LIBERIAN HYDROLOGICAL SERVICE,
MINISTRY OF LANDS, MINES AND ENERGY,
LIBERIA

NORWEGIAN WATER RESOURCES AND
ENERGY DIRECTORATE,
NORWAY

LIBERIA RIVER BASINS 2016

Drainage Divisions and River Basin Boundaries

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HYDRO-CONSULTING

NVE

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ABBREVIATIONS

ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
CA	Cooperation Area
CA4	CA 4 Upgrading National Hydrometeorological Network and Database
DEM	Digital Elevation Model
GDEM V2	Global Digital Elevation Model Version 2
GIS	Geographical Information System
GOL	Government of Liberia
GON	Government of Norway
HIS	Hydrologic Information System
JOG	Joint Operations Graphic
LEC	Liberia Electricity Corporation
LHS	Liberian Hydrological Service
MLME	Ministry of Lands, Mines and Energy
NVE	Norwegian Water Resources and Energy Directorate
RREA	Rural and Renewable Energy Agency

1. INTRODUCTION

1.1 THE MLME – NVE COOPERATION

The Programme Institutional Capacity Building and Strengthening of the Energy and Water Resources sectors in Liberia 2010-2015 was funded by the Government of Norway. The Programme initiated institutional cooperation between the Norwegian Water Resources and Energy Directorate (NVE), and the Liberian Ministry of Lands, Mines and Energy (MLME). The intended outcome of the Programme was to increase the professional level, knowledge and the capacity of the staff at MLME and other agencies (RREA, LEC, etc.) within the electricity and water resources sectors.

The Cooperation Area 4 (CA4) *Upgrading National Hydrometeorological Network and Database* was un important component of the Programme and was implemented under the auspices of the Liberian Hydrological Service (LHS). The main objective for CA4 was to establish a minimum station hydrometric network, database and to make the hydrological data available for users of water resources. These activities included, among others, building the LHS capacity to deliver basic end-user oriented hydrological services and products (especially addressing needs of hydropower).

In many places of the world freshwater resources are under increasing pressure due to over-utilisation and pollution from human activities. The situation in Liberia is no exception. Although the current situation is generally good, projections of future water requirements show an increasing competition between different water users. Proper assessment and management of the water resources are therefore essential to overcome current and future problems of supplying water of adequate quantity and quality to all users in Liberia. Basin's and drainage network delineation is a prerequisite step needed for further systematic studies of Liberian hydrology, climate, hydropower potential and an effective water resources management. We hope that this report will contribute to increasing knowledge about Liberian river system and water resources.

1.2 BACKGROUND

The *Liberia River Basins 2016* Report has been produced, within the framework of CA4, by GIS experts of NVE and Hydro-Consulting with the valuable assistance of Liberian Hydrological Service (LHS).

The document and was created to serve as:

- general educational document on the rivers and river basins of Liberia,
- source of preliminary information about Liberian drainage network for those involved in the planning, design of hydropower and management of water resources systems.

The report was inspired by and it is a follow up of the work by carried out by LHS during early eighties of the 20th century. The first hydrological division of Liberia was proposed by Strupczewski and Meijers (1982) and the first coding system for Liberian basins by Strupczewski and Sua (1983). The *Liberia River Basins 2016* report provides condensed information on Liberian drainage network and river basins. The report updates drainage network and basin boundaries based on current data and GIS-based analysis.

The report is intended as the first small, basic step that could lead to development of the Liberian Water Resources and Hydropower Potential Atlas. We treat this report as an open document and hope that it will be continuously updated to achieve this goal. Therefore, we strongly encourage water and hydropower sector planners, managers and users in the

various organizations to review the report and submit corrections and suggestions for further development of the document to the authors through Liberian Hydrological Service.

We hope that the report will in the future become a real and vital source of information about Liberian Water Resources. Therefore, Liberian Hydrological Service will develop and ensure close contact with those working with existing projects, newly emerging river organizations, regional organizations and the donor community in order to secure input of reliable and updated information.

2. DEFINITIONS

The terminology list provides a short list of key and specialized terms used in this report along with their definitions. Many of the terms used in this report are common hydrologic terms, but they may be used in a different context in this report.

River	A linear path along which water flows due to gravity
Main river	The river flowing into an outlet that drains the largest area of all rivers flowing into that outlet **in case of this report Atlantic Ocean**
River basin	The area of land from which all surface run-off flows through a sequence of streams and rivers into a single river mouth
River basin boundary:	A linear feature separating multiple river basins. Flow crosses a basin boundary only at one location
Principal river basin	**In this report:** the area of land from which all surface run-off flows through a sequence of streams and rivers into the sea at a single river mouth, estuary or delta
Drainage Area	**In this report:** an area that drains to a given location on a landscape. Drainage areas may contain multiple rivers
Coastal drainage area	**In this report:** one or a group of streams forming a coastal drainage area and draining into Atlantic Ocean
Outlet	The point along the basin area boundary through which all flow leaves the drainage area.
River mouth	Site of discharge of a river into a large water body such as a sea or a lake
Confluence	An outlet at which two or more rivers intersect. Only one river flows out of a confluence
Tributary	In this report: the river flowing into an outlet that adds flow to the main river. Tributaries drain subbasins i.e areas smaller than the principal basin drained by the main river flowing into the Atlantic Ocean
Subbasin	In this report: the river basin with an outlet to main river
Classified tributary	Coded tributary
Classified subbasin	Coded subbasins
Catchment	the area of land drained by a single stream or river with a single outlet for its surface. In hydrology term often used synonymously with river basin
Interbasin	In this report: the area draining to a reach of the main river at given characteristic point.
DEM	Digital elevation model

3. BASIN DELINEATION

Liberian basins and river network were derived by automated ArcGIS procedures using:

- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) at 30.34 x 30.34 meter resolution.
- 12 Joint Operations Graphic (JOG) raster maps in scale 1:250,000 prepared by United States Defence Mapping Agency Topographic Center
- 12 Joint Operations Graphic (JOG) vector maps in scale 1:250,000 bought from East View Geospatial, Inc.

Delineation procedure of Liberian river basins included following major steps:

1. Establishment of river network
2. Generation of flow direction and flow accumulation grids
3. Generation of basins using watershed tools

Establishment of River network

Rivers as lines with digitized direction towards the sea allowed for identification of main rivers and tributaries. Temporary catchment polygons were generated to divide the country into usable units. Centrelines in rivers and lakes described as polygons were generated using Thiessen polygons interpolation method. Together with rivers as lines, a geometric network was generated catchment by catchment. The outlet points were digitized at the end of all lines in the sea. Flow direction of all rivers in the network was set downstream.

Generation of flow direction and flow accumulation grids

To be able to generate watersheds automatic hydrologic correct grids must be generated. To enhance the DEM, rivers from the river network was used both in generating the hydrologic correct DEM and were burned into the DEM to make sure that lowest points are in the river. Flow direction and flow accumulation grids where generated from this hydro DEM. Flow direction grids determines the direction of flow for every cell in the raster. Flow accumulation grids give the number of cells that flow into each cell.

Delineation of basins

Generating watersheds from flow grid is a standard tool in Spatial Analyst extension to ArcGIS. Model builder and python scripts were used with ArcGIS to create a usable tool (point in river and generate watershed).

Limitation of the delineation procedure

River network products derived from DEM are prone to various errors. The quality of basin delimitation for Liberia depends on the characteristics of the ASTER-based elevation model. ASTER DEM elevation information is obtained through analysis of stereo image pairs and it is subject to obstruction by cloud cover as well as it may include noise and artefacts from the automatic image processing procedure.

More than 500 km long Liberian coastline is bordered by a flat coastal plain with a width varying from 15 km to 40 km. The prevailing part of the coastal plain has an elevation of less than 30 m. The rivers crossing this region toward the Atlantic Ocean are meandering, form lagoons and frequently flow parallel to the shoreline before discharging into the Ocean.

Limited resolution of the ASTER DEM and limitations of automated GIS procedures makes delineation of basin boundaries for this type of flat slope drainage network uncertain. Floodplains and floodplain flow paths are inadequately represented at the 30 m DEM resolution. There will also be uncertainty around the location of individual stream links within the braided and anastomosed channel networks though they will be contained within the larger scale coastal basin boundaries.

Other known errors include the following:

1. Definition of inland sinks is often ambiguous, and their occurrence may be temporary in nature.
2. Applied single flow direction algorithm does not allow for the depiction of river bifurcations and braided rivers and cannot represent deltas correctly.
3. Natural gorges that are less than 30 meters wide can appear closed on the elevation surface at 30 m resolution.

At the present stage of developing of Liberia river basins division, the final data accuracy has not been evaluated systematically.

To improve the quality of division, a manual correction protocol was implemented. Particularly:

- the derived rivers were visually compared with the vector river layers and
- Visually detected inconsistencies of the outputs of the automated procedure were corrected by a manual post-processing.

4. BASIN CLASSIFICATION AND CODING SYSTEM

1.3 BASIN CLASSIFICATION

The first standardized classification of natural drainage basins in Liberia was completed in 1982 by Liberian Hydrological Service. This drainage basin system divided Liberia into 19 principal catchments and 16 minor coastal catchments. The concept of the 1982 classification of Liberian drainage basins into two main categories was retained in the present study. We changed however, basin classification terminology from **"principal catchments" to "principal basins"** and from "**minor coastal catchments' to "coastal drainage areas"**. Additionally, we found a definition of principal catchments as catchments "*collecting the water from considerably large areas*" somehow imprecise. Therefore, we re-grouped the Liberian basins into two categories based on their location and size using a typology of catchment size of the European Water Framework Directive (2000).

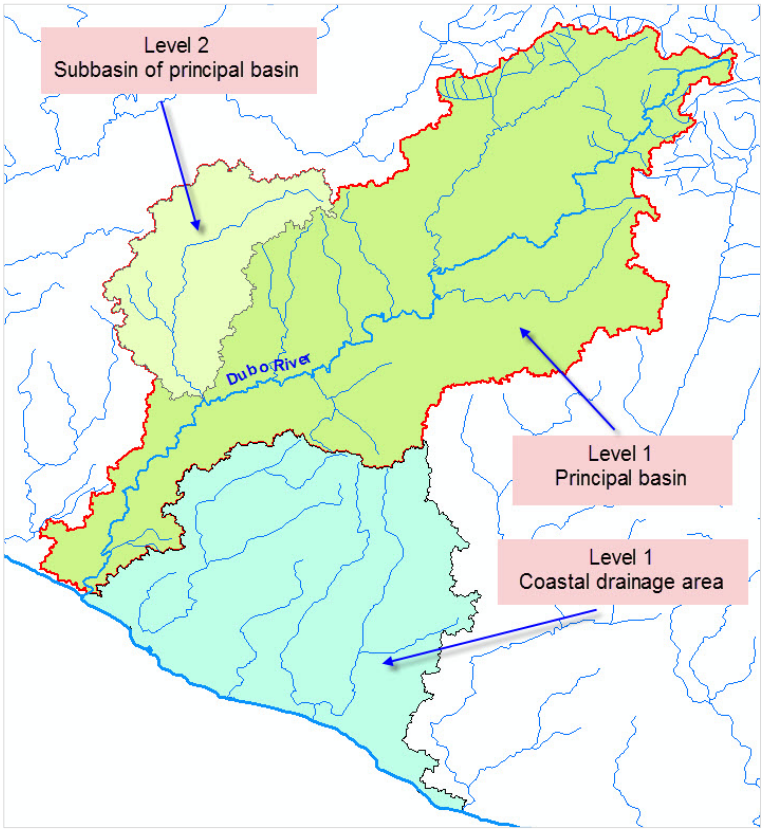

Figure 4-1 Two- level classification of Liberian drainage basins

At the first level of classification basins which drain into the Atlantic Ocean were classified into:

- **Principal basins** with size larger than 1000 km^2 which all surface runoff flows through a sequence of streams and rivers into the Atlantic Ocean at a single river mouth or estuary.
- **Coastal drainage areas** with size smaller than 1000 km^2 drained directly into the Atlantic Ocean by one river to a single outlet or more streams to multiple outlets (frontal drainage).

At the second level of classification the principal basins were classified into:

- **Subbasin of principal basins** i.e. basins of rivers (tributaries) having outlet to main river. Within each principal basin, only the largest tributaries and their basins were identified.

The coastal drainage areas were not divided into sub-basins due to their small as compared to principal basins. According to the present classification system Liberia is now divided into **15 principal basins, 23 coastal drainage areas and 87 subbasins of principal basins.**

5. BASIN CODING SYSTEM

The Liberian method of hydrographic coding was established in 1983 by Liberian Hydrological Service. The details of this coding system were described by Strupczewski and Sua (1983). The 1983 coding follows natural properties of river systems, is hierarchical and alpha-numeric. The 1983 system, with some minor modification, was adopted for the present study. Considering the current amount of information about Liberian water resources and to make this system easily readable we decided to limit the expansion of the system to two levels. Correspondingly, in this report, Liberian drainage system is divided and sub-divided into successively smaller hydrologic units which are classified into two levels:

- Level 1 - principal basins and coastal drainage areas
- Level 2 – subbasins of main tributaries

1.4 LEVEL 1: PRINCIPAL BASINS AND COASTAL DRAINAGE AREAS

At the highest level all basins drains to the Atlantic Ocean. The level 1 includes principal basins and coastal drainage areas which are identified by two digit code segment. Principal catchments are numerated from west to east. They are denoted by two-digit number beginning from **00** for the Mao River basin to **15** for the Cavalla River Basin.

Main rivers drain principal basins and each principal basin drained by only one main river. All other rivers joining the main river are its tributaries. The main river can be uniquely defined close to the mouth, but upstream at every confluence, it has to be decided which of the two rivers is the main river. In practice this problem arises only in the case of two rivers having similar size. To identify the main river the criterion based on comparison of basin areas upstream the confluence was applied; i.e. the river having larger basin area indicates the main river upstream the confluence.

The St. Paul, the St. John and the Cestos rivers have different names in Guinea and Liberia. Many rivers changes name along its course and different parts of the same river have different local names. A good example is the Mano River. Advancing upstream, some 230 km from the river mouth the Mano receives the local name Gbeya and holds it for some 15 km till the confluence of the Gbeya River with the Kaiha River. Comparison of the Kaiha and the Gbeya basins size upstream the confluence shows that Kaiha basin area of 1,682 km^2 is much larger that the Gbeya basin area of 311 km^2 which indicates that the main river upstream of the confluence is Kaiha. In turn some 75 km from the Gbeya confluence, upstream of Kolahun town the Kaiha changes its local name to Zeliba.

The code string of main rivers consists of the code of its main catchment followed by “00”. The list of all Principal catchments and main rivers is given in Table 5-1.

Table 5-1 Codes of principal basins and main rivers

Basin Code	Basin Name	River Code	Main River Name (outlet-source direction)
00	Moa River	0000	Moa -Makona
01	Mano River	0100	Mano - Gbeya - Kaiha - Zeliba
02	Mafa River- Lake Piso	0200	Mafa
03	Lofa River	0300	Lofa River
04	St. Paul River	0400	St. Paul - Diani (Nianda)
05	Farmington River	0500	Farmington
06	St. John River	0600	St. John - Mani
07	Timbo River	0700	Timbo
08	Cestos River	0800	Cestos - Nuon
09	Sehnkwehn River	0900	Sehnkwehn - Butudi
10	Sinoe River	1000	Sinoe - Pane
11	Dugbe River	1100	Dugbe
12	Dubo River	1200	Dubo - Wu
13	Grand Cess (Nuch) River	1300	Grand Cess (Nuch) River
14	Po-Joda River	1400	Po-Joda
15	Cavalla River	1500	Cavalla

Principal river basins are separated by smaller areas which are drained directly into the sea or into the coastal lagoons by one river to a single outlet or more streams to multiple outlets (frontal drainage). Because of a difference in size as compared to the principal river basins, coastal drainage areas are not divided into sub-basins. They are coded by separate two-digit numeration. Some semi closed (or closed) lagoon catchments were included into larger coastal drainage areas. The coastal drainage areas are numbered from west to east starting from 50 for area between the Moa and the Mano River principle basins to 72 for small basins between the Decoris River coastal drainage area and the Cavalla River principal basin. Table 5-2 includes the list of identified and coded coastal drainage areas.

Table 5-2 Codes of coastal drainage areas

Coastal drainage area code	Coastal drainage area name	Coastal drainage area code	Coastal drainage area name
50	Moa River-Mano River	62	Cestos River-Sehnkwehn River
51	Mano River-Mafa River	63	Sehnkwehn River-Sinoe River
52	Mafa River-Lofa River	64	Sinoe River-Dugbae River
53	Lofa River-Mafa River	65	Dugbae River
54	Po River	66	Dugbae River-Dugbe River
55	Po River-St. Paul River	67	Dugbe River-Dubo River
56	St. Paul River-Farmington River	68	Dubo River-Grand Cess
57	Farmington River-St. John River	69	Grand Cess-Po-Joda River
58	St. John River-New Cess River	70	Po-Joda River-Decoris River
59	New Cess River	71	Decoris River
60	New Cess River-Timbo River	72	Decoris River-Cavalla River
61	Timbo River-Cestos River		

1.5 LEVEL 2: SUBBASINS OF MAIN TRIBUTARIES (CLASSIFIED SUBBASINS)

Tributaries of a main river are called main tributaries. To identify the course of main tributary, the same rule based on comparison of catchment areas as in the case of a main river was applied (see paragraph 5.1).

For each main river, only the largest main tributaries and their subbasins were identified. The identified and coded main tributaries and their basins are further named **"classified tributaries"** and **"classified subbasins**" respectively. Classified tributaries are counted for each main river from its mouth in upstream direction towards headwaters. The separate numeration was assign to the left and right-hand side classified tributaries. The code string of a first order classified tributary consists of the two-digit code of the principal catchment followed by the letter "L" or "R", denoting left or right-hand side tributary respectively and two-digit number denoting tributary position counted from the main river mouth.

We didn't create a specific string code for classified subbasins and their codes are exactly the same as the codes of corresponding classified tributaries. For instance the code **03L20** denotes the second left-hand classified tributary in the 3rd principal basin (Lofa River) as well as the second left-hand subbasin in the Lofa principal basin. To the part of principal basins that are outside boundaries of the coded classified subbasins are denoted by the same code as the string code for the corresponding principal basin. The principles of coding system are illustrated

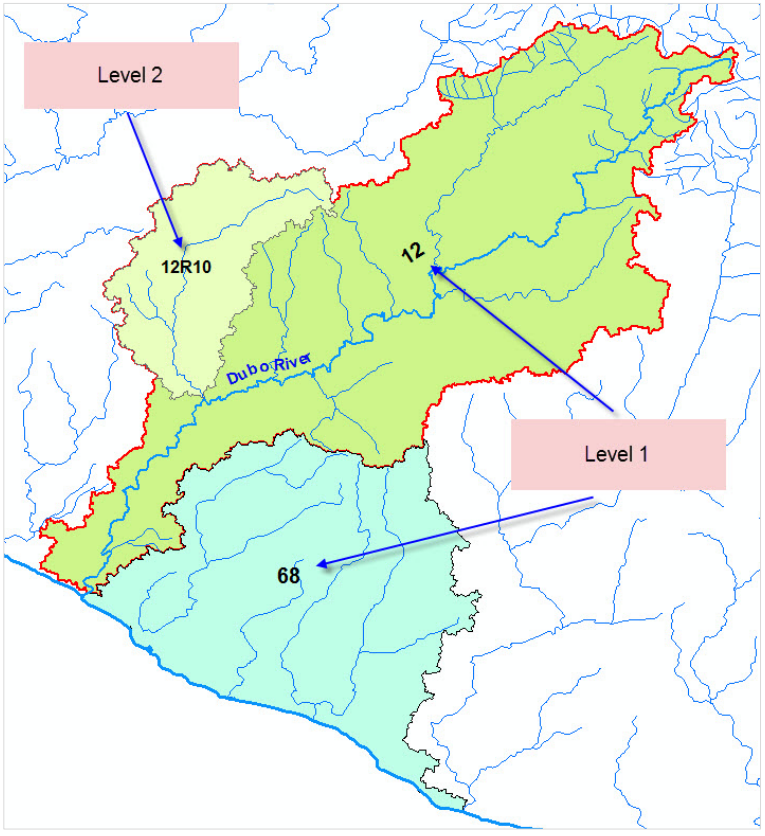

Figure 5-1 Principles of basin's coding system

As mentioned above, at this stage only the largest main tributaries and their subbasins were identified and coded. In the future, if needed, within each principal basin additional subbasins can be delineated and classified. The adopted code system allows inserting up to 9 new subbasins between two subsequent classified tributaries. For example between the second (04L20) and third left-hand (04L30) subbasins of the St.Paul principal basin one can insert additional subbasins: 04L21, 04L22 up to 04L29.

We used letters “L” and “R” for indicating left and right-hand tributaries in order to allow for its fast recognition in tables and on the maps. In the future, it might be more convenient to use a string of totally numeric characters. This can be easily done by replacing the letter "L" and "R" by numeric symbols, for instance "4" and "8" respectively.

1.6 CODING OF HYDROMETRIC STATIONS AND SPOT MEASUREMENT SITES

The code of operational hydrometric stations consists of the two-digit code of the principal basin in which the station is located, two alpha-numeric characters being abbreviation of the name of main river followed by two digits denoting the station number. For instance the code **03LO01** denotes station number 01 Lofa Bridge on the Lofa River in the principal basin of Lofa. Numeration of the stations does not follow stations positions with respect to the main river mouth. The list of hydrometric stations and their characteristics is given in Table 6-3.

6. KEY INFORMATION

The morphometric and spatial analysis of the drainage basins, drainage areas and drainage network was largely carried out by automated procedures with ArcGIS software. It should be noted that a raster DEM is only a partial representation of the landscape and identification of drainage network and drainage network boundaries is uncertain in the lowland coastal areas where altitude differences/slope are very small. The delineated basin boundaries, boundaries of drainage areas and their corresponding areas may therefore contain minor errors.

1.7 PRINCIPAL BASINS AREAS

The Liberian principal basins are drained by rain-fed rivers discharging into the Atlantic Ocean. All largest rivers, with the exception of the middle reaches of the Cavalla River flow from their headwaters in the south-west direction towards Atlantic Ocean. The river basins are generally narrow and the largest rivers are distributed regularly across the country. Table 2 summarizes information about the size of principal basins.

Six largest principal basins in Liberia are transboundary river basins, which can be defined as basins shared by two or more riparian states. The Mano River, the Lofa, the St. Paul, the St. John, the Cestos and the Cavalla River have headwaters in Guinea or in Sierra Leone and the rivers cross all the Liberia territory from north-west to south east. This situation could put upstream countries in a position of advantage over their downstream neighbour Liberia. The complexity of relations and potential conflicts of interest within transboundary river basins can make equitable management of their water resources especially challenging.

Table 6-1 Basin areas of principal basins

Basin code	Name of principal basin	Total basin area (km^2)	Basin area in Liberia (km^2)	Basin area in Liberia (%)
00	Moa River	19,617	1,730	9
01	Mano River	7,520	5,539	74
02	Mafa River – Lake Piso	2,082	2,082	100
03	Lofa River	10,612	9,189	87
04	St. Paul River	20,281	10,991	54
05	Farmington River	5,249	5,249	100
06	St. John River	16,930	14,363	85
07	Timbo River	3,196	3,196	100
08	Cestos River	12,709	10,389	82
09	Sehnkwehn River	5,659	5,659	100
10	Sinoe River	2,258	2,258	100
11	Dugbe River	2,820	2,820	100
12	Dubo River	1,061	1,061	100
13	Grand Cess (Nuch River)	1,685	1,685	100
14	Po-Joda River	1,042	1,042	100
15	Cavalla River	30,277	12,240	40

1.8 INFORMATION ABOUT COASTAL DRAINAGE AREAS

As highlighted in the paragraph 5.1, by definition, coastal drainage areas are drained directly into the Atlantic Ocean by one river to a single outlet or more streams to multiple outlets. The drainage system of coastal plains is complex. Close to the Atlantic shore, rivers are meandering and frequently flow parallel to the shoreline before discharging into the Ocean. Many small streams drain to coastal lagoons that have only intermittent connection with the Ocean. The outlets of lagoons are often blocked by sand during a dry season. Table 6-2 provides the size of delineated units and indicates if the coastal drainage area is drained by a single river or belongs to a frontal drainage type**.**

Table 6-2 Size of coastal drainage areas and type of drainage system

Coastal drainage area code	Coastal drainage area name	Drainage area size (km^2)	Type of drainage system
50	Moa River-Mano River	12	FD
51	Mano River-Lake Mafa River	50	FD
52	Mafa River-Lofa River	199	FD
53	Lofa River-Mafa River	27	FD
54	Po River	861	SR
55	Po River-St. Paul River	46	FD
56	St. Paul River-Farmington River	207	FD
57	Farmington River-St. John River	59	FD
58	St. John River-New Cess River	67	FD
59	New Cess River	704	SR
60	New Cess River-Timbo River	355	FD
61	Timbo River-Cestos River	103	FD
62	Cestos River-Sehnkwehn River	515	FD
63	Sehnkwehn River-Sino River	546	FD
64	Sino River-Dugbae River	209	FD
65	Dugbae River	486	SR
66	Dugbae River-Dugbe River	63	FD
67	Dugbe River-Dubo River	417	FD
68	Dubo River-Grand Cess	505	FD
69	Grand Cess-Po-Joda River	161	FD
70	Po-Joda River-Decoris River	404	FD
71	Decoris River	295	SR
72	Decoris River-Cavalla River	201	FD

Type of drainage system: SR - single river, FR – frontal drainage (drained by several streams)

1.9 HYDROMETRIC STATIONS AND SPOT DISCHARGE MEASUREMENT SITES

For nearly 30 years, since late eighties, the Liberian Hydrological Service (LHS) did not measure or collect any meteorological and hydrological data in Liberia. The NVE Capacity Building Programme, started in 2011, has changed fundamentally this situation. CA4 helped to re-establish a minimum Liberian hydrometeorological network. LHS is operating and regularly maintaining 10 hydrometric stations in five largest principal river basins. The supporting information on dry season streamflow is sampled at spot discharge measurement sites. This information is needed for hydropower potential studies. Salient characteristics of the operational hydrometric network are given in Table 6-3.

Table 6-3 LHS hydrometric stations and spot discharge measurement sites

Code	Name of station or spot discharge measurement site	River Name	Principal basin	Station basin area (km2)	River length (km)	Latitude North (DDMMM)	Longitude West (DDMMM)
01MA001	Kaiha River at Kolahun	Kaiha	01 Mano	673	71	8.278	-10.078
01MA002	Kaiha River at Sambehun	Kaiha	01 Mano	731	82	8.228	-10.125
01MA003	Mano River at Kongo	Mano	01 Mano	5,514	297	7.327	-11.143
DMS1	Zeliba River at Vezala Town	Zeliba	01 Mano	350	38	8.365	-9.901
DMS2	Kaiha River at Kimbalahun	Kaiha	01 Mano	907	102	8.134	-10.195
DMS4	Kaiha River at Mbaloma	Kaiha	01 Mano	961	114	8.057	-10.203
DMS6	Makona River at TelkpelembuTown	Makona	01 Mano	2,256	132	8.446	-9.990
03LO001	Lofa River at Lofa Bridge	Lofa	03 Lofa	8,194	329	7.067	-10.880
DMS7	Lofa River at Barkedu Town	Lofa	03 Lofa	1,534	90	8.291	-9.633
DMS8	Lofa River at John Town	Lofa	03 Lofa	1,638	107	8.214	-9.736
04SP001	St. Paul River at Haindi	St. Paul	04 St. Paul	18,277	381	6.902	-10.362
04SP003	St. Paul River at Piatta	St. Paul	04 St. Paul	13,734	297	7.203	-9.819
04SP004	Via River at Piatta	Via	04 St. Paul	3,613	189	7.208	-9.815
DMS9	Via River at Bridge on Vojnjama Road	Via	04 St. Paul	620	60	7.914	-9.521
DMS13	Du River at Bridge (Firestone?)	Du	05 Farmington	845	94	6.290	-10.386
06SJ001	St. John River at Frank Diggs	St. John	06 St. John	10,862	338	6.466	-9.526
06SJ002	St. John River at Mt. Finlay	St. John	06 St. John	15,724	424	6.084	-9.870
DMS10	Yah River at Gbahnwin Town	Yah	06 St. John	544	44	7.185	-8.698
DMS11	St. John River at Gbedin Town	St. John	06 St. John	1,784	100	7.341	-8.848
08CE001	Cestos River at Iti	Cestos	08 Cestos	11,585	426	5.617	-9.319
DMS12	River Gee at Kitoken Town	River Gee	15 Cavalla	1,024	99	4.930	-7.639

7. COMPILED MAPS AND TABLES

Maps, tables and graphs supporting the information contained within the main text are presented in appendices.

The appendices 1-3 provide a set of country/Liberia maps including the overview map of principal river basins, the map of hydrological subvision of the principal basins into classified subbasins and the physical map of Liberia with location of hydrometric network.

The appendices 4-6 provide maps of delimited coastal drainage areas.

The appendices 7-22 include tables, graphs and maps showing various data for individual principal basins.

Except for the appendix 7 that summarizes data for the Moa River principal basin located nearly entirely outside of the Liberian territory the content of the remaining appendices is the same and consists of:

(1) A fact page that shows a table with basic morphometric parameters of principal basin, table with basic information about classified subbasins and a graph of hypsometric curve of principal basin. The following set of parameters was determined for each principal basin:

Parameter		Description/formula
A	- Basin area	Area is delimited by the water divide
L_{MR}	- Main river length	Distance along the main river from its source to its outlet to Atlantic Ocean
HS	- Elevation at main river source	Altitude at main river source as delimited by ArcGIS procedure
H_{Out}	- Minimum basin elevation	The minimum altitude of a basin
H_{Max}	- Maximum basin elevation	The maximum altitude of a basin
L_B	- Basin length	A straight-line distance between the mouth of the basin and the point on the drainage divide nearest to the source of main river
R_F	- Form factor	Ratio of the area of the basin and square of the basin length. $R_F = A/(L_B)^2$
R_E	- Elongation ratio	Elongation ratio is defined as the ratio of diameter of a circle having the same area as of the basin and basin length. $R_E = 2/L_B * (A/\pi)^{0.5}$

(2) Table summarizing sequentially information about the main river from its source to the outlet at characteristic points. The following characteristic points were identified:

- The source of a main river
- The point where a main river enters Liberian territory
- Points of confluence of classified tributaries with the main river
- The outlet of a main river to Atlantic Ocean
- Location o hydrometric station on a main river
- Location of spot discharge measurement sites on the main river

Location of the points is given by its latitude and longitude coordinates in degrees and minutes (MMM). For every point the corresponding inter-basin boundary, inter-basin area and the length

of the main river from its source were estimated.

(3) Map of hydrological subdivision of the principal basin into classified subbasins. This map shows the boundaries of principal river basin, boundaries of classified subbasins, their codes and names of classified tributaries. .

(4) Map of the principal basin with location of characteristic points on the main river. This map also shows relief of the basin (shown by colours) and location of major settlements.

The names of some classified tributaries in the south-eastern principal basins 09, 10, 11, 12 and 13 are not known. These tributaries were denoted in tables and on the maps by “No Name”. The Liberian Hydrological Service will identify names of these tributaries during future hydrological field trips

8. REFERENCES

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