CHAPTER VI

HYDRO–ELECTRIC POWER DEVELOPMENT PLAN

6-1 General

Development potentialities and scales of development of sites tentatively selected on topographical maps (scales of 1/50,000 and/or 1/250,000) and based upon aerial inspections were roughly studied with regard to five major rivers of Liberia, the Mano, Lofa, St. Paul, St. John and Cestos Rivers, and accordingly, a general policy for future investigations for hydroelectric power development projects in Liberia has been formulated.

The following steps were applied in studying hydroelectric power development projects.

(1) For every project site tentatively selected, the maximum output, annual energy production and construction costs were roughly calculated taking the capacity of the reservoir into consideration. From an economic stand-point, priority was determined upon comparison with the economics of an alternative thermal power plant.

(2) For each site selected as described above, the possibility of maximizing the output of the project through more effective utilization of the stream discharge during the rainy season is studied to determine the development scale.

(3) For each site selected according to (2) above, the possibilities for development of other sites located in the downstream area were also studied taking the effect of reservoir regulation at the upstream site into consideration. Then, the recommendable scale of the development is estimated for the case of developing all possible project sites on the river in series.

6-2 Hydrology

6-2-1 Stream Gaging Stations and Meteorological Observation Stations

The locations of stream gaging stations and meteorological observation stations in the Republic of Liberia on which the Survey Team obtained information and data are illustrated in Fig. 6-1. The periods for which data have been recorded at these gaging and observation stations are shown in Table 6-1 and Table 6-2, respectively.

Almost all of the stream gaging stations were established from 1958 through 1961 during which the hydroelectric power development survey was performed by the Stanley Engineering Company. As a result, data on stream flow from 1958 onward have come to be available. As regards these data, the longest period of continuous observation covers 14 years while some data provide the values of observation covering only one year. These gaging stations are under the control of the Ministry of Lands and Mines.

Most of the observations of stream flow are being made by reading staff gages periodically every day, but there are a few stations where observations are being carried out with automatic recording gages. The rating curves for converting elevations read on staff gages into stream discharges were established by the Stanley Engineering Company from 1958 through 1961 and are still being used at present.

Meteorological data are obtainable from the meteorological observation stations under the control of the Division of Meteorology, Department of Public Works and Utilities and from stations controlled by concessions.

Most of the meteorological observation stations in this country started observations from 1951 or later. Data and information regarding stream flow discharge and precipitation are shown in Appendix.

Table 6-1 Runoff Gaging Station and Existing Data

Basin	River	Name of Station	Location		Catchment Area (km²)	Period																		Remarks
			Lat (N)	Long (W)		'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	
Mano	Mano	Kawilahun	7°-20'-55"	11°-08'-15"	6.420		Sep.											Aug.							
	Zeliba	Bolahun	8°-12'-55"	10°-07'-45"	795		Sep.											Aug.							
	Wawo	Bolahun	8°-14'-00"	10°-09'-50"	104		Sep.							Aug.											
Lofa	Lofa	New hope	6°-44'-00"	10°-58'-15"	10.650		Apr.				Mar.														
	Lofa	Dougomai			1.580																May			Jan.	Gaging Height
St. Paul	St. Paul	Mt. Coffee	6°-31'-35"	10°-36'-25"	21.430		Apr.															Mar.			
	St. Paul	Gweyie	7°-20'-45"	5°-29'-50"	10.790		Apr.															Mar.			
	Via	Gbakwele			5.357		Apr.															Mar.			
	Tuma	Belleyella			755		Apr.															Mar.			
Farmington	Farmington	Owensgrove			2.750	Feb.					Jul.														
	Du	Fireston Plantation Co. Division 22	6°-24'-20"	10°-23'-05"	519		Sep.				Jul.														
	Du	Piemo	6°-36'-45"	10°-25'-50"	187		May		Feb.																
St. John	St. John	Mt. Finley	6°-03'-35"	9°-52'-15"	16.930	Aug.		Jul.																	
	St. John	St. Johnfalls	8°-26'-25"	9°-38'-05"	11.370		Aug.												Apr. May		Dec.				
	St. John	Bailo	7°-03'-45"	9°-09'-50"	3.860		Sep.													Jul.		May		Dec.	
	Ya	Yasono	7°-03'-25"	8°-52'-14"	1.040		Sep.				Jul.														
Cestos	Cestos	Sawolo	6°-26'-25"	8°-37'-55"	4.580		Oct.		Sep. Jul.															Dec.	
Sehnkwehn	Sehnkwehn	Sehnkwehn			4.330			Apr.																Jan.	Gaging Height
Cavalla	Cavalla	Nyaake	4°-51'-00"	7°-35'-30"	12.610				Apr.		May														

Table 6-2 Rainfall Observatory Station and Existing Data (Monthly Records)

County	No.	Name of Station	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74
Lofa	①	Belleyella		Jun.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Aug.	Feb.	⊢	Nov.				Oct.	⊢	⊢	Nov.			
	②	Bopolu		May	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Sep.	Mar.	⊢	Nov.								
	③	Kolahun			Nov.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Sep.		May	⊢	⊢	⊢	⊢	⊢	Nov.			
	④	Salayea																		May	⊢	⊢	Aug.				
	⑤	Voinjama			Nov.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
	⑥	Zorzor					Jan.	⊢	⊢	⊢	⊢	⊢	⊢	Apr.													
	⑦	Zuie			Sep.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Jul.													
Grand Cape Mount	⑧	Robertsport			Mar.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
Bong	⑨	Blazie									Nov.	⊢	Mar.														
	⑩	Bongmines													Jan.	⊢	⊢	Oct.		Jun.	⊢	Aug.					
	⑪	Salala		Oct.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Aug.	Nov.	⊢	Feb.												
	⑫	Suakoko		Jul.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Oct.	Aug.	⊢	Dec.			
	⑬	Totota					Jan.	⊢	⊢	⊢	Oct.																
Montserrade	⑭	Bomihills		Sep.	⊢	⊢	⊢	⊢	⊢	⊢	Jul.								Nov.	⊢	⊢	⊢	⊢	Nov.			
	⑮	Goodrich						Jan.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
	⑯	Harbel	Mar. 1936	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.														
	⑰	Klie				Jun.	⊢	⊢	⊢	⊢	⊢	Dec.															
	⑱	Monrovia	Jun.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Nov.	Jan.	⊢	Dec.
	⑲	Robertfield	May 1949	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.							May	⊢	⊢	⊢	Dec.			
Grand Bassa	⑳	Buchanan										Sep.	⊢	May													
Nimba	㉑	Cocoapa I		Sep.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
	㉒	Cocoapa II										Jun.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Nov.				
	㉓	Ganta	Jan. 1939	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
	㉔	Kpein										May	⊢	Apr.													
	㉕	Mount nimba								Jan.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.							
	㉖	Sanokole		Oct.	⊢	⊢	⊢	⊢	⊢	Nov.					Jun.	⊢	⊢	⊢	⊢	⊢	⊢	Aug.				
	㉗	Tapeta		Jul.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
Grand Gedeh	㉘	Nyaake		May	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Jul.					Jan.	⊢	Aug.				Jan.	⊢	⊢	Nov.		
	㉙	Pine town		May	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
	㉚	Zia town										Jan.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Nov.			
	㉛	Zwedru									Jan.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Nov.			
	㉜	Chiehn		Jun.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.													
Sinoe	㉝	Flahun town		Jul.	⊢	⊢	⊢	⊢	⊢	Sep.																	
	㉞	Greenville		Jan.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.			
	㉟	Sinoefalls			Jun.	⊢	⊢	⊢	Jan.																		
Maryland	㊱	Buah		Jun.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Aug			
	㊲	Cavalla	Jan. 1928	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.														
	㊳	Harper				Mar.	⊢	⊢	⊢	⊢	⊢	⊢	⊢	Dec.													

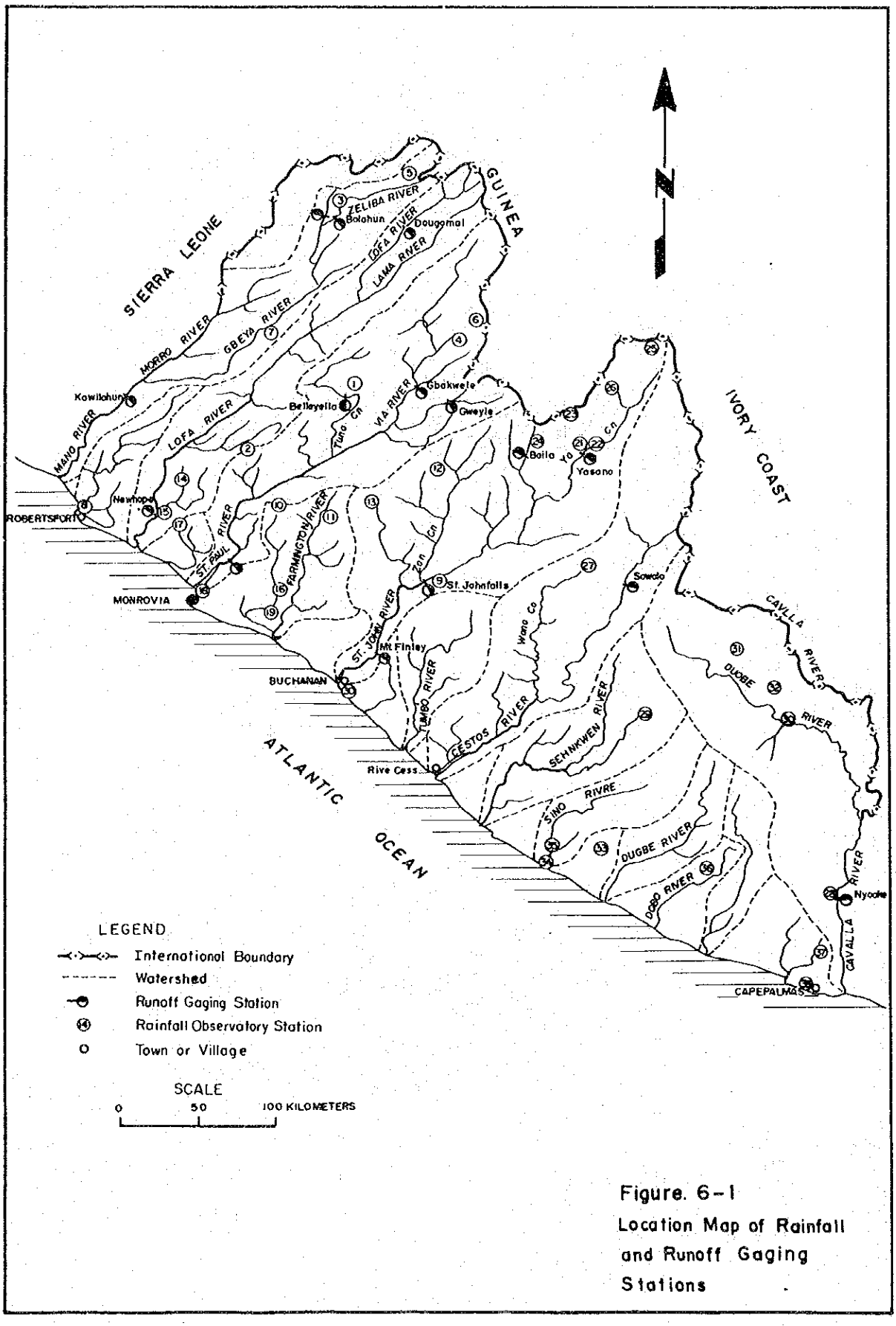


Figure. 6-1
Location Map of Rainfall and Runoff Gaging Stations

6-2-2 Precipitation

The Republic of Liberia is situated between 4°30' and 8°30' north latitude and its climate is classified as "savanna climate" due to its high temperature and high humidity.

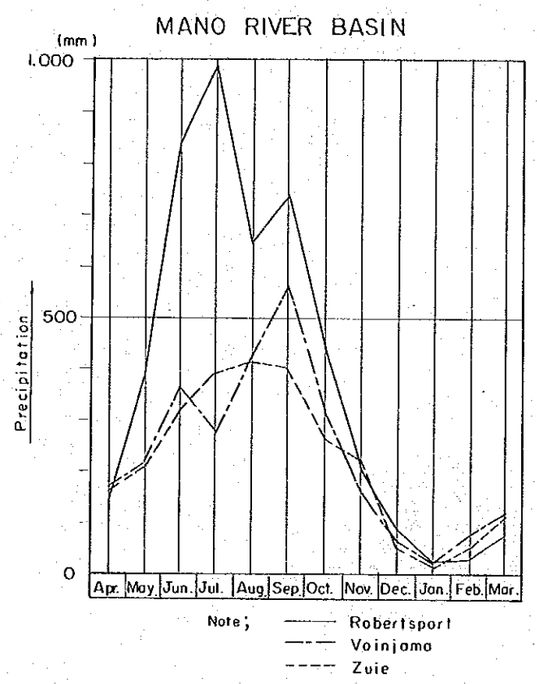
The rainfall distribution of this area is strongly affected by the location of the intertropical convergence front. From December through April of the following year, the front is apt to stay near the seacoast and there is little rainfall owing to northeast seasonal winds from the Sahara, while on the other hand, from May to December, the front moves north and there is abundant rainfall due to the southwest seasonal winds from the Atlantic Ocean. In effect, a distinct difference between dry and rainy seasons of the year exists in the rainfall pattern of Liberia. Monthly rainfall patterns at a typical meteorological observation station are illustrated in Fig. 6-2.

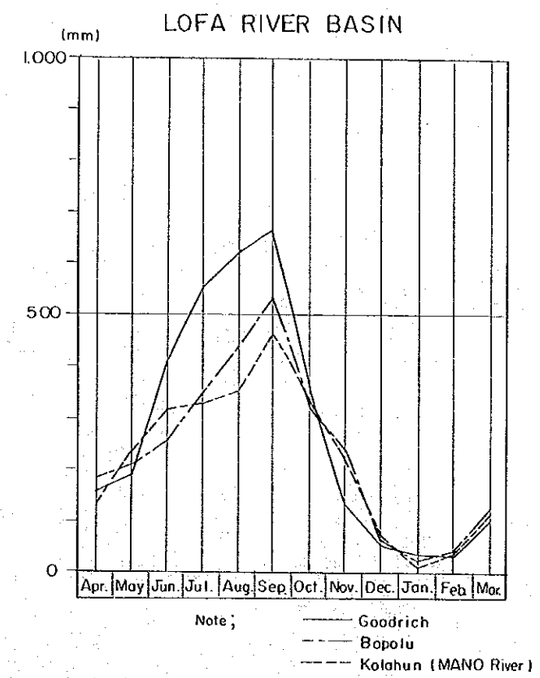
Regional distributions of annual rainfall in Liberia is shown as an isohyetal map, Fig. 6-3, derived from the precipitation data issued by the Ministry of Lands and Mines from 1953 through 1973. From this figure, a belt of 60 to 70 km in width along the seacoast has over 4,500 mm of rainfall annually, the highest in the country. The amount of precipitation gradually decreases going inland and comes down to 1,700 mm - 2,000 mm. The lines of the isohyetal map run parallel to the coastline except in the Mano and Lofa River basin areas where they are bent inland indicating more rainfall than in other areas.

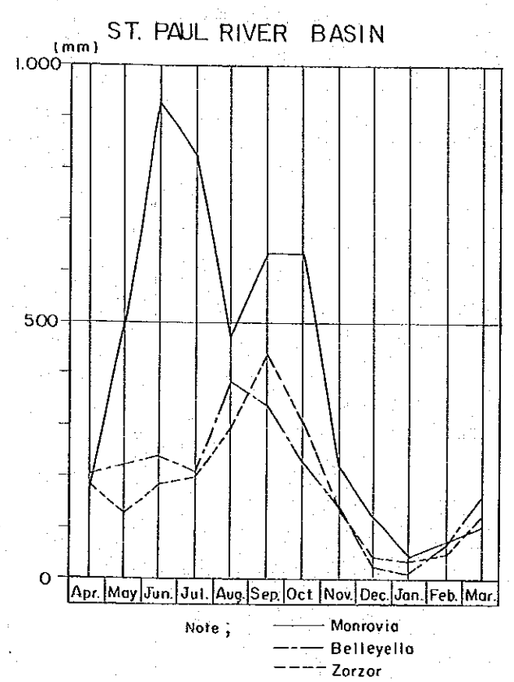
6-2-3 Stream Flow Discharges

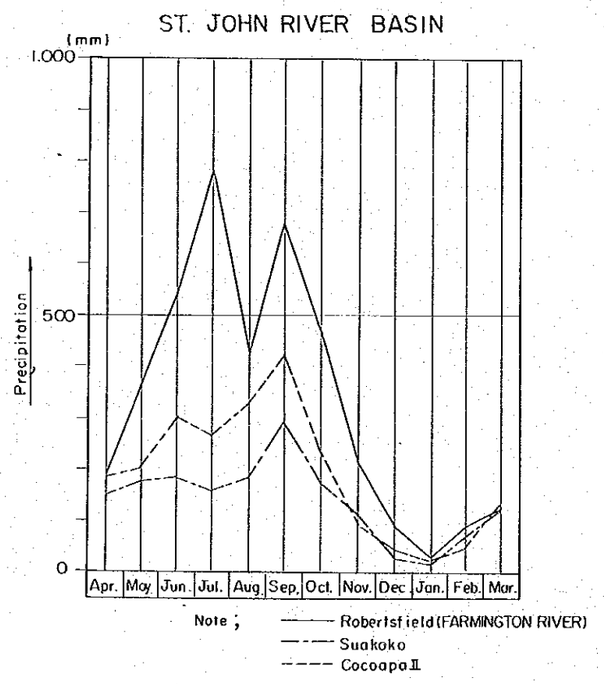
The major streams in the Republic of Liberia are the six rivers of Mano, Lofa, St. Paul, St. John, Cestos and Cavalla. These rivers flow parallel to each other in a northeast to southwest direction owing to topographical and geological conditions, and pour into the Atlantic Ocean.

The catchment areas of the major rivers are as shown in Table 6-3.









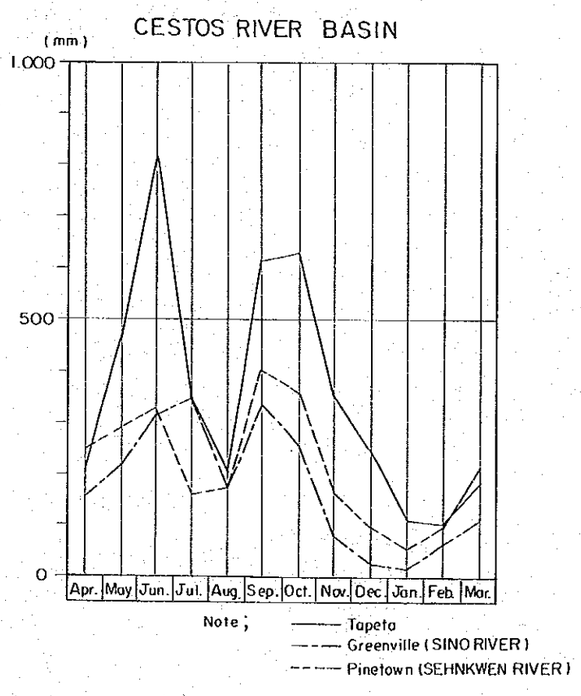


Figure 6-2 Monthly Precipitation

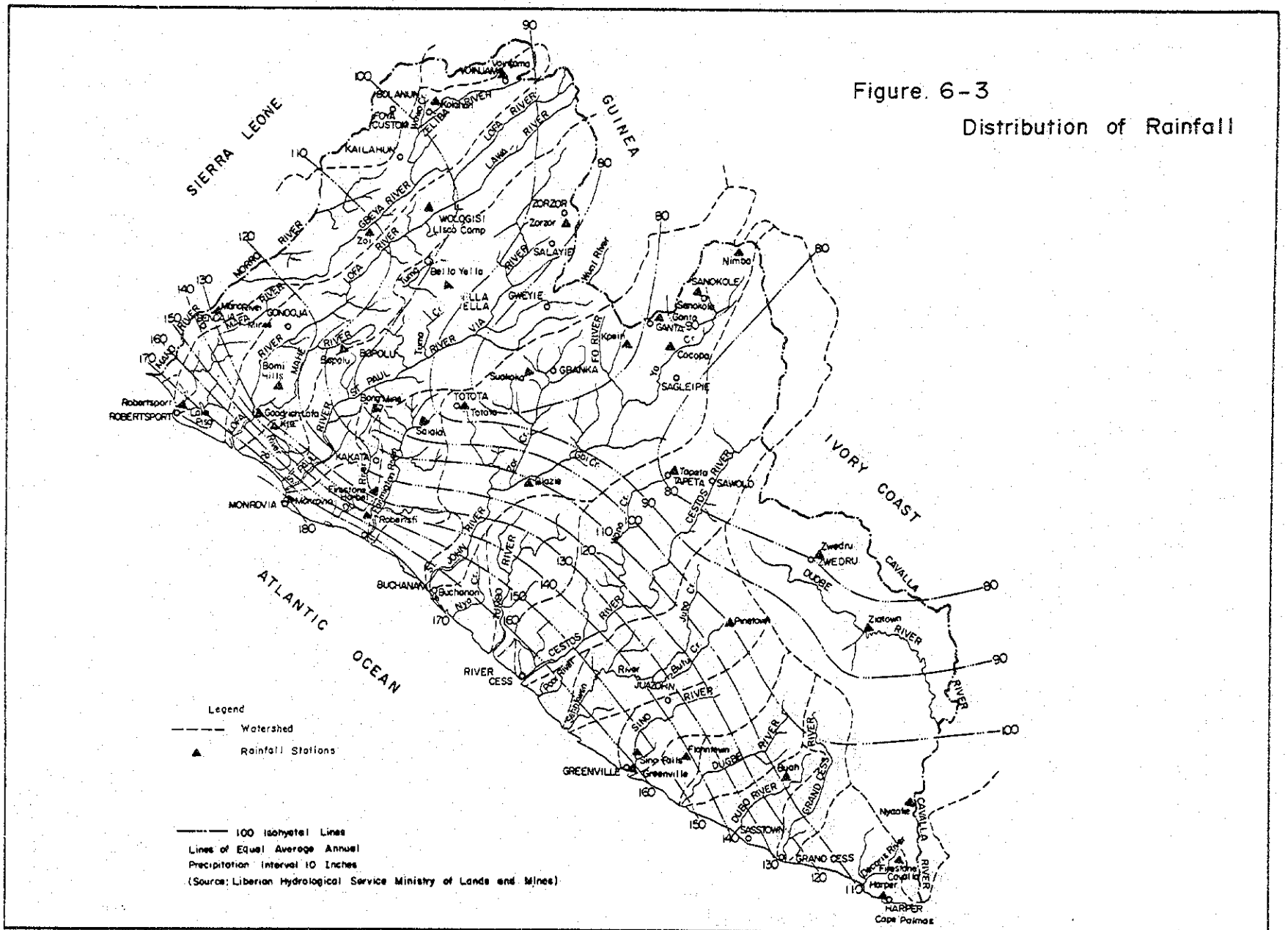


Figure. 6-3

Distribution of Rainfall

Table 6-3 River Basins

RIVER	RIVER BASIN in sq. km	
	TOTAL	IN LIBERIA
MANO RIVER	8,250	6,320
LOFA RIVER	10,620	9,195
ST. PAUL RIVER	21,910	12,810
ST. JOHN RIVER	17,220	14,760
CESTOS RIVER	12,560	10,100
CAVALLA RIVER	30,225	13,730

Source: Stanley Engineering Company, Power-Resources, Requirements and Development, Republic of Liberia, 1960

Comparisons of specific discharges at representative gaging stations on the major rivers are as indicated in Fig. 6-4 which shows that with the exception of the St. John River, the Mano and other rivers in the west have comparatively high specific discharges, whereas the specific discharge of the Cestos River in the east is low. Accordingly, it can be said that the specific discharges of the major rivers in Liberia have a tendency to become lowerer from west to east. The annual stream flow discharge records are as summarized in Fig. 6-5, from which the return period of rainy and dry years is judged to be approximately 10 years.

The monthly variations in specific discharges of the various rivers are given in Fig. 6-6. According to this, the comparisons between September when discharges are largest and March when they are smallest result in a ratio of 40:1 for the St. John River with the poorest stream regime and approximately 7:1 for the Cestos River which has a comparatively good stream regime, while for the Mano River and the St. Paul River, the ratios are 10:1 and 12:1, respectively. In effect, it may be said that the discharge of a river in Liberia during the dry months is approximately one tenth of that in rainy months.

Figure 6-4 Comparison of River Runoff in 1960

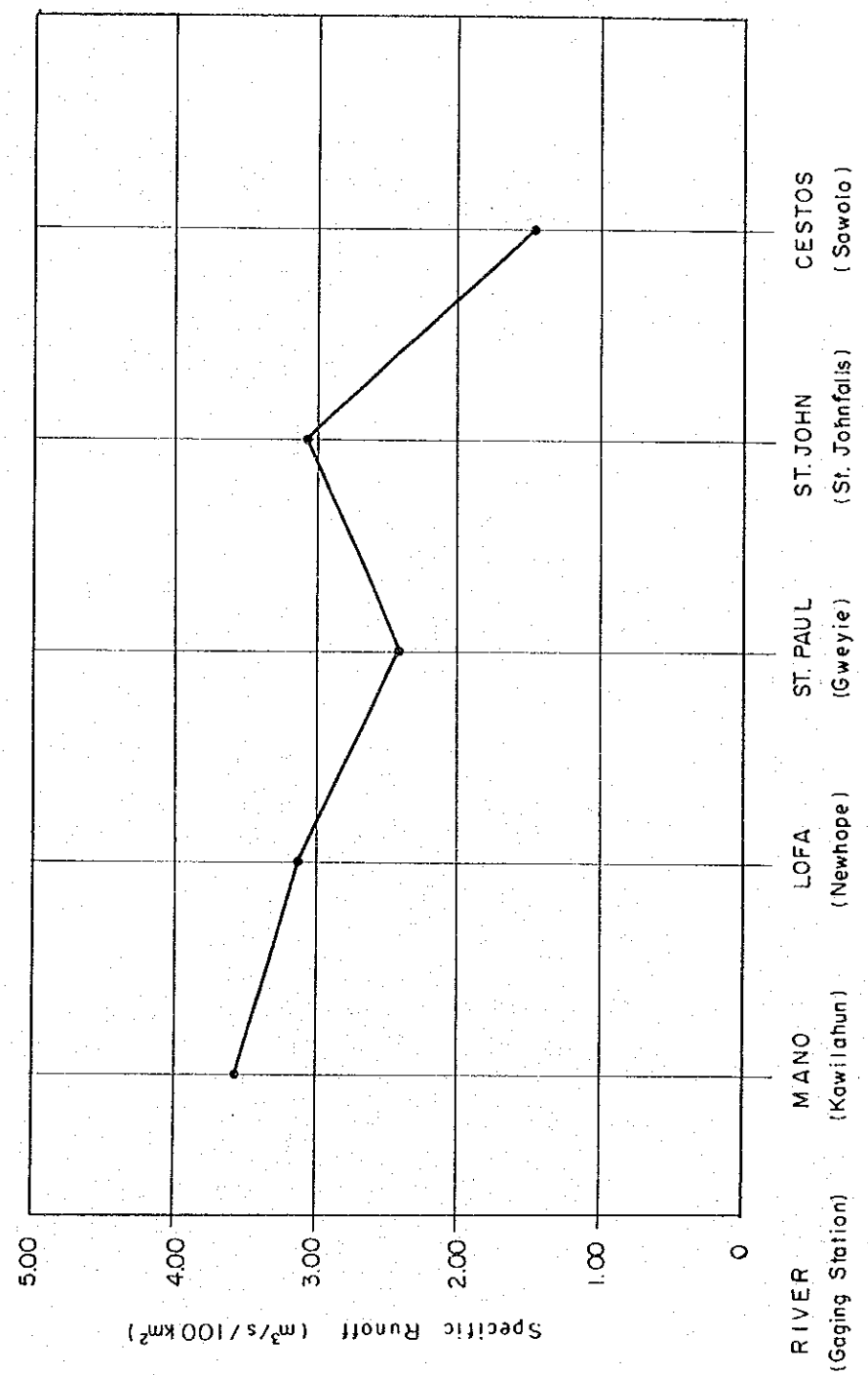
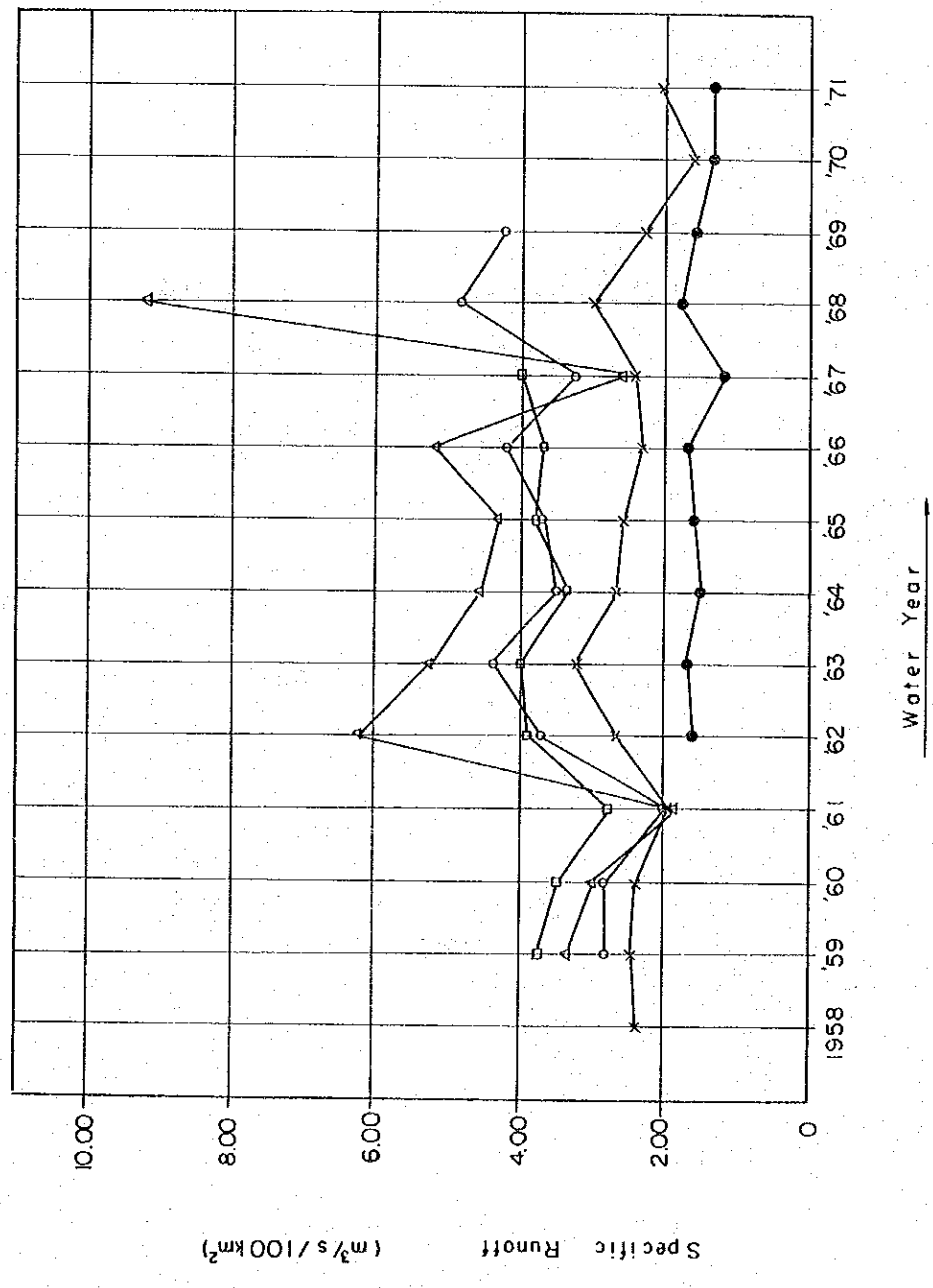


Figure 6-5 Annual Runoff



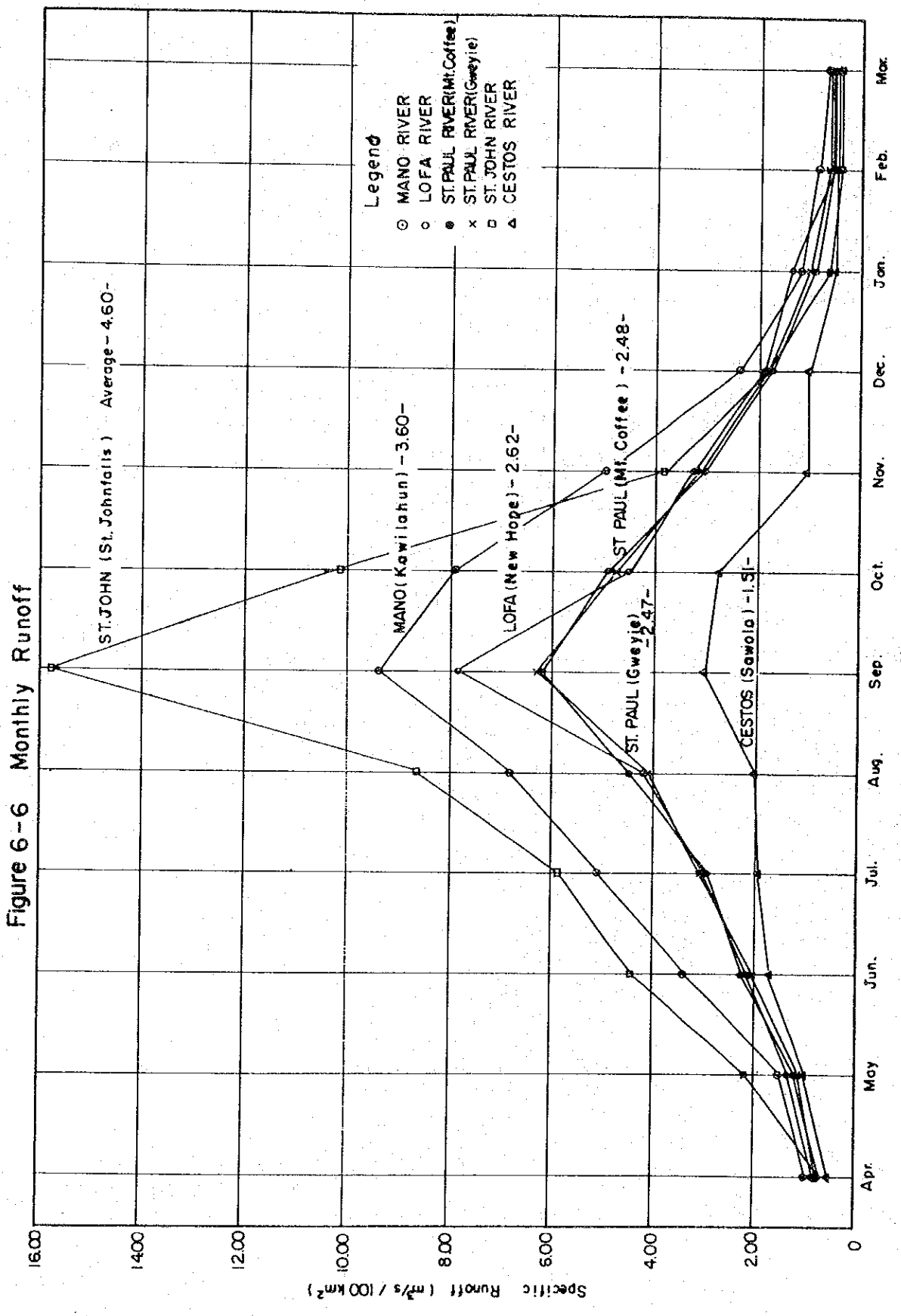


Figure 6-6 Monthly Runoff
Legend
MANO RIVER
LOFA RIVER
ST.PAUL RIVER(Mt.Coffee)
ST.PAUL RIVER(Gweyie)
ST. JOHN RIVER
CESTOS RIVER
ST.JOHN (St. Johnfalls) Average - 4.60
MANO (Kawillahun) - 3.60
LOFA (New Hope) - 2.62
ST PAUL (Mt. Coffee) - 2.48
ST. PAUL (Gweyie) 2.47
CESTOS (Sawola) - 1.51
Specific Runoff (m³/s / 100 km²)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Month

6-3 Topography and Geology

6-3-1 Topography

Topographic maps of Liberia having contour lines available are of scales of 1/250,000 and 1/50,000, and the mapped scopes are as shown in Fig. 6-7.

The 1/250,000-scale topographic map covers all of Liberia, but with the 1/50,000-scale map, only a very small percentage of the main part of the country has been surveyed.

Liberia is on the west coast of Africa situated from 4°20' to 8°25' north latitude and 7°20' to 11°30' west longitude. The area of the land is approximately 110,000 km^2, and is a roughly rectangular shape of approximately 500-km length along the Atlantic Ocean coast and 160-km to 240-km width.

The topography of Liberia, except for the coastal plains, is represented by a low, rolling hilly area. Mountainous areas are in the northcentral part and the northwestern part. The southeastern part is a broad plain with scattered hills.

The topography of Liberia may be divided into four topographic provinces parallel to the coastline and with different elevations, as indicated in Fig. 6-9(1).

(1) Coastal Plains

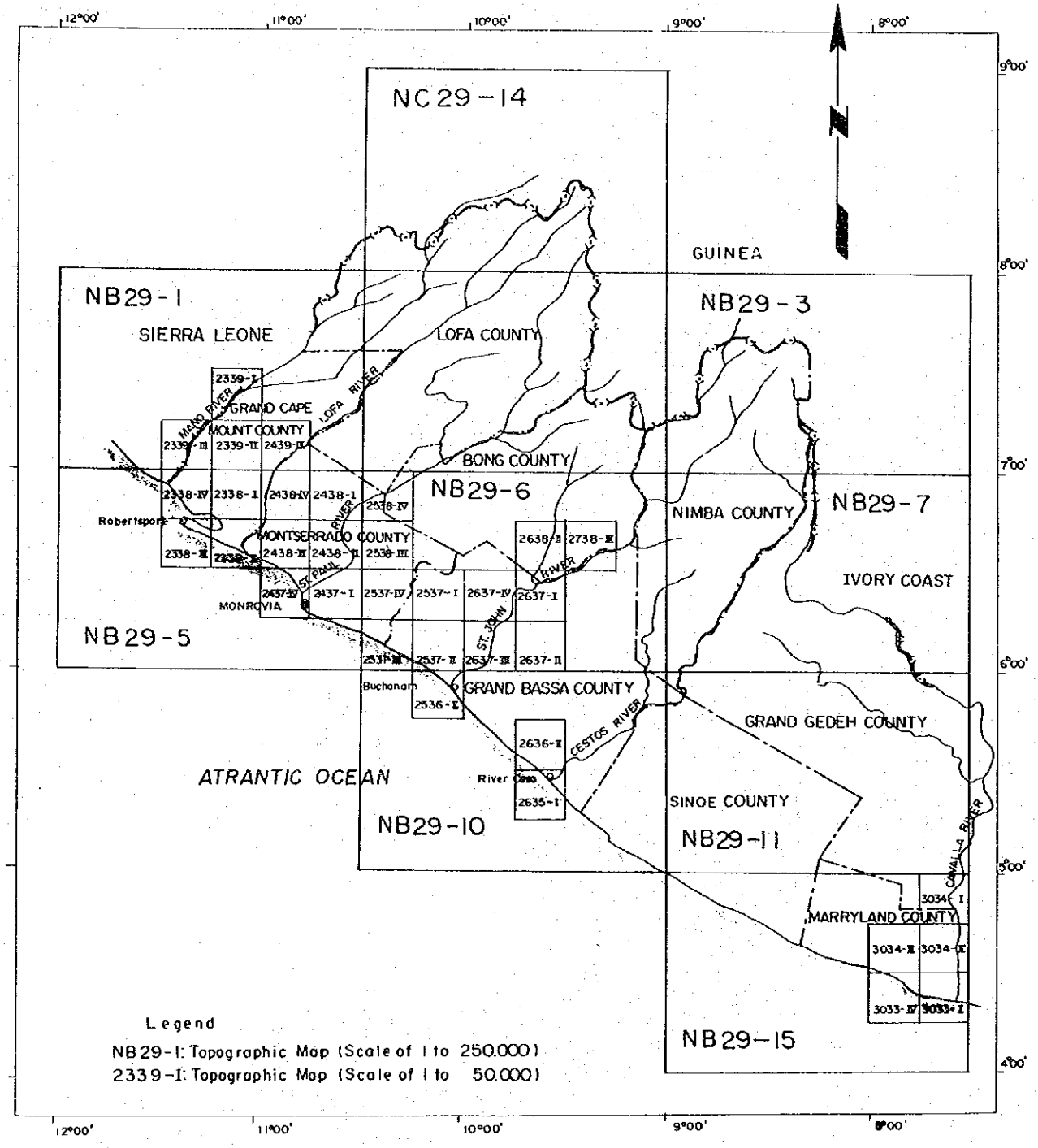
The width of the coastal plains ranges between 16 km to 40 km with elevation being between 0 m and 30 m. There are locations such as Mt. Barclay near Monrovia and a part west of Greenville which are higher than 45 m. The coastline is even and is featured by lagoons and sand-bars at the mouths of rivers.

The rivers run all over the plains at times forming ox-bow lakes.

(2) Rolling Hills

Next to the coastal plains, there is a low hilly region with gentle undulations and elevations between 60 m and 150 m.

Figure 6-7 Index of Topographic Map in Liberia



The southern part of this region has many hills such as Mt. Coffee (El. 180 m), while in the case of rivers there are numerous swift streams as those near White Plain and Nyaak. At the northern part the topography rises sharply to become a transition area from the hilly and plateau zone.

(3) Plateaux and Mountains Zone

The area of this region occupies more than half of the interior of Liberia, and the portion of greatest width between the Lofa River and the St. Paul River is as much as 130 km in the north-south direction. The normal elevation of this region is from 180 m to 300 m.

On the other hand, there are several mountain ranges of which elevation is between approximately 400 m and 600 m. Among them are included the Gibi, Bong, Mano and Putu Mountain Ranges.

At the transition area with the northern highlands, there are numerous rapids and waterfalls to be seen as represented by the waterfalls near Tengata on the St. Paul River and near Bo on the St. John River.

(4) Northern Highlands

The highlands of the northern part of Lofa and Nimba Counties are a part of the Guinea highlands known as the Futa Jalton Mountain Range.

The features of the northern highlands are long mountain ranges and dome-shaped hills.

The length of the Wologisi Mountain Range in the western part is 60 km with the elevation of Mt. Wologisi being 1,335 m.

The Nimba Mountain Range runs for 30 km on the Guinea side and its elevation reaches 1,820 m. The highest peak at the Liberian side is Guest House Hill in the concession area of LAMCO at 1,360 m. Domeshaped hills, or granite domes, are seen in the Vainajama district.

The general direction of the mountain ranges is from northeast to southwest reflecting the geologic structure.

The gradients of the rivers of Liberia, as shown in Fig. 6-8, are from approximately 1/700 to about 1/2,000 with river valleys generally being flat. Consequently, there are almost no sites where high dams of 100-m class can be constructed, and with dams of 50- to 60-m class there would be dikes required at several places in each reservoir, while with dams of 20-m class, crest lengths would be as long as 400 to 500m.

6-3-2 Geology [cf. Figs. 6-9(2) and 6-9(3)]

(a) General

According to the geologic map on a scale of 1/5,000,000 by ASGA-UNESCO[2], the 1/10,000,000-scale geologic map compiled by S.A. Musylev, et al.[3] and the 1/1,000,000-scale geologic map by the Ministry of Lands and Mines, Republic of Liberia[4], the basement complex of the Liberian national area is composed of Precambrian rocks which are the oldest on the earth.
The rocks in the Precambrian formation are granitic series and various kinds of metamorphic rocks which in cases have been changed into gneiss, crystalline schist and quartzite. During this process of metamorphism, strata of iron-silica formed rock of iron-quartz, namely, itabirite. The abundant itabirite resources comprise a basis for the iron ore mining industry of the country. Also, it is reported that a distribution of an Archean stratum of width of 20 km to 100 km along the St. Paul River[3]. It appears that distributions of Post-Precambrian formations are not wide. The stratigraphy of the Liberian land may be summarized, as shown in Table 6-4.

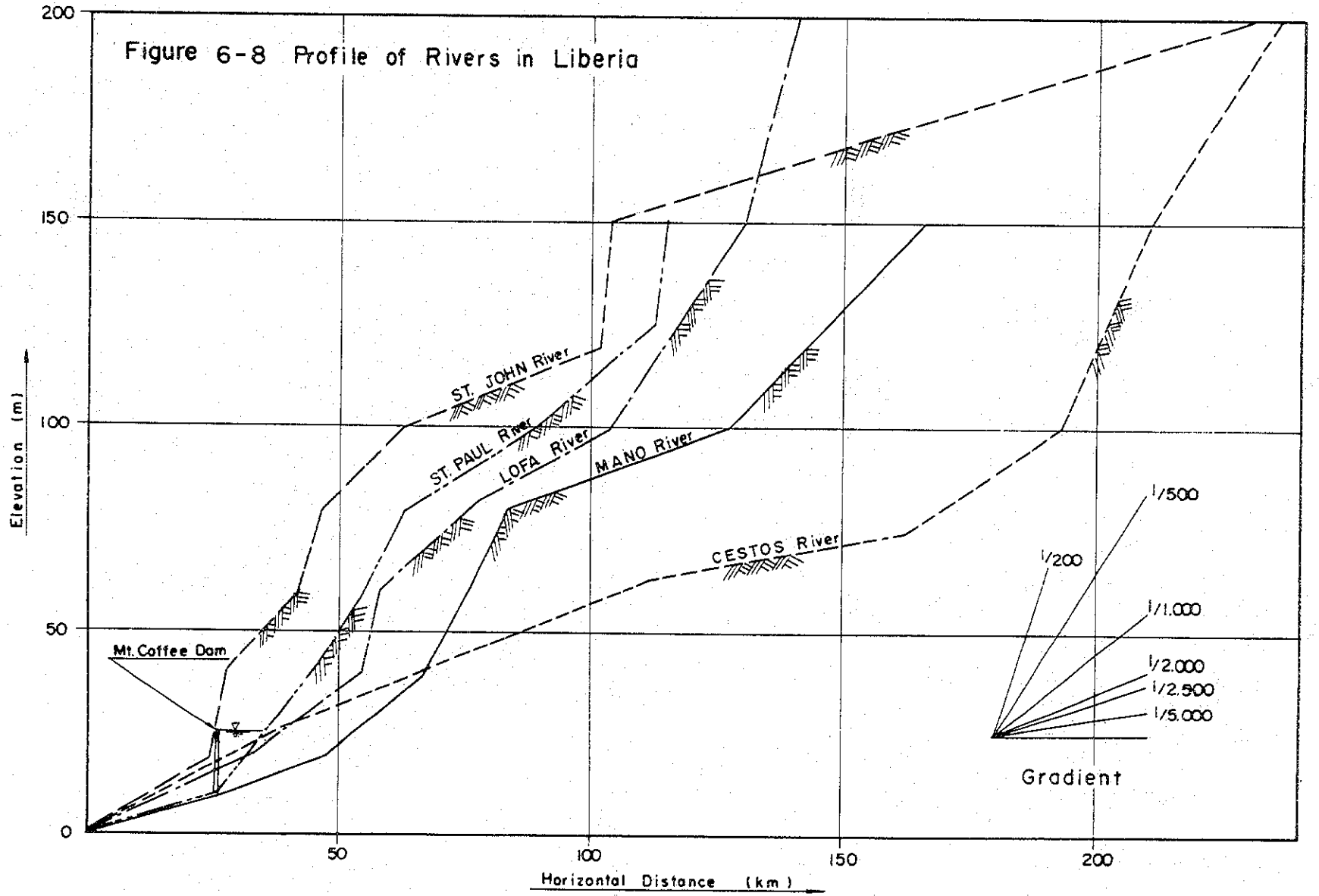


Figure 6-8 Profile of Rivers in Liberia
200
150
100
50
0
Elevation (m)
ST. JOHN River
ST. PAUL River
LOFA River
MANO River
CESTOS River
Mt. Coffee Dam
1/500
1/200
1/1.000
1/2.000
1/2.500
1/5.000
Gradient
50
100
150
200
Horizontal Distance (km)

Table 6-4 Summarized Stratigraphic Sequence in Liberia

Era or Period		Types of Rocks or Deposits	Principal Area of Distribution	Economic Value
Ceno-zoic	Quater-nary	Lagoon and coast sands and river deposits	Lagoons, coast and rivers	
	Tertiary	Coastal sandstone and lateritic soils	Sandstone: coastal region Lateritic soils: covers of most areas of land	Bauxite ?
Mesozoic		Diabase and peridotite dykes ? Wacke and conglomerate	Unmetamorphosed sedimentary rocks: central to northern areas of coastal region Igneous rock: scattered dykes in northern mountain lands	Diamond
Paleozoic		Paynesville sandstone Diabase, norite and peridotite		
Precambrian		Granitic rock, gneiss, crystal-line schist and quartzite	Bedrocks of almost entire land area	Iron ore (itabilite) Gold

The Paleozoic system, according to Geological Survey Special Paper No. 3 [5], is distributed at part of the coastal area of Liberia from the capital of Monrovia to about 60 km southeast by east in a width of around 15 km. This Paleozoic system is divided into two portions by a Mesozoic system distributed in the vicinity of Marshall. The Paleozoic system is composed of two rock units of Paynesville sandstone and Monrovia diabase.

Paynesville sandstone is an unmetamorphosed sendimentary rock which is fine-grained with well-rounded quartz grains cemented by quartz overgrowths in which can be seen detritals of plagioclase and small amounts of muscovite and opaque minerals. There are widely spaced vertical joints in this sandstone, and although the surface portion of the rock has become porous and friable due to weathering of the plagioclase, it appears porosity is low in unweathered portions at greater depths.

Monrovia diabase intrudes Paynesville sandstone in the forms of dykes and stocks. The diabase is fine to medium grained with joints widely spaced and its resistance to weathering action is greater compared with other rock types distributed in the coastal area.

The Mesozoic system has been found in the vicinity of Marshall and to the northwest of Edina, but the area of its distribution is small and it has been named the Farmington River Formation[5]. This formation is chiefly composed of the two rock facies of wacke (a sandstone high in argillaceous matrix content) and polymict conglomerate. These two facies are interbedded in places, but the conglomerate is more abundant at the basal part of the Mesozoic system.

There are basic or ultrabasic rocks which have intruded and filled numerous cracks and faults in the Precambrian strata and Paleozoic formations. Most of these intrusive rocks are diabasic rocks or peridotites, both of which are mainly distributed from the northeast part of the country near the Guinea and Ivory Coast Borders towards the interior. Other than the above, kimberite and pegmatite are known to exist although in small quantities. In particular, kimberite is known to contain diamonds, and the diamond export was 214,254 carats of industrial use and 536,192 carats of gem stones and cutables, in 1968[1].

Some of intrusive rocks previously mentioned would be derived from igneous activities at the Mesozoic era.

Cenozoic formations are represented by the coastal sandstones and soils. The distribution of the coastal sandstones is limited to a belt of approximately 20 km along the coastline, and these appear to be not consolidated deposits. Soils may be classified as lateritic soils, sandy soils along the coast, and swamp soils in the coastal lagoons and in the interior, and it is said lateritic soils cover 75% of the national area.

The geologic structure of Precambrian rocks is predominant in the NE-SW direction and the arrangement of fold axes, faults and intrusive rocks are governed by the direction of the structure. On the contrary, the structure of consolidated Post-Cambrian rocks follow a NW-SE direction.

Crossing with the older geologic structure oriented in the NE-SW direction there is a zone of parallel faults from a point approximately 30 km upstream from the estuary of the Mano River, forming the boundary between Liberia and Sierra Leone, which runs roughly parallel to the coastline until it plunges under the sea at a point approximately 50 km southeast of the city of River Cess. This fault zone has a length of more than 300 km, and particularly, between the St. Paul and St. John Rivers, there are many parallel faults. Almost all of the major rivers appear to have tectonic valleys produced by the faults in the NE-SW direction.

(b) Engineering Geological Consideration

There were ten dam and power station sites on which studies were conducted. The outlines of the geographic and topographic conditions at these sets are as given in Table 6-5.

Table 6-5 Geographic and Topographic Condition of Proposed Damsites

River System	Proposed Site	Distance from Coast 1/ (km)	Elevation of River Bed x H 2/	Topography of Project Area 1/	L 2/	L/H 2/
		Approx.	Approx.			
Mano	Mano No. 1	25	15 x 30	Coastal plains	500	16.7
	Mano No. 2	70	80 x 50	Lower plateaux	400	8
Lofa	Lofa No. 1	25	15 x 25	Coastal plains	400	16
	Lofa No. 2	55	70 x 30	Rolling hills	400	13.3
St. Paul	St. Paul No. 1	50	70 x 28	Coastal plains	950	34
St. John	St. John No. 1	20	35 x 25	Rolling hills	600	24
	St. John No. 2	50	95 x 25	Rolling hills	450	18
	St. John No. 3	90	140 x 40	Lower plateaux	350	8.8
Cestos	Cestos No. 1	55	30 x 20	Rolling hills	500	25
	Cestos No. 2	105	70 x 30	Lower plateaux	1,700	56.5

1/ cf. Fig. 6-9(1)

2/ L, length of crest: H, height of dam

These dam sites are generally in the southern half of the country, selected respectively at swift parts of rivers, while the heights of dams proposed are all low to medium scale.

Since the topographic and geologic features of the dam sites are similar in many respects, only the geological view will be stated from an overall standpoint.

(1) The Mano No. 2, St. John No. 3 and Cestos No. 2 sites are located in the lower plateaux zone, but many of the sites are in the coastal plains or the rolling hills zone.

(2) Dissection by rivers has progressed in the plateaux and rolling hills zones and the topography is that of gentle undulations while river valleys are wide. The undulations are even more gentle in the coastal plains zone and the river valleys are still wider. The shapes of the valleys at the respective dam sites in terms of L/H ratio (H: height of dam, L: length of crest) show the ratios to be large as indicated in Table 6-5. Consequently, all of the dams are to be fill dams.

(3) Reservoir areas are low and flat, while parts of mountain masses surrounding reservoir basins are lower than the proposed normal high water surface levels so that saddle dams will be required to be provided in view of the topography. And even when ground surface levels are higher than the proposed normal high water surface levels, in cases where impervious beds for practical puposes are at low elevations, proper works for protection from leakge will be required.

(4) The basement in terms of geology consists principally of Precambrian granitic rocks while in part there are also areas of metamorphic rocks. These rocks where fresh and undisturbed are considered to have adequate bearing capacities and shear friction resistances for the action of the dams proposed. However, with regard to permeabilities, the results of in-situ testing utilizing holes of core boring and auger should be awaited.

(5) According to the geologic map of the Liberian Geological Survey[4], except for the St. Paul River where the existing Mt. Coffee Dam and Power Station and the proposed St. Paul No. 1 Project are located, all of the project rivers have tectonic valleys.

Seen from the distribution of rock types, the bedrocks are fairly prominently displaced by these tectonic lines. Also, since the valleys are along tectonic lines, it is thought that the proposed dams and power stations, although with some differences in degree, cannot escape being influenced by these lines. A tectonic line in the WNW-ESE direction also crosses the St. Paul No. 1 Project site. Consequently, it is necessary for careful consideration to be given to the existence of the tectonic line in selection of locations of civil structures, especially dams, and in order to find the tectonic line or geologic defects due to the line in regard to the dam and power sites selected, every method available including core boring and seismic prospecting should be used in carrying out a thorough geologic investigation.

(6) Soluble rocks are not known to exist at the basements of the reservoir basins. However, the possibility of leakage of stored water occurring cannot be precluded because of the existing tectonic lines and resulting defects. It would be important from such a viewpoint to know the characteristics of the tectonic lines.

(7) Weathering has progressed considerably due to the humid tropical climate and the relative flatness of the topography, and hillsides are covered widely with fairly thick lateritic soil and residual soil. Consequently, weathered rocks and soils must be taken into consideration as foundations for dams. In such case, the properties of these foundations should be ascertained through in-situ and laboratory tests and the results used in determining excavation lines for dam foundations and in studying foundation works and treatments.

(8) Due to transgressions in the Cenozoic era, there are unconsolidated sand layers deposited as far as approximately 15 km inland in the Monrovia district and there are areas where thicknesses exceed 20 m. Damsites have been selected avoiding such geologic conditions, but since it is imaginable that there will be former

river channels, terraces and thick riverbed deposits in valleys causing upheavel and subsidences of the earth crust, thorough surveys will be necessary.

(9) For embankment materials for fill dams, it is conceivable for lateritic soil and weathered rock to be utilized as impervious materials. As for rock materials and aggregate for concrete, these would probably be taken from consolidated rock masses, such as granitic rocks, metamorphic rocks, igneous rocks and Pre-Tertiary sedimentary rocks, distributed near damsites.
In selection of quarries, monadnocks will serve as guides.
Needless to say, the qualities of soil and rock materials for embankment, and concrete aggregates should be investigated through testings.

(10) The national territory of Liberia is at a far distance from the seismic zone along the Mid-Atlantic Range, while earthquake nests are not known to exist in the country and the earth mass is thought to be stable.

References

1) Willi Schulze (1973), A New Geography of Liberia, Longman Group Limited, London and Others.

2) Association of African Geological Surveys and United Nations Educational, Scientific and Cultural Organization (1963), Geological Map of Africa, Sheet 4, Scale 1:5,000,000.

3) S.A. Musylev et al. (1969), Geological Map of Africa, Scale 1:10,000,000.

4) Ministry of Lands and Mines, Republic of Liberia, Geologic Map of Liberia, Scale 1:1,000,000.

5) Liberian Geological Survey, Ministry of Lands and Mines (1972) Stratigraphy and Structure of Basins on the Coast of Liberia
— Geological Survey Special Paper No. 3 —

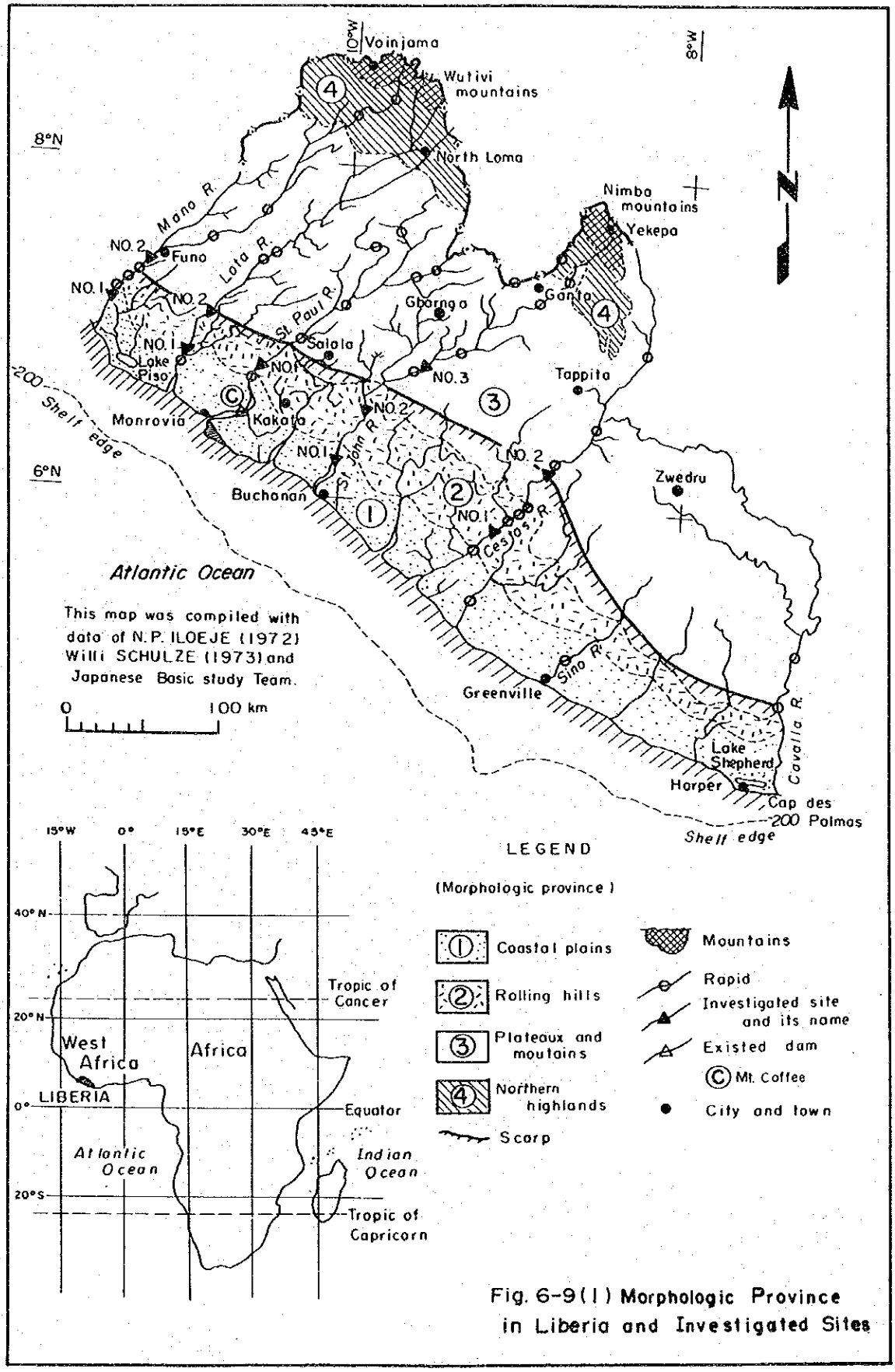


Fig. 6-9(1) Morphologic Province in Liberia and Investigated Sites

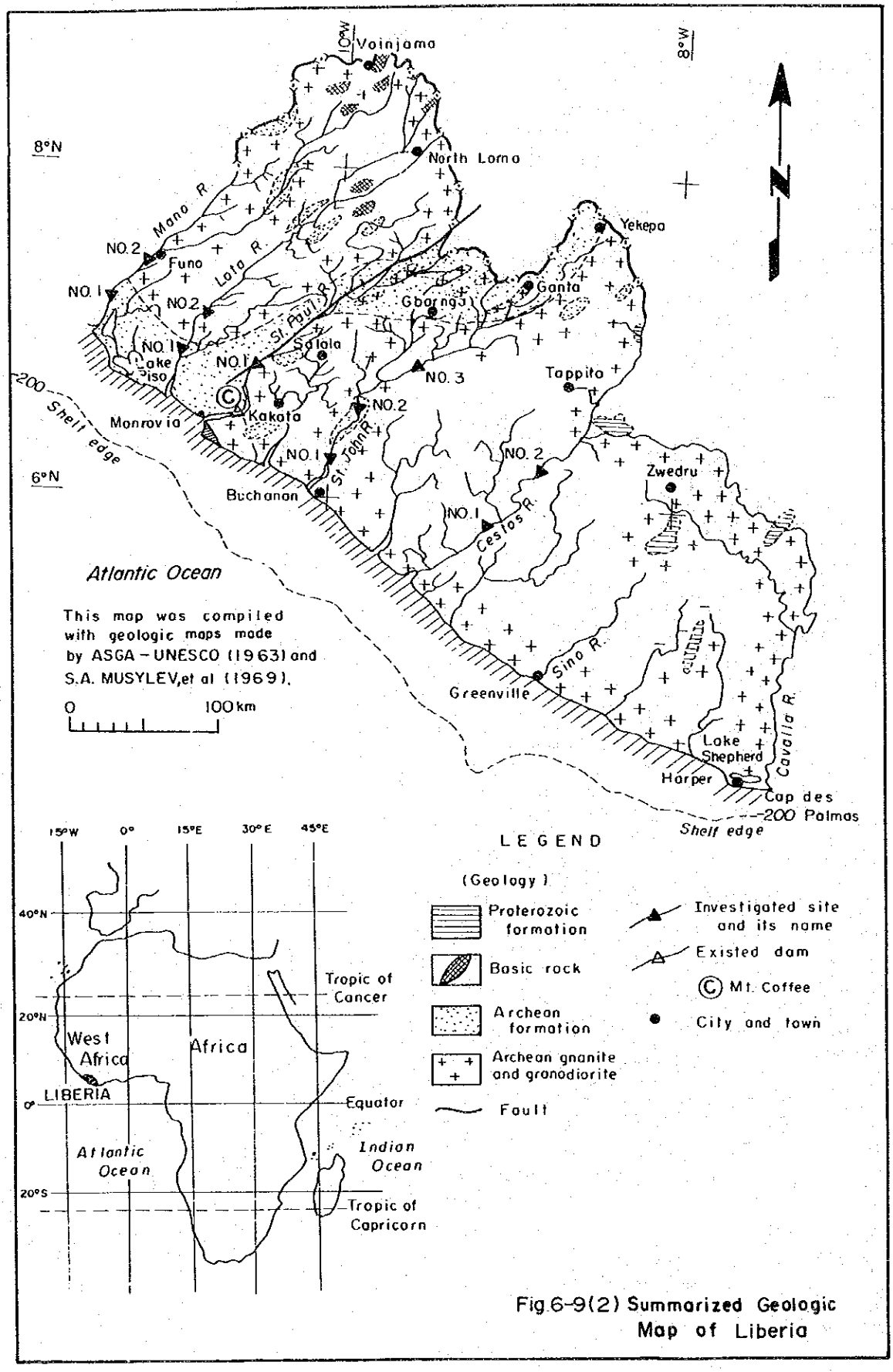


Fig.6-9(2) Summarized Geologic Map of Liberia

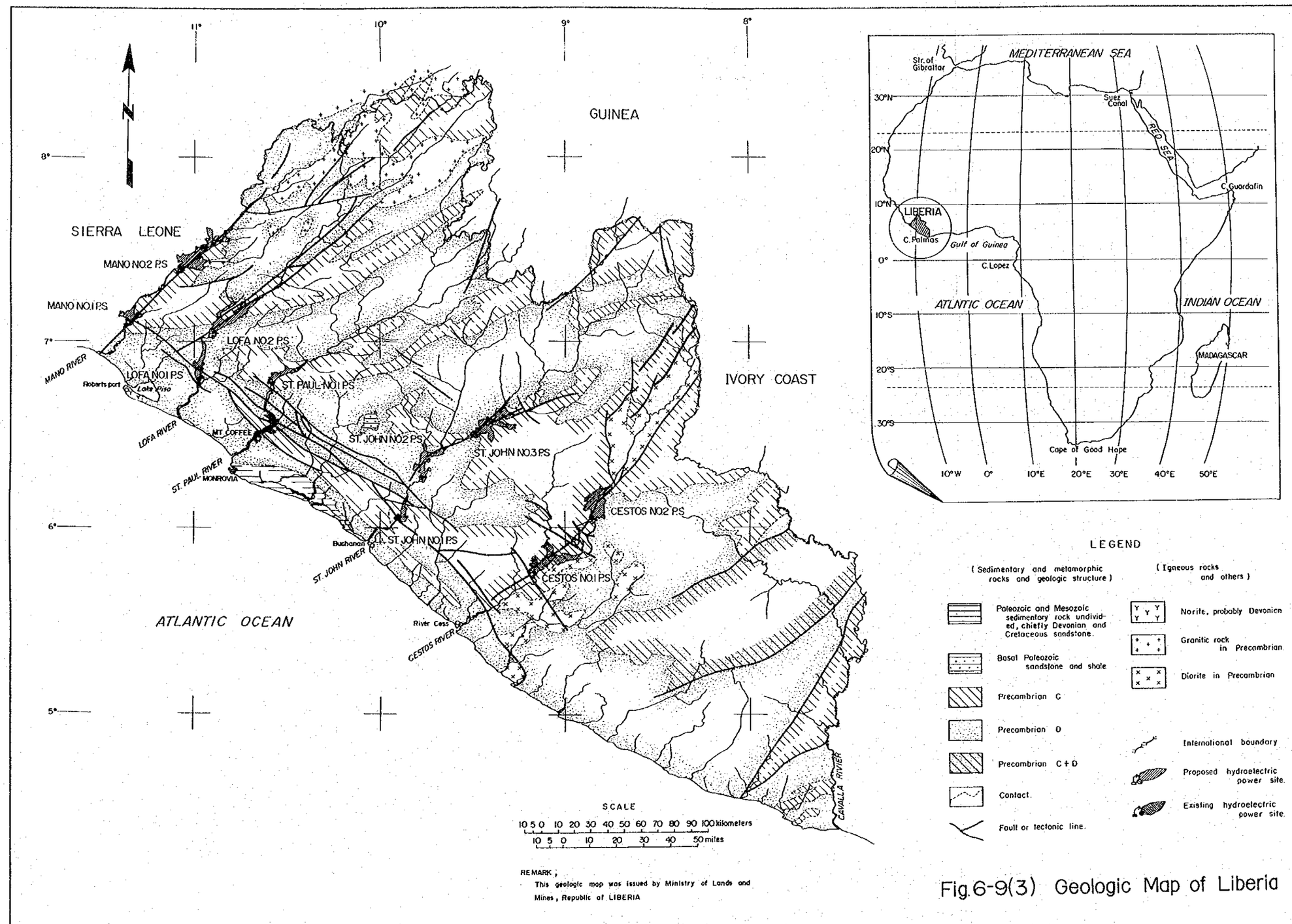


Fig.6-9(3) Geologic Map of Liberia

6-4 Selection of Project Sites

6-4-1 Basic Conditions for Project Planning

(1) General

As results of aerial inspections and on the basis of topographical maps of scales of 1/50,000 and/or 1/250,000, probable project sites were selected in conformity with the basic considerations described below taking account of the electric power situation, hydrological characteristics and topographical conditions of the country.

1) The power demand of the Monrovia Power System in the future, that is, the power necessary from new generating facilities will be around 110 MW and 150 MW in 1981 and 1986, respectively, and the duration time of the peak demands will be around 18 hours.

2) Since there is a sharp difference in stream flow between the dry and rainy seasons, with the discharge in the dry season becoming one tenth that of the rainy season, in order to secure a power source capable of effectively utilizing river water and supplying reliable electric power, the dam site should be one where a reservoir of a capacity as large as possible can be constructed enabling yearly regulation to be performed.

3) Since the gradients of rivers are very gentle, run-off-river type power stations are not advantageous, and dam-type power stations securing heads with dams should be constructed.

Based on the above, one to three sites were selected on the major rivers for a total of 10 sites. The locations are shown in Figs. 6-10 through 6-15.

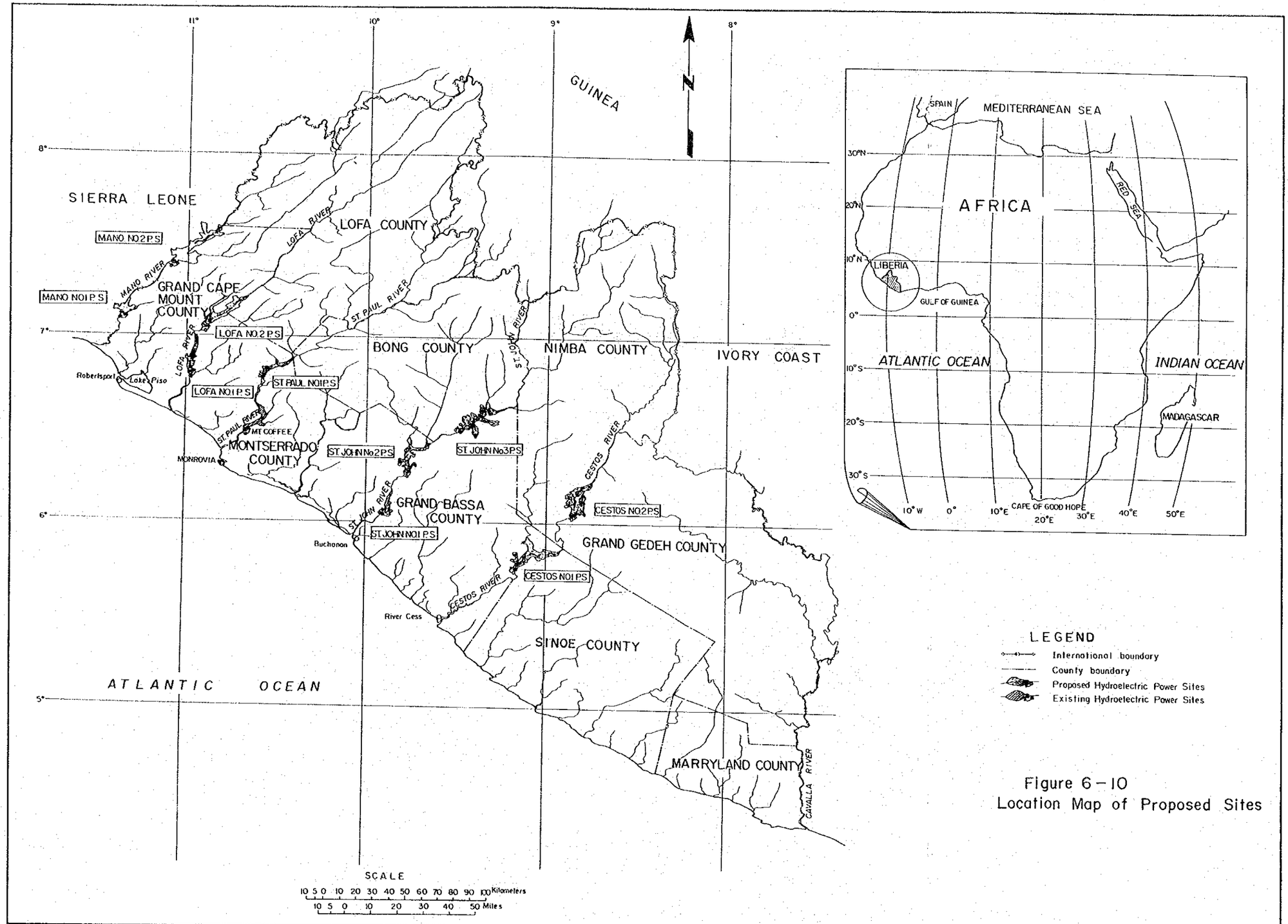


Figure 6 – 10
Location Map of Proposed Sites

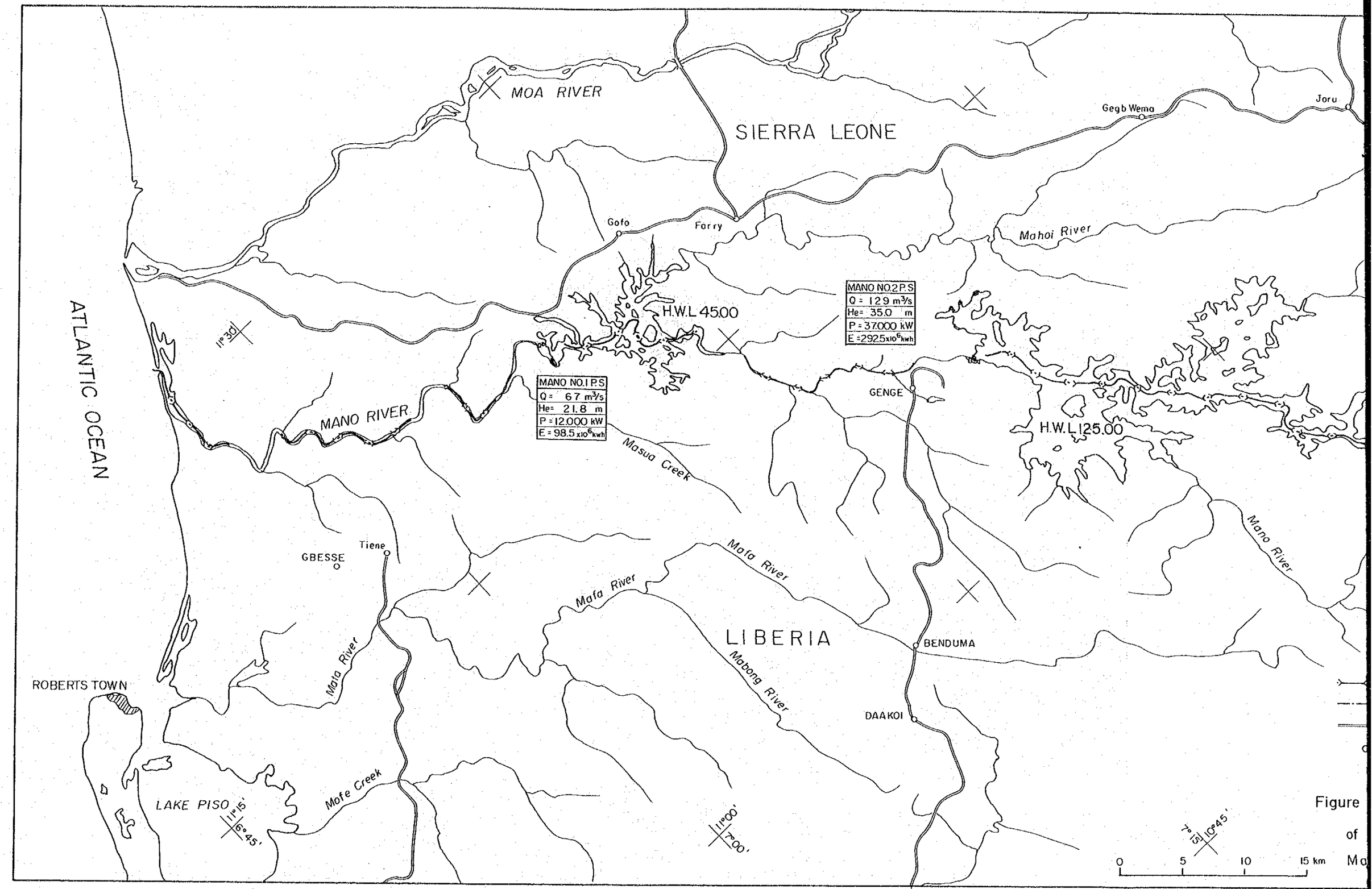

MOA RIVER
SIERRA LEONE
Gegb Wema
Joru
Gofo
Farry
Mahoi River
H.W.L 45.00
MANO NO.2 P.S
Q = 129 m³/s
He= 35.0 m
P = 37.000 kW
E = 292.5x10⁶kwh
MANO NO.1 P.S
Q = 67 m³/s
He= 21.8 m
P = 12.000 kW
E = 98.5x10⁶kwh
ATLANTIC OCEAN
11°30'
MANO RIVER
Masua Creek
GENGE
H.W.L 125.00
Tiene
GBESSE
Mafa River
Mano River
LIBERIA
BENDUMA
Mobong River
DAAKOI
ROBERTS TOWN
Mafe Creek
LAKE PISO
11°15'
6°45'
11°00'
7°00'
7°15'
10°45'
0
5
10
15 km

Figure
of
Ma

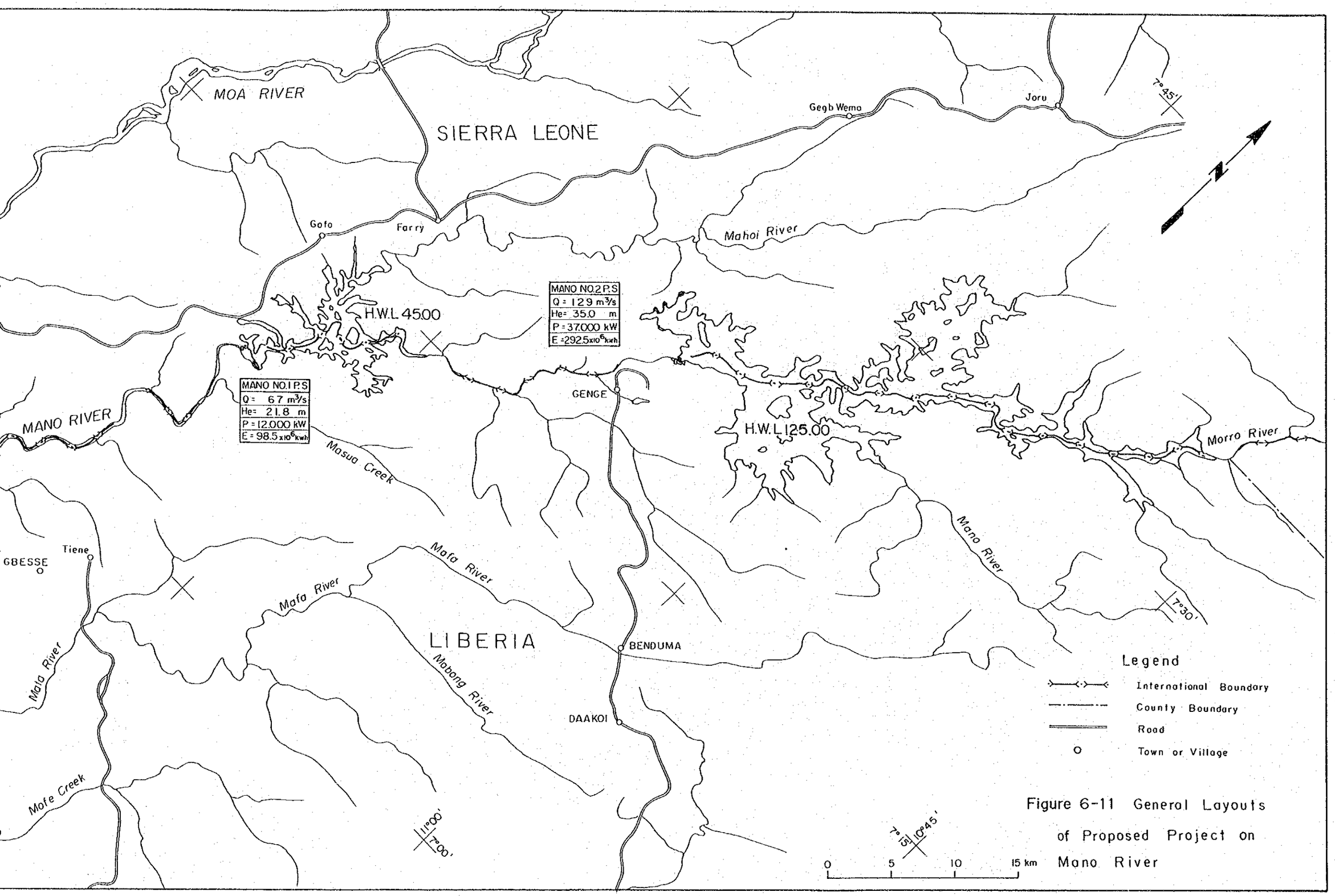


Figure 6-11 General Layouts of Proposed Project on Mano River

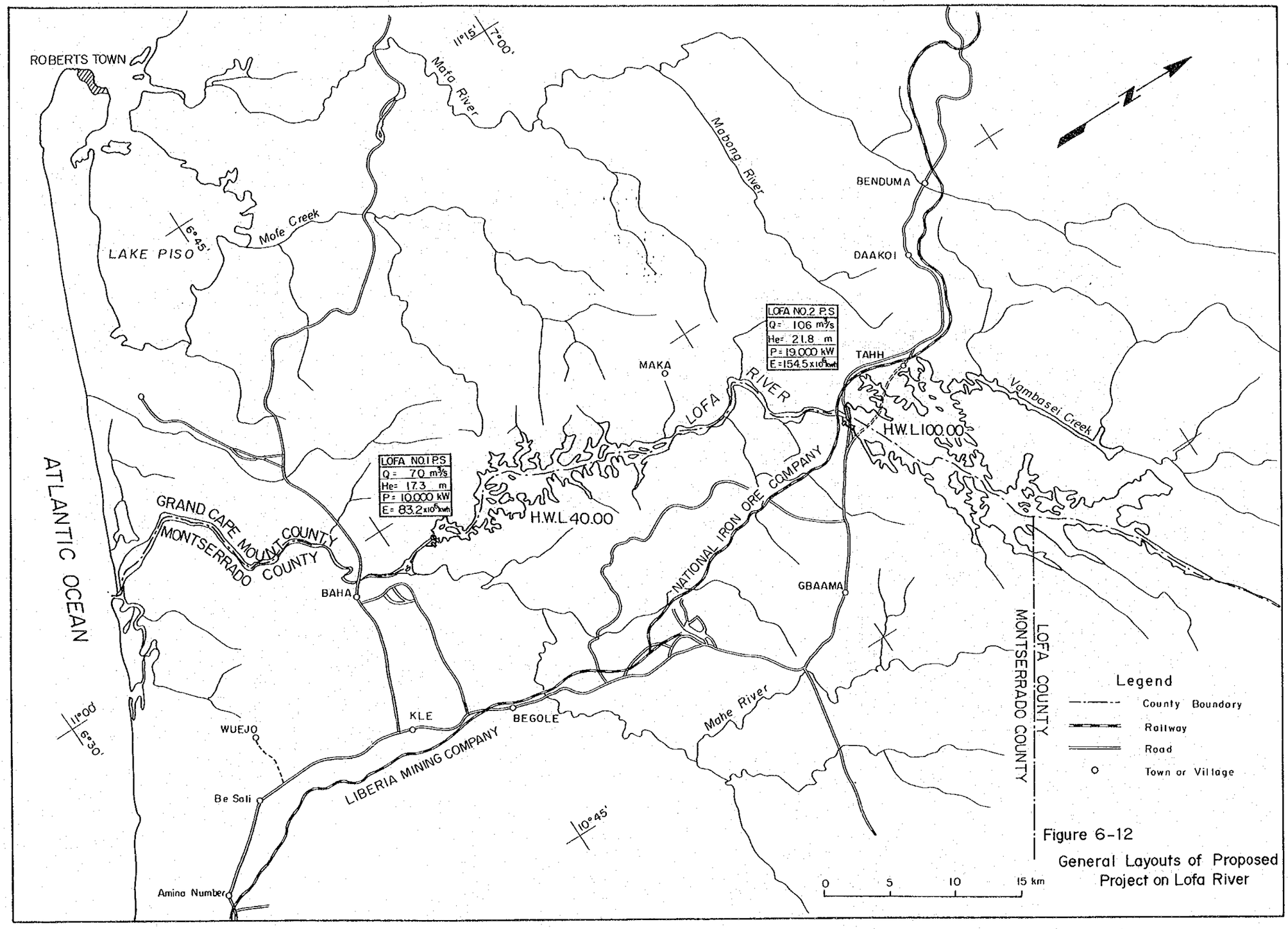


Figure 6-12
General Layouts of Proposed Project on Lofa River

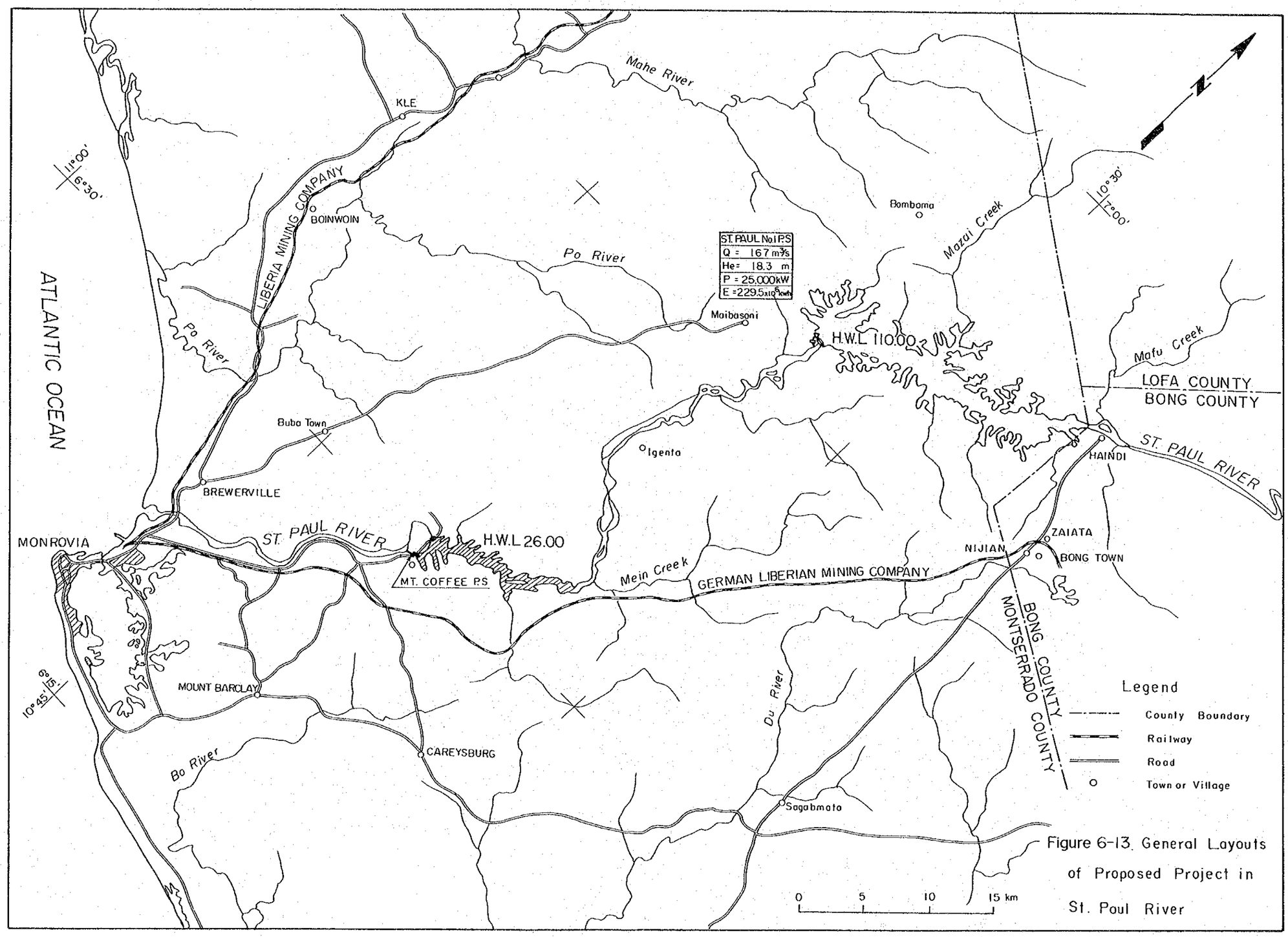


Figure 6-13. General Layouts of Proposed Project in St. Poul River

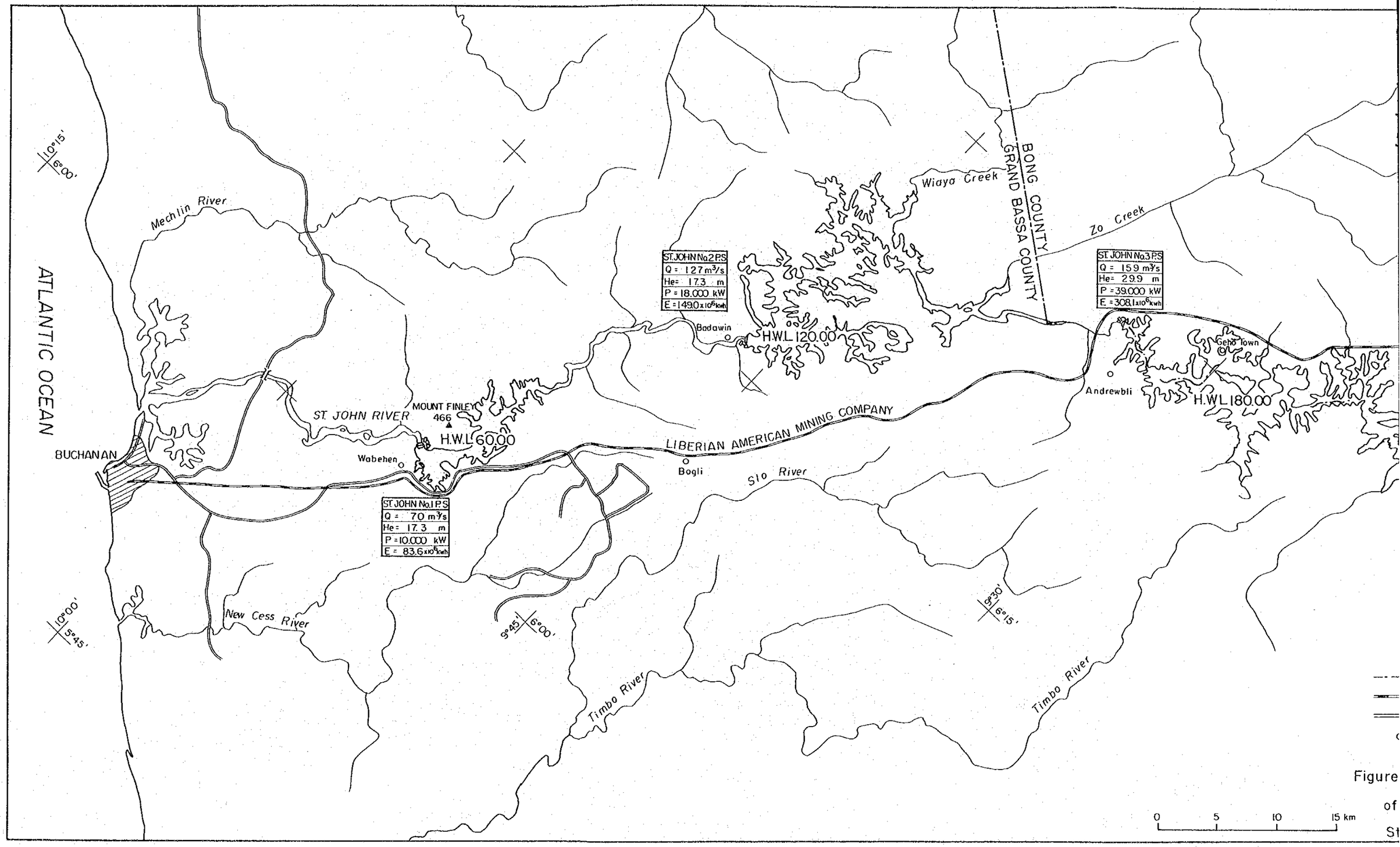

ATLANTIC OCEAN
10°15'
6°00'
Mechlin River
ST. JOHN No.2 P.S
Q = 127 m³/s
He = 17.3 m
P = 18,000 kW
E = 149.0 x 10⁶ kwh
Wiaya Creek
BONG COUNTY
GRAND BASSA COUNTY
Zo Creek
ST. JOHN No.3 P.S
Q = 159 m³/s
He = 29.9 m
P = 39,000 kW
E = 308.1 x 10⁶ kwh
Badawin
H.W.L 120.00
Gehō town
Andrewbli
H.W.L 180.00
ST. JOHN RIVER
MOUNT FINLEY
466
H.W.L 60.00
LIBERIAN AMERICAN MINING COMPANY
BUCHANAN
Wabehen
Bogli
Slo River
ST. JOHN No.1 P.S
Q = 70 m³/s
He = 17.3 m
P = 10,000 kW
E = 83.6 x 10⁶ kwh
10°00'
5°45'
New Cess River
9°45'
6°00'
9°30'
6°15'
Timbo River
Timbo River
0
5
10
15 km

Figure
of
St

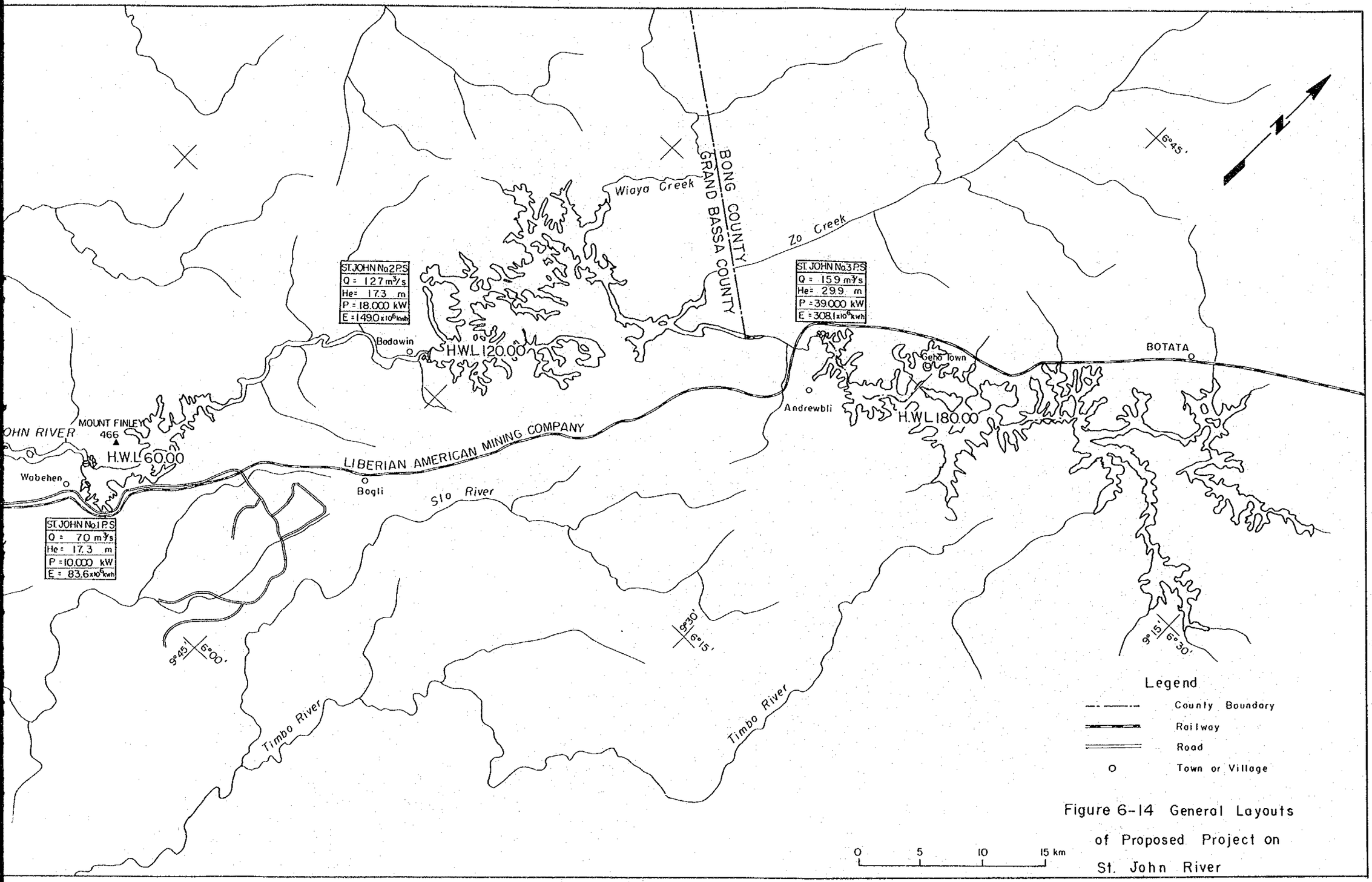


Figure 6-14 General Layouts of Proposed Project on St. John River

ATLANTIC OCEAN

Laboug

Wawabli

Mollibli

Wheregaros

Do River

Kwahli

River Cess

CESTOS RIVER

Bokoa Town

Baliablio

Po River

GRAND BASSA COUNTY
SINOE COUNTY

Sehn Kwehn River

Shani River

9°30'
5°45'

5°30'

Wone River

Tikpa

Bassa Town

Dro Town

9°15'
6°00'

Badeve

MOUNT WOAU
402

H.W.L 50.00

Nemo Town

CESTOS No.1 P.S
Q = 108 m³/s
He = 18.0 m
P = 16.000 kW
E = 125.7 x10⁶ kwh

GRAND BASSA COUNTY
NIMBA COUNTY

Gwen Creek

Natumpka

9°00'

Droya Town

CESTOS No.2 P.S
Q = 122 m³/s
He = 25.0 m
P = 25.000 kW
E = 188.6 x10⁶ kwh

Bilowapa

H.W.L 100.0

Daluse

Dalu

Jepie

GRAND JIDE COUNTY
SINOE COUNTY

Jobo

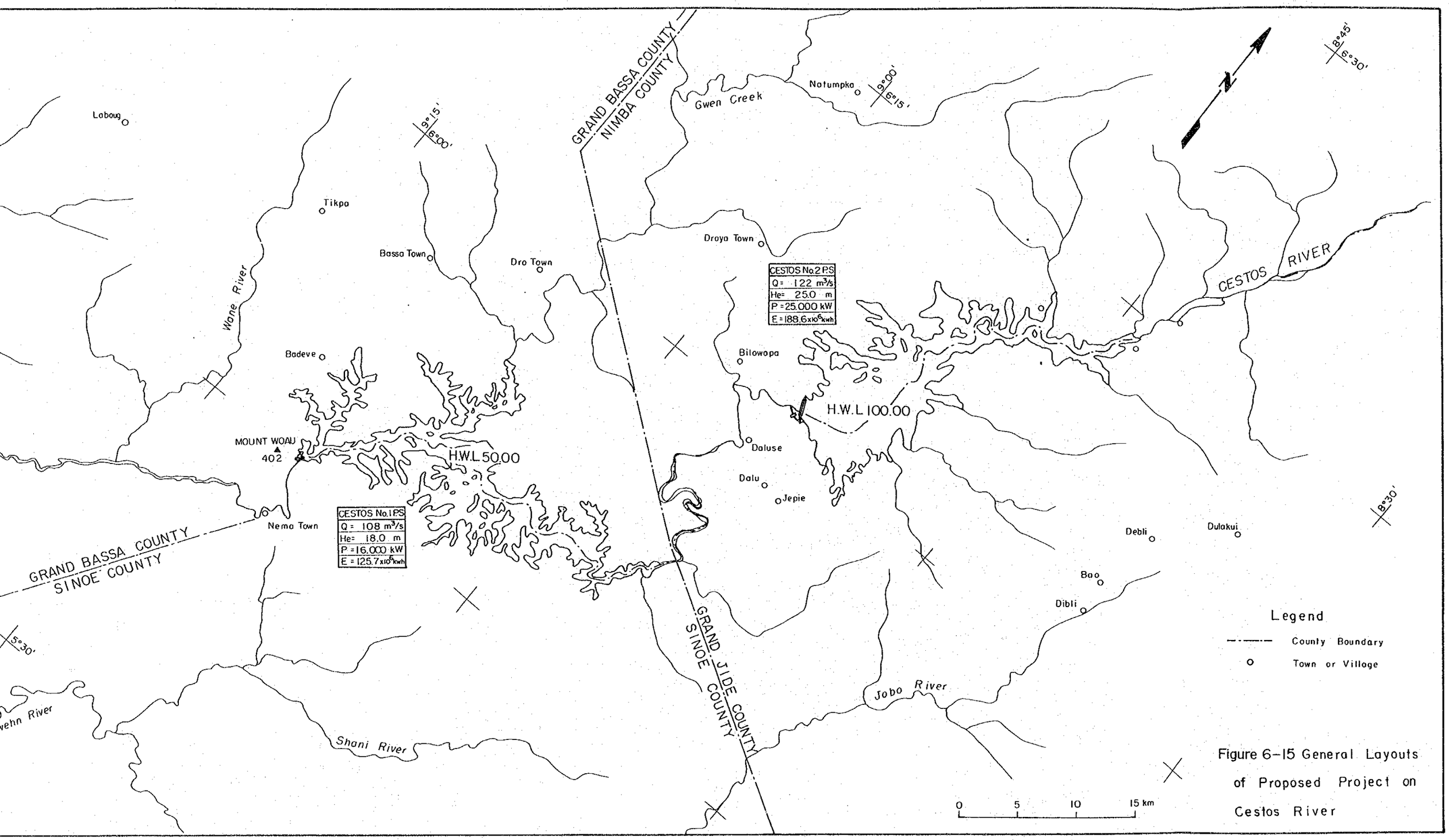


Figure 6-15 General Layouts of Proposed Project on Cestos River

(2) Estimations of Stream Flow Discharges at Proposed Damsites

In Liberia, the return period of hydrological phenomena is predicted to be around ten years as illustrated in Fig. 6-5. The Gweyie Gaging Station on the St. Paul River was selected as a representative station having sufficient gaging records to cover the hydrological return period while the data are comparatively complete.

On the basis of stream flow discharge data for 14 years at Gweyie Gaging Station, typical design years were selected in order to respectively estimate firm discharge and calculate energy production.

The design year for estimation of the firm discharge is 1961 which is the second driest year in the series of data for the 14 years from 1959 to 1972. Meanwhile, 1960 was selected as the design year for calculation of energy production being close to the mean for the 14 years.

As for the variations in the specific discharges by catchment area for the St. Paul River, there are hardly differences depending on size of catchment area as shown in Fig. 6-16, but there is a trend of slight increase closer to the estuary. As a result, the applicable gaging station and discharge calculation method for each project site were determined in accordance with Table 6-6.

Figure 6-16

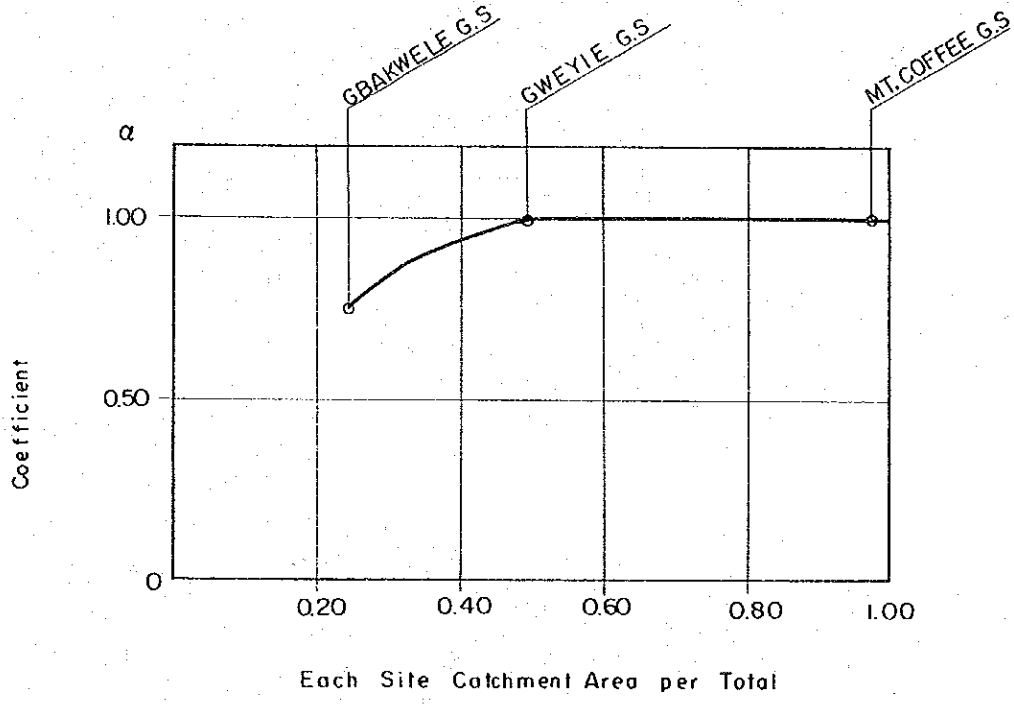

GBAKWELE G.S
GWEYIE G.S
MT.COFFEE G.S
α
1.00
0.50
0
0.20
0.40
0.60
0.80
1.00
Coefficient
Each Site Catchment Area per Total

Table 6-6 Calculation Method of Run-off at Proposed Project Site

Name of River	Proposed Project Site	Name of Gaging Station	Culculation Equation
MANO	MANO No. 1 MANO No. 2	KAVILAHUN G.S.	$Qp=Q_{G.S.} \times \frac{CAp}{CA_{G.S.}}$
LOFA	LOFA No. 1 LOFA No. 2	NEW HOPE G.S.	$Qp=Q_{G.S.} \times \frac{CAp}{CA_{G.S.}}$
ST. PAUL	ST. PAUL No. 1	MT. COFFEE G.S.	$Qp=Q_{G.S.} \times \frac{CAp}{CA_{G.S.}}$
ST. JOHN	ST. JOHN No. 1 ST. JOHN No. 2 ST. JOHN No. 3	ST. JOHN FALLS G.S.	$Qp=Q_{G.S.} \times \frac{CAp}{CA_{G.S.}}$
CESTOS	CESTOS No. 1 CESTOS No. 2	SAWOLO G.S.	$Qp=Q_{G.S.} \times \frac{CAp}{CA_{G.S.}} \times \alpha$

Note: Qp: Run-Off at Proposed Project Site

$Q_{G.S.}$: Run-Off at Gaging Station

CAp: Catchment Area of Proposed Project

$CA_{G.S.}$: Cathment Area of Gaging Station

α : Specific Run-Off Obtained from Fig. 6-15

(3) Firm Discharges

In case firm discharge were to be based on the discharge of the driest year, there would be the advantage of discharge being guaranteed every year, but this would be excessively conservative and is apt to impair the economics of a project, while water resources would not be effectively utilized, and therefore, does not result in the optimum scale for a development plan.

The firm discharge in this study was taken to be slightly larger than discharge in the driest year in which shortage in power supply occured. Up to now, such deficit has been made up for by dint of the reserve capacity of the power system.

Consequntly, an inflow mass-curve was prepared for each of the proposed istes based on 1961, the second driest year, and the firm discharge of each site was determined in accordance with the effective storage capacity of the site.

(4) Maximum Discharge

As explained in the preceding Chapter, the duration time of peak demand in the future will be approximately 18 hours. Therefore, the maximum discharge for each proposed site was determined in accordance with the firm discharge and on the basis of operation for 18 hours of peak dem and duration time.

(5) Output and Energy Production

The installed capacity and rated output of each proposed site were estimated based on the previously described maximum discharge and firm discharge.

The probable annual energy production of each proposed site was calculated by means of the inflow mass-curve for the site for 1960, the year of average annual stream flow discharge.

6-4-2 General Descriptions of Projects

The outlines of the projects based on the 10 selected sites are given in Table 6-7.

6-5 Comparisons of Project Sites

6-5-1 Method of Economic Evaluation

(1) Selection of Alternative Thermal Power Plant

1) The scale of the alternative thermal power plant is assumed to be approximately equivalent to the maximum capacity of the hydroelectric power station which can physically be developed in Liberia.

2) The location of the alternative thermal power plant is to be in the area adjacent to the City of Monrovia.

Table 6-7 Summary of Proposed Hydro-Electric Power Development Scheme

Item	Unit	MANO RIVER		LOFA RIVER		ST.PAUL RIVER	ST. JOHN RIVER			CESTOS RIVER	
		No. 1	No. 2	No. 1	No. 2	No. 1	No. 1	No. 2	No. 3	No. 1	No. 2
Type of Generation		Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type
Catchment Area	km^2	7,660	6,300	8,590	8,180	20,780	16,010	15,610	11,160	10,400	7,250
Annual Inflow	10^6m^3	8,606	7,077	8,467	8,061	15,832	15,640	15,250	10,902	4,834	3,347
Reservoir											
High Water Level	m	45	125	40	100	110	60	120	180	50	100
Water Surface Area	km^2	29	88	34	68	58	23	78	93	122	130
Effective Storage Capacity	10^6m^3	155	763	159	363	464	107	364	744	406	693
Available Drawdown	m	8	13	7	8	8	7	7	12	5	8
Dam											
Type		Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill
Height	m	30	45	25	30	28	25	25	40	20	30
Crest Length	m	500	360	400	400	950	600	450	350	500	1,700
Power Production											
Effective Head	m	21.8	35.0	17.3	21.8	18.3	17.3	17.3	29.9	18.0	25.0
Maximum Discharge	m^3/s	67	129	70	106	167	70	127	159	108	122
Installed Capacity	KW	12,000	37,000	10,000	19,000	25,000	10,000	18,000	39,000	16,000	25,000
Annual Energy Production	10^6KWh	98.5	292.5	83.2	154.5	*229.5	83.6	149.0	308.1	125.7	188.6
Transmission Line											
Length	km	50	80	15	40	30	20	30	70	100	120
Voltage	KV	110	110	110	110	110	110	110	110	110	110

Note: * includes an incremental energy production of 22.2×10^6KWh at Mt. Coffee Power Station.

Taking the above conditions into consideration, the alternative thermal power plant was assumed as being an oil-fired thermal power plant with an installed capacity of 50 MW, comprising 1 unit, constructed in the vicinity of Monrovia.

(2) Annual Costs of Alternative Thermal Power Plant

The annual costs of the said alternative thermal power plant, (the oil-fired thermal power plant) with an installed capacity of 50 MW can be divided into annual fixed costs and variable costs, as summed up in Table 6-8.

The benefit per KW of the hydroelectric power plant is assumed to be equivalent to the value obtained by multiplying the annual fixed costs per KW of the alternative thermal power plant by the KW adjustment factor.

The benefit per KWh of the hydroelectric power plant is assumed to be equivalent to the annual variable costs per KWh of the thermal power plant.

Consequently,

Annual benefit per KW: $91/KW

Annual benefit per KWh: 22 mills/KWh

Table 6-8 Alternative Steam Power Plant

Plant Capacity	50,000	(KW)
Plant Factor	70	(%)
Annual Energy Production	306.6	(Million KWh)
Station Service Use	5	(%)
Thermal Efficiency at Sending End	32	(%)
Construction Cost	37,500	(Thousand $)
Serviceable Life	34	(Years)
Interest	7	(%)
Annual Cost		(Thousand $)
Fixed Cost		
Amortization	2,918	
Operation and Maintenance	600	

Annual Salaries	30	
Adminstration Cost	60	
Sub-total	3,608	
Variable Cost		
Fuel Cost	6,592	
Operation and Maintenance	150	
Sub-total	6,742	
Total Cost	10,350	
Fixed Cost	76	($/KW)
Variable Cost	22	(Mills/ KWh)
Total Cost	34	(Mills/ KWh)

(3) Annual Costs of Hydroelectric Power Plant

The annual costs of the hydroelectric power plant are separated into the costs of power generating facilities and the costs of power transmission facilities, multiplying the respective construction costs by equalized cost factors corresponding to the respective serviceable lives. The annual cost factors are calculated according to the conditions given below and the details are shown in Table 6-9.

1) The discount rate is to be assumed as 7%.

2) The serviceable life of the power generating facilities is to be taken as 50 years since the construction cost of the dam constitutes a large proportion of the total construction cost. The serviceable life of power transmission facilities is to be 40 years as is commonly used.

Table 6-9 Annual Cost

Item	Generating Plant	Transmission Line
Serviceable Year	50 Years	40 Years
Annual Discount Rate	7.0 %	7.0 %
(1) Annual Cost Factor Amortization	7.25 %	7.50 %
(2) Operation and Maintenance	0.70 %	2.50 %
(3) Administration	0.30 %	0.30 %
Total	8.25 %	10.30 %

6-5-2 Comparisons of Project Sites

The main features of the project sites and their economics are compared in Table 6-10.

In order to regulate the entire stream flow discharge to be completely uniform throughout the year, although depending on the stream regime to an extent, a reservoir having a capacity of about the same size as the annual inflow at the site is necessary. In other words, a reservoir having a regulating efficiency of 100 percent would be required. However, at damsites in Liberia, because of the topographical characteristics, dams can be built no higher than 20 to 50 meters damming up to the limits permitted by the topography. Reservoirs thus formed will only have regulating efficiency of around 20 percent at the most.

Of the 10 sites selected by the Survey Team, the Mano River No. 2 and the St. John No. 3 sites are economically advantageous with relatively high heads available while storage capacities are large.

The project sites on the Lofa and St. Paul Rivers have relatively large inflows, but heads are low and storage capacities are small, and in addition, concessionaire-owned railroads and major highways would be inundated, so that the economics are somewhat poor.

The project site on the Cestos River would provide a large storage capacity due to its topographical features, but the head would be low and the inflow is small, while the access road and power transmission distance would be long so that the economics would be poor.

Table 6-10 Comparative Studies on Development Alternatives

Item		Unit	MANO RIVER		LOFA RIVER		ST.PAUL RIVER	ST. JOHN RIVER			CESTOS RIVER	
			No. 1	No. 2	No. 1	No. 2	No. 1	No. 1	No. 2	No. 3	No. 1	No. 2
Maximum Output		MW	12	37	10	19	25	10	18	39	16	25
Dependable Power		MW	8.5	28.0	7.6	14.1	19.3	7.5	13.9	29.4	12.1	18.0
Annual Energy Production		10^6kWh	98.5	292.5	83.2	154.5	*229.5	83.6	149.0	308.1	125.7	188.6
Utilization Ratio of River Run-Off		%	23.0	51.9	24.9	38.6	31.4	13.6	24.8	41.5	63.4	99.0
Regulation Ratio		%	1.8	10.8	1.9	4.5	2.9	0.7	2.4	6.8	8.4	20.7
Plant Factor		%	93.7	90.2	95.0	92.8	94.7	95.4	94.5	90.2	89.7	86.1
Construction Costs	Generating Facility	$10^3$$	43,000	90,200	41,200	67,500	95,700	61,400	56,400	102,400	61,200	108,400
	Transmission Facility	"	1,100	1,600	230	600	600	400	600	1,400	2,000	2,400
	Total	"	44,100	91,800	41,430	68,100	96,300	61,800	57,000	103,800	63,200	110,800
	Construction Cost/kW	$	3,680	2,480	4,140	3,580	3,852	6,180	3,170	2,660	3,950	4,430
	Construction Cost/kWh	$	0.448	0.314	0.498	0.441	0.420	0.739	0.383	0.337	0.503	0.587
Project Economics	Net Benefit(B-C)	$10^3$$	-540	1,800	-800	-720	-243	-2,480	0	1,300	-1,200	-3,000
	Benefit/ Cost Ratio (B/C)		0.85	1.23	0.77	0.87	0.97	0.52	1.00	1.15	0.77	0.67

Note: (1) Utilization Ratio of River Run-off = Annual Discharge/Annual Inflow x 100 (%)

(2) Regulation Ratio = Effective Storage Capacity/Annual Inflow x 100 (%)

(3) Plant Factor = Annual Energy Production/8,760 x Maximum Output x 100 (%)

* includes an incremental energy production of 22.2 x 10^6KWh at Mt. Coffee Power Station.

6-6 Power Development Scales of Project Sites

6-6-1 Examination of Installed Capacities

Examinations were made for increasing installed capacities to effectively utilize stream flow discharges in the rainy season with regard to the Mano River No. 2 and St. John River No. 3 sites found in the preceding paragraph to be economically advantageous compared with the other sites. The results are summed up in Table 6-11 and Fig. 6-17 for the Mano River No. 2 site and in Table 6-12 and Fig. 6-18 for the St. John River No. 3 site.

As easily seen from Figs. 6-17 and 6-18, the optimal scale of the Mano River No. 2 Site and St. John River No. 3 Site would be approximately 74 MW and 52 MW, respectively in order to enable net benefits (B-C) of these sites to be maximized.

In the future, when more peak supply becomes required in the power system it will be possible for the Mano River No. 2 Project to be brought on load for peak duration time bands of 9 hours and the St. John River No. 3 Project for peak duration time bands of 13 hours, which will further improve the economics of these projects.

Table 6-11 Studies on Scale of Mano No. 2 Power Project

Item		Unit		Remarks
Effective Head		m	35	
Maximum Discharge		m^3/s	257	
Maximum Output		KW	74,000	
Annual Energy Production		10^6 KWh	439.4	
Utilization Ratio of River Run-off		%	73	
Regulation Raio		%	10.8	
Plant Factor		%	68	
Construction Cost	Generating Facility	10^3 $	119,500	
	Transmission Facility	"	1,600	L=80km 110 KV
	Total	10^3 $	121,100	
	Construction Cost/KW	$	1,640	
	Construction Cost/KWh	$	0.276	
Project Economics	Net Benefit (B-C)	10^3	2,430	
	Benefit/Cost Ratio (B/C)		1.26	

Figure 6-17 Study on Installed Capacity of Mano No.2 Power Station

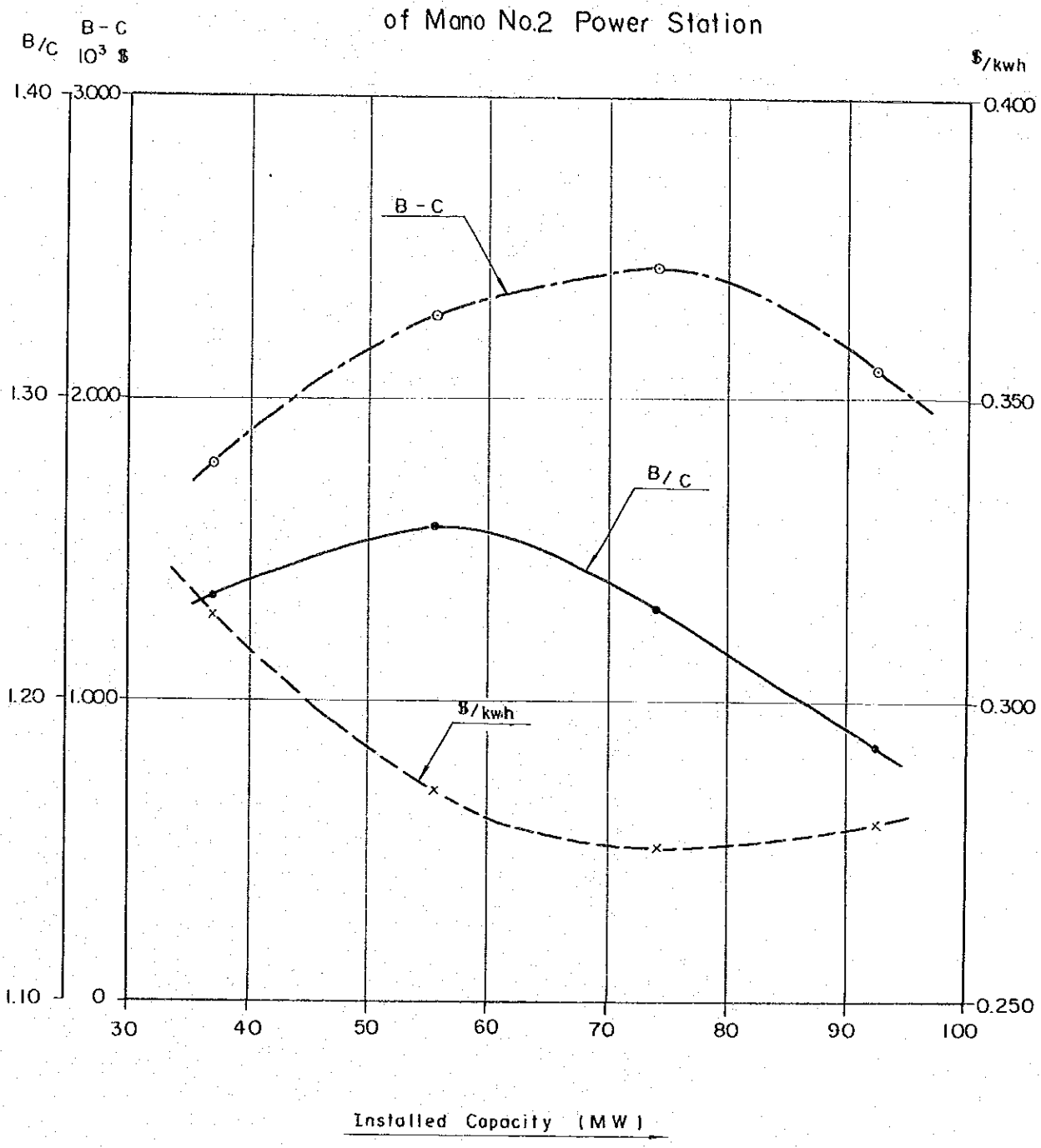
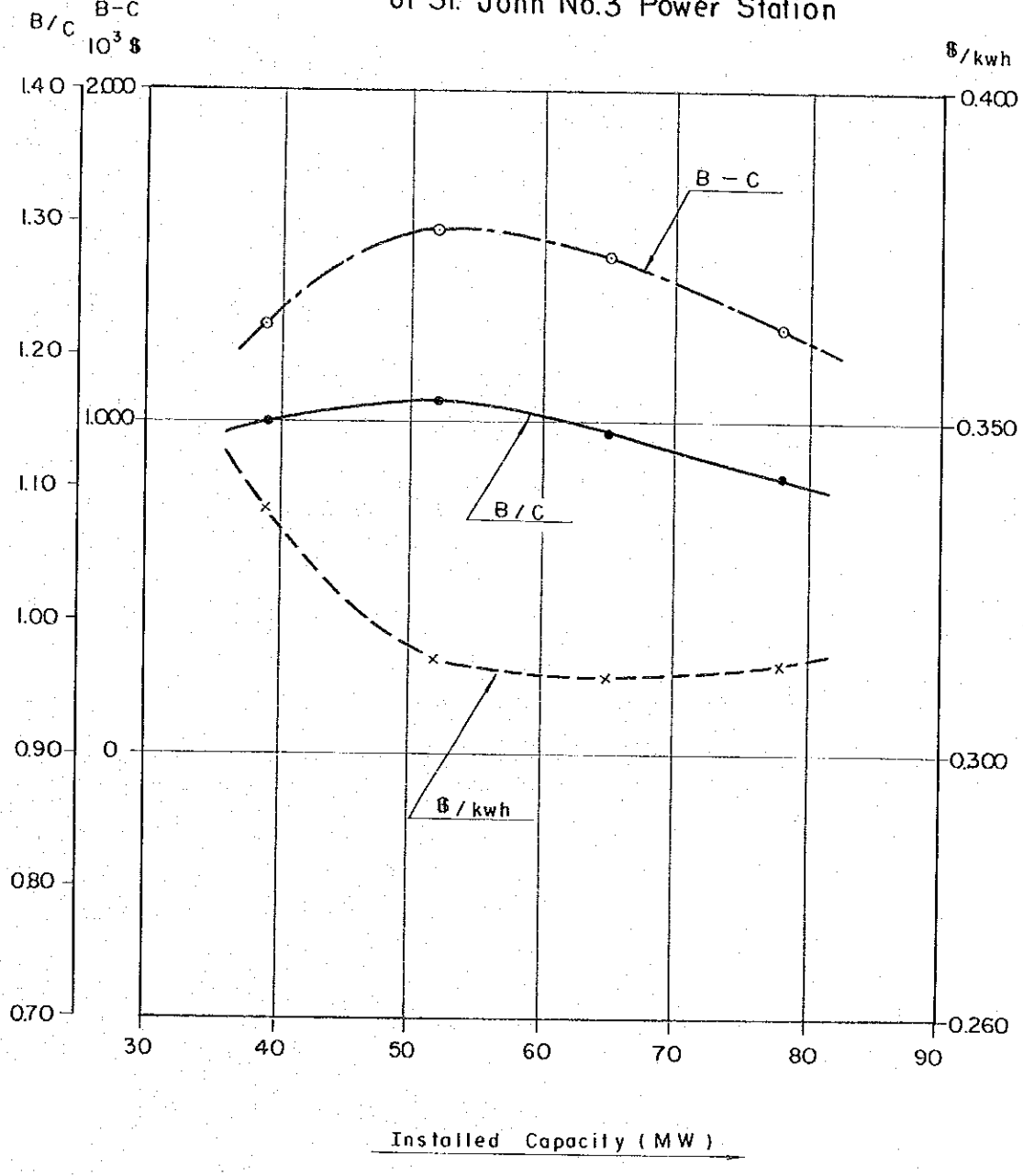


Table 6-12 Studies on Scale of St. John No. 3 Project

Item		Unit		Remarks
Effective Head		m	29.9	
Maximum Discharge		m^3/s	212	
Maximum Output		KW	52,000	
Annual Energy Production		10^6KWh	367.4	
Utilization Raio of River Run-off		%	50	
Regulation Ratio		%	6.8	
Plant Factor		%	81	
Construction Cost	Generating Facility	10^3\$	114,000	
	Transmission Facility	"	1,400	L=70km 110KV
	Total	"	115,400	
	Construction Cost/KW	\$	2,200	
	Construction Cost/KWh	\$	0.314	
Project Economics	Net Benefit (B-C)	10^3\$	1,600	
	Benefit/Cost Ratio (B-C)		1.17	

Figure 6-18 Study on Installed Capacity of St. John No.3 Power Station



6-6-2 Hydroelectric Power Development on Mano and St. John Rivers

In general, in series development of a river, a power station with a large capacity reservoir is planned on the upstream part of the river and the stream flow discharge regulated by this reservoir is taken in by power stations planned in succession downstream.

The scales in case of series development of the Mano and St. John Rivers which were found to be economical were therefore studied.

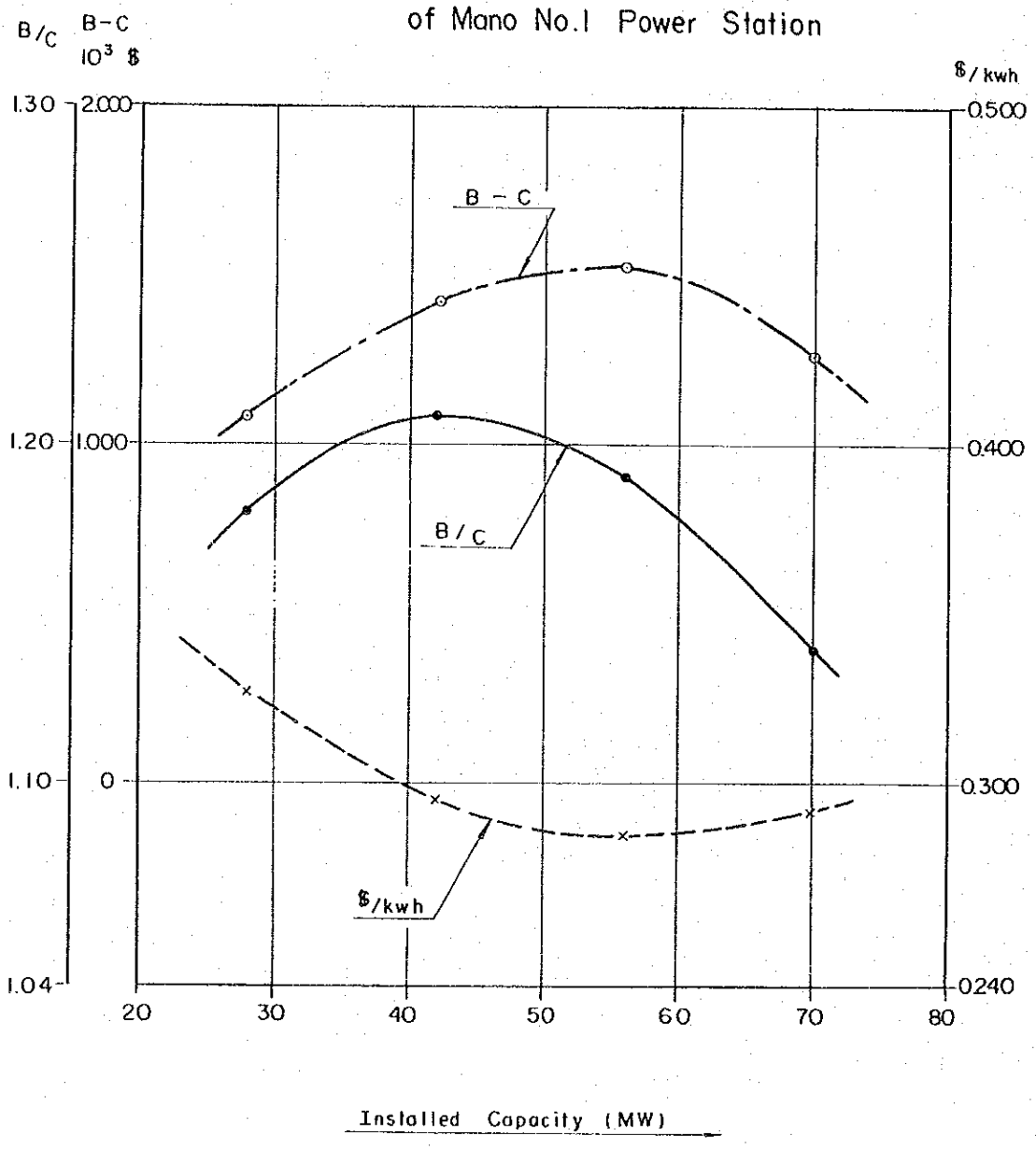
(1) Development of Mano River

The Mano River No. 1 site is a damsite downstream of the No. 2 site studied with respect to installed capacity in the preceding paragraph. As a result of examination of the development scale for the No. 1 site varying the maximum available discharge taking into account the regulating effect of the upstream No. 2 site, it would be economically advantageous and net benefit (B-C) would be a maximum at a scale of 56 MW for the No. 1 site as shown in Fig. 6-19. Therefore, added to the optimum scale for the No. 2 site of 74 MW, it is possible for a total of 130 MW to be developed on the Mano River. The outline of this project is given in Table 6-13. The project layout is shown in Fig. 6-20.

Table 6-13 Studies on Scale of Mano River Project

Item		Unit	No. 2 P.S.	No. 1 P.S.	Total
Maximum Discharge		m^3/s	257	313	
Maximum Output		KW	74,000	56,000	130,000
Annual Energy Production		10^6KWh	439.4	333.8	773.2
Utilization Raio of River Run-off		%	73	78	
Regulation Ratio		%	10.8	1.8	
Plant Factor		%	68	68	
Construction Cost	Generating Facility	$10^3$$	119,500	94,200	213,700
	Transmission Facility	"	500	1,650	2,150
	Total	"	120,000	95,850	215,850
	Construction Cost/KW	$	1,620	1,710	1,660
	Construction Cost/KWh	$	0.273	0.296	0.279
Project Economics	Net Benefit (B-C)	$10^3$$	2,500	1,500	4,000
	Benefit/Cost Ratio (B-C)		1.26	1.19	1.23

Figure 6-19 Study on Installed Capacity of Mano No.1 Power Station



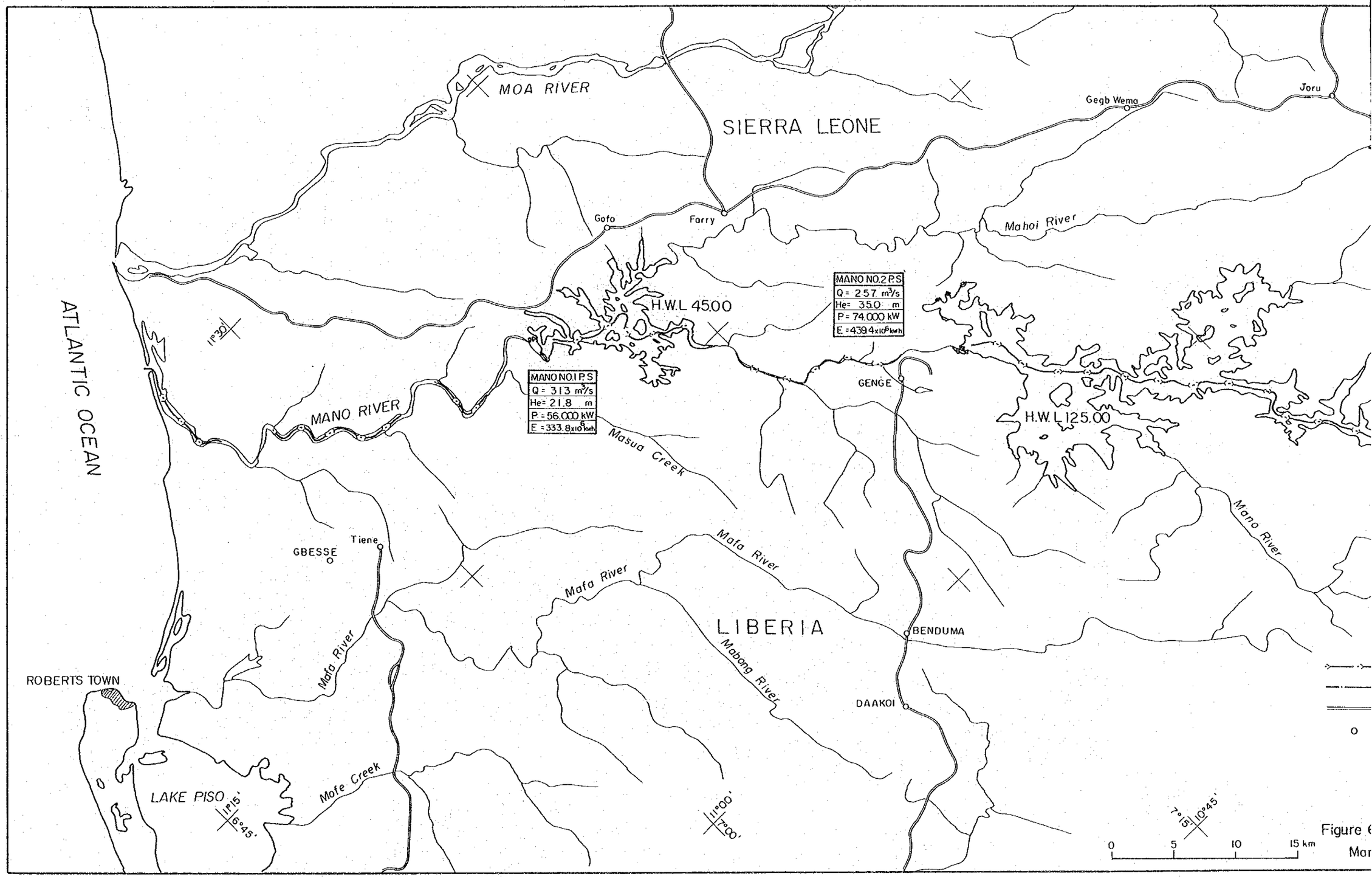

MOA RIVER
SIERRA LEONE
Gegb Wema
Joru
Goto
Farry
Mahoi River
H.W.L 45.00
MANO NO.2 P.S
Q = 257 m³/s
He = 35.0 m
P = 74.000 kW
E = 439.4x10⁶kwh
MANO NO.1 P.S
Q = 313 m³/s
He = 21.8 m
P = 56.000 kW
E = 333.8x10⁶kwh
GENGE
H.W.L 125.00
ATLANTIC OCEAN
11°30'
MANO RIVER
Masua Creek
Mano River
GBESSE
Tiene
Mafa River
Mafa River
Mafa River
LIBERIA
BENDUMA
Mabang River
DAAKOI
ROBERTS TOWN
LAKE PISO
1°15'
6°45'
Mofe Creek
11°00'
7°00'
7°15'
10°45'
0
5
10
15 km

Figure 6
Mar

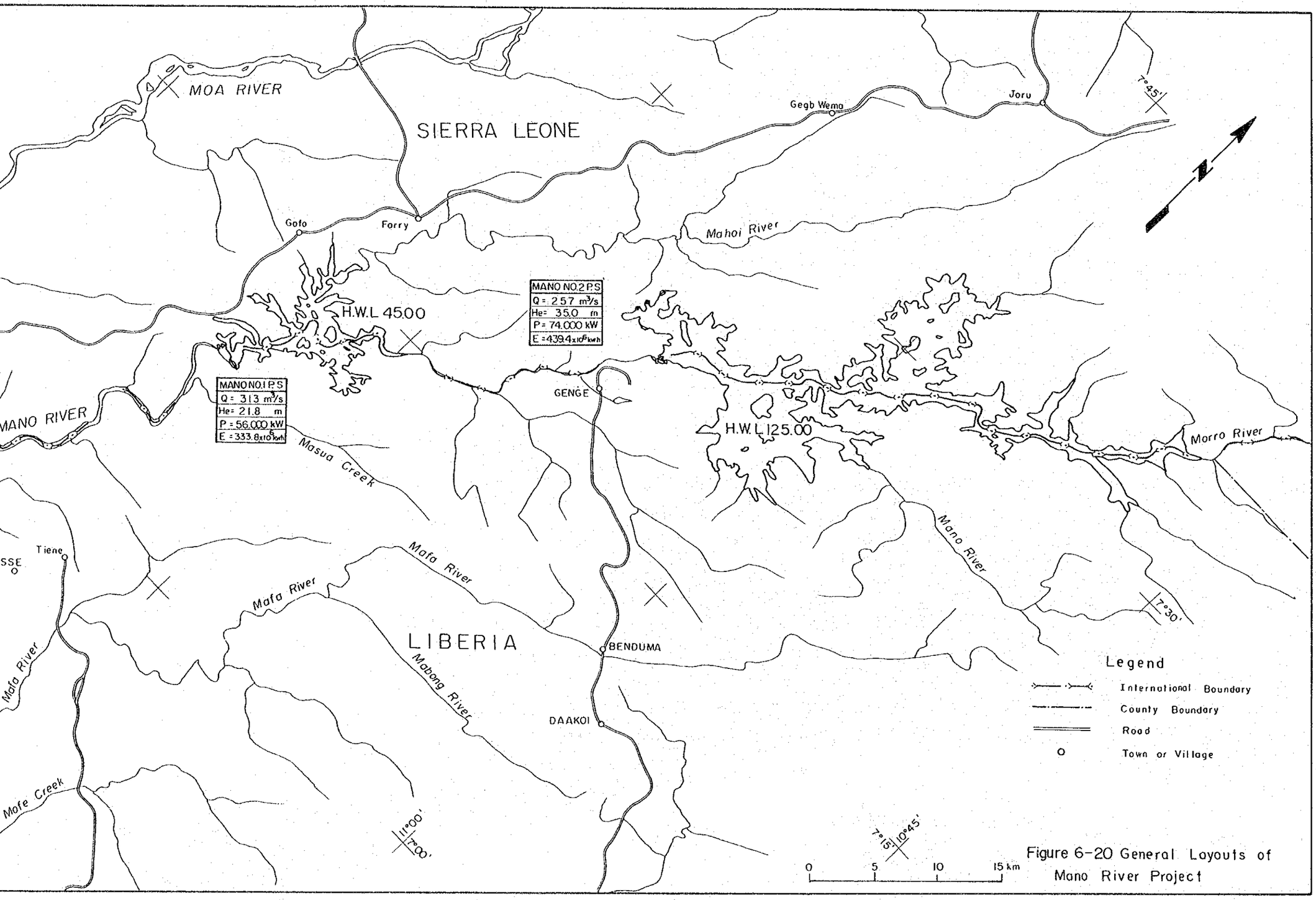


Figure 6-20 General Layouts of Mano River Project

(2) Development of St. John River

Two damsites, the No. 1 and No. 2 sites, can be considered downstream of the No. 3 site on the St. John River. However, for the No. 1 site, as a result of examination for independent development in 6-5-2, the benefit-cost ratio (B/C) was found to be low at 0.52 and even if the regulating effect of the reservoir at the No. 3 site were to be considered in determining the installed capacity, there would be no possibility of B/C becoming more than 1, and therefore, the No. 1 site was eliminated from the study.

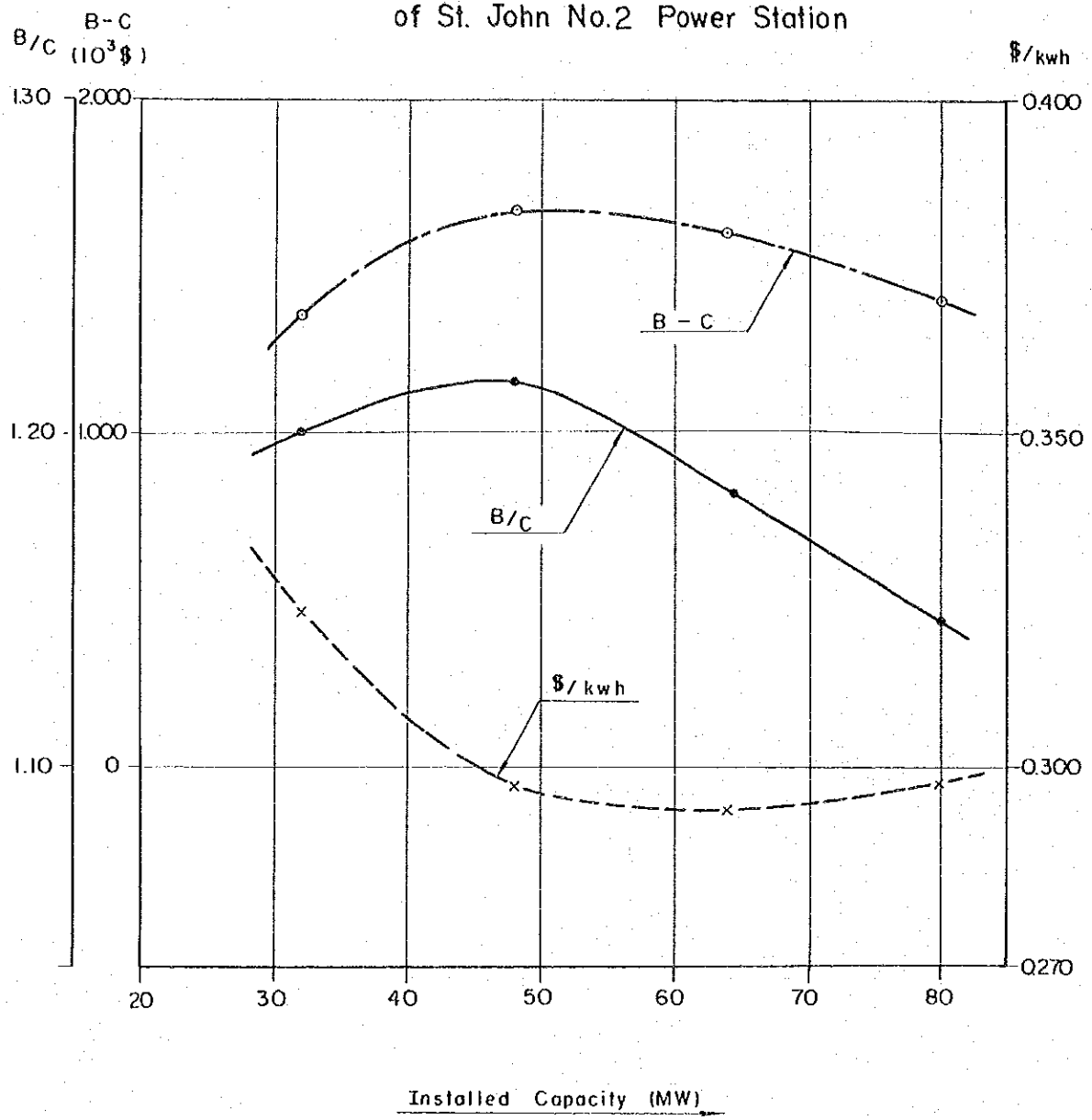
Consequently, an examination of installed capacity was made for the No. 2 site considering the regulating capacity of the reservoir at the No. 3 site as in the case of the Mano River and the resulting optimum development scale was 48 MW (see Fig. 6-21).

Therefore, together with the optimum development scale of 52 MW for the No. 3 site, the development scale for the St. John River would be 100 MW. The outline of the project is given in Table 6-14. The project layout is shown in Fig. 6-22.

Table 6-14 Studies on Scale of St. John River Project

Item		Unit	No. 3 P.S.	No. 2 P.S.	Total
Maximum Discharge		m^3/s	212	339	
Maximum Output		KW	52,000	48,000	100,000
Annual Energy Production		10^6 KWh	367.4	316.1	683.5
Utilization Raio of River Run-off		%	50	53	
Regulation Ratio		%	6.8	2.4	
Plant Factor		%	81	75	
Construction Cost	Generating Facility	10^3 $	114,000	93,000	207,000
	Transmission Facility	"	800	900	1,700
	Total	"	114,800	93,900	208,700
	Construction Cost/KW	$	2,210	1,960	2,087
	Construction Cost/KWh	$	0.312	0.297	0.305
Project Economics	Net Benefit (B-C)	10^3 $	1,660	1,640	3,300
	Benefit/Cost Ratio (B/C)		1.17	1.22	1.19

Figure 6-21 Study on Installed Capacity of St. John No.2 Power Station



ATLANTIC OCEAN

10°15'
6°00'

Mechlin River

ST. JOHN No.2 P.S
Q = 33.9 m³/s
He = 17.3 m
P = 48.000 kW
E = 316.1x10⁶ kwh

Badawin

H.W.L 120.00

Wiaya Creek

BONG COUNTY
GRAND BASSA COUNTY

Zo Creek

ST. JOHN No.3 P.S
Q = 21.2 m³/s
He = 29.9 m
P = 52.000 kW
E = 367.4x10⁶ kwh

Geho Town

Andrewbli

H.W.L 180.00

ST. JOHN RIVER

MOUNT FINLEY
466

LIBERIAN AMERICAN MINING COMPANY

BUCHANAN

Wabehen

Bogli

Sio River

10°00'
5°45'

New Cess River

9°45'
6°00'

9°30'
6°15'

Timbo River

Timbo River

0 5 10

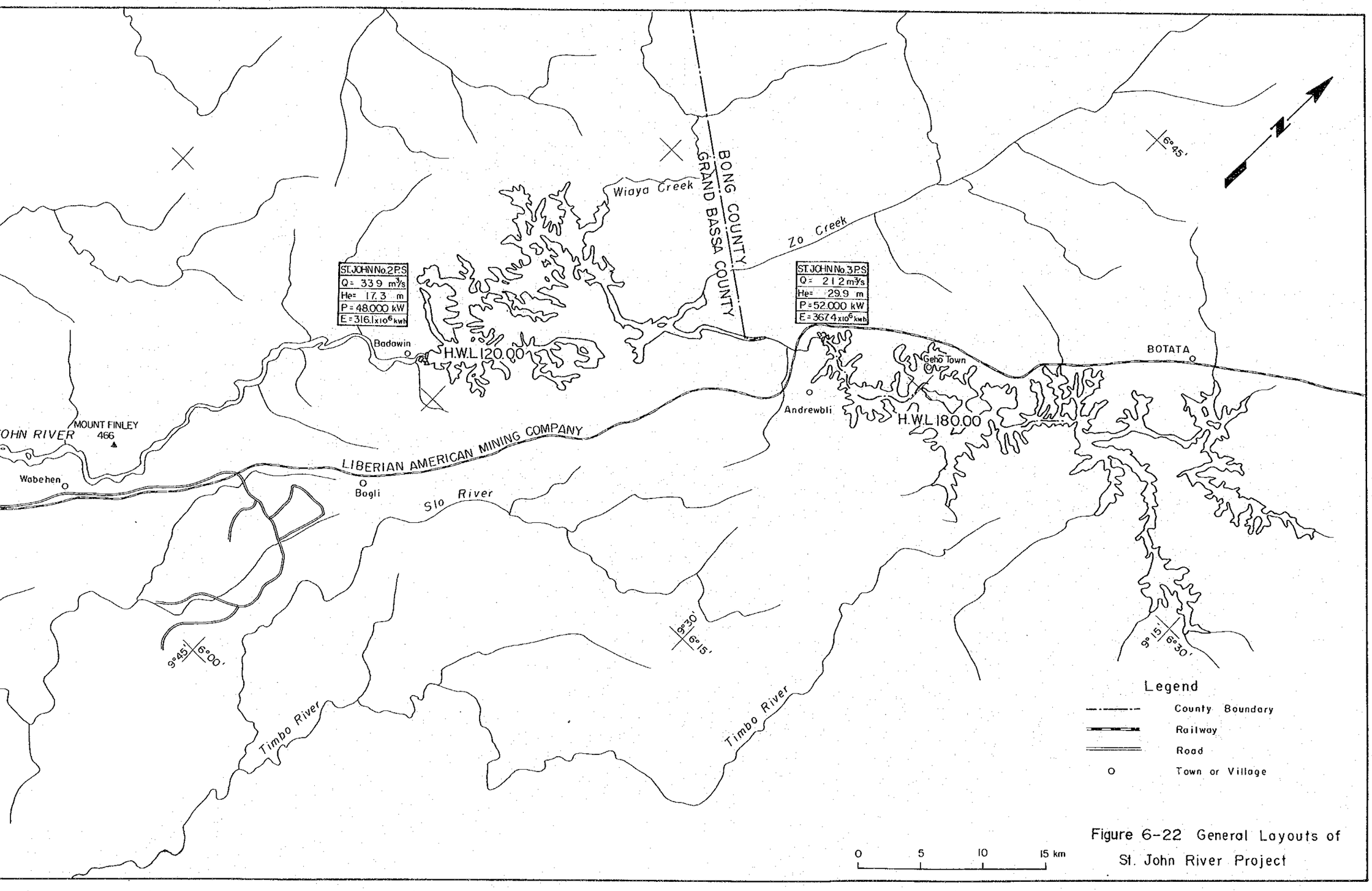


Figure 6-22 General Layouts of St. John River Project

6-7 Summary

The following conclusions were arrived at as a result of various studies on hydroelectric sites in the Republic of Liberia selected by the Survey Team taking into consideration information obtained in the field investigations, topographical conditions and hydrological phenomena.

(1) Of the 10 hydroelectric power development project sites selected by the Survey Team, the sites which when developed independently, show B/C ratios of more than 1 are the No. 2 site on the Mano River and the No. 3 and No. 2 sites on the St. John River. The said dam sites are located in places where relatively high dams for Liberia can be built and large storage capacities will be obtained and the annual inflows are also comparatively large.

(2) The optimum development scales for the Mano River No. 2 and St. John River No. 3 sites are 74 MW and 52 MW, respectively.

(3) When the No. 1 site on the Mano River is developed utilizing the river water regulated by the reservoir at the No. 2 site, the economics of the No. 1 site will be improved with its development scale becoming 56 MW and development of a total of 130 MW together with the No. 2 site will be made possible.

(4) When the No. 2 site on the St. John River is developed utilizing the river water regulated by the reservoir at the No. 3 site, the economics of the No. 2 site will be improved with its development scale becoming 48 MW and development of a total of 100 MW together with the No. 3 site will be made possible.

(5) Hydroelectric power development of the Mano River would be the most economical, but it is an international river flowing along the border with Sierra Leone, and in order to proceed with this project it will be necessary for diplomatic arrangements to be made with Sierra Leone.

(6) On the other hand, although hydroelectric power development of the St. John River would be slightly poorer in economics than in the case of the Mano River, the implementation of any projects on the St. John River will be free from any international restrictions.

(7) Project sites on both the Mano and St. John Rivers are judged to be economical. However, the present study was made based on an extremely brief field investigation and with very rough basic information such as 1/50,000- and 1/250,000-scale topographical maps to examine the possibility of hydroelectric power development in Liberia from a broad point of view. Consequently, the technical and economic feasibilities should be examined by conducting detailed studies such as field reconnaissances, topographical surveys and hydrological investigations.

6-8 Items for Future Investigation

Which of the two, the Mano River Project and the St. John River Project, to be taken up is a matter for the Government of the Republic of Liberia to decide. In this regard, it will be essential that a feasibility study incorporating the following items be performed in connection with the project that will be decided by the said Government as soon as possible.

(1) Hydrological Surveys

Hydrological data comprise important basic information for project planning in hydroelectric development, and therefore, gaging stations on the Mano and St. John Rivers should be fully provided and efforts made to gather accurate data.

(2) Topographical Surveys

Aerial photogrammetric maps on a scale of 1/10,000 with a contour line interval of 5m should be prepared for the project areas including reservoir areas.

(3) Geological and Materials Surveys

Geological surveys of the project areas and investigations of materials in respect of their quality and quantity for dams and related structures should be performed by specialists.

(4) Sedimentation Studies

It is essential that necessary sedimentation studies be conducted on the reservoirs.

APPENDIX

APPENDIX

A-1 PRECIPITATION

Precipitation STATION Belleyella CATCHMENT AREA sq.km

RIVER, IN THE BASIN OF ELEVATION m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952			237	295		555	155	132	37	24	64	53	
1953	314	271	378	260	378	261	296	66	0	20	97	148	2,495
1954	240	226		187	291	449	434	265	44		91	293	
1955	113	120			447	312	287	39			50	132	
1956	201	151	198		237	372	259	86		4			
1957		264	305	366	393		322				63	69	
1958	303	171	132		124		176				53	155	
1959	94	254	154				117	196	2	23	26	160	
1960	94	142	125	65	512	261	154	138	42	0		76	
1961	356				631								
1962													
1963													
1964		453	413		933		256	109			179	381	
1965						381	15						
1966		224	308	2	5								
1967													
1968							313	217	50	3	41	83	
1969	143	178		343	281						15	106	
1970	214	214	164				155	149					

Precipitation STATION Bopolu CATCHMENT AREA sq.km

RIVER, IN THE BASIN OF ELEVATION m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952		268	307	370	670	813	273	79	34	18		160	
1953	166	138	346	462	546	374	370	70	66	59	102	169	2,868
1954	244	161	187	316	295	501	264	330	26	2	50	115	2,491
1955	97	224	271	404	587	407	430	48	1	0		51	
1956	118	349	280	341	295	400	178	102	182	24	0	88	2,357
1957	137	118	253	259	268	319	469	273	71	77	31	105	2,380
1958	165	252	75	128	114	661	282	264	6	0	66	196	2,209
1959	327	59	66	220	441	592				0	21	210	
1960	173	185	381	208	104	417	431	843	55	23	45	137	3,002
1961	179	196	223	312	406	508	324	166	55	29	41	155	2,594
1962	327	360	408		573	836							
1963												135	
1964	206	100	333	560		491	387	151		48	46	30	
1965	80	367	261	598	547	886	153	117					

Precipitation STATION Kolahun CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952								59	5	18		93	
1953	230	213	321	269	356	447	308	149	185	10	82	247	2,817
1954	100		240	15	318	671		302	61	15	48	179	
1955	105	202	317	395	635	660	559	152	132	0	10	46	3,214
1956	36	196	335	384	438	418	238	328	87	5	1	97	2,563
1957		231	483	432	306	646	399	326	39	1	32	188	
1958	169	215	348			669	430	465	27	25	24		
1959	112	233	240	404	237	578		307	102	24	6	31	
1960	125	195	167	343	189		226	0	80			52	
1961	216	226	165		244	246	125	123	21	1			
1962		240		372	426	455							
1963													
1964													
1965		194	297	181	375	364	281	219			72	131	
1966	85					215		85	9			64	
1967	70		426	440	278	410	495	125	4	14		111	
1968					363		466	402	78	12	58	140	
1969	211	293		558	487					13	18	57	
1970	137	394	435	156	294	283	173	155					

Precipitation STATION Salayea CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1967		381		217	214	56	54	45	15			115	
1968	309		369		360		279	150	247	12			
1969	195				407								

Precipitation STATION Voinjama CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952								96	32	16	104	195	
1953	174	211	449	286	410		120	179	40	3	50	128	
1954	133	159	300	256	295	401	364	311	70	31	38	145	2,503
1955	123	125	352	195	471	216	330	59	89	0	104	239	2,303
1956	147	124	211	420	243	386	201	221	90	6	3	160	2,232
1957	227	402	466	935	463	406	419	431	5	90	127	289	4,260
1958	481	328	463	325	399	853	453	723		0	0	11	
1959	274	460	434	662	319	456	364	135	157	0	0	167	3,428
1960	144	230	439	288	635	508	322	167	69		10	54	
1961		178	131	407			184	89		0	68	39	
1962	157	206	343	542	587	428	197	352			123		
1963			367	267		240	382	230	17			152	
1964	104	154			497	485	76	170		18	46	166	
1965		194	163	244	445	322	153					64	
1966	47	114	176	408	328	326	225	53	6		6	29	
1967	86	219	407	449		388	381	66				26	
1968	227		382		512			246	36	4	14	62	
1969	159	80		350						39	12	104	
1970	54	201	115	236	417	241	89	200	11				

Precipitation STATION Zorzor CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1954										42	42	159	
1955	170	199	200		597	414	152	12	53		50	151	
1956	245	46	182	137	117	672	333	155	5	9	71	119	2,091
1957	239	104	264	331	359	376	338	104	94	68	52	109	2,438
1958	283	114	221	117	232	466	247	264	47	28		87	
1959	97	228	101	273	242	257	481	131	3	26	28	130	1,997
1960	149	78	146	132	241	450	310	133	40		58	118	
1961	133												

Precipitation STATION Zuie (201) CATCHMENT AREA ____ sq.km

____ RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952						467	373	152	17	46	30	130	
1953	248	207	341	205	446	536	314	116	13	28	28	13	2,495
1954	94	98	200	213		470	363	93	93	12	41	171	
1955	21	188	434	396	479	407	434		33	40	421	86	
1956	211	122	380	455	519	547	248	175	74	7	0	79	2,817
1957	114	220	510	704		1,071	321	268	165	32	16	148	
1958	197	267	198	173	465				20			13	
1959	23	140	173	230	198	433				0	0		
1960							188	187	176	37	105	319	
1961	460	502	705	608									

Precipitation STATION Robertsport CATCHMENT AREA ____ sq.km

____ RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951												71	
1952	35		849	996	1,433	1,133	356	135	48	47	75	58	
1953	225	607	1,312	1,296	559	899	473	135	123	17	76	123	5,845
1954	240	463	648	608	262	854	514	258	48	30	32	191	4,148
1955	272	240	1,073	1,084	659	614	533	57	262	3	18	42	4,857
1956	154	544	956	1,197	194	545	298	265	244	7	17	34	4,454
1957	27	290	735	978	773	812	872	325	178	121	44	124	5,281
1958	299	779	852	240	380				61	25	153	101	
1954	69	204	888	1,341	241		232	146		23	8	181	
1960	165	373	914	764	563	131	316	114	142	38	0	83	3,603
1961	68	227	939	1,323	677	621	262	60	0	41	25	11	4,254
1962	180	305	769	892	382	762	259	480	3	58	33	42	4,165
1963		237	538	771	968	686	104	260	31	3	0	26	
1964	3	294	732	1,061	334	1,069	250	264		2		45	
1965	132	307	781	1,064	715	781	851	165	7	1	16	75	
1966	217	289	596	1,106	1,050	565	822	142	111		1		
1967	148	93	1,097	1,109	679	995	565	217	25	3		103	
1968	115		598		1,196		426	275	105		9	47	
1969	281	772		1,390	592					6		25	
1970	99	334	816	619	507	599	363	79	21				

Precipitation STATION Blazie CATCHMENT AREA ____ sq.km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT ____ S ____ W ____

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958								94	48	0	84	58	
1959	21	357	191	195	189	448	171	126	48	0	22	27	1,795

Precipitation STATION Bongmines CATCHMENT AREA ____ sq.km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT ____ S ____ W ____

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1962										28	138	88	
1963	156	115	464	413	589	580	401	110	20	7	11	114	
1964		1,374									51	592	
1965			318	517	382	427	330	177					
1966		168	345			360	413						
1967													
1968			1,250		1,161		249	210	167	15	43	216	
1969	159	194		320	360								

Precipitation STATION Salala CATCHMENT AREA ____ sq.km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951							597	124		0	50	21	
1952	189	356	42	98	299	214	42	14				52	
1953	179	183	272	554	540	450	144	134	56	28	61	191	2,792
1954	192	205	171	288	191	407	393	189	0	0	91	150	2,277
1955	146	199	284	465	357	520	538	70	119	14	68	266	3,046
1956	133	220	391	160	112	495	262	84	85	61	32	130	2,163
1957	185	200	242	343	321	556	396	98	100	49	28	211	2,729
1958	133	84	140	129	287	378	299		65	1	40	99	
1959	113	201	282	316	227								
1960							229	85	94				
1961			177		241	487	248	162	90	246	249		

Precipitation STATION Suskoko CATCHMENT AREA ____ sq.km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951				204	25		474			15		159	
1952		207	309	138	222	442	259	95	23	11	68	74	
1953	241	241	87	270	138	237	178	44	18	43	76	277	1,850
1954	159	148	125	79	-	346	274	191	24	24	99	179	
1955	72	142	393	327	235	361	301	92	13	28	125	118	2,207
1956	273	217	233	87	93	356	196	70	104	10	19	113	1,771
1957	207	217	177	227	270	496	162	-	23	38	-	116	
1958	194	168	94	18	74	325	248	161	40	3	106	235	1,660
1959	193	360	200	275	-	361	277	82	1	9	15	248	
1960	145	268	263	144	398	431	227	79	82	0	7	8	2,052
1961	80	35	22	253	74	337	120	62	1	8	122	63	1,177
1962	135	179	280	168	272	291	130	-	0	-	287	144	
1963	-	180	211	170	197	112	-	-	-	1	0	0	
1964	-	-	-	62	-	123	81	-	-	10	26	40	
1965	100	137	198	-	-	135	8	-	-	-	-	-	
1966	-	108	-	109	-	-	199	202	-	-	24	-	
1967	114	74	124	98	154	201	130	-	-	-	-	-	
1968	-	-	-	-	-	-	-	-	-	-	-	-	
1969	-	-	-	-	-	-	-	-	-	-	10	36	
1970	117	201	165	70	128	262	48	137	11	-	-	-	

Precipitation STATION Totota CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ ' W ____ ° ____ '

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1955										10	71	290	
1956	160	168	358	102	162	327	225	73	150	42	38	164	1,969
1957	158	189	183	327	332	495	382	157	123	64	7	200	2,617
1958	133	98	147	113	129	652	183	-	-	-	-	-	

Precipitation STATION Bomi Hills CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ ' W ____ ° ____ '

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951						400	550	309	10	0	42	106	
1952	160	216	430	528	747	550	-	155	21	3	70	103	
1953	212	343	679	629	478	662	-	-	-	-	111	146	
1954	219	220	377	319	303	770	270	297	105	28	51	245	3,204
1955	110	217	646	346	743	705	411	158	86	27	16	158	3,623
1956	153	286	359	321	348	722	351	127	191	28	34	149	3,069
1957	154	308	277	536	416	699	177	263	77	45	82	188	3,222
1958	198	329	167	234	-	-	-	-	-	-	-	-	
1959	-	-	-	-	-	-	-	-	-	-	-	-	
1960	-	-	-	-	-	-	-	-	-	-	-	-	
1961	-	-	-	-	-	-	-	-	-	-	-	-	
1962	-	-	-	-	-	-	-	-	-	-	-	-	
1963	-	-	-	-	-	-	-	-	-	-	-	-	
1964	-	-	-	-	-	-	-	-	-	-	-	-	
1965	-	-	-	-	-	-	-	-	-	-	-	-	
1966	-	-	-	-	-	-	-	-	-	-	278	64	
1967	218	118	-	1,072	463	-	311	2,536	104	-	-	212	
1968	388	-	-	-	2,470	-	367	219	42	1	68	71	
1969	266	-	-	-	-	-	-	-	-	-	30	106	
1970	180	377	269	138	393	55	182	120	-	-	-	-	

Precipitation STATION Goodrich CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1955	118									10	126	165	
1956	107	385	468	308	236	760	353	105	169	20	4	61	
1957	-	-	-	593	-	707	614	-	16	-	68	218	
1958	152	173	107	155	335	784	419	179	-	33	-	78	
1959	98	175	322	1,066	214	939	278	183	-	26	21	134	
1966	136	194	679	532	686	560	389	75	61	6	0	100	3,418
1961	225	169	467	659	774	703	248	-	22	76	41	106	
1962	248	205	597	563	478	598	205	275	47	54	64	73	
1963	140	116	322	747	649	703	-	73	42	-	-	61	
1964	20	224	452	301	496	525	212	73	-	-	17	-	
1965	157	97	286		649	472	289	107	-	-	28	42	
1966	189	232	465	445	1,422	669	552	224	30	30	2	-	
1967	212	136	428	593	558	695	380	82	67	-	-	58	
1968	205	-	-	-	-	-	-	-	53	-	13	-	
1969	193	-	-	1,070	1,134	-	-	-	-	-	-	-	
1970	102	-	273	159	451	545	-	138	9	-	-	-	
1971	-	-	-	-	-	-	-	-	-	-	-	-	

Precipitation STATION Harbel CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1936	204	296	449	236	412	706	319	325	160	1	92	33	3,233
1937	108	243	278	464	388	594	434	198	89	0	3	179	2,978
1938	218	341	301	339	404	618	524	145	53	7	100	208	3,258
1939	102	466	494	532	515	424	578	160	145	74	13	116	3,619
1940	151	211	345	454	682	544	416	220	67	23	9	58	3,180
1941	185	410	440	253	684	557	147	129	45	53	37	84	3,024
1942	122	241	265	611	391	599	344	209	39	57	61	91	3,030
1943	203	264	436	123	550	754	330	235	92	19	7	233	3,246
1944	76	150	518	764	495	805	318	147	135	43	52	109	3,612
1945	162	199	369	432	350	421	456	169	30	27	9	169	2,793
1946	249	342	369	253	411	619	556	138	52	2	37	84	3,112
1947	206	256	644	538	910	716	288	135	139	1	16	85	3,934
1948	153	225	255	369	291	612	252	235	23	8	53	113	2,589
1949	142	407	375	485	731	537	288	257	47	21	9	88	3,387
1950	128	98	423	420	321	670	337	158	47	64	126	73	2,865
1951	73	400	342	347	524	768	538	252	45	7	61	131	3,488
1952	142	366	521	587	596	600	319	166	60	24	50	132	3,563
1953	194	419	620	1,203	596	628	290	120	37	48	104	201	4,460
1954	211	133	319	279	205	691	407	219	80	24	141	364	3,073
1955	213	221	457	540	436	656	490	144	163	53	84	202	3,659
1956	218	295	507	179	192	453	385	118	99	86	20	106	2,658
1957	180	210	407	563	546	657	646	137	143	52	69	125	3,735
1958	145	129	138	167	361	510	245	252	128	37	110	210	2,432
1959	107	425	285	777	210	709	287	298	87	28	47	123	3,383
1960	127	251	681	204	565	673	420	136	88	18	71	154	3,388
1961	157	292	387	797	231	543	432	212	24	139	-	-	
1962	-	-	-	-	-	-	-	-	-	-	-	-	
1963	-	-	-	-	-	-	-	-	-	-	14	53	
1964	-	-	-	1,038	1,568	-	2,206	-	-	-	-	-	

Precipitation STATION Kle CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1954			352		283	671	380	264		8	71	181	
1955	232	331	537	494	790	753	471	71	55	4	110	140	3,988
1956	124	280	488	363	460	684	392	217	235	15		92	
1957	98	239	320	678	453	924	479	85	128	41	80	103	3,628
1958	124	216	221	328	282	832	461	161	55				

Precipitation STATION Monrovia CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1944								241	53	26	6	39	
1945	109	373	1,003	475	117	467	404	191	77	6	5	66	3,293
1946	130	556	767	536	272	826	1,052	157	17	19	20	103	4,455
1947	234												
1948													
1949													
1950			1,114	523	241	722	331	124	108	85	75	48	
1951	201	328	948	757	324	833	561	296	23	71	69	96	4,777
1952	178	427	1,077	1,179	1,227	922	523	326	60	46	39	45	6,017
1953	161	686	1,067	1,356	712	697	757	254	91	29	102	129	6,041
1954	191	437	489	561	102	732	792	175	28	28	40	104	3,679
1955	254	427	1,364	1,071	305	801	770	132	245	16	45	105	5,535
1956	265	454	1,326	522	149	687	504	188	296	88	14	131	4,624
1957	96	544	921	675	586	513	865	255	142	88	51	86	4,822
1958	367	731	480	302	164	634	595	400	164	36	108	123	4,104
1959	11	389	811	1,326	253	934	739	229	41	70	54	150	5,007
1960	44	281	1,473	490	587	972	462	174	99	26	48	126	4,782
1961	210	447	1,078	1,298	826	788	492	164	140	101	260	303	6,107
1962	110	242	801	860	320	591	313	351	31	33	62	100	3,814
1963			800	985	632	591		138	61	15	1	28	
1964	112	293	766	928	260	662	740	119		41		43	
1965	204	453	784	735	773	607	544	145	60		135	42	
1966	154	370	570	1,355	685	497	610	263	69		23		
1967	160	251	1,027	652	150	681	997	242	150	12		79	
1968	54		882		1,143		637	315	205			91	
1969	397	1,181		755	526						49	48	
1970	117	588	1,080	468	315	338	338	258					

Precipitation STATION Robertsfield CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1949		275	414	910	569	529	184	149	31	42	10	97	
1950	91	179	643	511	296	1,001	351	147	65	84	100	8	3,476
1951	61	233	581	651	659	887	511	200	39	107	93	179	4,201
1952	52	310	836	864	717	875	465	189	50	4	37	97	4,496
1953	241	420	757	1,530	770	657	533	136	60	27	77	157	5,365
1954	189	194	509	497	172	520	478	448	55	27	120	154	3,363
1955	241	321	606	659	470	721	596	91	146	8	113	124	4,096
1956	281	361	359	348	240	709	326	167	91	99	33	68	3,082
1957	113	256	902	955	779	828	549	94	102	50	43	82	4,753
1958	175	304	209	275	290	646	375	289	90	15	165	158	2,991
1959	112	789	455	1,181	261	651	412	295	105				

Precipitation STATION Buchanan CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958						441	499	489	211	59	167	218	
1959	115	414	817	949	332	472	552	202	25	10	53	170	4,111

Precipitation STATION Cocoapa I CATCHMENT AREA ____ sq.km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951						231	555	131	54	0	13	252	
1952	243	221	179	304	252	496	246	84	3	8	51	96	2,183
1953	90	128	337	353	195	520	271	35	1	14	108	184	2,236
1954	247	170	228	250	283	491	287	168	67	0	97	295	2,583
1955	160	231	408	271	223	328	282	33	39	18	97	98	2,188
1956	163	146	289	144	170	319	143	120	53	17		221	
1957	124	78	205	296	253	472	295	71		48	3	217	
1958	112	149	163	65	153	315	294	248	16	6	76	87	1,684
1959	135	247	385	376	126	601	186	88	10	4	7	212	2,377
1960	150	172	142	147	487	383	164	39	155		26	76	
1961	191	146	250	260	93	450		70	4	3	64	203	
1962	344		331	197	336	596	206	161	62	36	117	90	
1963	221	307	281	344	363			98	1	0	29	91	
1964	133	225	371	235								87	
1965	185	199	237	214		383	319	39		10	28	137	
1966	206	151	306	268	441	260	278	77	54		28	78	
1967	161	448	672	789	900	398	211	32	103	77			
1968	417	242					202	157		25	35	78	
1969	158	234		237	272					74	33	49	
1970	115	138	253	80	208	344	78	108	1				

Precipitation STATION Cocoapa II CATCHMENT AREA ____ sq.km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DED.	JAN.	FEB.	MAR.	ANNUAL
1958			152	85	141	449		231	51	6	70	158	
1959	90	284	393	402	97	603	183	.3		2	10	230	
1960	202	180	184	134	496	464	194	29	64	0	35	60	2,042
1961	202	155	260	254	139	560	94	49	10	2	82	135	1,942
1962	221		234	358	373	586	296	144	43	75	79	88	
1963	81	406	276	272	439			107	1		26	97	
1964	163	184	308	300								101	
1965	127	189	358	357	335	517		33		22	24	188	
1966	135	110	312	278	548	488	251	100	21	22		118	
1967	197	89	192	178	172	480	354	54	26	6			
1968	223		216				252	93					

Precipitation STATION Ganta CATCHMENT AREA ____ sq·km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1927	217	192	390	278	403	332	236	119	22	31	32	56	2,308
1928	126	229	361	238	417	394	224	42	0	20	50	145	2,246
1929	144	94	182	137	173	429	245	112	0	13	35	135	1,699
1930	64	211	340							-	-	-	
1931										-	-	-	
1932		124	174	142	245	274	290	91	23	0	79	-	
1933										0	35	188	
1934	117	95	257	207	394	305	183	60	0	57	41	127	1,843
1935	121	163	330	173	302	356	206	99	25	6	83	58	1,922
1936	156	344	281	165	137	335	196	213	18	1	61	99	2,006
1937	56	206	227	285	297	543	203	43	0	0	50	198	2,110
1938	71									0	3	110	
1939	129	201	289	400	227	371	305	182	22	4	34	29	2,193
1940	117	191	295	383	318	495	405	83	18	31	6	111	2,453
1941	93	295	340	380	375	296	148	147	44	77	14	113	2,322
1942	208	164	234	146	302	451	326	89	121	10	18	93	2,162
1943	180	268	283	130	373	384	229	134	65	24	60	183	2,313
1944	128	200	196	413	434	497	228	41	4	19	35	128	2,323
1945	117	228	176	223	277	359	461	104	7	1	33	117	2,103
1946	85	67	215	116	160	412	536	119	56	27	78	85	1,956
1947	40	217	490	350	278	369	172	91	58	0	83	109	2,457
1948	154	122	147	168	247	400	195	183	8	19	10	194	1,847
1949	198	181	298	394	482	474	176	126	0	16	14	159	2,518
1950	132	210	195	283	176	375	318	92	24	47	162	65	2,079
1951	186	212	310	167	392	274	402	398	20	8	30	157	2,556
1952	114	155	327	233	214	408	348	102	10	47	104	75	2,137
1953	207	257	230	344	278	406	267	95	9	28	47	203	2,372
1954	226	185	178	115	164	441	211	165	44	4	21	183	1,937
1955	188	274	283	341	276	439	227	145	91	0	126	151	2,541
1956	156	178	309	144	163	421	158	139	39	17	68	155	1,947
1957	163	217	141	255	329	314	173	151	36	0	27	157	1,963
1958	156	116	95	52	100	410	265	270	46	16	99	131	1,756

Precipitation STATION Ganta CATCHMENT AREA ____ sq·km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1959	86	183	244	299	104	393	151	129	4	13	25	164	1,795
1960	180	155	162	246	386	400	254	79	60	0	8	61	1,991
1961	111	125	296	307	165	559	119	173	-	41	-	130	
1962	314	434	450	349	415	519	305	-	-	-	-	107	
1963	201	-	-	-	-	-	-	86	10	1	55	141	
1964	90	280	-	559	828	315	300	127	-	-	-	89	
1965	38	-	-		-	696	377	107	-	32	147	-	
1966	-	332	248	286	393	397	-	107	86	-	-	-	
1967	-	156	149	184	126	419	135	55	1	-	-	46	
1968	248	-	363	-	465	-	258	106	103	20	3	288	
1969	99	89	-	5	6	-	-	-	-	47	-	51	
1970	109	232	-	133	290	315	45	188	1	-	-	-	
1971	-	-	-	-	-	-	-	-	-	-	-	-	

Precipitation STATION Kpein CATCHMENT AREA ____ sq km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958		158	72	67	150	460	180	177	4	6	12	117	
1959	143	183	343	408	100	478	163	83	8	0	29	161	2,099
1960	146												

Precipitation STATION Flahuntown CATCHMENT AREA ____ sq km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1953				599	217		597	210	133		82	259	
1954	183	320	334	62	221		533	276	130	89	118	253	
1955	268	268	683	179	176		607	392	261	73	157	145	
1956	293	473	358	92	123	702	458		223	71	149	267	
1957	292	310	1,037	197	463	458							
1958				48									

Precipitation STATION Mount Mimba CATCHMENT AREA ____ sq-km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° ' W ° '

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1956										5	41	211	
1957	179	147	544	556	508	747	528	188	180	46	8	135	3,766
1958	135	99	191	173	284	607	307	310	41	71	81	150	2,449
1959	112	201	310	655	236	662	305	233	37	9	22	234	3,016
1960	188	132								0	27	94	
1961	173	171	371	319		656		327	89	16	126	195	
1962	217		396	405	616		237	362	37		102		
1963	99	322	304	504			610	166			61	196	
1964										33			
1965						548	205					259	
1966	199	30	373		694				15				

Precipitation STATION Sanokole CATCHMENT AREA ____ sq-km

RIVER IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° ' W ° '

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951							376	113	8	8	88	96	
1952	152	132	158	357		372	293	100	31	44	102	103	
1953	102	275	192	402	646	364	387	58	5	15	39	221	2,706
1954	128	148	391	347	134	433	356	190	14	3	1	64	2,209
1955	101	119	496	644	545	468	280	73	60	4	183	152	3,125
1956	114		446	658	559	734	170		56	18	37		
1957			198	380		496	311	158	61	38	48	102	
1958	168	239	115	66	136	471	113	83	59	30	22	47	1,549
1959	90	166	287	341	96	531		44					
1960													
1961													
1962			267	312	348	389	273	206	57	24	98	186	
1963	144	340	278	371	543	845	408			18	53	111	
1964		492		161	436	278	192	233			190	74	
1965	9	217	333	223	441	354	462	133		5	11	163	
1966	80	224	340	449	361	343	424	142	20			83	
1967	146	169	122	132	339	442	273	38	513	7		235	
1968	253		278		398		369	163	33	31	100	88	
1969	87			233	248								

Precipitation STATION Tapeta CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951				189	259	343	481	106	6	0	88	182	
1952	131	290	212	188	146	431	303	92	40	5	85	109	2,032
1953	226		184	411	108	258	263	9	30	13	84	39	
1954	48	156	204	66	115	348			0	0	58	264	
1955	108	180	380	250	93	382	203	31	48	0	122	118	1,915
1956	170	234	324	101	104	360	214	41	18	87	20	90	1,763
1957	95	250	331	219	172	376	309	82	34	43	64	103	2,078
1958	135	93	164	34	77		174	255	37	33	91	82	
1959	111	329	302		121							145	
1960						335		38	8				
1961			333	133	52	428	124	75	25	5	40	220	
1962	210	208	421	163	225	350	174						
1963				365	244	216		63	18		16	59	
1964	192	345	472	2,529	168	247	194	74		15		88	
1965	198	254	350	223	361	407	277	53			42	70	
1966		158	278	581	230	265	264	33		7	23	97	
1967	169	140	278	196	262								
1968	59						533	279	26	1	102	46	
1969	273	204		162	174					33	45	105	
1970		160	325	32	211	318	133	56	17				

Precipitation STATION Nyaake CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952		11	545	52	17	250	256	371	252	74	95	279	
1953	159	235	257	204	27	219	240	183	130	30	128	301	2,113
1954	225		197	20	74	185	429	175	135	60	89	367	
1955	190	249	307	19	71	345	229	480	220	171	141	312	2,734
1956	194	355	200	24	37	274		344	268	155	304	558	
1957	553	447	404	315	347	433	359	1,503	379	278	286	280	5,584
1958	267	367	218	465	352		294			340	236	268	
1959	322	221	297	311								294	
1960						300							

Precipitation STATION Pine town CATCHMENT AREA ____ sq·km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952		270	236	23	759	402	415	228	87	75	16	84	
1953	111	438	380	186	24	253	164	48	76	120	101	176	2,077
1954	165	247	208	55	148	485	424		26	44	89	199	
1955	170	296	341	255	181	336	427	110	41	17	211	166	2,551
1956	201	211	196	60	84	416	350	165	185	17	29	174	2,088
1957	150	165	211	142			361	127	180	109			
1958	242	122	114	27	45	364	266	252	108		128	160	
1959	230	291	450	190	58	364	619		123	37	115	309	
1960	336	380	450	88	164	465	75	118	18	18	82	216	2,410
1961	298	173	293	220	6	471	274	221		25	110	310	
1962	165	156	588	65	108	309		274	48			193	
1963	283	226	238	693		594	375	220		38	37	195	
1964	101	323	194	191	162	375	342	129		149	77		
1965	405	429	214			367	283	101			164		
1966	215	286	672		207	193	697	123					
1967	318	374	379	97	127	436		125	130	69		268	
1968	440				286		350	210	208	43	29	292	
1969	267	427		179	209					4	108	195	
1970	293	397		58	217	670	290	150	65				

Precipitation STATION Zia town CATCHMENT AREA ____ sq·km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEPT	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952			300	93	36	365	241	113	74	3	48	291	
1953	101	399	383	758	53	187	230	79	121	27	129	70	2,537
1954	230	296	240		142	318	335	99		71	23	85	
1955	197	330	406	166	90	490	309	123	138	32	154	195	2,630
1956	339	145	146	53	106	232	403	74	132	10	98	231	1,969
1957	248	294	241	129	335	326	373	168	80	141	97	150	2,582
1958	275	309	329	22	74	289	150	220	205	38	152	195	2,258
1959	38	373	179	222	53	396	263		95	5	94	130	
1960	105	190	278	66	111	396	288	125	121				

Precipitation STATION Zwedru CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ W ____

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1959										15	51	159	
1960	132			66	203	317		96	83	24	21	67	
1961	342	131		138	9	379	255	86		0	95		
1962	145	113	399	100	172	227	149	239	55				
1963		146	339	752	296	426	404		49	27	20		
1964		311	267	191	304	522	215	315		41		99	
1965			321	128	125		159	92			28	211	
1966		106		325	315	162	320	65	60		87	65	
1967	238	117	300	57	112	424	281		14	8		80	
1968	195		208		273		360	188	287	29	36	119	
1969	235	357		206	111					34	50	113	
1970	166	170	236	20	85	359	85	48					

Precipitation STATION Chiehn CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ W ____

YEAR	APR.	MAY	JUN	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952			285	142	47	511	-	124	41	0	107	131	
1953	80	278	272	389	43	222	207	37	-	41	152	149	
1954	297	221	180	61	119	371	297	140	18	47	19	154	1,914
1955	196	320	327	142	148	402	359	118	53	7	146	89	2,307
1956	229	120	184	121	80	359	272	80	152	4	21	110	1,732
1957	164	210	312	237	187	353	533	123	132	62	32	66	2,411
1958	225	154	79	47	104	230	290	281	58	23	60	125	1,676
1959	128	306	242	284	112	461	240	-	94	15	51	159	
1960	46	230	281	66	203	306	496	94	83				

Precipitation STATION Greenville CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1951											34	137	
1952	80	592	1,066	382	33	1,001	777	308	115	84	53	144	4,635
1953	293	829	626	735	125	611	994	192	-	182	294	236	
1954	10	359	421	452	43	492	688	136	161	178	177	252	2,369
1955	230	492	951	202	106	766	868	366	489	103	104	279	4,956
1956	305	487	440	125	77	825	802	372	645	101	92	208	4,479
1957	173	542	1,529	212	386	383	1,099	468	259	373	239	205	5,868
1958	348	1,109	346	58	69	229	185	504	120	95	63	229	3,355
1959	160	364	696	253	413	-	801	264	205	87	133	376	
1960	170	663	1,280	296	179	615	777	326	362	39	76	82	4,865
1961	43	164	125	122	224	487	484	257	368	179	179	438	3,070
1962	475	492	468	90	165	-	-	460	204	106	82	182	
1963	232	193	-	1,310	474	650	312	203	149	91	61	30	
1964	66	455	922	281	113	528	-	690	-	63	-	125	
1965	372	127	967	214	415	-	523	490	111	38	96	111	
1966	189	221	1,815	895	139	718	572	187	80	15	25	4	4,860
1967	345	188	751	69	112	636	249	508	326	62	-	91	
1968	182	-	360	-	-	-	376	204	102	30	19	212	
1969	192	663	-	-	346	-	-	-	-	166	43	136	
1970	233	384	1,068	165	-	703	567	385	69				

Precipitation STATION Sinoefalls CATCHMENT AREA ____ sq.km

____ RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1953	-	-	697	488	238	-	691	172	114	-	83	274	
1954	146	323	454	100	234	-	746	292	162	34	98	312	
1955	284	348	705	243	173	-	690	344	223	43	74	136	
1956	189	579	243	118	141	787	517	-	398	72	-	-	
1957													
1958										28	106		

Precipitation STATION Buah CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1952			421	125	43	-	785	507	-	51	94	191	
1953	170	273	312	207	33	225	342	115	104	102	149	288	2,320
1954	184	236	167	44	103	259	294	267	144	27	77	243	2,045
1955	184	206	250	248	107	-	-	282	211	53	80	169	
1956	256	277	176	46	81	418	336	207	-	89	243	339	
1957	353	231	459	128	676	453	411	459	492	144	64	249	4,119
1958	295	276	68	-	69	159	241	459	101	41	88	94	
1959	215	304	322	110	-	-	458	234	51	19	49	332	
1960	-	392	-	107	220	478	-	554	17	56	56	124	
1961	253	305	370	39	1	283	304	224	-	167	212	200	
1962	331	366	555	174	71	284	194	-	153	53	158	206	
1963	189	202	623	802	103	479	500	154	-	23	-	134	
1964	148	358	350	138	76	178	171	89	-	76	28	52	
1965	147	352	-	61	124	195	193	137	65	1	83	234	
1966	146	279	574	530	125	372	528	287	97	38	94	81	3,151
1967	250	197	353	785	119	308	-	184	-	-	-	94	
1968	-	-	404	-	341	-	425	-	121	-	74	120	
1969	299	222	-	173	-	-	-	-		276	-		
1970	267	309	-	-	130	-	-						

Precipitation STATION Cavalla CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ W ____ °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1927										190	19	174	
1928	183	343	519	415	205	455	312	231	87	18	99	277	3,144
1929	256	366	404	103	72	87	261	168	116	93	160	88	2,174
1930	88	430	411	126	46	191	160	245	96	98	54	113	2,058
1931	118	313	190	37	156	266	425	138	113	9	153	157	2,075
1932	60	432	490	179	33	190	319	282	125	79	78	287	2,554
1933	216	440	552	178	189	333	195	319	167	4	75	254	2,922
1934	62	183	234	427	204	370	541	145	115	95	39	81	2,496
1935	194	317	336	129	85	328	485	219	126	84	198	168	2,669
1936	200	419	357	109	29	204	287	347	264	10	133	141	2,500
1937	161	318	473	71	107	274	459	185	72	62	94	107	2,383
1938	208	595	305	66	22	404	178	356	77	96	197	280	2,784
1939	111	381	405	93	123	76	68	137	166	54	53	102	1,769
1940	290	833	266	98	244	262	282	382	151	54	36	153	3,051
1941	226	649	365	196	207	396	366	244	180	182	85	74	3,170
1942	119	303	448	100	35	215	275	115	135	49	158	306	2,258
1943	317	345	223	52	135	327	366	326	183	36	82	244	2,636
1944	53	116	902	100	171	493	391	156	130	110	177	120	2,919
1945	108	228	258	92	97	479	346	216	164	21	9	140	2,158
1946	172	347	238	31	31	294	648	270	83	14	134	165	2,427
1947	264	169	558	202	446	408	358	232	82	73	126	122	3,034
1948	201	201	254	105	115	353	228	141	105	128	69	118	2,018
1949	78	225	777	102	121	515	362	186	98	89	127	163	2,843
1950	229	191	763	20	19	134	397	175	132	130	115	112	2,417
1951	52	388	416	74	111	705	1,026	340	134	39	136	306	3,727
1952	133	330	621	145	37	430	305	370	221	108	92	236	3,028
1953	117	541	360	294	27	172	335	182	155	79	181	243	2,686
1954	233	316	342	22	97	457	509	317	177	105	158	308	3,041
1955	165	456	669	33	98	488	452	294	159	167	119	115	3,215
1956	179	381	104	53	44	336	421	378	214	89	158	221	2,572
1957	190	205	686	67	166	129	370	383	119	135	90	165	2,705
1958	348	672	98	12	56	118	144	119	394	52	140	163	2,316
1959	114	463	291	141	176	672	449	150	418				

Precipitation STATION Harper CATCHMENT AREA ____ sq.km

RIVER, IN THE BASIN OF ____ ELEVATION ____ m UNIT mm S ____ ° ____ ' W ____ ° ____ '

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1954	168	442	636	244	61	339	430	470	199	227	124	324	3,664
1955	228	1,133	1,483	324	234	439	323	115	482	136	249	77	5,223
1956	85	364	66	142	20	258	305	464	410	231	119	118	2,582
1957	83	417	534	22	172	57	263	320	363	213	83	216	2,743
1958	565	428	69	-	55	78	139	267	220	14	14	-	
1959	183	475	388	1	37	-	331	71	55	71	74	115	
1960	42	61	468	147	96	234	299	285	288				

APPENDIX

A-2 MONTHLY DISCHARGE

MONTHLY DISCHARGE STATION KAWILAHUN CATCHMENT AREA 6,420 sq.km

WOWO RIVER IN THE BASIN OF MANO RIVER ELEVATION m UNIT m^3/s-d N 7°20'55" W 11° 08'-15"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	--	-	-	-	-	18,403	15,995	13,837	7,421	3,421	1,791	1,522	
1959	1,529	4,400	8,045	13,406	12,916	18,264	12,251	9,216	4,148	2 093	1.540	682	88,490
1960	1,881	4,120	6,627	7,161	18,259	19,050	11,780	8,670	3,240	1,423	717	567	83,495
1961	819	2,496	4,587	9,297	10,633	15,345	11,492	5,346	3,072	1,259	580	741	65,667
1962	1,809	1,867	8,172	9,136	14,039	17,763	15,247	12,111	4,783	2,496	2,700	1,795	91,918
1963	1,167	2,414	8,874	7,881	13,147	15,173	23,333	10,523	4,802	2,414	2,151	2,069	93,948
1964	2,392	2,443	5,288	6,817	14,211	17,094	12,744	7,376	5,493	2,990	1,765	1,637	80,250
1965	1,250	2,615	6,207	11,075	10,845	20,102	16,370	9,326	4,630	2,328	-	-	
1966	-	2,069	2,726	11,305	9,780	20,074	18,297	10,022	4,658	2,443	-	-	
1967	2,782	2,472	3,088	14,010	14,614	18,877	20,139	9,353	4,371	2,357	2,016	--	
1968	2,921	4,716	11,219	10,499	17,146	-	-	-	-	-	-	-	
Mean	1,839	2,961	6,483	10,059	13,559	18,015	15,765	9,578	4,662	2,322	1 658	1,288	88,189

MONTHLY DISCHARGE STATION BOLAHUN CATCHMENT AREA 795 sq.km

ZELIBA RIVER IN THE BASIN OF MANO RIVER ELEVATION m UNIT m^3/s-d N 8° 12'-55" W 10° 07'-45"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	-	-	-	-	1,974	1,714	1,497	791	360	185	155	
1959	156	465	858	1,435	1,383	1,959	1,302	1,026	484	229	157	164	9,618
1960	237	425	552	939	1,851	1,953	1,262	969	546	229	123	115	9,201
1961	138	214	294	862	1,076	1,638	1,011	579	270	158	129	127	6,496
1962	147	192	546	1,070	1,504	1.905	1,634	1,623	781	353	283	214	10.252
1963	144	251	450	840	1,407	1,626	2,505	1,125	508	251	223	214	9,544
1964	249	254	561	725	1,522	1.833	1,364	786	583	313	182	167	8,539
1965	126	273	660	1,184	1,159	2,157	1 755	996	490	242	-	-	
1966	-	214	285	1,209	1,045	2,155	1,962	1,071	493	254	-	-	
1967	291	257	324	1,500	1,566	2,025	2,161	999	462	245	209	-	
1968	306	499	1,200	1,122	1,838	-	-	-	-	-	-	-	
Mean	199	304	573	1,089	1,435	1,923	1,667	1,067	541	263	186	165	9,412

MONTHLY DISCHARGE STATION BOLAHUN CATCHMENT AREA 104 sq-km

WAWO RIVER, IN THE BASIN OF MANO RIVER ELEVATION m UNIT m3/s-d N 8°14'-00" 10°09'-50"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	-	-	-	-	236	178	139	60	33	20	18	
1959	15	60	78	124	124	230	151	88	45	24	15	20	974
1960	17	44	62	86	147	156	125	92	62	23	15	12	841
1961	26	47	64	121	115	177	105	57	34	19	17	22	804
1962	30	37	72	143	149	177	112	144	53	34	28	22	1,001
1963	15	53	51	59	149	156	205	66	31	19	12	25	841
1964	15	31	66	74	140	-	-	-	-	-	-	-	
Mean	20	45	66	101	137	189	146	98	48	25	18	20	913

MONTHLY DISCHARGE STATION NEW HOPE CATCHMENT AREA 10,650 sq-km

LOFA RIVER, IN THE BASIN OF LOFA RIVER ELEVATION m UNIT m3/s-d N 6° 44'-00" 10° 58'-15"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	3,360	3,813	4,980	4,309	6,417	18,480	15,097	11,670	6,355	3,689	2,492	1,798	82,460
1959	2,190	5,766	8,310	16,151	10,323	25,230	11,718	8,340	5,053	5,053	1,566	1,559	101 259
1960	2,391	3,930	7,650	9,455	24,986	30,750	17,732	10,920	7,378	4,588	921	784	121,485
Mean	2,647	4,503	6,980	9,971	13,908	24,820	14,849	10,310	6,262	4,443	1.659	1,380	101,732

GAGING HEIGHT STATION DUOGOHAI CATCHMENT AREA 1,580 sq.km

LOFA RIVER, IN THE BASIN OF LOFA RIVER ELEVATION m UNIT m S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
73	-	1.06	1.32	1.53	2.36	2.59	2.11	1.67	1.15	-	-	-	
74	-	-	-	-	-	-	-	2.02	1.42	1.09	-	-	

MONTHLY DISCHARGE STATION MT. COFFE CATCHMENT AREA 21,430 sq.km

ST. PAUL RIVER, IN THE BASIN OF ST. PAUL RIVER ELEVATION m UNIT m^3/s-d N 6° 31'-35" W 10° 36'-25"

YEAR	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	3,000	7,806	9,792	6,674	11,947	38,073	32,020	26,520	13,073	7,437	3 900	4,008	164,250
1959	3,828	14,936	20,994	26,812	21,285	42,396	20,482	17,553	8,736	3,528	2,155	3,119	185.824
1960	5,451	7,921	13,050	18,222	38,403	41,682	28,350	17,964	10,112	4,139	1,842	1,569	188.705
1961	2,841	6,389	11,124	21,756	27,113	42,273	30,966	16,074	7,620	3,559	1,840	2,359	173,914
1962	5,178	10,512	17,682	25,085	35,042	41,772	31,769	27,261	13,491	6,845	5.328	6,836	226,801
1963	5,127	11,300	15,528	29,332	41,540	43,077	46,175	28,383	12,707	6,482	2,842	3,661	246 154
1964	3,111	7,508	15,888	21,725	40,365	47.499	32,175	20,181	13,718	7,753	4,197	4,002	218,122
1965	5,052	8,265	17,151	31,155	28,687	41,343	36,093	17,136	8,699	4,163	2.055	2,455	202.254
1966	4,389	5,689	13,248	16,560	39,007	40,884	29,450	18,000	9,300	7,595	2,352	2,852	189,326
1967	4,995	6,448	9,078	17,329	23,622	42,300	45,012	17.760	11,625	9,579	5,510	5,704	198,962
1968	7,428	9,920	25,260	23,994	34,844	50,520	31,465	22,620	15,066	8,804	5,600	5,084	240.605
1969	5,940	4,123	7,980	15,438	31,341	29,880	30,721	26,400	13,330	6,510	3,444	5,270	180,377
1970	6,480	6,510	10,920	9,951	20,677	28,860	17,484	10,860	5.890	3,038	2,520	3,286	126,476
1971	2,220	4,712	9,090	11,935	21,142	31,560	40,982	13,050	18,631	9,021	4,843	2,604	169,790
Mean	4,646	8,003	14,056	19,712	29,644	40,151	32,367	19,983	11,571	6,318	3.459	3,772	193,682

MONTHLY DISCHARGE STATION GWEYIE CATCHMENT AREA 10,790 sq-km

ST. PAUL RIVER IN THE BASIN OF ST. PAUL RIVER ELEVATION ____ m UNIT m^3/s-d N 7° 20'-45" 5° 29'-50" W

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	1,500	3,875	4,800	3,317	6,879	30,201	15,872	13,260	6,572	3,720	1,952	2,006	93,954
1959	1,914	7,468	8,559	12,902	9,750	21,198	12,605	11,733	7,663	1,764	1,047	1,559	98,162
1960	2,778	4,656	6,429	8,832	19,201	20,841	14,176	8,982	5,056	2,071	708	784	94,514
1961	1,422	3,196	5,562	10,878	11,358	18,624	12,347	7,692	4,058	1,848	921	1,163	79,069
1962	3,726	5,062	8,100	12,881	12,543	16,731	14,679	13,026	7,846	4,303	3,797	4,325	107,019
1963	3,609	3,729	8,367	22,019	19,598	21,003	22,689	12,294	6,795	3,751	1,853	2,768	128 475
1964	2,040	2,108	6,384	9,908	19,823	23,751	15,441	9,690	7,285	4,799	3,018	3,140	107,387
1965	2,667	4,628	8,577	15,562	14,607	22,365	14,697	8,865	5,162	2,099	1,299	2,052	102,580
1966	2,904	3,419	5,796	7,437	15,463	18,906	16,870	9,786	4,982	3,835	1,182	1,423	92,003
1967	1,596	3,221	4,524	8,665	10,881	21,156	22,518	8,895	5,825	4,799	2,749	2,868	97,697
1968	3,708	4,960	12,243	11,991	17,416	25,272	15,736	11,310	7,536	4,399	2,794	2,548	119,913
1969	2,979	2,065	4,035	7,738	15,671	14,943	15,357	13,206	6,662	3,267	1,722	2,641	90,286
1970	3,249	3,277	5,457	4,976	10,683	14,439	8,742	5,433	2,942	1,522	1,252	1,637	63,609
1971	1,119	2,368	4,548	5,977	10,580	15,771	20,491	6,531	9,328	4,517	2,424	1 308	84,962
Mean	2,515	3,859	6,742	10,220	13,890	20,372	15,873	10,050	6,265	3,335	1,908	2,159	

MONTHLY DISCHARGE STATION GBAKWELE CATCHMENT AREA 5,357 sq-km

VIA RIVER IN THE BASIN OF ST. PAUL RIVER ELEVATION ____ m UNIT m^3/s-d S ° W °

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	354	918	1,287	784	2,173	12,447	6,126	5,004	2,040	880	462	474	32,949
1959	453	2,434	2,946	4,821	3,435	8,490	4,690	4,335	2,517	415	247	369	35,152
1960	657	1,197	2,004	3,032	7,586	8,334	5,379	3,126	1,373	490	216	183	33 577
1961	336	756	1,623	3,931	4,142	7,362	4,576	2,559	961	437	216	273	27,172
1962	882	1,376	2,739	4,811	4,662	6,528	5,599	4,902	2,598	1,042	902	1,051	37,092
1963	855	2,068	2,856	8,826	7,762	8,406	9,120	4,581	2,136	887	438	854	48,589
1964	483	843	1,983	3,503	7,890	9,612	5,937	3,435	2,353	1,259	714	744	38,756
1965	630	1,184	2,946	5,989	5,568	9,003	5,608	3,075	1,420	496	305	484	36,708
1966	687	809	1,725	2 418	5,946	7,485	6,563	3,477	1,339	908	280	335	31,972
1967	378	763	1,167	2,957	3,931	8,472	9,043	3,087	1,711	1,259	650	679	34,097
1968	876	1,330	4,557	4,421	6,801	10,281	6,064	4,149	2,461	1,085	661	601	43,287
1969	705	487	954	2,548	6,036	5,745	5,899	4,980	2,077	772	406	623	31,232
1970	768	775	1,575	1,336	3,844	5,523	2,992	1,566	694	360	294	388	20,115
1971	264	561	1,176	1,776	3,801	6,108	8,153	2,049	3,249	1,135	574	310	29,156
Mean	595	1,107	2,110	3,654	5,256	8,128	6,125	3,595	1,924	816	455	512	

MONTHLY DISCHARGE STATION BELLEVELIA CATCHMENT AREA 755 sq.km

TUNA RIVER IN THE BASIN OF ST. PAUL RIVER ELEVATION m UNIT m^3/s-d S ° W °

YEAR	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	66	171	210	146	304	2,538	1,119	879	288	164	84	87	6,056
1959	84	329	417	831	521	1,656	800	729	338	78	44	68	5,895
1960	120	205	282	431	1,448	1,620	955	459	223	90	39	34	5,906
1961	60	140	246	632	679	1,404	775	339	177	81	39	50	4,622
1962	162	223	372	828	794	1,218	1,004	855	344	189	165	189	6,343
1963	159	291	399	1,724	1,485	1,638	1,789	783	298	164	81	121	8,932
1964	90	155	282	536	1,513	1,905	1,079	528	319	211	132	136	6,886
1965	117	205	120	1,091	995	1,770	1,004	447	226	90	73	90	6,228
1966	126	149	255	329	1,079	1,431	1,218	537	220	167	50	62	5,623
1967	69	140	198	415	632	1,653	1,770	450	257	211	119	124	6,038
1968	162	217	780	741	1,271	2,055	1,107	687	332	192	123	112	7,779
1969	129	90	177	341	1,101	1,044	1,070	873	295	143	76	115	5,454
1970	141	143	240	217	611	993	422	240	127	65	53	71	3,323
1971	48	102	201	264	601	1,125	1,572	270	481	198	104	56	5,022
Mean	110	183	299	609	931	1,575	1,120	577	280	146	84	94	

MONTHLY DISCHARGE STATION OWENSGROVE CATCHMENT AREA 2,750 sq.km

FARMINGTON RIVER IN THE BASIN OF FARMINGTON RIVER ELEVATION m UNIT m^3/s-d N 6 °24'-20" 10° 23'-05"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1955	-	-	-	-	-	-	-	-	-	-	871	1,307	
1956	2,324	2,540	5,946	6,238	2,452	5,377	6,020	2,954	2,212	1,222	729	986	39,000
1957	1,274	2,243	3,843	982	5,475	10,715	8,637	4,630	4,126	1,506	974	1,325	45,730
1958	1,494	1,339	1,285	968	2,223	5,244	5,220	4,602	2,803	1,204	906	1,885	29,173
1959	1,413	3,969	4,111	6,952	5,352	10,041	7 136	3,978	2,572	1,167	824	1,187	48,680
1960	2,005	3,976	7,441	6,004	7,496	7,934	5,056	3,432	2,159	1,080	604	1,062	48,249
1961	1,580	3,502	4,579	7,382	-	-	-	-	-	-	-	-	
Mean	1,682	2,928	4,534	4,754	4,600	7,862	6,414	3,919	2,775	1,236	818	1,292	

MONTHLY DISCHARGE STATION FIRESTONE PLANTATION CO. DIVISION 22 CATCHMENT AREA 519 sq.km

DU RIVER IN THE BASIN OF FARMINGTON RIVER ELEVATION m UNIT m3/s-d N 6° 24'-20" W 10° 23'-05"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	-	-	-	-	1,373	1,540	1,115	655	-	151	359	
1959	188	910	782	3,065	2,132	1,691	698	661	431	244	101	409	11,312
1960	493	246	1,033	999	1,364	3,196	1,849	636	517	292	159	195	10,979
1961	264	476	1,732	2,279	-	-	-	-	-	-	-	-	
Mean	315	544	1,182	2,114	1,748	2,087	1,362	804	534	268	137	321	

MONTHLY DISCHARGE STATION PLEMO CATCHMENT AREA 187 sq.km

DU RIVER IN THE BASIN OF FARMINGTON RIVER ELEVATION m UNIT m3/s-d N 6 °36'45" W 10 °25'50"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	61	58	29	90	375	391	140	62	57	57	-	

MONTHLY DISCHARGE STATION MT. FINLEY CATCHMENT AREA 16,930 sq.km

ST. JOHN RIVER IN THE BASIN OF ST. JOHN RIVER ELEVATION ____ m UNIT m^3/s-d 62°03'35"W 9°52'15"N

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1957	-	-	-	-	19,050	43,150	45,880	16,790	-	4,417	-	-	
1958	4,484	3,264	3,643	2,503	-	-	-	-	-	-	-	-	

MONTHLY DISCHARGE STATION ST. JOHN FALLS CATCHMENT AREA 11,370 sq.km

ST. JOHN RIVER IN THE BASIN OF ST. JOHN RIVER ELEVATION ____ m UNIT m^3/s-d 8°26'25"W 9°38'05"N

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958					1,914	13,919	18,327	10,118	4,978	1,909	1,237	1,538	
1959	1,268	5,812	10,800	23,472	9,086	37,772	28,997	9,365	5.081	1,986	1.120	1.828	136,587
1960	3,971	5,416	6,821	5,942	24,666	42,645	21,155	9,344	4,809	1.869	951	1,000	128.589
1961	1,902	4,520	6,362	8,005	5,091	23,700	17,029	5,946	3,248	1,317	793	1,317	79,230
1962	5,267	29,230	40,349	24,226	21,944	62,148	33,092	29,051	6,671	3,336	3,885	1,843	261,042
1963	2,463	4,477	8,240	21,417	45,647	55,897	49,246	23,275	5,442	2,282	1,067	1,229	220,689
1964	1,614	7,198	21,151	15,800	51,616	61,504	16,678	7,815	4,740	2,194	1.506	966	192,782
1965	2,124	4,477	10,488	35,462	8,602	55,218	48,456	8,070	3,336	1,580	951	1,229	179,953
1966	2,124	2.897	6,031	13,166	45,208	62,863	66,714	10,873	4,301	2,107	951	1 229	218 464
1967	2,803	3,950	2,463	5,091	5,530	34,488	44,066	5,691	2,458	1,404	903	1,580	110,427
1968	3,483	7,373	32,959	43,049	89,538	81,552	64,959	30,495	19,223	3,072	951	3,248	379,902
1969	3,398	-	-	-	-	-	-	-	-	-	-	-	
1970		12,552	19,877	30,985	58,989	93,446	34,233	15,290	15,185	1,931	1.110	1,053	
1971	1,529	4,915	-	-	28,088	69,659	24,314	3,823	3,823	-	-	-	
Mean	2,662	7,734	15,049	20,601	30,455	53,447	35,943	13,012	6,407	2,082	1.285	1 505	

MONTHLY DISCHARGE STATION BAILA CATCHMENT AREA 3,860 sq.km

ST. JOHN RIVER IN THE BASIN OF ST. JOHN RIVER ELEVATION m UNIT m^3/s-d N 7 °03'45" W 9 °09'50"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	-	-	-	-	9,811	6,513	5,229	2,998	1,527	-	1,264	
1959	807	2,423	3,381	6,443	3,871	7,093	6,179	4,477	2,317	1,018	539	602	39,150
1960	1,393	1,440	1,427	2,230	7,602	10,110	6,654	4,154	2,730	1,132	495	461	39,828
1961	917	1,352	1,546	2,238	3,248	7,926	4,740	2,752	1,448	793	983	736	28,679
1962	1,121	2,563	4,545	5,275	7,031	9,854	7,365	6,176	2,967	1,826	1,625	1 650	51,998
1963	1,240	3,230	2,769	5,793	10,010	12,230	12,600	6,286	2,984	1,756	1,150	1,668	61,716
1964	1,444	2,458	3,589	3,906	8,339	10,580	6,057	4,502	3,511	2,063	1,506	1,361	49,816
1965	1,232	1,931	3,398	6,934	5,442	11,430	14,760	4,502	2,502	1,404	872	1,053	52,460
1966	1,402	1,580	4,120	5,793	11,590	11,210	11,670	5,522	2,984	1 756	813	658	59,098
1967	1,232	1,887	2,888	4,038	6,934	5,267	15,270	4,757	3,028	1,975	903	1,229	49,408
1968	1,656	2,458	5,776	6,671	12,070	14,270	11,810	4,502	3.336	1 975	991	1,668	67,183
1969	637	966	2,718	6,671	12,070	14,270	11,850	4,460	3,336	1,975	991	1,668	61,612
1970	637	966	2,718	6,671	-	-	-	-	-	-	-	-	
1973	-	4,389	6,966	8,076	12,820	-	13,910	-	3,292	-	-	-	
Mean	1,143	2,126	3,526	5,441	8,419	10,338	9,721	4,777	2,879	1,600	988	1,168	

MONTHLY DISCHARGE STATION YA[illegible]RO CATCHMENT AREA 1,040 sq.km

YA RIVER IN THE BASIN OF ST. JOHN RIVER ELEVATION m UNIT m^3/s-d N 7 °03'25" W 8 °52'14"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	-	-	-	-	1,038	972	775	401	155	75	55	
1959	42	269	722	1,485	834	1,592	1,185	710	410	120	44	-	
1960	178	165	321	608	2,179	2,612	1,525	671	483	163	61	55	9,021
1961	94	120	240	685	-	-	-	-	-	-	-	-	
Mean	104	185	428	926	1,507	1,747	1,227	719	431	146	60	55	

MONTHLY DISCHARGE STATION SAWOLO CATCHMENT AREA 4,580 sq.km

CESTOS RIVER IN THE BASIN OF CESTOS RIVER ELEVATION ____ m UNIT $m^3/s \cdot d$ N 6°26'25" W 8°37'55"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	-	-	-	-	-	8,146	2,809	3,388	-	-	395	
1959	390	351	2,056	5,424	3,950	5,349	-	-	-	-	-	-	
1960	* 878	* 902	*2,139	*2,293	*3,825	*3,806	*3,143	*2,863	*1,567	* 744	* 415	* 398	*22,273
1961	-	-	-	2,370	1,404	3,355	2,984	1,682	632	526	396	491	
1962	671	1,632	2,956	4,029	3,291	4,417	3,634	2,675	1,562	1,132	872	1,158	28,029
1963	726	1,764	2,030	3,195	4,512	4,553	5,530	2,977	1,650	912	377	588	28,814
1964	407	1,597	2,752	2,405	3,748	4,774	3,265	2,085	1,698	983	772	491	24,977
1965	764	2,058	2,854	3,081	3,335	4,256	4,248	3,123	1,141	772	309	368	26,309
1966	853	2,062	2,939	3,449	3,879	4,417	4,942	2,395	1,457	930	531	474	28,328
1967	866	991	1,061	1,746	1,667	4,281	4,406	1,749	1,193	544	500	557	19,561
1968	1,155	2,256	2,739	3,116	4,275	5,063	3,563	2,641	1,875	1,220	713	1,027	29,643
1969	943	895	2,234	1,694	2,054	2,973	4,275	4,723	2,931	324	1,696	1,738	26,471
1970	1,783	2,054	3,126	2,317	2,852	5,029	2,335	1,435	807	351	482	333	22,904
1971	361	614	3,722	1,790	2,137	2,616	2,422	1,019	912	333	491	373	16,790
1972	501	991	2,344	2,071	2,141	3,610	2,984	1,529	-	421	237	368	
1973	318	1,676	730	1,518	2,207	3,720	2,914	1,537	535	-	-	-	
Mean	748	1,457	2,384	2,728	2,960	4,175	3,974	1,412	1,521	704	614	643	

* gives estimated run-off of the St. John River which was obtained from cumulative correlations with run-off observed at Sowolo Gaging Station.

(June - Nov.) $Y = 0.192 X + 1,865$

Dec. - May) $Y = 0.5155X + 160$

GAGING HEIGHT STATION SEHNKWEHN CATCHMENT AREA 4,330 sq.km

SEHNKWEHN RIVER IN THE BASIN OF SEHNKWEHN RIVER ELEVATION ____ m UNIT Ft S ° ' W ° '

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	JAN.	ANNUAL
1959	1.81	3.07	3.52	2.61	2.09	2.55	2.21	2.84	2.42	2.75	2.47	2.23	
1960	2.33	2.76	3.03	2.27	2.12	2.65	-	2.49	2.20	2.46	1.81	1.88	
1961	2.00	1.85	2.31	2.02	2.09	1.96	2.15	2.11	2.10	2.11	2.13	2.05	
1962	2.25	2.78	2.54	2.36	2.02	-	-	-	-	-	2.52	2.36	
1963	-	2.10	3.05	2.82	2.37	2.57	-	2.37	2.20	-	-	2.27	
1964	2.29	2.87	2.99	-	2.32	2.71	-	-	-	2.28	-	2.59	
1965	-	2.60	3.05	-	3.03	-	3.32	2.82	-	2.29	2.31	2.30	
1966	2.91	-	2.77	2.91	8.26	3.12	3.07	2.81	-	2.42	2.27	2.39	
1967	2.70	2.70	2.83	2.54	2.82	-	2.62	2.68	2.58	-	-	2.47	
1968	2.68	2.72	2.71	-	3.37	3.30	2.92	2.76	-	2.45	-	2.45	
1969	2.56	2.79	3.11	2.76	2.61	2.58	3.14	2.69	2.55	2.53	-	2.78	
1970	2.71	2.86	3.23	2.44	2.99	2.63	3.01	-	-	2.61	-	2.39	
1971	2.41	2.58	-	-	2.91	2.85	-	-	2.51	2.47	-	-	
1972	-	-	-	4.49	2.84	-	-	-	-	2.30	2.60	2.60	
1973	2.60	2.90	3.00	2.90	2.60	2.90	2.70	2.60	2.05	2.60	-	-	

MONTHLY DISCHARGE STATION NYAAKE CATCHMENT AREA 12,610 sq.km

CAVALLA RIVER, IN THE BASIN OF CAVALLA RIVER ELEVATION ____ m UNIT m^3/s-d N 4°51'00"W 7°35'-30"

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL
1958	-	-	-	-	-	-	22,705	28,373	-	-	-	-	
1959	-	-	-	-	-	-	-	-	-	-	-	-	
1960	12,878	6,434	7,720	6,286	15,134	29,560	29,016	16,888	6,992	5,122	3.087	5,941	144.978