GVWC which are both Executing Entities. The funds flow diagram is as shown in Figure 17.

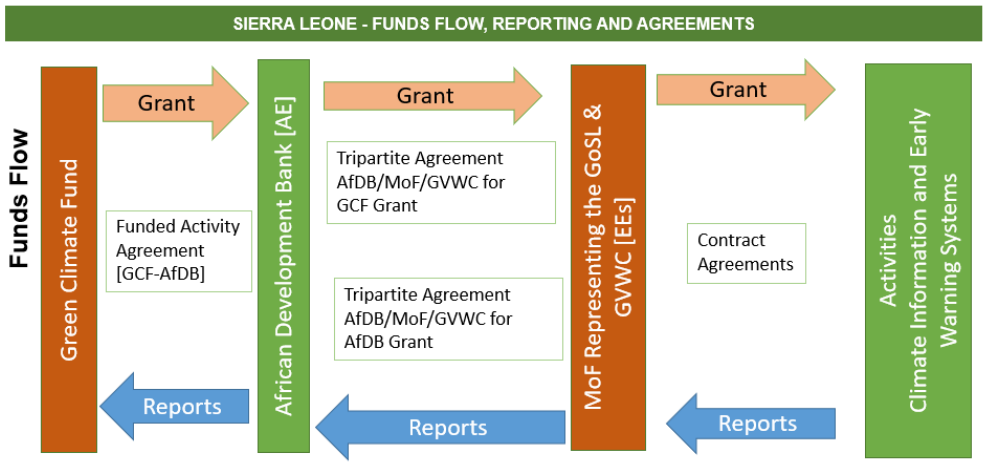


Figure 17: Cash Flow Diagram

The AfDB shall apply the experiences it has gained in managing the implementation of various projects and projects funded through loans and grants. AfDB technical and fiduciary teams shall conduct supervisory mission at least twice a year during the implementation period to ensure that the compliance with the legal agreements. In addition, the Bank shall provide constant advice and guidance in terms of technical aspects, fiduciary requirements, environmental & social aspects, and monitoring & evaluation..

The Implementation arrangements are as indicated in Figure 18 with details in the section that follow:

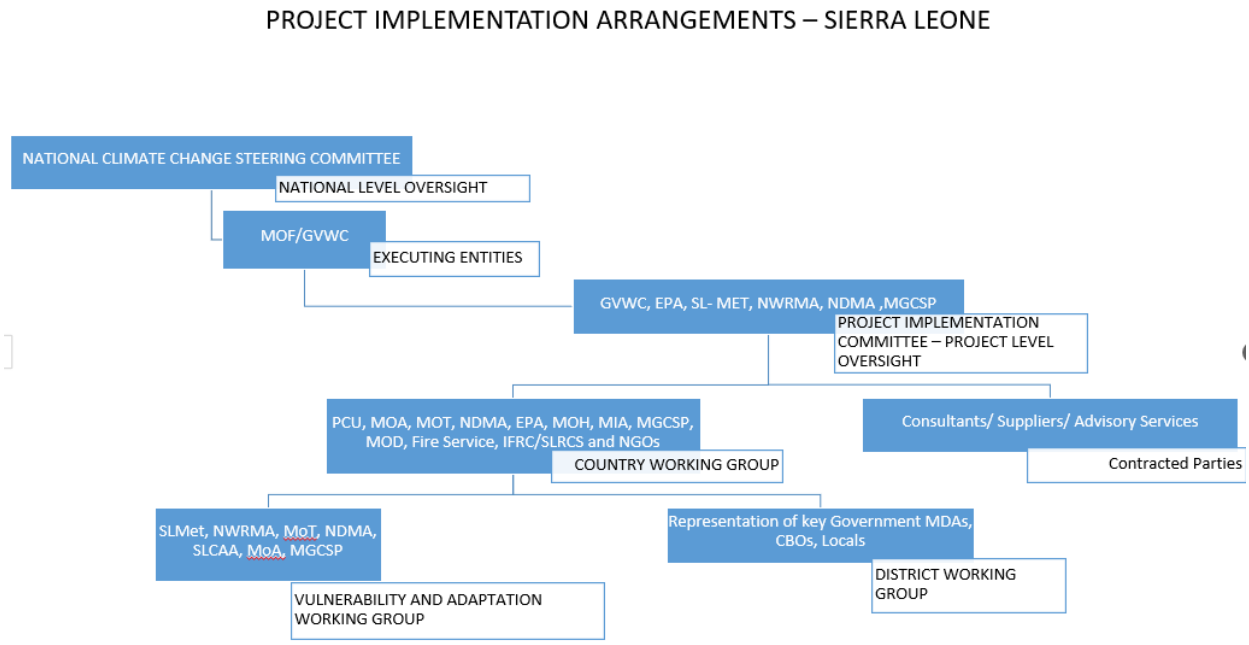


Figure 18: Project Implementation Arrangements

GVWC will execute the project in close collaboration with five relevant Government agencies who will provide oversight of the implementation of the activities directly related to their statutory responsibilities. The PIC will consist of (i) Project Coordinator, (ii) core project staff to undertake fiduciary functions as well as (iii) representatives from the five key technical Government Ministries and Agencies (EPA which is the NDA, Sierra Leone Meteorological Agency, National Water Resources Management Agency, Ministry of Gender, Children and Social Protection (MGCSP)and National Disaster Management Agency). GVWC will sign an MoU with each of the five Government Agencies that constitute the PIC under this project.

A National Climate Change Steering Committee (NCCSC) will be responsible for project oversight at the national level. NCCSC will consist of representatives from all collaborating government and international institutions will be established to provide strategic policy direction and oversight guidance for the project implementation. The NCCSC 's core activities shall include strategic policy direction, oversee planning, review progress and impact and review/ approval of annual work plans and budgets. The NCCSC, will meet at least twice a year. The NCCSC membership will comprise one representative from key Government MDAs as follows: (i) Ministry of Finance; Ministry of Water Resources; Ministry of Local Government; Ministry of Health and Sanitation; Ministry of Lands, Housing & Country Planning, Ministry of Gender, Children and Social Protection (MGCSP), Ministry of Youth and Employment, Ministry of Agriculture and Forestry, Ministry of Energy, Ministry of Transport, Ministry of Environment, Ministry of Energy, Environment Protection Agency, Environmental Protection Agency (EPA), GVWC (ii) one representative

each from selected public-sector bodies, agencies and institution ((Water Resources Management Agency; National Protected Areas Authority (NPAA)). The committee is established by letters of secondment from respective institutions written to GVWC, which condition will have been included in the MoUs signed.

To further work with the PIC specialised institutions will be procured through single source/direct procurement. This includes the World Meteorological Organization (WMO), the International Federation of Red Cross and Red Cresent societies (IFRC) Climate Centre and Sierra Leone Red Cross Society (SLRCS) that will support GVWC to implement the project. These agencies will be known as "Implementation Partners". The SLRCS will work closely with the IFRC Climate Center to develop the impact-based forecasting (IBF) methodology for Forecast based Financing (FbF) mechanism as well as ensuring that the last mile is reached through designing activities that address the needs of those at most risk of climate hazards. They will support the establishment of community early warning systems, promote their connection to national early warning systems and enable an effective forecast-based financing (FbF) mechanism, to ensure climate-informed decision-making, planning, and response by and for the communities most at-risk from climate shocks and extreme weather events. The IFRC Climate Centre is the founder of the forecast-based financing mechanism which is one of the interventions proposed for anticipatory response to imminent climate hazards in specific locations of the country. Furthermore, they have experience and can provide action on the ground to support the National Red Cross Society in implementing such proposed interventions in the country as highlighted in the project. A Vulnerability and Adaptation Expert Working Group will be constituted. This inter-sectoral working group consisting of personnel from SLMet, NWRMA, MoT, NDMA, SLCAA, MoA, Ministry of Gender, Children and Social Protection (MGCSP), MoH, the Red Cross Climate Centre and WMO will convene monthly to discuss progress and implementation-related issues.

A Vulnerability and Adaptation Expert Working Group will be constituted. This inter-sectoral working group consisting of personnel from SLMet, NWRMA, MoT, NDMA, SLCAA, MoA, Ministry of Gender, Children and Social Protection (MGCSP), MoH, the Red Cross Climate Centre and WMO will convene monthly to discuss progress and implementation-related issues. The project will establish climate-smart Labs for the hydromet service producers. The Labs will provide vital products on hydrology, meteorology, aviation, disaster risk reduction, and M&E. Also, the Labs will help to facilitate effective delivery of weather, water, and climate products and other relevant environmental services. The information generated will be communicated via the most effective and efficient channel to the county, district and community levels through their respective coordination and engagement structures (i.e., committees). The information will also be shared with the international collaborating partners including the IFRC, WMO, and others working on climate adaptation and disaster response such as the USAID and the UNDP.

At the county level, the working group membership is comprised of county level representation from Ministry of Agriculture (MOA), Ministry of Transport (MOT), National Disaster Management Agency (NDMA), Environmental Protection Agency (EPA), Ministry of Health County Health Team (MoH/CHT), Ministry of Internal Affairs (MIA), Ministry of Gender, Children and Social Protection (MGCSP), Ministry of Defense (MOD), Fire Service, IFRC/SLRCS and NGOs. The county workgroup is responsible for the dissemination of the information received in a timely manner to the district level working groups and onward to the communities, where the information can be used to make evidence-based decision-making.

The district-level working group comprises district officers from MOA, MGCSP, EPA, MoH, MIA, NDMA, SLRCS and community-based organizations such as farmer cooperatives. At community level, local structure including leadership and engagement modalities such as town-hall/community meetings will be utilized. Community actors such as community chair, women and youth, persons with disabilities, development committees, farmer cooperatives are very essential. The project implementation arrangement is presented in Figure 18. The members of the working Groups will be seconded on the basis of MoUs signed that include the need to nominate members from the respective institutions into the working groups.

The profiles of the Government agencies that makeup the Project Implementation Committee is below:

i. Guma Valley Water Company (GVWC)

GVWC is a parastatal utility company responsible for the provision of water supply services to the City of Freetown and the Western Area. The Company was established by the Guma Valley Water Company Ordinance 1961, which was repealed by the Guma Valley Water Company Act of 2017, published into Law on 17th August 2017. It is the Execution Agency of the WASHAERP Project and as such coordinates all the activities of the project.

II. Environmental Protection Agency (EPA)/National Designated Authority

Established through the Environment Protection Agency Act 2008, the Sierra Leone Environment Protection Agency is to provide for the effective protection of the Environment and for other related matters. The Agency shall, among other things: (a) advise the minister on environmental issues; (b) provide measures for the control of pollution; (c) issue environmental permits and pollution abatement notices; prescribe standards and guidelines relating to ambient air, water and soil quality, etc.

III. Western Area Rural District Council (WARDC)

The Western Area Rural District Council is one of the sixteen districts of Sierra Leone. It is located mostly around the peninsula in the Western Area of Sierra Leone. The Western Area Rural District Council, (WARDC) administers it. It is responsible for the general management of the rural district.

iv. National Water Resources Management Agency (NWRMA)

NWRMA's main purpose is to provide for the equitable, beneficial, efficient, and sustainable use and management of the country's water resources. It is to manage and regulate the use of water resources. The Act establishing NWRMA distinguishes between water resource stewardship (which is a function of government) and service provision (which may be public, private, or cooperative).

v. National Protected Areas Authority (NPAA)

The object for which the Authority is established is to exercise oversight authority over National Parks and Protected Areas designated for conservation purposes so as to protect the fauna and flora in its natural state, promote sustainable land use practices and environmental management.

vi. Ministry of Gender and Children's Affairs (MGCA)

The Ministry's mission is to ensure that social development and the rights of all Sierra Leoneans especially women and children are protected and promoted in general and that those socially marginalized,

disadvantaged, less privileged including the aged, the disabled, whether as groups, individuals, family units and the needy in our communities are equitably and adequately supported.

vii. Sierra Leone Meteorological Agency

The Sierra Leone Meteorological Agency (SLMet), formerly Sierra Leone Meteorological Department (SLMD) was established by an Act of parliament in 2017 (Gazette Vol. CXL VIII, No.64 dated 28th September 2017). It is a government agency with commercial activities and has the mandate to provide climate services for the country. The Agency has existing Memorandum with relevant organizations such as WMO for collaborative efforts. Basic services that are provided at the moment include Daily Weather Forecast – Rainfall data, temperature data; Seasonal Climate Outlook and Marine Forecast (3 days) enabled by the Africa Web Viewer (Model covering Africa) with direct access provided by Unite Kingdom Meteorological Office. Their services are used daily in the aviation industry but requires a cloud-based storage, automatic weather station, and transmissometer for measuring visibility (runway visual range – RVR) to provide quality services. Other sectors accessing weather information from SLMET include Agriculture (agrometeorological data), Researchers, Construction (Road and Transport), Mining, Fisheries, Tourism and Recreation, Insurance, Energy, Water Resources, Power etc. On capacity for early warning, forecast from SLMET are significantly generic but has provided information to prevent heatwaves and particularly flooding in the past.

viii. National Disaster Management Agency

The National Disaster Management Agency Act, 2020 provided for the establishment of the National Disaster Management Agency to manage disasters and similar emergencies throughout Sierra Leone, to establish offices of the Agency throughout Sierra Leone, to establish national, regional, district and chiefdom disaster management committees, to establish a National Disaster Management Fund to provide finances for the prevention and management of disasters and similar emergencies throughout Sierra Leone and to provide for other related matters.

The details of the implementation structure are depicted in Figure 18 and Table 9.

Table 9: Implementation Structure

Components	Outputs	Activities	Responsible	Oversight	Consulted	Informed
Component 1: Enhance Climate Information Services Delivery	1.1 Modernised weather, climate and hydrological observation networks	Activity 1.1.1 Modernised weather, climate and hydrological observation networks and Procurement of weather radar to improved flood forecasting	GVWC, EPA	EPA, SLMET, NDMA	SLMET	AfDB/ PSC
		Activity 1.1.2 Establish centralized Meteorological, Climatological and Hydrological (MCH) Database and operational decision support system	GVWC, EPA	EPA, SLMET, NWRMA, NDMA	SLMET	AfDB/ PSC

Components	Outputs	Activities	Responsible	Oversight	Consulted	Informed
	1.2 Established Guidelines for operationalization of NFCS	Activity 1.2.1 Preparation of policy documents and Standard Operating Procedures (SOPs) on the National Framework for Climate Services (NFCS)	GVWC, EPA	EPA, SLMET, MWRMA, NDMA		AfDB/ PSC
		Activity 1.2.2 Implement the Quality Management Systems (QMS) for hydrological and meteorological services	GVWC, EPA	SLMET, NWRMA	MOD, MAF, MHS, MTA	AfDB/ PSC
	1.3 Enhanced capacity at National and local levels	Activity 1.3.1: Enhance the capacity of MDA staff to produce, package and communicate user-targeted services by equipping them with adequate skills through education and training	GVWC, EPA	EPA, SLMET, NDMA, NWRMA		AfDB/ PSC
		Activity 1.3.2: Conduct trainings for public and private sector actors to enhance awareness and market products for the delivery of climate services	GVWC, EPA	SLMET, NWRMA, NDMA		AfDB/ PSC
		Activity 1.3.3: Establishment of Communities of Practice	GVWC, EPA	SLMET, MWRMA, WMO	MOHS MHS, WMO	AfDB/ PSC
		Activity 1.3.4: Community based actions and capacity building	GVWC, EPA	SLMET, NWRMA, WMO		AfDB/ PSC
		Activity 1.3.5: Specialised training for actors in climate information producers including SLMet, NWRMA and disaster risk management staff	GVWC, EPA	SLMET, NWRMA, WMO		AfDB/ PSC
	1.4 National hydromet programs aligned with Regional and Global observation systems	Activity 1.4.1: Implement WMO Information Systems and Integrated Global Observation Systems	GVWC, EPA	SLMET, NWRMA, WMO	WMO	AfDB/ PSC
		Activity 1.4.2: Collaboration and study tours with regional organisations	GVWC, EPA	SLMET, NWRMA, WMO	WMO	AfDB/ PSC
Component 2: Establishment of Impact-Based Multi-Hazard Early Warning Systems & Early Action	2.1Multi-Hazard Early Warning Systems established and operational	Activity 2.1.1 Delivering improved impact-based risk information services	GVWC, EPA	IFRC, SLRCS,		AfDB/ PSC
		Activity 2.1.2: Establishing community based Early Warning Systems	GVWC, EPA	NDMA	IFRC, SLRCS,	AfDB/ PSC
		Activity 2.1.3: Support the Meteorological Agency of Sierra Leone in designing an extreme weather early warning system (EWS) for different sections of the coast	GVWC, EPA	IFRC, SLRCS,	MGCSP, MOHS, WMO	AfDB/ PSC
	2.2Anticipatory Action, Forecast-based Action established and operational	Activity 2.2.1: Procure risk mapping equipment and software for the preparation and processing of weather and climate information for the DRR	GVWC, EPA	GVWC, EPA, NDMA,	MAF, MOWR, MOHS, MTA	AfDB/ PSC
		Activity 2.2.2: Flood and landslide hazard assessment and mapping for Improved Resilience in Sierra Leone	GVWC, EPA	GVWC, EPA, NDMA,	MAF, MOWR, MOHS, MTA	AfDB/ PSC
		Activity 2.2.3: Creation of Sierra Leone Climate Fund to facilitate climate risks	GVWC, EPA	EPA, NWRMA,	MOF	AfDB/ PSC

Components	Outputs	Activities	Responsible	Oversight	Consulted	Informed
		management activities including the forecast-based action		SLMET, NDMA		
		Activity 2.2.4: Development of thresholds of climate hazards and effective triggers for anticipatory action plans		IFRC, SLRCS		
Component 3: CIEWS for investment and financial decisions	3.1 Climate-resilient ecosystem-based infrastructure	Activity 3.1.1: Climate services for enhanced ecosystem-based disaster risk reduction (Eco-DRR)	GVWC, EPA	EPA, GVWC, NDMA	MOE	AfDB/ PSC
		Activity 3.1.2: Conservation and restoration of degraded critical habitats such as mangroves, wetlands	GVWC, EPA	EPA, GVWC, NPAA	MOE	AfDB/ PSC
		Activity 3.1.3: Climate services for climate-resilient infrastructure and user-resilience	GVWC, EPA	EPA, GVWC, NDMA	Districts	AfDB/ PSC
	3.2 Operational Weather, Climate and Hydrological Forecasting system established	Activity 3.2.1: E-infrastructure for weather and seasonal forecasting with support system including ICT infrastructure procured and established	GVWC, EPA	GVWC, EPA, SLMET, NWRMA, NDMA,		AfDB/ PSC
		Activity 3.2.2: Installing solar systems for sustainable and uninterrupted power supply for the enhanced hydromet services	GVWC, EPA	GVWC, EPA, SLMET, NWRMA, NDMA		AfDB/ PSC
		Activity 3.2.3: Enhance O&M through Cost-recovery mechanism through private sector engagement	GVWC, EPA	GVWC, EPA, SLMET, NWRMA, NDMA		AfDB/ PSC
Component 4: Project Management	4.1: A Project Management Technical Assistance	Activity 4.1.1: Recruitment of Technical Assistants, Preparation of the Operational manual and Project supervision	GVWC	GVWC, EPA, SLMET, NDMA	AfDB, Implementing Agencies	AfDB/ PSC
	4.2 Monitoring, Evaluation and Learning system is established	Activity 4.2.1: Monitoring, Evaluation and Learning System Activity 4.2.2: Impact evaluation	GVWC, EPA	GVWC, EPA, SLMET, NWRMA, NDMA	AfDB, Implementing Agencies	AfDB/ PSC

4. CONCLUSION AND RECOMMENDATIONS

This feasibility assessment has been undertaken on behalf of the Government of Sierra Leone in order to identify priority interventions and opportunities for funding development actions related to the use of Climate Information and Early Warning Systems in Sierra Leone.

Through the examination of recent reports and studies on climate impacts in Sierra Leone, as well as reviewing the current state of early warning systems and associated projects, this assessment has identified clear gaps in current information availability and dissemination.

(i) Tailored products and services, including ICT, to disseminate early warnings and climate information to vulnerable communities, including farmers and fishers.

(ii) Improving the information available for monitoring and forecasting floods and water resources, through decision support tools. This will result in an improvement in data assimilation from observations (of weather and hydrology) and weather/climate forecasts which will increase the lead time for flood warnings, providing data and more time to plan for flood evacuation and response. This will be supported through the installation of Automatic Weather Station and hydrological sensors covering currently unreported catchment areas.

(iii) Improving and extending community-based early warning systems to provide “last-mile” access to information and improve disaster preparedness. Training for first responders at the district and community level in technology and information dissemination to improve disaster preparedness and response, including how to use and interpret weather/climate/flood warnings and advisories, as well as translation into local languages and customs.

(iv) Improved dissemination and community outreach services through expansion of the Climate Centres, support to Agricultural Resource Centres, and dissemination mechanism including radio, print media and mobile phone technologies. The latter will include development of products which incorporate weather/climate information into existing services.

REFERENCES

Oates, N., et al. 2014. Adaptation to Climate Change in Water Sanitation and Hygiene. https://library.wmo.int/doc_num.php?explnum_id=5298

Ishizawa, Oscar A.; Bonnafous, Luc; Gaspari, Maria; Giron Gordillo, Alex; Muñoz Díaz, Joaquín; Pomonis, Antonios; Wandel, Nathalie. 2020. Sierra Leone Disaster Risk Management Diagnostic Note. World Bank, Washington, DC. © World Bank.

World Bank. (2018). Freetown Urban Sector Review: Options for Growth and Resilience (English). Washington, D.C.: World Bank Group.

Republic of Sierra Leone. 2012. Second National; Communication on Climate Change.

Sea-level rise projections are based on the Atmosphere-Ocean General Circulation Models (AOGCM) as part of the Intergovernmental Panel on Climate Change (IPCC) Fifth assessment report

World Bank (2018). Sierra Leone Multi-City Hazard Review and Risk Assessment: Freetown City and Hazard Risk Assessment

Model accounts for educational, government, healthcare, utility and industrial facilities, formal and informal residential buildings, and road infrastructure

The World Bank Sierra Leone Multi-City Hazard Review and Risk Assessment Final Report (Volume 5 of 5): Map Volume. 2018.

Ishizawa, Oscar A.; Bonnafous, Luc; Gaspari, Maria; Giron Gordillo, Alex; Muñoz Díaz, Joaquín; Pomonis, Antonios; Wandel, Nathalie. 2020. Sierra Leone Disaster Risk Management Diagnostic Note. World Bank.

Qualitative landslide hazard was assessed using a weighted scoring system, which classified and then combined slope angle and a built environment density factor with a weighting of 75:25.

World Bank (2017). Rapid Damage and Loss Assessment of August 14th, 2017, landslides and floods in the Western Area

UNDP (2017): Adapting to Climate Change Induced Coastal Risks in Sierra Leone

Harris, I. et al. (2020) 'Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset', Scientific data, 7(1), p. 109.

Sierra leone: National Water Resources Management Agency; Five-year Strategic Development Plan (2019 -2023)

Progress on drinking water, sanitation and hygiene in Africa 2000-2020: Five years into the SDGs. New York: United Nations Children's Fund (UNICEF) and World Health Organization (WHO), 2022.

APPENDICES

Appendix 1: Selected Ongoing Experiences

Selected Program	Amount	Donor	Year	Financier
West Africa Biodiversity and Climate Change (WABiCC)	$49million	USAID	2015 2020–	Tetra Tech
Building the Adaptive Capacity of Water Supply Services to Climate Change	$3 million	GEF	2012–2018	UNDP
Wetlands Conservation Project	$1.8million	GEF	2011 2016–	World Bank
Sustainable & Thriving Environments for West Africa Regional Development Phase III(STEWARD)	$18million	USAID/USFS	2011 2016–	CARE; Bioclimate; PCI Media Impact; Thomson Reuters; AUDER; and Fauna and Flora International
Environmental Governance and Mainstreaming Project	EU	2012 2016–	Sierra Leone Environmental Protection Agency	
Support for sustainable climate change adaptation in marine artisanal fisheries communities in West Africa	$300,000	FAO	2013– 2015	FAO
Integrating Adaptation to Climate Change into Agricultural Production and Food Security in Sierra Leone	$5.5million	GEF	N/A	IFAD
Preparation of a National Programme of Action for Adaptation to Climate Change	$200,000	GEF	N/A	UNDP
FEWS NET Country Program	USAID	Ongoing	Chemonics	
Building Resilience to Climate Change in the Water and Sanitation Sector	$33million	GEF (LCDF)	Approved	African Development Bank
Strengthening Climate Information and Early Warning Systems in Africa for Climate Resilient Development and Adaptation to Climate Change	$24.4million	GEF (LCDF)	Approved	UNDP
Adapting to Climate Change Induced Coastal Risk Management	$40.1million	GEF (LCDF)	Approved	UNDP

Appendix 2: Technical specifications of equipment

Introduction

Radar used to find precipitation, determine its motion, and determine its type is called weather radar. An essential component of every Automated Weather Observation System (AWOS) in the network of airport weather observatories is radar (Figure 1). Radars are the only meteorological monitoring device that can provide localized, incredibly detailed, timely, and three-dimensional sensing and observing capabilities. They can detect changes in precipitation rates at time intervals of the order of a few minutes, with resolutions of a few square kilometers or better. This is in addition to the ability to track quickly changing weather phenomena, which is essential for the delivery of severe and hazardous weather early warnings. This covers torrential downpours, hail, powerful winds (such tornadoes and tropical cyclones), and wind shear. Of all the meteorological factors, radar has the greatest effect on society. Information obtained by radar is particularly helpful for agricultural, aviation, and other weather-related operations.

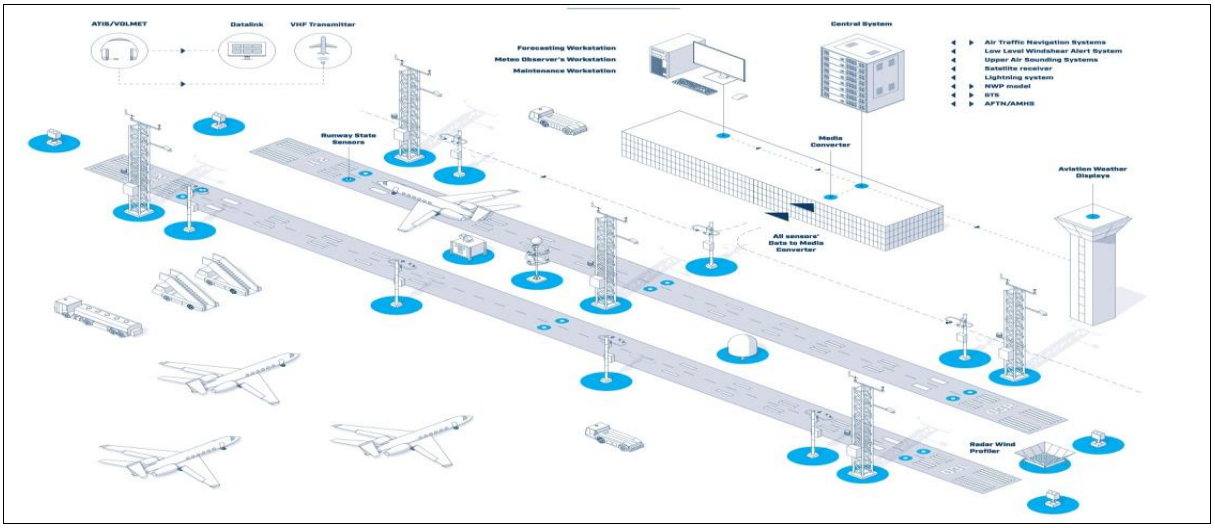


Figure 19: Setup for Automatic Weather Observation System of airport weather observing network

Lungi International Airport (LIA), often known as Freetown International Airport, is a major airport serving the coastal community of Lungi in Sierra Leone. In Sierra Leone, there is only one international airport. The capital city of Sierra Leone, Freetown, is separated from Lungi International Airport by the Sierra Leone River. The Sierra Leone Airports Authority runs the airport. It was a British Royal Air Force base before it was used as a civilian airport. A bridge to improve access between the airport and Freetown is currently being planned. The president announced the Lungi Bridge project in 2019. Parliamentary approval to allot the sum of USD $270 million for the airport development came after this announcement in December 2020. A new passenger terminal, a VIP terminal, new taxiways, and a wider runway are all included in the project. Three million passengers per year will be the capacity. On the northern side of the runway, near the eastern end, is where you will find the new terminal.

The Sierra Leone Meteorological Agency (SLMet) at the LIA, which is directly in charge of producing and transmitting consistent, timely, and reliable weather information for the SL and international airspace, is still in need of the contemporary tools and systems necessary to provide its services. Therefore, the LIA's meteorological services must be improved. By using the information provided by SLMet to reduce climate-related risks and take advantage of opportunities brought on by extreme weather events, the improved meteorological services will benefit economic activities and increase the capacities of citizens and institutions to adapt to climate change. Improved meteorological services are among those that benefit the airlines that fly into and out of airports in Sierra Leone as well as those that fly in Sierra Leonean

airspace to increase their operations' safety and profitability. This is one of the reasons why support is highly needed from the Green Climate Fund to improve the service delivery of the SLMet at the LIA. This will go a long way to improve its operations in terms of generating and delivering consistent, timely and accurate weather information for Sierra Leone and the international airspace.

Automated Weather Observation System (AWOS)

For regional, national, and international airports, the Automated Weather Observation System (AWOS) is a crucial part of the airport weather observation system. As seen in Figure 2, the AWOS collects, analyzes, records, communicates, and displays all meteorological data at the airport.

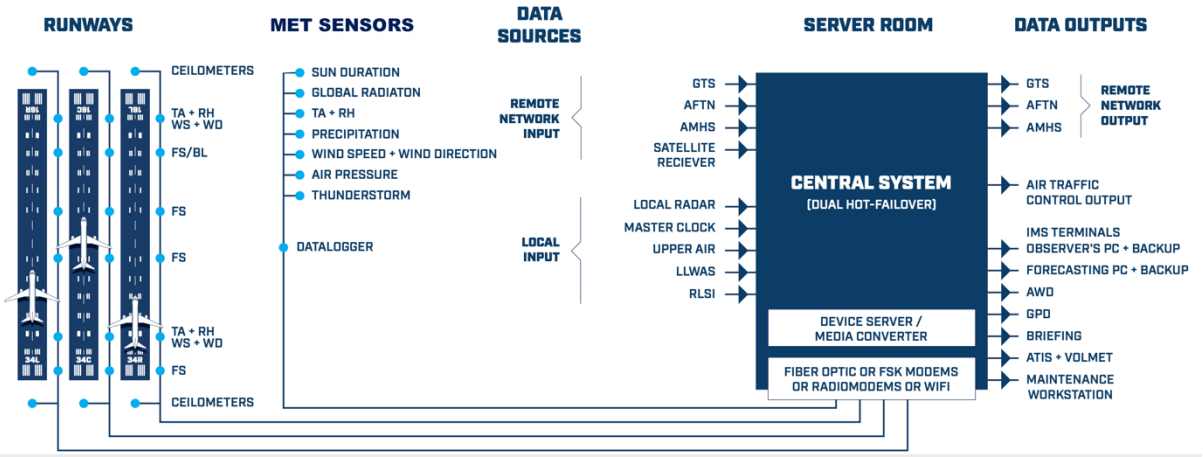


Figure 20: An ideal Automated Weather Observation System of airport weather observation

For observers, air traffic controllers, pilots, and other users, the system integrates and offers weather data in the form of real-time screens, graphs, WMO codes, alarms, and audio reports. It connects radars, low level wind shear alert systems, and upper air systems. Regardless of measurements and reporting, the AWOS is set up to follow all ICAO and WMO recommendations. It creates alerts, METAR, SPECI, SYNOP reports, national codes, and different derived meteorological data such as QNH, QFE, and Runway Visual Range. Numerous different data logger and sensor kinds can be interfaced by the system. It is built to measure, compute, and process a variety of meteorological quantities, including temperature (dry, surface, soil, soil under vegetation), wind speed and direction, pressure (station, QNH, QFE, QFF), relative humidity, precipitation (indicator and amount), runway surface temperature, freezing temperature for various deicing materials, runway condition (dry, damp, wet, etc.), visibility and RVR, cloud height, sunshine duration, solar and gamma radiation, cloud height, and runway condition. In order to back up these networks, the AWOS features a Central System that acts as the hub for all communication networks and connects field sensors, displays, and individual stations deployed on the airport. All preprocessed data is made accessible to distant workstations and displays, thick or thin clients, by the Central System.

Radar System

Radar is highly advanced technology with a variety of uses, including navigation, military operations, and weather monitoring. It is an essential component of the AWOS being offered at Lungi International Airport's weather observation system with GCF support. Platform, application, frequency spectrum, component, dimension, and regional variations in radar use are possible. It can cover the VHF, UHF, and L bands in terms of frequency. Antenna, Transmitter, Duplexer, Receiver, Display, Digital Signal Processor, and Stabilization System are some of its components. Additionally, its dimensions might be 2D, 3D, or 4D radars. In order to support national weather monitoring and forecasting in Sierra Leone, GCF revenues

will be utilized to purchase a distinctive and innovative X-band weather radar with a wide range of functions.

Figure 3: Phototype and functions of the modern X-Band Radar for LIA

Some key features of the X-Band Radar to be procured for the LIA are listed below while the minimum specification needed is provided in Table 1.

- Radar Studio Software for displaying meteorological spatial data in user-friendly graphic form
- Programmable scan of echoes from the radar range (including but not limited to full 3D volume scan, PPI scan, RHI scan)
- Data transformation into spatial matrix
- Input data processing;
- Data distribution to customer graphic workstation

Table 10:Technical Specification of the modern X-Band Radar to be procured

Height	1630 mm
Width	1310 x 1310 mm
Weight	125kg
Antenna	Parabolic, diameter 1160mm
Antenna elevation	-1 to +90°, angle span
Antenna scanning speed	0 to 15 rpm
Transmitter tube	Magnetron
Receiver sensitivity	-111 dBm 10dBz at 200km
Modulator type	Solid-state
Dynamic range	90 dB
Operating frequency range	9410 MHz (X-band)
Half power beam width	1.8°
Polarization	Horizontal
Antenna gain	40 dBi typical
Transmitter power peak	40 kW
Raw data resolution	32 bit
RF pulse width	2 μs
Pulse repetition frequency	250 Hz
Maximum range	200 km
Radial resolution	600 m

Consumption	250 W
Data update rate	3D full scan 1 min (depending on configuration)
Data transfer	TCP/IP (LAN, private networks, internet, etc)
Operating temperature range	-40 to +60^{o}C without AC

Radar Studio Software

The data processing is built on a web server architecture, allowing all goods to be freely accessible to anyone using a web browser and available over an HTTP interface. The web interface's password-restricted access is safeguarded via the encrypted (https) protocol. The earth's curvature and air refraction are taken into consideration by the data processing software. Non-meteorological data, such as ground clutters, are filtered out (removed) in the final display outputs during data processing. Different file formats, including BUFR, GRIB, HDF5, OPERA ODIM, and UF data formats, can be used to store the result. The radar can output images in GIF, Geo Tiff, PNG, and JPG formats.

Radar products

The product of the radar includes:

1) Standard meteorological products such as
   - Plan Position Indicator (PPI) one radar elevation
   - Constant Altitude PPI (CAPPI) horizontal cross section
   - Range Height Indicator (RHI) vertical cross section
   - Echo Tops heights of cloud tops
   - Composite Reflectivity (Column max) maxima in columns
   - Vertically Integrated Liquid Water (VIL) column sums

2) Hydrological products of which
   - Quantitative Precipitation Estimate (QPE)
   - Rainfall Accumulation
   - River basin statistics

3) Composite products from multiple radars such as
   - Generation of the composite products from the heterogenous radar networks

4) Nowcasting
   - Storm cell identification and nowcasting
   - Tracking radar echoes by correlation (TREC) nowcasting up to 2 h including QPE

Radar map server

This includes, but not limited to

- Zoomable maps with layers,
- Integration of Openly Licensed Maps for Offline use,
- Radar product layers,
- OGC Web Map Service

In addition, low emitted power will enable the device to comply with standards for operation in settled areas (towns, airports, highways, ports, etc.). Despite the low emitted power, the radar is able to monitor small precipitation up to distance of 200 km.

Proposed Budget (GCF Financed)

Component Description	Unit	Cost (USD)
X-band Weather Radar System including a map server, radar studio software, workstations, technical training and maintenance fee, an AWOS and other auxiliary accessories.	4	1,273,462.90
TOTAL COST		1,273,462.90

*****_The radar system will be procured through International Competitive Bidding (ICB) method_

Appendix 3: Proceedings of stakeholder consultation

INTERIM
STAKEHOLDER CONSULTATION REPORT

PREPARATION OF FREETOWN WASH AND AQUATIC ENVIRONMENT REVAMPING PROJECT (WASHAERP) GREEN CLIMATE FUND (GCF) FUNDING PROPOSAL

MAY – JUNE 2022

ABBREVIATIONS

ACMAD	African Centre of Meteorological Application for Development
ADCP	Acoustic Doppler Current Profiler
AfDB	African Development Bank
AWS	Automatic Weather Station
CEFCON	Climate Change Environment & Forrest Conservation Consortium
CONOPS	Concept of Operations
ECOWAS	Economic Community of West African States
EPA	Environmental Protection Agency
EWS	Early Warning System
GCF	Green Climate Fund
GEF	Global Environmental Facility
GIS	Geographic Information System
GPS	Global Positioning Systems
GVWC	Guma Valley Water Company
IFAD	International Fund for Agricultural Development
MCH	Meteorological, Climatological and Hydrological Database
MDA	Ministries, Departments and Agencies
NAP	National Adaptation Plan
NDA	National Designated Authority
NDC	Nationally Determined Contributions
NDMA	National Disaster Management Agency
NDMO	National Disaster Management Organization
NEMA	National Emergency Management Agency
NiMET	Nigerian Meteorological Agency
NWRMA	National Water Resources Management Agency
OEMs	Original Equipment Manufacturers
PIC	Project Implementation Committee
PIU	Project Implementation Unit
PSC	Project Steering Committee
RVR	Runway Visual Range
SALWACO	Sierra Leone Water Company
SLMET	Sierra Leone Meteorological Services
UN	United Nations
UNDP	United Nation Development Programme
WASH	Water Sanitation and Hygiene
WASHAERP	Freetown WASH and Aquatic Revamping Project
WMO	World Meteorological Organisation
WONES	Women's Network for Environmental Sustainability

1. INTRODUCTION

This interim report presents the details and outcomes of the consultations held with some of the identified stakeholders for the purpose of understanding the gaps in the availability, accessibility and quality of climate information and early warning systems in Sierra Leone for the purpose of preparing a Funding Proposal to Green Climate Fund (GCF). The Freetown WASH and Aquatic Revamping Project (WASHAERP), amongst other intervention activities, seeks to mainstream climate change and variability, strengthen hydro-meteorological resilience, and enhance climate information and early warning systems in Sierra Leone. Meetings were held with key stakeholders including the National Designated Authority (NDA) - Sierra Leone Environmental Protection Agency (EPA); the institutions primarily responsible for producing hydrometeorological services in Sierra Leone (Sierra Leone Meteorological Services - SLMET and the National Water Resources Management Agency -NWRMA); the National Disaster Management Agency (NDMA) and the executing entity for the proposed interventions – Guma Valley Water Company (GVWC). Additional consultations have been scheduled to be held with other stakeholders while supporting documents are attached to this report. The final report will be produced after all the stakeholders have been consulted.

2. CONSULTATION OUTCOMES

2.1 Guma Valley Water Company (GVWC)

Guma Valley Water Company is currently executing the Freetown WASHAERP which also covers the interventions for which the GCF financing is being sought. The Project Engineer, Ing. Ishmail Bundu noted on the 28th of May 2022 during the consultation with him on the availability of technical and financial capacity of the organisation to execute the proposed projects to be financed by GCF. GVWC has previously executed other projects while the WASHAERP is ongoing. The WASHAERP has also recruited Technical Assistants to support the GVWC team with the execution of the project.

The implementation structure of WASHAERP includes the Project Steering Committee (PSC) which includes Ministers of the different relevant Ministries; the Project Implementation Committee (PIC) whose members includes the representatives of the project's implementing partners/agencies (Freetown City Council, Western Area Rural District Council, National Water Resources Management Agency, National Protected Area Authority, Ministry of Gender and Children Affairs, Ministry of Finance etc.); as well as the Project Implementation Unit (PIU) that comprises of the GVWC staff and the Technical Assistants on the project.

2.2 Sierra Leone Meteorological Services (SLMET)

The Director General of SLMET, Mr. Ibrahim Kamara alongside the top management and technical staff provided responses to the consultation focus questions on the 31st of May 2022. He noted that while the coverage of their services should be national, this is currently not the situation due

to limited capacity and resources. They have a staff strength of 76 whilst a minimum 250 well-trained technical personnel are required to cover the entire country. SLMET has 8 Automatic Weather Station (AWS) provided by Global Environmental Facility (GEF); 8 others provided by International Fund for Agricultural Development (IFAD); 2 by FREP, 1 Pulsonic AWS by United Nation Development Programme (UNDP) and another to be procured by Action Against Hunger. Majority of these stations are not operational due to poor maintenance as they are often supplied without plans for sustainability. Spare parts are not available in the country and there are no technical capacities or competencies for maintenance, calibration and repairs. There are private companies especially in the mining sector that have installed their own weather stations. Although SLMET is meant to regulate/register, provide specification and issue license to them according to Sierra Leone Meteorological Agency Act 2017 (amended in 2022) this is not currently being done.

SLMET has a National Framework for Climate Service (2020) and a Strategic Action Plan that was prepared with the support of the World Meteorological Organisation (WMO). There has been capacity assessment conducted in the past and the reports are shared alongside this stakeholder consultation report. The framework is not operational at the time of the consultation while the Strategic Action Plan needs to be updated.

Basic services are provided at the moment including Daily Weather Forecast – Rainfall data, temperature data; Seasonal Climate Outlook and Marine Forecast (3 days) enabled by the Africa Web Viewer (Model covering Africa) with direct access provided by Meteorological Office, United Kingdom (Met Office). Their services are used daily in the aviation industry but requires a cloud-based storage, automatic weather station, and transmissometer for measuring visibility (runway visual range – RVR) in order to provide quality services. Other sectors accessing weather information from SLMET include Agriculture (agrometeorological data), Researchers, Construction (Road and Transport), Mining, Fisheries, Tourism and Recreation, Insurance, Energy, Water Resources, Power etc. On capacity for early warning, it was noted that the forecast from SLMET is significantly generic but has provided information to prevent heatwaves and particularly flooding in the past.

It was noted that there are significant gaps in the capacity for maintenance, quality control, calibration and checking of meteorological station equipment and instruments. One of the technicians in the organisation is currently undergoing training in one of the regional meteorological training centers. Capacity for forecasting, observation, monitoring and analysis is limited. The institution needs four forecasters, two observers each to operate one station according to WMO standards. There is no equipment for monitoring and analysis, unavailability of operational vehicles and the repeated vandalization of equipment at the weather stations around the country. Solar panels and battery are often stolen rendering these stations incapable

of operation. There is no equipment for surface weather observation with capacity gap for officers to conduct analysis and produce charts. Hence, they are unable to provide short-term, medium-term and long-term forecasting.

Unavailability of funding or insufficient budgetary allocation to SLMET has hampered the efficiency of the institution. The available government subventions cannot cover specialized trainings for staff for which they have relied on other partners. Purchase and operations of Automatic Weather Stations; centralized Meteorological, Climatological and Hydrological (MCH) Database, marine station, IT Infrastructure due to the excessive cost is a major drawback to the efficiency the organisation. Internet data subscription has not been done in the last 6 months which means data cannot be downloaded from the functional weather stations). There has also been challenges with the payment of annual contributions to the World Meteorological Organisation (WMO). SLMET does not generate revenue because the services rendered are free of cost to the users.

SLMET has existing collaboration with regional and global climate centers including World Meteorological Organisation; Centre Regional AGRHYMET; Nigerian Meteorological Agency (NiMET) – sends forecasts for Sierra Leone on daily basis but the data is sometimes unreliable; and African Centre of Meteorological Application for Development (ACMAD). Action Against Hunger is the only organisation providing donor intervention to SLMET at the time of the consultation with the procurement and installation of a weather station at Moyamba.

There is currently no policy on data/information sharing other than the country level – Right to Access Information Act. SLMET does not have any dedicated user interface platform. Hence, climate information and data dissemination has been through SLMET App, Facebook page, website (www.slmet.gov.sl), public WhatsApp, Quarterly media engagement on seasonal outlook. SLMET has historical data from 1981 for some stations and are available at the climatological office. There was no data collection during the war as the weather stations were destroyed except two at Makeni and Lungi. Collaboration with media outlets on data sharing is bedeviled by their request for money prior to disseminating to the public. Resource constraints has limited stakeholder engagements with user community and the channels of feedback have been during workshops and media campaign. There is limited publicity for their services and only specific requests has been received by the public. The Director General mentioned that the WMO has provided documents for Network Observation Plan for the entire country to expand from 11 synoptic stations and 112 rainfall stations, 32 agrometeorological station and 2 upper air stations.

2.3 National Water Resources Management Agency (NWRMA)

Consultation was held with NWRMA on the 31st of May 2022. The Director of Hydrological Services Department, Mr. Mohammed Juana and other technical personnel under the

Department were present. It was noted that there were hydrological monitoring networks available under the Ministry of Water Resources but were destroyed during the war including loss of some historical data. The Agency is nascent however with the support received from international donors they have reestablished a network of monitoring stations.

Details of donor interventions for hydrological monitoring networks at NWRMA

Donor name	**Year of support/ intervention**	**Hydrological monitoring networks**
United Nation Development Programme (UNDP)	2015	13 hydrological/surface stations (11 installed) 15 groundwater monitoring station (all installed)
African Development Bank (AfDB) funded Climate Risk Management Infrastructure Project through Sierra Leone Water Company (SALWACO)	2018-2019	17 surface water monitoring station (14 installed and operational) 20 groundwater monitoring station (17 installed and operational)

Some of the stations are not transmitting (offline) at the time of the consultation as a result of loss of some components through theft/vandalism (solar panel, battery etc.); unavailability of internet data; absence of operational vehicles for personnel to conduct monitoring and spot-checks at the stations amongst others. There is paucity of funds which has made data collection and receipt of data from the loggers including those read by staff gauge readers difficult and ineffective due to non-payment of stipends.

The services/products the Agency should be offering include:

- Hydrological data – Water level and Discharge data
- Water quality data
- GIS data

At the time of the consultation, service offered at the Agency is limited to water level measurement and water quality monitoring. There are 12 river basins in the country and 41 sub catchments in the western area peninsula. Water quality monitoring is conducted only on Rokel River. There is capacity for basic data collection but processing, analysis and dissemination through a user interface platform is non-existent. Unfortunately, incomplete data is currently collected (no discharge measurement), although they have the Hydromet V2 software further limiting processing, analysis and interpretation. There is a 5-Years Strategic Plan which is expected to ensure there is a minimum of 60 surface water monitoring stations and 100 groundwater monitoring stations to improve the quality of services and data products.

Provision of climate information and support for early warning is limited to flash floods which is a major climatic hazard in Sierra Leone particularly in communities around streams and rivers. Monitoring of water levels help to provide information to the National Disaster Management Agency. There is no capacity for maintenance, quality control, calibration and checking of hydrological equipment. This has limited capacity for presenting flood forecast as part of support for early warning in Sierra Leone. Engagement with user communities has not been done because they are currently not providing river discharge data which is significantly required by the users.

The identified users of hydrological data are:

- Government agencies: Agriculture, Water Resources, Energy, Transport etc.
- Researchers (Independent/private sector Consultants and Students)
- Construction companies
- Mining companies

NWRMA does not have any policy on data or information sharing but has consistently provided information on request to members of the identified list of users above. Some historical data are available particularly for 1971 – 1976 while water level data and water quality data for Rokel River from 2015 and 2019 to date are available, respectively.

Donor interventions has previously not considered the sustainability of the infrastructure and equipment provided to the Agency which has impacted in the quality of operation against the backdrop of limited government allocation. Revenue generation form water right charges paid by water users is low but will improve with regulations that empowers the agency to seal off facilities for non-payment.

There is currently no regional and global collaboration with hydrological and global climate centers other than World Meteorological Organisation. Also, there is no donor intervention at the Agency at the time of the consultation.

The Agency has active social media platforms for interfacing with user communities but there have not been feedbacks on service delivery.

The major needs of the Agency according to the team include:

- Equipment (Boats, Acoustic Doppler Current Profiler (ADCP) – deep river/stream measurement, Current Velocity Meters – shallow/low flow measurement)
- Vehicles
- IT infrastructure - Hardware, software, server, portal for data dissemination
- Spare parts, maintenance, after-sale support by OEMs
- GIS Infrastructures – Hardware and

- Differential GPS
- Basic Photometer
- Standard Laboratory
- Technical support for training and capacity building for technicians.
- Funding (prohibitive cost of data management platforms – telemetry systems, data loggers.

2.4 National Disaster Management Agency

Mr. John Vandy Rogers, Director at the National Disaster Management Agency (NDMA) noted during consultations on the 1st of June 2022 that the Agency has at various times obtained weather prediction data from Sierra Leone Meteorological Services. Unfortunately, weather prediction has been false sometimes which is embarrassing for emergency planning. There is need for capacity building for SLMET and Hydrological Services Department to prevent information and system failure. Data disseminated must be accurate and useful to aid decision-making in disaster risk prevention and emergency planning. Disasters associated with climate hazards in Sierra Leone is primarily flooding and water shortage. Specific hydrometeorological data that has been obtained by NDMA include: Rainfall data; Water quality and Water level

NDMA has Sierra Leone Disaster Management Policy and has built collaboration with the following institutions:

- Economic Community of West African States (ECOWAS)– Disaster Risk Reduction (DRR)
- National Disaster Management Organization (NDMO), Ghana
- National Emergency Management Agency (NEMA), Nigeria
- National Disaster Management Agency (NDMA), Liberia

There is a revised National Hazard Profile (2016) for Sierra Leone. It was recommended that harmonized coordination engagements between all the stakeholders around climate information and early warning systems should be promoted. There was a National Early Warning Committee supported by the UN but is currently not existent. The committee had members including scientists – engineers, hydrologist, farmers, women, tribal heads etc. It was recommended that established structures must be grounded in terms of regulations, capacity to be effective.

2.5 Environmental Protection Agency (EPA)

The EPA, which is also the NDA has a Climate Change Secretariat with the Climate Information Officers of MDAs as members. The secretariat coordinates climate-based/related activities with the different MDAs. Contacts of key stakeholders were provided by the EPA Focal Persons including details of additional stakeholders suggested to be consulted. They are:

- Sierra Leone Institute of Agribusiness.
- Sierra Leone Agricultural Research Institute.

- Women's Network for Environmental Sustainability (WONES); and
- Climate Change Environment & Forrest Conservation Consortium Sierra Leone (CEFCON-SL)

3. LIST OF DOCUMENTS SHARED BY STAKEHOLDERS

The stakeholders have shared some documents listed below, which are submitted separately.

1. **SL-MET**
    - Aide-memoire: Joint Mission of WMO, UK Met and AfDB
    - Concept of Operations (CONOPS) for SLMET and NWRMA
    - Strategic Plan 2018 – 2023
    - National Framework for Climate Services (NFCS) and Implementation Plan (2020 – 2025)
    - Proposed Strategy for Strengthening Hydromet and EWS Capacities in Sierra Leone
2. **EPA**
    - Updated Nationally Determined Contributions (NDCs).
    - National Adaptation Plan 2021
3. **NWRMA**
    - 5 Year Strategic Development Plan (2019 – 2023)
4. **NDMA ***
    - National Hazard Profile
    - Flash Points of Disaster in Sierra Leone

*Yet to be received

4. FURTHER CONSULTATIONS

The stakeholder consultations are still ongoing, and the outcomes will be shared in the coming weeks.

PREPARATION OF FREETOWN WASH AND AQUATIC ENVIRONMENT REVAMPING PROJECT (WASHAERP) GREEN CLIMATE FUND (GCF) FUNDING PROPOSAL

STAKEHOLDER CONSULTATION REPORT (II)

JUNE 2022

List of Abbreviations

CIEWS	Climate Information and Early Warning System
COP	Conference of Parties
EHS	Environmental Health and Safety
EPA	Environmental Protection Agency
GCF	Green Climate Fund
GEF	Global Environmental Facility
MDA	Ministries, Departments and Agencies
NDA	National Designated Authority
NDMA	National Disaster Management Agency
NGO	Non-Governmental Organisation
NPAA	National Protected Area Authority
NWRMA	National Water Resources Management Agency
SLMET	Sierra Leone Meteorological Services
SLRTC	Sierra Leone Road Transport Cooperation
UNDP	United Nation Development Programme
WASH	Water Sanitation and Hygiene
WMO	World Meteorological Organisation

1. INTRODUCTION

The Interim Report I contained the outcomes of the consultations with specific stakeholders such as the GCF National Designated Authority (NDA) – the Sierra Leone Environmental Protection Agency (EPA) and the institutions responsible for producing hydrometeorological services in Sierra Leone (Sierra Leone Meteorological Services – SLMET and the National Water Resources Management Agency – NWRMA).

This Interim Report II (final) contains the outcome of additional consultations that have been held with users of climate information. It should therefore be read in conjunction with Interim Report I. The EPA which also houses the Climate Change Secretariat in Freetown volunteered the contact information of the respective desk officers who were subsequently invited to a stakeholder consultation. Consultations were held with the Climate Change Information focal persons of the different MDAs on the 7th of June 2022. The representatives of the primary producers of hydrometeorological information (SLMET and NWRMA) in Sierra Leone were in attendance.

2. CONSULTATION WITH CLIMATE INFORMATION USERS

2.1 Ministry of Water Resources

The representative from the Ministry of Water Resources (Mohammed S. Kamara) noted that hydrometeorological data is germane to the ministry with emphasis on daily weather forecast such as rainfall, humidity, transport, sunrise/sunset which are available through the SLMET. A tool is being developed by the NDMA and SLMET to make data available on mobile phones. A server is needed to host the software for automatic information transfer and modelling. Similarly, limited resources have hampered the plan for the tool to accommodate information in local dialects. There is plan for a community approach to coastal alert where the use of color codes could be employed to ensure preparedness for flooding and coastal erosion.

Access to data is difficult in terms of the bureaucratic requirements but information should be available on the website and using a weather app. SLMET representative however noted the SLMET is available on Google Play store freely for download for public user to obtain daily updates on weather forecast.

2.2 Ministry of Transport and Aviation

Mr. Beran Forster indicated that the Ministry requires hydrometeorological data for planning and operations at the airport, ports, maritime and including information for assessing flood risks on land transport particularly for Sierra Leone Road Transport Cooperation (SLRTC). Targeted meteorological data is also required for road construction while it is indicated that it is a daily need for the aviation industry. It was noted that the marine meteorological department of the SLMET is not fully equipped but basic marine data is currently available and is useful for fishers particularly data on sea level rise which is made available through mobile phones to some focal persons. The marine weather station automatically update/sends alerts to their phones of the

focal persons. The Project is supported by UNDP (Adapting to Climate Change Coastal Induced Management Project) through GEF (2018 -2023). SLMET would need ocean buoys to enable measurement of air temperature above the ocean surface, wind speed (steady and gusting), barometric pressure, and wind direction. One of the critical data requirements is tidal level. Information needs such as those relevant for forewarning on windstorm that would make shipping and berthing at the port difficult.

The Ministry receives data from SLMET on demand particularly for Integrated and Resilient Urban Project when it comes to engineering designs for road construction. There is currently no mainstreaming of hydrometeorological data in planning yet. However, environmental consideration is being mainstreamed into planning and transitioning of SLRTC from providing bus services to a regulator whereby engine specifications will be provided to prevent air pollution.

2.3 Ministry of Agriculture, Forestry and Food Security

SLMET through the agrometeorological department provides seasonal climatic information including dry sell, rainfall, and cessation of rainfall. This information is useful in preparing yearly farming calendar. The analysis of the 30 years' climatic data was helpful for projection of seasonal calendar while the sectoral projection and seasonal calendar for 2022 is available. SLMET through the agrometeorological department annually produces the seasonal climatic outlook which is helpful in informing the farmers on when to expect rain, onset of rain, long or short dry spell etc. They also develop farming calendars which is useful for smallholder farmers and farmer field school. The Seasonal Climatic Outlook for the year 2022 has been published. This projection is critical in determining the types of crops or species to plant depending on the weather projection to support farming resilience and prevention of losses.

2.4 Ministry of Health and Sanitation

Two officers from the Directorate of Environmental Health and Safety (EHS) and Water Sanitation and Hygiene (WASH) of the Ministry of Health and Sanitation noted that climatic data important. However, they have not been receiving information from either SLMET or NWRMA. They have however been working with the Ministry of Water Resources and other MDAs to develop Climatic Adaptation Plans towards attaining key targets committed to at COP15. They are keen to receive daily updates from SLMET and NWRMA as public health specialists to facilitate the development of preparedness and emergency response plans for climate-related hazards. The Seasonal Climatic Outlook for 2022 already showed that there will be increase in vector borne diseases which should be of interest to health agencies and institutions.

It was requested that the SLMET app should be enhanced to support data visualization necessary for decision making. There is ongoing conversation between SLMET and NDMA in terms of using climate information to trigger alert useful for different Agencies to plan for disasters.

2.5 National Protected Area Authority

Mr. Babar Turay the NPAA representative, indicated that there is limited climatic information that can be used for planning purposes at the Authority. Water level and water quality affect species, both in the wetlands and terrestrial ecosystem and access to this information is vital. He noted that he has hitherto obtained weather and climatic information from Capital Radio. There have been forest fires although anthropogenic, the climatic situation exacerbates the severity of the fires. The rivers and water resources are getting drier and especially as the amount of rainfall is declining because of deforestation, increased construction, and reduced evapotranspiration.

2.6 Climate Change, Environment, and Forest Conservation (CEFCON)

The NGO according to Mohammed Nallo creates awareness on coastal erosion across Freetown including supporting reforestation. Other activities include discouraging sand mining and degradation of the mangroves. They have relied on visual observation and desktop research for information to support their awareness campaign. Reliable date from SLMET and NWRMA are critical to support information dissemination and intervention planning.

3. RESULT OF THE ANALYSIS OF SURVEY QUESTIONNAIRE

Considerations for provision of reliable and timely climate information and early warning systems is critical for specific industries and communities that are susceptible to climate-related hazards. These systems provide useful information that is necessary to proactively prevent and/or minimize the impacts of these hazards on life and livelihood supporting infrastructures thereby helping to build resilience. The questionnaire was administered on the 7th of June 2022 for all twelve (12) respondents except representatives of the flood prone communities as detailed below:

- Kroo Bay Community – 13th June 2022.
- Crab Town – 13th June 2022; and
- Kolleh Town – 16th June 2022

These respondents are drawn from the either from Ministries, Departments and Agencies (MDAs), Civil Society Organisation and flood-prone communities.

List of institutions and Communities Consulted

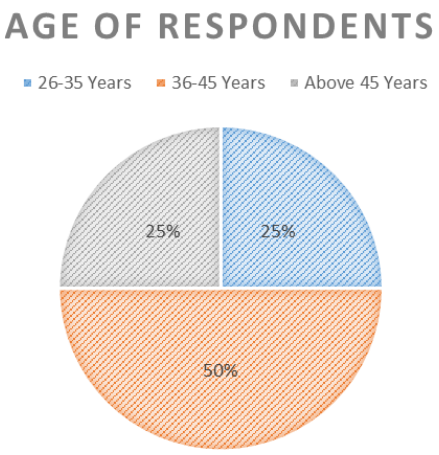
MDAs	NGO	Flood-prone Communities
• Ministry of Water Resources. • Ministry of Transportation and Aviation. • Ministry of Health and Sanitation.	• Climate Change, Environment, and Forest Conservation (CEFCON)	• Kolleh Town, Freetown. • Crab Town, Freetown • Kroo Bay Community

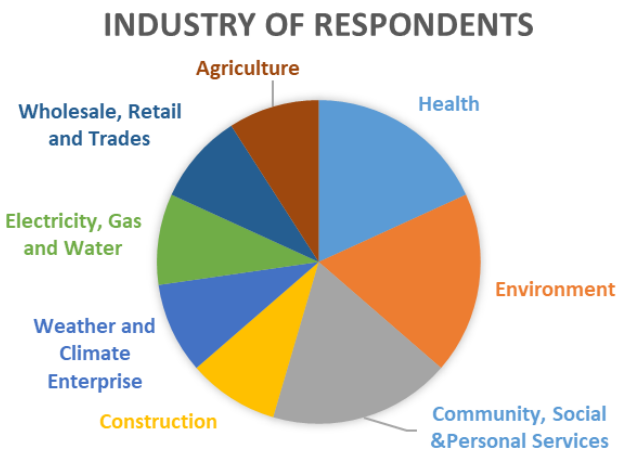
MDAs	NGO	Flood-prone Communities
• National Protected Area Authority (NPAA); and • Ministry of Agriculture, Forestry and Food Security		

3.1 Age, Gender, Academic Qualification and Occupation of Respondents

All the respondents were males and reside in Freetown while their various occupations include Businessmen, community representatives, Students, and civil servants from various Ministries, Departments and Agencies (MDAs).

Six out of the twelve respondents were aged 35-45 years while three respondents each were aged 26-35 years and above 45 years, respectively. None of the respondents falls within the 15-25 years' age bracket. There are four persons each with degree and postgraduate qualification while one person has no formal education and the remaining three persons possessing WACSE GCSE/O-Level. Below is the distribution of the industry the respondents are directly or indirectly engaged.



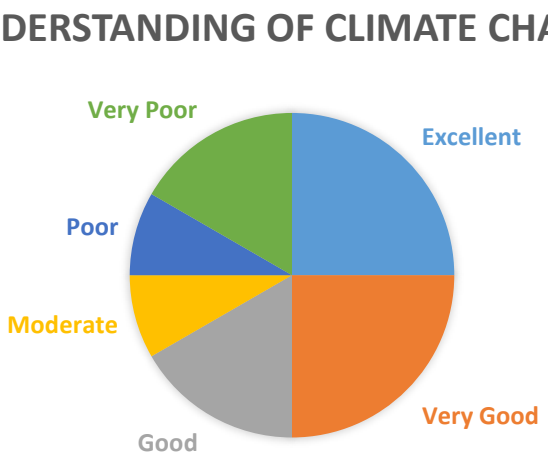


Two respondents each work in the health, environment and community, social and personal Services whilst one person each works in the remaining five industries indicated during the consultations.

3.2 Climate Change Issues

Climate change issues are considered ***especially important*** by 10 respondents (83%), 1 respondent indicated it is ***quite important*** while 1 person declined to respond. Their consideration for its importance is noted to be either related to its importance to water resources management and agricultural productivity. Others indicated that it is important as a result of its

implication for environmental destruction, flooding, wetland degradation and impacts on socioeconomic activities and health.



Three persons each noted that their understanding of climate change is ***excellent*** and ***exceptionally good*** while two people rated their understanding as ***moderate***. It is indicated that climate change has negative impacts with the under listed indicating how it has impacted them:

- Incidences and outbreaks of diseases.
- Flooding
- Declining water resources
- Erosion
- Heavy Rainfall

3.3 Climate-related Hazards affecting Sierra Leone

The observed climate-hazards affecting Sierra Leone according to respondents who are primarily from the Western Area Urban and Western Area Rural District in Freetown are:

- Windstorm
- Heatwaves
- Heavy rainfall
- Flood
- Forest fires
- Air Pollution
- Coastal Erosion
- Drought
- Insects, Pests and Diseases

Respondents were required to rank climate hazards mentioned in terms of how they affect their district, below is the analysis of the ranking of the hazards: (1 = low; 2 = medium; 3 = high)

- Heavy Rainfall = 3

- Flood = 3
- Coastal Erosion = 3
- Windstorm = 2
- Insects, Pests, and Diseases = 2
- Drought = 2
- Air pollution = 1
- Heatwaves = 1
- Fog = 1
- Forest Fire = 1
- Thunderstorm = 1

In establishing how often the above hazards occur in terms of time scale from the analysis of responses received within the context of on climate-induced incidences, below is the frequency of their occurrence:

Daily – Coastal Erosion, Insects, pests and diseases, Air pollution

Seasonal occurrence – Heavy rainfall, Windstorm, Thunderstorm, Flood

Annually – Flood

3.4 Climate Information and Early Warming Systems (CIEWS) in Sierra Leone

Three respondents (25%) indicated they do not receive any climate information. However, 75%of respondents (9 persons) noted that they receive weather/climate information or early warning systems from Sierra Leone Meteorological Services (SLMET) or hydrological services department of the National Water Resources Management Agency (NWRMA). The type of information received include weather condition such as rainfall projection and wind speed. This information is received from SLMET, radio, and television.

Two of the respondents indicated that the information received ***often meet*** their requirement. Four noted that information ***sometimes meets*** their requirements while three did not provide information on whether the information meets their requirements. The most recurrent preference for accessing climate information is radio 7 respondents (58%) followed by WhatsApp, internet, and text messages. The type of weather information services respondents prefers to receive are annual rainfall forecast, temperature, humidity, sea water level, water level, water discharge. Majority wants the information to available daily. However, two respondents declined to provide information of their willingness to pay for climate information services. Two stated they are not willing to pay while seven respondents are disposed to pay for CIEWS services. The cost of climate information in the opinion of respondents is between Le500 and Le20,000. A respondent indicated institutions should pay US$200 annually to access climate information services.

On the awareness of the respondents on the existence of ***weather forecasts services*** in Sierra Leone in the last five years, 7 respondents (58%) noted answered in the affirmative. The rest either noted they are unaware or declined to provide response. Only three respondents (25%) are aware of the existence of hydrological ***forecasts services*** in Sierra Leone. Only five respondents (42%) noted that the climate information available today is more accurate in comparison to the last five years.

Across all the sectors and industries, climate information services that are considered useful are daily weather forecasts, rainfall data, temperature, water level and discharge. The order of importance with regards to the means of communication ideal for the respondents are highlighted below.

- Radio – High
- Mobile App – High
- Text Messages – High
- Television – Medium
- Newspaper – Low
- Website – Medium
- Town Crier – Medium

3.5 Impact of Climate-related Hazards

Ten respondents (83%) noted that either their sector, friends or family has been adversely affected by climate hazards. The major hazard that has impacted the people the most is flooding (50%), windstorm, heat rash/disease outbreak and coastal erosion. It is accepted that climate related hazard has different impact on men, women, children, physically challenged and elderly people. Furthermore, women are noted to be more adversely impacted than men by climate-related hazard and especially those with children.

Some of the suggestions or recommendations to reduce hazards as suggested by respondents include:

- Effective hydrometeorological stations and services within vulnerable communities including collection and dissemination of reliable/quality data in a timely manner (real time information sharing).
- Procurement of recent weather and climatic automatic stations that meets WMO specifications and institutional strengthening/training of climate information service providers.
- Co-opting Meteorological Agency as an implementation partner in weather project development whilst incorporating community coping strategies into such interventions.

- Improvement on waste collection, drainage and sanitation infrastructures will reduce the damage caused by flooding.
- Catchment protection and basin management, forest protection including prevention of deforestation and bush burning through awareness campaigns and community engagements.
- Improvement on inter-ministerial and agency collaboration on climate change as well as policy implementation that prohibits deforestation.
- Development of actionable work plan to mitigate climate change and environmental hazards; and
- Utilization of climate information data for decision making, planning and execution.

4. CONCLUSION

As was indicated in Interim Report I, this Interim Report II covers the second round of consultations and effectively concludes the Stakeholder Consultations with both providers and users of climate information.

The stakeholder consultations exercise has availed the opportunity to appraise the technical capacity vis-à-vis equipment and human resources of the two key providers of hydrometeorological services in Sierra Leone. It has been observed that there is a significant gap in their capacity to support climate resilience in the form of climate information and early warning systems in the country despite several interventions by developing partners. The reports provide a list of equipment and training needs which if provided will support and strengthen the provision of quality, accessible and peradventure affordable climate information in Sierra Leone. This will also significantly ensure that the demand side i.e., the users of these information will be able to improve on preparedness, decision making and climate proof the different sectors that are susceptible to climate hazards.

Sustainability of interventions remain a major concern in Sierra Leone because of limited budgetary allocations by the government to the Agencies that produces vital climate information. Hence, interventions must prioritize strengthening agencies to continue to operate at optimum capacity following receipt of intervention.

Appendix 4: Economic and Financial Analysis

Appendix 4-1: financial viability based on NPV

Period	Project cost	PV – 5%	NPV - 5%	PV - 10%	NPV - 10%	PV - 15%	NPV - 15%
2027	$31 096 800	$2 275 959	-$28 820 841	$4 551 919	-$26 544 881	$6 827 878	-$24 268 922
2032	$31 096 800	$5 303 077	-$25 793 722	$10 606 156	-$20 490 644	$15 909 233	-$15 187 567
2037	$31 096 800	$9 266 390	-$21 830 409	$18 532 782	-$12 564 018	$27 799 172	-$3 297 628
2040	$31 096 800	$12 254 889	-$18 841 910	$24 509 779	-$6 587 021	$36 764 669	$5 667 869
2044	$31 096 800	$17 618 287	-$13 478 513	$35 236 575	$4 139 775	$52 854 862	$21 758 062

Appendix 4-2: Present value of modelled climate losses due to hazards (USD)

Year	Annual costs of climate hazards	Present value of projected annual climate cost with various discount rates			
		3,5%	5%	10%	15%
2023	7 946 898	7678162,3	7568474,29	7224452,73	6910346,09
2024	8 439 436	7878303,8	7654817,23	6974740,5	6381426,09
2025	8958370	8079936,5	7738576,83	6730555,97	5890273,69
2026	9500482	8279121,2	7816070,05	6488957,04	5431931,42
2027	10674000	8987221,6	8363358,3	6627714,2	5306864,47
2028	10663254	8674564	7957084,31	6019128,89	4610018,97
2029	11285202	8870066,8	8020182,37	5791093,02	4242525,43
2030	11936767	9064918,8	8079273,76	5568589,9	3902150,31
2031	12616660	9257234,2	8132811,53	5350695,46	3586442,2
2032	14 040 487	9953565,4	8619641,06	5413215,54	3470593,65
2033	14069160	9636610,8	8225946,47	4931154,75	3024070,59
2034	14843054	9822885,2	8265167,87	4729454,43	2774272,92
2035	15651715	10007772	8300438,64	4533744,32	2543841,26
2036	16495144	10190400	8331168,61	4343686,96	2331236,56
2037	18 207 187	10867699	8757968,26	4358655,81	2237562,87
2038	18301003	10554297	8383900,34	3982831,47	1955732,47
2039	19256891	10730012	8401717,76	3809873,22	1789463,67
2040	22 212 082	11958122	9229578,86	3995038,19	1794849,93

Appendix 4-3: estimated cash flow at various discount rates (USD)

	,5%	5%	10%	15%
2023	268735,681	397344,9	794689,8	1192034,7
2024	295380,26	421971,8	843943,6	1265915,4
2025	313542,95	447918,5	895837	1343755,5
2026	332516,87	475024,1	950048,2	1425072,3
2027	373590	533700	1067400	1601100
2028	373213,89	533162,7	1066325,4	1599488,1
2029	394982,07	564260,1	1128520,2	1692780,3
2030	417786,845	596838,35	1193676,7	1790515,05
2031	441583,1	630833	1261666	1892499
2032	491417,045	702024,35	1404048,7	2106073,05
2033	492420,6	703458	1406916	2110374
2034	519506,89	742152,7	1484305,4	2226458,1
2035	547810,025	782585,75	1565171,5	2347757,25
2036	577330,04	824757,2	1649514,4	2474271,6
2037	637251,545	910359,35	1820718,7	2731078,05
2038	640535,105	915050,15	1830100,3	2745150,45
2039	673991,185	962844,55	1925689,1	2888533,65
2040	777422,87	1110604,1	2221208,2	3331812,3