3B. 2. 2 The Niger

The Niger, having its sources in the Futa Jalon Mountains in the Republic of Guinea, is an international river running through such countries as Guinea, Mali, Niger and Nigeria for the total distance of some 4,200 km. Its total catchment area reaches approximately 1,143,000 km^2 at the river mouth of the Niger, including the Benue river system, the catchment area of which is approximately 338,000 km^2. The catchment area of the Niger in Nigeria occupies an area of approximately 575,500 km^2 or about 60 percent of the total area of the country.

The catchment of the Niger upstream of the western international border occupies a total area of approximately 461,000 km^2. The annual mean runoff at the border has been recorded at about 19,000 MCM (millions of cubic meter). Accordingly, its average runoff yield is estimated at approximately 40 mm.

The Niger river system between the international border and the confluence with the Benue belongs to the water resources subdivisions HA-I and -II and is being utilized mainly for domestic use, irrigation and electricity. The river system comprises a number of tributaries including such major ones as Sokoto and Kaduna. Kainji Dam (with a total capacity of 15,000 MCM) is also one of the prominent features along the main stream. The Niger river basin to the left of the main stream consists mainly of the sub-basins formed by such major tributaries as Sokoto-Rima, Malendo and Kaduna, while that to the right consists of an aggregate of small sub-basins formed by a number of minor tributaries. These minor tributaries, forming drainages of roughly rectangular shapes, join the main stream of the Niger at nearly perpendicular angles. With these physiographic characteristics, they have relatively strong flows which bring flooding to downstream areas rather quickly. The total catchment area of the Niger river system in the subdivisions HA-I and -II is approximately 751,000 km^2 with an annual mean runoff of some 55,000 MCM at Lokoja at Niger side which is about three times that of the above mentioned runoff at the international border.

The Niger downstream of the confluence with the Benue, forms an extensive delta area together with the river systems in the South-Western and the South-East Regions. Figure 3B-1 shows the drainage pattern of the Niger and Benue.

The Niger originates in Futa Jalon Mountains with an elevation of about 900 m in Guinea, passes through large alluvial plains in Mali and Niger and flowing into Nigeria. The river, after entering Nigeria, flows down through the Central-West region with the flow direction to the southeast. After joining with the Benue at Lokoja, it runs straight to the Gulf of Guinea dividing the south littoral regions into the two basins, the west and the east. At the mouth, the Niger is ramified with a number of small rivers and empties into the Gulf of Guinea forming the Niger Delta. The Niger river flowing down within Nigeria from the border of Niger to the Gulf of Guinea, has the length of abut 1,250 km, of which the length between the border and Lokoja is about 650 km.

Features of the main stream of the Niger river are summarized as follows;

- In the upper reach of 100 km from the Sokoto confluence, the river flows in vast alluvial plains with gentle slopes of 1/7,000 to 1/8,000 and forms a number of swamps in the flood season.
- In the upper reach of 200 km from the Sokoto confluence to Jebba, the river passes through narrow valleys with rock out-crops in both banks presenting steep slopes of 1/3,000 to 1/4,000.

  Kainji and Jebba hydropower dams are constructed in this reach to take advantage of the greater available head.
- In the middle reach of 250 km from Jebba to Lokoja, the river flows with gentle slopes of 1/5,000 to 1/7,000. Many sandbars formed by transported sediments have developed in this river reach. The large area formed by sandbar development is expanding along both river banks and has been used for agricultural areas called Fadama.
- The Kaduna river, another big tributary of the Niger, joins at the mid-point between Jebba and Lokoja.
- The Niger changes its flow direction at right angles to the south at Lokoja where it joins the Benue river, and goes straight to the Gulf of Guinea. This lower reach of the river has a length of 450 km and is formed with very gentle slopes of 1/10,000 to 1/12,000. The river in the lower reach flows down depositing a large amount of

sediment transported from the upper basin, which require continuous dredging to maintain the river navigation.

- At the Niger delta inundation and coastal erosion problems occur as a result of overflowing of surplus water from a number of small tributaries.
- The Niger has abundant runoff in the period from June to March brought by the White and Black Floods. The White flood is formed by runoff of the river basin within Nigeria from June to October, and the Black Flood is brought from outside of the country during the period between November to March due to the flow time lag.
- The Niger river between the border with Niger and Lokoja had the annual water level fluctuation with 4 to 5 m in the past, but its fluctuation is presently decreasing by a reduction in runoff as influenced by dry climate tendency and flow control of the Kainji dam.
- Although the Niger has suffered from a lot of sediment transport, the sediment is presently depositing upstream of Kainji dam and is decreasing at the river downstream of the dam. However, many sandbars which had been formed before the Kainji dam construction, remain in the river downstream of the dam due to decreasing of the water level caused by reduced runoff.

3B. 2. 3 The Benue

The Benue is also an international river entering into Nigeria across the border with Cameroon, and runs for a distance of about 900 km from the border to the confluence with the Niger river at Lokoja, Kogi State. The catchment of the Benue upstream of the international border occupies an area of approximately 98,000 km^2 with the annual mean runoff of some 13,000 MCM or the average runoff yield of 130 mm. The Benue river basin between the international border and Lokoja belongs to the HA-III and -IV and is being utilized mainly for irrigation, domestic use and inland water transport.

The river system, comprising Gongola, Taraba, Donga and Katsina-Ala rivers including their tributaries, occupies the total catchment area of approximately 240,000 km^2 with the annual mean runoff of some 70,000 MCM, which is twice that at the international border, or with the average runoff yield of 290 mm.

The Benue river basin to the left of the main courses consists mainly of sub-basins formed by major tributaries such as the Taraba, Donga and Katsina-Ala rivers, while that to the right of the main course consists of an aggregate of sub-basins formed by minor tributaries except for the sub-basin of Gongola river having its headwater in Jos Plateau.

The main river of the Benue, after passing the Garua alluvial plain, joins the Faro river running along the border between Nigeria and Cameroon. The Faro river transports huge sediment loads containing very coarse sandy materials eroded by heavy rainfall. The sediment loads are transported by floods and accumulated in the Benue near Yola city in Nigeria. Therefore, the river beds near Yola city are probably rising every year and as a consequence, this area will be liable to flood damage.

The Benue, after entering Nigeria, changes its flow direction towards the west and flows down to Lokoja after joining the major tributaries such as the Gongola, Taraba, Donga, and Katsina-Ala. The Benue river has a total catchment area of 338,000 km^2, of which, 240,000 km^2 or about two third of the total catchment area is in Nigeria. The upper basin from the border to the confluence with the Taraba, a major tributary, has a catchment area of about 137,000 km^2 and the lower basin from the confluence to Lokoja occupies an area of 102,500 km^2.

In the upper reach, the river flows with a relatively steep slope greater than 1/4,000 and carries heavy loads of muddy sediments. The Gongola tributary originates in Jos Plateau and discharges into the Benue near Numan which is located at its right bank. The Gongola river has a catchment area of 53,800 km^2 and a length of 610 km. The river also transports a large amount of sediment which accumulates at the river mouth near Numan.

In the lower reach, the river flows with a gentle slope of 1/7,000 to 1/8,000 and with a width of 2 to 3 km in the flood season. The major tributaries of Taraba, Donga, and Katsina-Ala originate from high mountains along the border of Cameroon and discharge into the Benue at the left bank. These tributaries have a river length of 300 to 350 km and catchment areas of 20,000 to 22,000 km^2. The tributaries have abundant discharge and clean runoff even in the wet season, compared with the Gongola, because their runoffs come down from high rocky mountains with rainfall of 2,000 to 2,500 mm per annum. The

Benue near Umaisha, just upstream of the Lokoja confluence, has a very gentle slope of 1/10,000 and forms a wide stream with width ranging from 2 to 3 km during the flood season. Accordingly, sand banks are well developed by sediment loads transported from its upstream reaches.

The change of runoff of the Niger and the Benue since 1960 are shown in Tables 3B-1, 2, 3.

3B. 2. 4 Major Tributaries of the Niger

The Sokoto-Rima river, the largest tributary of the Niger in the subdivision HA-I originates in the Katsina Mountains, flows near the northern border to the Republic of Niger changes its course to the southwest near Sokoto City and join the Niger at Gwamba. A number of tributaries are well developed in the left bank of the Sokoto-Rima river, while these in the right bank are not developed. The drainages to the left bank consist mainly of the Bunsura, Gagere, Zamfara, and Gulbin-Ka rivers and occupy the total catchment area of some 70,000 km^2. The Sokoto-Rima river, with its total length of 628 km, has a total catchment area of 98,300 km^2 and an annual mean runoff of some 6,000 MCM or the average runoff of 68 mm at the conjunction point of the Niger. The north basins of the Sokoto-Rima and its tributaries, underlain by the Basement Complex, have annual mean rainfalls ranging between 500 and 600 mm, and relatively low runoff rates even in the wet season. The rivers in the south basins flowing through sedimentary rock terrains covered extensively by thick alluvials, are meandering and braiding on gentle slopes, which results in loss of runoff due to seepage and evaporation in the alluvial plains.

A flood plain, called Fadama, is developed along the Sokoto-Rima river, a major tributary of the Niger. An area liable to flooding in the wetland forms a zone with widths ranging from two to four km. A number of small streams with widths less than 10 m meander in the wetland during the dry season, while almost the entire wetland is flooded during the wet season. Fertile sediments and soils are hence deposited in the flood plain during the rainy season, and present a vast area of land suitable for cultivation during the dry season. This is a traditional way of agriculture in this part of the country. It is not too difficult for the people living in the wetland to avoid damage due to flooding during the rainy seasons because houses are built on relatively high grounds, 10 m or higher above the maximum water level, and the increase of water levels is gradual at a rate of several centimeters a day.

Another major tributary is the Kaduna river which originates in Jos Plateau with elevations ranging between 1,200 and 1,500 m and an annual mean rainfall of 1,500 mm. The river runs through the west-central part of Nigeria to join the Niger at Muregi. Its drainage basin, underlain by the Basement Complex, has a total catchment area of approximately 63,700 km^2 with the annual mean runoff of 13,800 MCM or an average runoff yield of 217 mm.

3B. 2. 5 Major Tributaries of the Benue

The Gongola river is the largest tributary of the Benue and occupies a total catchment area of approximately 53,800 km^2 for a total length of 611 km. Its annual mean runoff of 5,500 MCM, and average runoff yield of 102 mm, appear to be relatively small for its catchment area. The river, originating in high mountains of the Jos Plateau underlain by the Basement Complex, has relatively high runoff rate in the upper basin, because of high precipitation with the annual mean rainfall of about 1,500 mm. However, the runoff rate decreases gradually towards the lower reaches, because the river runs through terrains underlain by sedimentary rocks or covered by extensive thick alluvials. Along the Gongola river, there are major dams such as Dadin Kowa (total capacity 2,855 MCM) and Kiri (total capacity 615 MCM). The wetland areas are also developed along the mid and lower reaches of the river. While tributaries with catchment areas of 3,000 to 10,000 km^2, such as Dolvona, Divana and Hgwal rivers, are developed on the left bank of Gongola river, there are only minor tributaries on the right bank.

Other major tributaries of the Benue are Taraba, Donga and Katsina-Ala rivers with total stream lengths and catchment areas of 322 km and 22,400 km^2, 338 km and 21,200 km^2, and 346 km and 31,100 km^2 respectively. These tributaries of the Benue originates in the high mountains along the border of Cameroon and their average runoff yields range between 500 and 1,000 mm. Rainfall in their watersheds increase from east to west with the maximum annual mean rainfall of about 3,000 mm at the highest elevation. Accordingly, the runoff rates increase from the Taraba to the Katsina-Ala basins.

3B. 3 The Lake Chad Basin

3B. 3. 1 Lake Morphology

The Lake Chad (Figure 3B-2) situated between Lat.12°20'- 14°30' N and 13°00' - 15° 30' E in the borderland south of the Sahara Desert is placed off-center and westwards within the Chad Basin that is occupies an area of approximately 2.4 $\times 10^6$ km^2 encompassing of four countries, Nigeria, Niger, Chad and Cameroon. About eight percent or 0.2 $\times 10^6$ km^2 of the Basin area and less than 3 percent of the Lake's surface fall within Nigeria. The Lake is landlocked with no surface outlet and had areal dimension of 26 $\times 10^3$ km^2 in 1962 which was reduced to 10 $\times 10^3$ km^2 in 1983. The Lake Chad that is called "the largest shallow Water Lake in Africa", is characterized by be (1) duneserrated northern and eastern shores and (2) fresh water. It is remarkable that the Lake is fresh with the electric conductivity of 180, salinity of 0.165 permil gr and pH of 8.0 to 8.5, in spite of a total inflow of 10 - 20 $\times 10^6$ ton of dissolved salt.

The Chari river in Chad has its source in the Central Africa Republic, while its main tributary, the Logone originated in the Adamawa Highlands in Cameroon. With the combined catchment area of 551 $\times$ 10 km^2, the two rivers water account for nearly 90 percent of the Lake's total inflow. Other contributing inflows are the El Beid river in Cameroon, the Yedseram river and the Komadugu/Yobe river in Nigeria. Their relative contributions are shown below:

Lake Chad: Annual Inflow (Sikes: 1972)

	Water Source	Annual Inflow	
		10^6 cu.m	%
Rivers:	Chari-Logone, Chad	40.4	81
	El Beid, Cameroon	2.0	4
	Komadugu/Yobe, Nigeria	0.5	1
	Yedseram, Nigeria	0.1	1
	Sub-total	43.0	87
Rainfall		6.6	13
	Total	49.6	100

Sikes explains that since the contribution of rainfall is very small, the water level of the Lake is very much dependent on Chari-Logone hydrological system. The evaporation from the Lake approximately balances the inflows from the rivers and the rainfall. Loss of water by transpiration from widespread vegetation accounts for 17 percent of the total loss, according to Sikes, while the loss by evaporation is estimated at 80 percent. The remaining three percent loss is attributed to infiltration into the groundwater system in the northern and eastern shores.

The Lake has two outflow channels:

- The Bahr et Ghazal, an easterly outflow channel, links to the Bodele Depression, 500 km to the northeast, that is at an elevation of 150 m.
- The other outflow channel is a small river flowing out of the southern shore between the Lagone and the Yedseram. Flooded water during the high flow season of the Chari-Lagone, runs through the river and flows, via the El Beid, ultimately into the Benue river. The river forms a sizable valley which has been once filled with sediments.

The Yedseram river also called the Mbuli river in its lower reach, rises in Mandara Hills along with its upper tributaries such as the Vintim and the Delicum. While flowing northwards through a 7 km wide flood plain, it loses much of surface water. An eighty sq.km swamp is formed at the confluence of the Yedseram and the Ngadda, 32 km west of Bana. No distinct water course is observed downstream of the swamp.

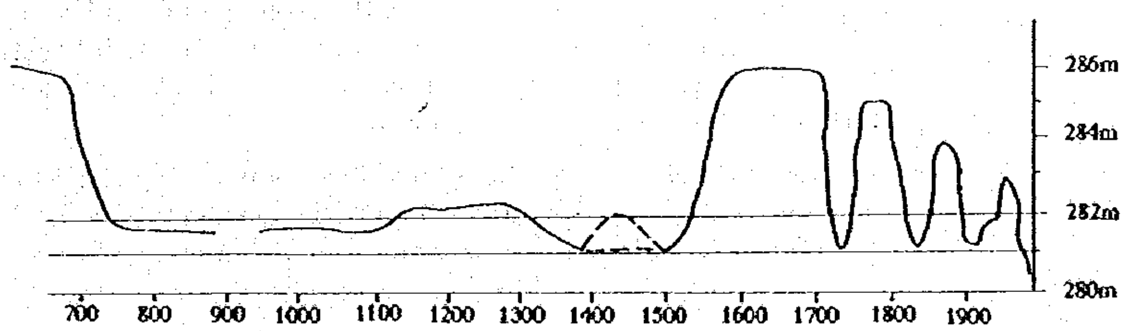
The Komadugu/Yobe river flows the northernmost part of the Borno State, and in its lower course, forms along the international boundary with the Niger Republic before entering the Lake near the fishing village of Afunuri. A curious hydrological phenomenon is the dry-season flood which push back the Komadugu/Yobe water as far as 130 km westwards. The flood, caused by the late arrival of rainfall water down the extremely gentle slope of the basin, occur three to four months after the end of the rainy season in the Chad Basin. The overall gradient at the slope is estimated at 1/250,000 which is imperceptible. The hydrological system of the region west of Lake Chad has found their water very much depleted while flowing through the Pleistocene (Quaternary) deposits, called "the Chad Formation".

The hydrography of the Lake Chad environs is highly conditioned by its shallowness and numerous submerged paleo-dunes. The submerged valleys account for the maintenance of open channels of an otherwise swamp domination, and also the northern basin is separated from the southern by a swamp belt anchored to the underwater sandy ridge as the grand barrier from Baga Kawa (western shore) to Baga Sola (eastern shore). In view of the extreme shallowness of the Lake and of the shoreline topography as well as the Chad Basin in general, frequent seasonal inundations have been in common place. The southern basin is more shallow than the northern under the circumstance of the Chari-Logone river system which produces the seasonal floods with higher rainfall over its catchment. Such inundations of the shore regions as recorded even more a century ago also took place as a consequence of rainfall during the months of June to September.

3B.3.2 Water Levels

The present phenomenon of the receding shoreline of the Lake Chad has re-awakened the alarming prospect of a shrinking lake, although this is not a new one with the evidence of previous fluctuations of the Lake levels and its areal dimensions as appeared in historic documents, travelers' diaries and official records. When viewed in the context of the recent Sahel Drought since 1968 as related to fundamental changes in global atmospheric circulation patterns and the circumstance of a continuing desiccation, a shrinking lake has become of real concern since the low and high levels of the Lake Chad do reflect the rainfall fluctuations within the climatic zone where it is located.

It is on record that in 1962 the Lake was at its highest level in this century, being one meter higher than the mean lake level of EL.282 m. This high lake level is also viewed in comparison with its low level in 1908 when villagers had sprung up on the dried-up lake bed in the northern part. Although it is one record that in 1904 the lake was substantially navigable, a British explorer had in 1905 to have his boat hauled through liquid mud in search of water. The low water periods, viz. 1905 - '08 and 1916 were characterized by the lake taking on the appearance of a vast swamp permitting the establishment of amabach trees which is currently extinct. Soon after, the lake water rose again during the years 1909 - 13 and 1917 - 20 when the amabach trees died off gradually and replaced by extensive papyrus and whole variety of reed-grasses. The generalized Lake Chad levels during the period of 700 AD to 1980 [adapted from: Pote, 1974; Nicholson, 1080; Mary, 1981] are shown below:



Water Level Fluctuation of Lake Chad

Figure 3B.3 shows water levels of the Lake Chad at Kirenowa at intervals of two years from 1976 to 1989.

3B. 3. 3 Proposals on Z-C-N and TRANS-AQUA

Aside from the proposed Hawal transfer from the Upper Gongola to the Chad Basin through the Ngadda river, there are two proposal for a hydrological linkage of the Zaire and Chad Basin to recharge the Chad Basin. The first proposal is referred to as TRANS-AQUA that is the Italian based involving the construction of a 2,500 km canal system from Eastern Zaire along the north-eastern Zaire River Basin rim into the heart of the Central African Republic, from where the Zaire water will flow by gravity in the Lake Chad. An outline scheme of the Zaire-Chad-Niger (Z-C-N) Interbasin Water Transfer is widely circulated in Nigeria (Umolu, undated).

The Z-C-N scheme to link the Zaire river and a tributary of the Benue river to the Chad basin via dams, canals and hydro-power pumping stations is proposed as a three stage operation. The Umolu brief report indicates:

- The West Central African sub-region is endowed with immense energy resources which could be used for the implementation of the interbasin water transfer at local and sub-regional levels.

- Including 12 items for the scheme benefits, the scheme would involve seven countries, Zaire, Congo, Central African Republic, Chad, Cameroon, Niger and Nigeria and would add new dimensions to the socio-economic conditions within the catchment areas and along the transfer routes.
- The scheme admits a major impact on the ecology and environment which should be thoroughly researched, and the financial section suggests that implementation could be achieved through international cooperation and assistance.
- One additional element on the map folio accompanying the scheme is a Trans Sahel Canal/Pipeline which will run from the Lake Chad to the Niger river along a course of the Hadejia and Sokoto river.

As a result of discussing major inter basin water transfer schemes in many parts of the world where semi-arid lands border on well-watered river basins, the proposed mega-scale Z-C-N scheme would not be thought to have a major role to play in sound environmental management, and can be probably ignored for the foreseeable future during the NWRMP period.

Above-mentioned scheme is included in the master plan for the development and environmentally sound management of the natural resources of the Lake Chad conventional basin by the Lake Chad Basin Commission.

3B.4 RIVERS IN SOUTH LITTORAL

3B.4.1 Special Features of Rivers

(1) The Rivers in the South-West Region

In the South West Littoral basin, meidum-scale rivers such as Oyan, Ogun, Oshun, Omi, Osse, etc., originate in the northern plateau in the basin, flow down through hilly areas with medium slope and discharge into the Gulf of Guinea.

Individual catchment areas and river lengths are about 2,000 to 10,000 sq.km and 150 to 250 km, respectively. The rivers present rich runoff due to a rather high rainfall of 1,500 to 2,000 mm in the basin. Large flood caused by high rainfall intensity are common and bring about the flood disasters in urban areas located in the lower basin.

The river mouths are clogged by transported sediment from the upstream reaches and a number of the coastal lagoons are formed.

(2) The Rivers in the South-East Region

The south east littoral basin is mostly covered with the Cross river and its tributaries. The Cross river originates in high mountain areas of Cameroon, enters Nigeria across the eastern border, flows down through undulating hilly areas with medium slope and empties into the Gulf of Guinea. The river presents a largest unit runoff in Nigeria due to considerably high rainfall of 3,000 to 3,500 mm in the upper basin. These rivers also cause extensive flooding in the lower basins.

There are many areas suffering from soil erosion and land slides in these river basins due to high rainfall and the presence of sandy soils.

3B. 4. 2 Delta and Lagoon

(1) Niger Delta

The Niger Delta is a vast delta formed at the Niger river mouth and has a 480 km coastline. The Niger forms a large alluvial fan after its confluence with the Benue river and flows downstream through the narrow pass between Onitsha and Asaba and into the Niger Delta. The river gradient of the Niger in the Niger Delta is remarkably gentle being less than 1/20,000, so that it meanders before flowing into the Gulf of Guinea forming a reticula pattern. Almost all outlets form sand spits so that locally the coastline is uneven but as a whole, it forms a gently curving coastal lowland. The soil of the Delta is made up of gravels, sands and silts which have been transported by the Niger. Sand is especially abundant along the coastline. In the central part of the Niger Delta, the flood plains are heavily cropped. The original vegetation of this area is tropical rain forest but recently it has largely been converted to cultivated fields, with only small pockets of rain forest remaining around the central part of the delta. Originally the coastline was covered by primeval mangrove forests which are being destroyed by deforestation and coastal erosion. Coastal marshes are expanding gradually and replacing the mangrove forests.

The climate of the Niger Delta area belongs to tropical rain forest. Its annual rainfall, generally more than 2,500 mm, is particularly high in Rivers State where it often exceeds 3,000 mm.

Generally, the most important factor influencing the upstream distance to which seawater invades in a river is the velocity of a river flow. The methods of invasion of seawater are classified into three types. The velocity of upstream saltwater movement decreases with distance from the river mouth. The point of maximum upstream penetration is the place where the inflowing salt water velocity balances that of the river flow. The gradient of the Niger River in the Niger Delta is as small as 1/20,000. The upstream river flow velocity is dependent on the depth of the channel at the river mouth and is proportional to the square of the depth. The depth of the Niger River mouth is several meter even in the dry season. For these reasons, it can be said that the water of the coastal estuaries of all rivers of the Niger Delta which have large river mouth, is brackish.

The tidal range is great along the Gulf of Guinea. The range of the spring tides at Port Harcourt reaches 2.35 m. The gradient of the Escravos river which is one of the branches of the Niger River, is 1/20,000. Therefore the maximum sea level in this area suggests that saltwater can reach as far as 47 km upstream of Port Harcourt. However the actual penetration of saltware is usually somewhat less than that predicted from the relative levels of river and ocean due to the dynamic resistance of the river flow. In case of the Escravos river, seawater practically reaches near the point where the level of the river becomes equal to that of the surface at the time of the rising tide, because the tidal cycle is observed at the town of Koto, 42 km upstream of Port Harcourt. In almost all rivers in the Niger Delta, it can be estimated that seawater can flow upstream almost to the point where sea level equals the elevation of the river's surface.

(2) Lagos Lagoon

Lagos Lagoon is a shallow marsh which is isolated from the ocean by sandbars produced by sediments transported by the Ogun, Oshun and other rivers. The former capital city, Lagos, is the largest city in Nigeria and was built on the only tidal inlet of the Lagos lagoon. Generally, sediments carried in the river that discharge into the lagoon and sands transported from the coast by tidal movement settle inside the lagoon and form tidal deltas. But, in the case of the Lagos Lagoon, erosion exceeds sedimentation so that coastal erosion problems have become serious. In particular, the coastal erosion problem of Victoria Island which is a part of Lagos City, is remarkably serious. Locally, this phenomenon is caused by a man-made breakwater which has cut off the supply of sand. On a regional scale, the cause of serious coastal erosion is the change of the tidal flows in the Gulf of Gunea after the construction of commercial ports in Ghana and Benin. Damage due to coastal erosion has spread widely from Ghana to Cameroon in areas facing the Gulf of Guinea.

The coastal plain around the Lagos Lagoon is 10 ~ 20 km wide and originally has covered by primeval mangrove forest. Recently coastal erosion and deforestation have destroyed the mangrove forests. It is only around the mouth of Osse river that the mangrove forests can still be found as most of the coastal plain has been converted into vast salt marshes.

3B.5 FLOODING AND ERODED SEDIMENT PROBLEMS

3B.5.1 River Flooding

(1) River Flooding Regime

Flood problems and its countermeasures are described in Part 7B "Flood Control and Drainage", therefore, in this chapter, only an outline is described.

There is almost no flooding problem due to flash flood runoff along major rivers except for floods in the Upper Benue Basin due to misoperations resulting in the uncontrolled release of flood water at Lagbo Dam in Cameroon and also for some rivers in the South Region because of severe land degradation over their watersheds. On the other hand, there are many flooded areas so-called "Fadama" during the wet seasons. These wetlands generally developed at the transitional sections between the Basement Complex and the sedimentary terrains are an extensive series of swamps, grasslands and woodlands, the extents of which are determined by flood discharge. The Fadama supports diverse economic activities including wet season cultivation mainly of rice; residual soil moisture cultivation following the wet season; dry season irrigation using simple wells and water lifting devices; dry season grading, fishing and hunting. The pattern of resource use in these wetlands is complex in space because of physical diversity in the floodplain and in time because of change in the flooding patterns and changes in the socio-economic position of different households; thus, the Fadama rehabilitation and sustainable development is currently one of the major issues in terms of re-establishing a natural flooding pattern to be included in the NWRMP Study.

As for the extraordinary flash floods in the Niger and Benue Rivers from dams outside Nigeria, it is explained that the Water Resources Sector, FMAWRRD has initiated comprehensive program to monitor the impact of these problems; however, the available information had not reached the JICA Team during the course of Field Work (II and III).

(2) Problems in the Niger Delta

The Niger Delta is an extensive plain criss-crossed by a maze of meandering rivers and creeks. The banks of these water channels consist of levees which slope down into backswamps and flooded depressions. When the Niger and its distributaries are in flood, these banks are eroded especially on the outside of meander bends which are transformed into vertical faces. The flooding normally lasts for three to five months in the year, and the level differences between low and flood flow are six to ten m. As the flood water recedes, the river banks become unstable with the subsequent collaps of large earth masses. Tidal movements also accelerate bank erosion in some places. Rates of bank erosion are two to five m per year along the larger channels, poseing serious threats to towns, villages and farmland in the region.

Aside from the Niger Delta, erosion along some of the country's rivers and creeks in Nigeria is similar to coastal erosion. The riverine erosion is mainly caused by the waves generated by the movement of watercraft, canoes and speed boats in particular, but also by rises in water level during floods.

(3) Eroded Sediment Problem

Sediment pollution of water bodies as a result of accelerated soil erosion is a serious and widespread problem in Nigeria. The area particularly affected are in the Northern Region, the gully erosion disaster areas of Anambra and Imo as well as other parts of the Southern Region where agricultural practices leave the soil bare at the start of the rainy season. The recent operations of mechanized farming especially in the Central Region is aggravating the erosion and sediment problems.

High river water turbidity well above the permissible levels have been observed in many parts of the country. These include the Ife-Ife area, the Zaria area, the Jos plateau, the Chaluwn and Rano river basins and the Kainji Lake basin. Sediment pollution of water creates several problems, such as the early silting-up of reservoirs which shortens their life-span, low water transparency in rivers and reservoirs, which adversely affect fish populations and increases water treatment costs, reduce navigability, increase flooding, and block irrigation canals. In Oyo, Osun and Ogun States, several reservoirs which were built for domestic water supplies have been virtually silted up. Lake and reservoir siltation often results in accelerated weed infestation. In the the Lake Chad, the weeds have formed a great underwater ridge known as the Grand Barrier which has effectively separated the lake into two parts with waters on one side unable to mix with those on the other. The weeds also waste water because of increased transpiration and decrease algal productivity thereby reducing fish productivity.

The delivery of large amounts of sediment into rivers results in the formation of shoals and shifting bars of sands and the change of river bed configuration and river regime as whole, which makes water diversion and navigation difficult. This is a major problem in the main rivers particularly the Niger and the Benue where navigation even in the flood times depends upon frequent resurveying of the salvage and the relocation of buoys. Sedimentation of the river channels and canals also raised their beds resulting in increased flooding in the case of rivers and waterlogging of irrigated fields in the case of canals.

As described in chapter 7B, the land degradation is one of the crucial problems in Nigeria which is creating serious erosion problems from the view point of water resources conservation. It appears that up to date, attempts to address the land degradation problem have been made by farmers and their traditional leaders. However, the scale on which these remedies have been successfully applied by successive governments has been small in relation to the immensity of the degradation problems. If the problems of land degradation are to be tackled on the scale required to mitigate the emergence of such catastrophic situations as mentioned above, this will call for a much more vigorous "Integrated Watershed Management Approach" including agronomic countermeasures to conserve the upstream watersheds and the civil engineering steps to check the incoming sediments over the upstream problematic valleys.

3B. 5. 2 Excess Runoff in Urban Areas

In the South Region, the high local intensities and long durations of rainfall in the wet season often generate rainfall-runoff volumes in excess of the local drainage capacity. In recent years, as a result of inadequate construction of the social infrastructure particularly in urban areas in addition to serious land degradation in their catchments, drainage has been impede and aggravates the flooding conditions, and also promote gully erosion particularly in Anambra and Imo.

During the extensive field reconnaissance by the JICA River Planner, two towns such as Calabar and Aba were reported to have problems caused by flooding. As the residential and industrial areas are expanding over the flood plains, local people are seriously affected by damages to their own properties and to public transportation caused by flooding, to alleviate these problems flood control plans have been programmed. The project in Calabar, capital of Cross River State includes the construction of new channels comprising six main and a number of branch channels which are inter-connected and flow to the coast, with the length of 40 km in total. At present, seven km has been completed together with the arterial roads constructed on channel banks for protection. In general, the public works are being carried out to repair and reconstruct the arterial roads on banks and dikes which are considered effective to prevent the flooding; however, people living along the river are afraid of adverse effects of these works on their cropping rather that of the damages to their properties by flooding. This means that the flooding appears to bring more advantages than damages to the local people living near the river. If cultivation styles are considerably changed in future, different measures to mitigate the flooding problems may have to be seriously considered.

The town of Abain Abia State is located in a basin which has no natural river outlet. It consequently suffered from flooding almost every time it rained. The Cross RBDA has constructed two drainage conduits, 3.3 km long; however, these are not working properly at the present time due to heavy sedimentation. Maintenance of these conduits is being taken care of by LGA with serious budgetary constraints.

3B.5.3 Change in River Channel and Bed

(1) Management Agencies

As river management produces benefits to the entire economy, it is in principle a government task. In 1954, the World Bank recommended that a government department be established to collect detailed information on the behavior of Nigerian rivers and to hold this information ready for studies of flood control, irrigation, and reclamation projects as well as for navigation and hydro-electric schemes. In 1956, the FGN established the "Federal Inland Waterways Department" (FIWD) in charge of conservation of inland and coastal waters taking this roll over Nigerian Marine. The FIWD has following responsibilities that have a direct bearing on the navigability:

- the operation and maintenance of Government craft.
- maintenance and improvement of channels; control of navigation.
- wrecks, lights, buoys and piers, licenses, examinations and surveys of craft.
- hydrological and hydrographic surveys, including map production:
  - water-levels, archives and publications.
  - hydrographic surveys.
  - mapping.
  - channel demarcation (buoys, beacons, mile-boards, patrols, contact pilots, buoy-cleaning)
  - dredging.
  - communications such as radio and meteorological bulletins.
- hydraulic engineering:
  - Hydraulic engineering, i.e., the design and execution of temporary and permanent training-works, bank stabilization, and eventually also the operation and maintenance of dams, reservoirs and locks.

In connection with this, a full-scale investigation of the Rivers Niger and Benue with the objective of determining how the shipping conditions on these rivers could be most effectively improved, was commenced by NEDECO in 1954, and the Final Report: River Studies and Recommendations on Improvement of the Niger and the Benue "in 1959 that is called "NEDECO Bible" has established the foundation of the FIWD activities. The planning, design and supervision of the construction of works to improve the navigability of the Niger in the reach from Baro to Warri and Port Harcourt was started by LCHF (Laboratories Central d'Hydraulique de France) in 1981 with the Final Report: Niger River Channel Development Programme" (1984). In a similar way, Hidroservices, Brazil presented in 1984 the Final Report: Improvement of Navigability on the Benue River in the Territory of Nigeria.

In 1975, the Federal Ministry of Water Resources was initially created, however, the responsibility of nation-wide river management administration has not been attached to the said Ministry, and the FIWD is still responsible for the management of the Niger and the Benue in terms of inland navigation as is shown in the Navigable Waterways Decree (No.56 of 1988). Actually, there are several hydrological gaging stations along the Niger and the Benue under FIWD management where it appears that the FIWD has much concern about the river water level observation for navigation purposes. However less emphasis has been placed upon runoff measurement, which has resulted in several doubts as to the reliability and availability of data as pointed out in Part 3A. In addition, special remark is made as to the responsibility of the National Committee for Water Resources where a sub-committe with respect to the river management and administration is not provided. It can be said that at this stage, there is no single government agency who is in charge of integrated river management including use and conservation of the water resources and river systems for public interests. The Water Resources Decree, promulgated and enforced in August 1993, is expected to strengthen the proper undertaking of the mandated responsibility for effective control and efficient management of the nation's water resources and river systems. However, there will be need for adjustment of river management activities between the Water Resources Section, FMWRRD and the FIWD.

The watershed management may be defined as the natural counterpart of soil conservation, and soil conservation is strictly purposed. The effect of the runoff is two-fold: less sediment is carried to the rivers, and the water discharges are more evenly distributed over a longer period. However it takes a long time before these effects are realized. While the overall programs and priorities for soil conservation are formulated largely by the National Committee on Ecological Problems, the main Federal institutions concerned with natural resources management and conservation policy are the Federal Department of Forestry and Agricultural Land Resources, the Agriculture Sector, FMWRRD, the FEPA and the NARESCON. In order to strengthen the activities of watershed management programs, positive involvement of the

Water Resources Sector, FMWRRD should be promoted to execute proper river management and administration in future.

(2) Lack of River Maintenance Flow Concept

Virtually, there is lack of considerations in the policy and administration to maintain the minimum flows in various rivers for the downstream water users and related environment. It is apparent that the recent tendency of the Sahelian drought and of the socio-economic activities to extract more water in the upstream has accelerated this problem. In coastal section of the Niger River after Lokoja, a strict attention should be paid to the increase in salinity due to the salt water intrusion, lowering of groundwater tables, changes in flora and fauna, and so forth, and a countermeasure to release the minimum flow from the upstream water storages at NEPA-Jabba, Shiroro, Upper Benue-Kiri and others for the environmental protection in the Niger downstream may need to be discussed during the NWRMP period. On the other hand, the older customary water use right mainly for agricultural and various rural activities in Fadama areas for several centuries are currently difficult to be comprehended and protected due to the construction of upstream reservoirs.

(3) Lack of Basic Reference Control Points

A total of 358 gaging stations are identified through the NWRIS as reported in PART 3C. Surface Water Resources. These gaging stations are managed by the State Water Agencies (148 stations), RBDAs (89 stations), FDWR (59 stations), FIWD (44 stations) and NEPA (14 stations).

These facilities are set up to properly manage dams for efficient power generation by NEPA and to maintain routes for water transport by FIWD who measures mainly water levels. The State Water Agency utilizes these facilities to study the actual status of drainage systems by obtaining fundamental data for creating future projects.

Differences in run-off rates in the dry and wet seasons are considerable in tropical drainage systems. Major rivers often expand their widths up to several kilometers during the rainy season, and it is particularly difficult to properly measure flow-rates, water levels and other parameters.

There appears to be a number of occasions where gaging stations fail to obtain proper measurements. This may be partly because there is no consensus among the managements concerned with the water resources in the country. River gaging stations should be set up at important locations to obtain useful data for planning and controlling river systems and for construction of necessary facilities.

The reference control points at strategic locations are the most important tools in carrying out the adequate river management and administration under a single government and administration. These reference control points should be the permanent structures equipped with the accurate observation facilities of river flows in quantitative and qualitative terms and a series of survey vessels to monitor the river morphology, and the information and data thus obtained should be promptly transmitted to the headquarters of a River Management Agency for subsequent processing and instruction to operate various hydraulic structures and to undertake the forecasting and warning on flood and drought for the public.

Since rivers run continuously from upstreams to downstream, measurements of various parameters at different points of river courses will furnish useful fundamental data to understand status and characteristics of rivers. With a full understanding of the status and characteristics of rivers, it becomes possible to make a decision on how to use and control rivers. For example, there may be some doubt if it is appropriate to construct Dadin Kowa and Kiri dams along the Gongola river which have much larger capacities than the annual mean run-off of the river.

As development of rivers progresses, various problems may arise. For example, reckless development of rivers may sometimes activate erosion and resultant soil and sediment accumulation may cause river beds to rise, which leads to problems such as unstable stream courses and obstacles for inland water transport. It is important to measure water levels, run-off rates, river bed levels and other parameters for efficient river management.

(4) River Training Program

The river training programs have been conceived by the Water Resources Sector, FMWRRD to improve flow in the river channels downstream of major hydraulic structures and to observe perennial rivers. The objectives of the programs is to increase the rate of river flow through (1) reduction in conveyance losses by evaporation and seepage, (2) increase in flow volume by higher driving gradient and conveyance speed, and (3) increase in flow volume by removal of obstructions along the river beds. These programs which examine the mechanics of riverflow downstream of the dam are being studied at the following sections:

I. River Ogun between Lagos Lagoon and Olokemeji.
II. River Ogun between Olokemeji and Ikere Gorge.
III. River Gongola between Numan and Dadin Kowa Dam.
IV. River Hadejia between Hadejia and Geidam.
V. River Hadejia between Hadejia and Tiga Challawa.
VI. Jama'are River between Katagum and Zakidam.
VII. Komadouguo-Yobe River between Geidam and Lake Chad.
VIII. River Sokoto between Bakolori and Sokoto.
IX. River Rima between Birnin Kebbi and Goronyo Dam.

During the Field Work (II and III), JICA Team could obtain the data of project I, IV, VIII and IX. The actual works carried out in project I "River Ogun between Lagos Lagoon and Olokemeji" is as follows.

- Beacon placement on the bank of the river
- Leveling to provide heights of the pillars and details for the cross-sections at every 500m
- Traversing the course of the river and
- Collection of water and soil samples

In the project IV, VIII and IX, the tasks were also carried out and together with the studies of geology, topography and hydrological observation for irrigation and water supply planning. The review of project "Improvement of River Channels Along River Hadejia between Geidam and Hadejia" (Chifana, 1985) is described in Chapter 5.3.6. Therefore, in Nigeria, river training, in the strict sense of the word, is not carried out at present.

According to the field survey, there would not be shifting of major river courses, but there would be needs to stabilize the river channels and banks at critical points due to local scours and sediment deposits. Generally speaking, adequate countermeasures for these local problems have not been observed. It may be practical to improve the depth in some critical shoal areas by constructing local training works using locally available materials such as bamboo poles, mats and brushwood arranged to form simple fences aligned so as to induce the deposition of sediment in a controlled pattern in one part of the channel and scouring in another due to the concentrated flow. Such works would be temporary in nature and would have to be reconstructed each year in the majority of cases. Scouring can also be induced artificially by means of bottom and floating vanes.

TABLE 3B - 1 MAXIMUM, MINIMUM AND AVERAGE DISCHARGES

River : Niger
Station : Jiddere Bode
Catchment area : 563,600 sq.km

Year	Minimum		Maximum		Average
	Month	cu.m/sec	Month	cu.m/sec	(cu.m/sec)
1960					
1961					
1962					
1963					
1964					
1965					
1966					
1967					
1968					
1969					
1970	Jun.	174	Sep.	2,379	1,482
1971	Jun.	9	Sep.	2,275	1,111
1972	May	76	Feb.	2,214	1,035
1973	May	2	Jan.	1,613	839
1974	May	5	Sep.	2,529	1,036
1975	Jun	19	Oct.	2,041	1,082
1976	May	169	Jan.	1,912	1,074
1977	May	129	Jan.	1,750	1,098
1978	Apr.	137	Sep.	2,093	928
1979	May	52	Oct.	2,134	1,134
1980	May	35	Jan.	1,919	1,027
1981	May	29	Dec.	1,645	858
1982	May	65	Jan.	1,692	920
1983	May	2	Dec.	1,324	969
1984	May	32	Oct.	1,332	571
1985	May	1	Sep.	1,785	744
1986	May	52	Oct.	1,383	739
1987	May	39	Oct.	1,289	642
1988	May	55	Sep.	2,694	979
1989	May	54	Sep.	1,666	779

TABLE 3B - 2 MAXIMUM, MINIMUM AND AVERAGE DISCHARGES

River : Niger
Station : Lokoja
Catchment area : 1,089,500 sq.km

Year	Minimum		Maximum		Average
	Month	cu.m/sec	Month	cu.m/sec	(cu.m/sec)
1960	May	1,256	Oct.	22,420	6,754
1961	May	977	Oct.	15,520	4,906
1962	May	1,151	Oct.	23,290	6,915
1963	May	1,679	Oct.	20,540	6,724
1964	May	1,161	Oct.	20,810	6,143
1965	May	1,306	Sep.	18,620	5,927
1966	Apr.	1,323	Oct.	20,070	6,567
1967	May	928	Oct.	10,710	5,819
1968	May	1,771	Sep.	18,910	7,019
1969	Apr.	1,368	Sep.	23,550	7,962
1970	Jun.	289	Sep.	20,220	6,031
1971	Apr.	1,309	Sep.	17,630	5,376
1972	Apr.	1,417	Sep.	13,960	4,474
1973	Apr.	838	Sep.	12,290	3,702
1974	Apr.	833	Oct.	17,150	5,288
1975	Apr.	1,298	Oct.	19,640	5,850
1976	Apr.	1,501	Oct.	12,090	5,212
1977	Jun.	1,308	Oct.	15,180	4,658
1978	Feb.	1,130	Sep.	17,050	5,642
1979	May	1,299	Sep.	17,880	6,315
1980	Feb.	1,236	Oct.	22,790	5,952
1981	Apr.	1,321	Sep.	17,990	5,269
1982	May	1,227	Sep.	11,540	4,221
1983	Feb.	1,068	Sep.	9,130	2,021
1984	May	873	Sep.	8,540	2,847
1985	Apr.	1,036	Sep.	15,920	4,608
1986	Feb.	1,253	Oct.	11,050	3,958
1987	Feb.	1,237	Sep.	11,760	3,830
1988	Mar.	1,072	Oct.	15,640	4,705
1989	Mar.	1,066	Sep.	16,310	5,406

TABLE 3B - 3 MAXIMUM, MINIMUM AND AVERAGE DISCHARGES

River : Beune
Station : Makurdi
Catchment area : 305,000 sq.km

Year	Minimum		Maximum		Average
	Month	cu.m/sec	Month	cu.m/sec	(cu.m/sec)
1960	Mar.	208	Oct.	12,520	3,647
1961	Mar.	278	Oct.	10,900	2,720
1962	Feb.	319	Oct.	12,170	
1963	Mar.	319	Oct.	11,510	3,759
1964	Mar.	335	Oct.	11,210	3,345
1965	Apr.	397	Sep.	10,810	3,178
1966	Mar.	317	Oct.	10,620	3,561
1967	Feb.	383	Oct.	9,870	2,948
1968					-
1969	Feb.	18	Sep.	13,860	4,278
1970					
1971					
1972					
1973					
1974					
1975					
1976					
1977					
1978	Feb.	208	Sep.	10,070	3,049
1979	Apr.	208	Sep.	10,300	2,621
1980	Apr.	201	Sep.	10,930	2,902
1981	Mar.	180	Sep.	10,500	2,700
1982	Feb.	221	Sep.	8,700	2,599
1983		-	Sep.	7,300	
1984	Mar.	150	Sep.	6,446	1,959
1985	Feb.	203	Sep.	9,184	2,703
1986	Feb.	205	Sep.	6,765	2,049
1987	Feb.	214	Sep.	6,562	1,300
1988	Feb.	207	Oct.	9,990	2,719
1989	Feb	.210	Sep.	10,920	3,098

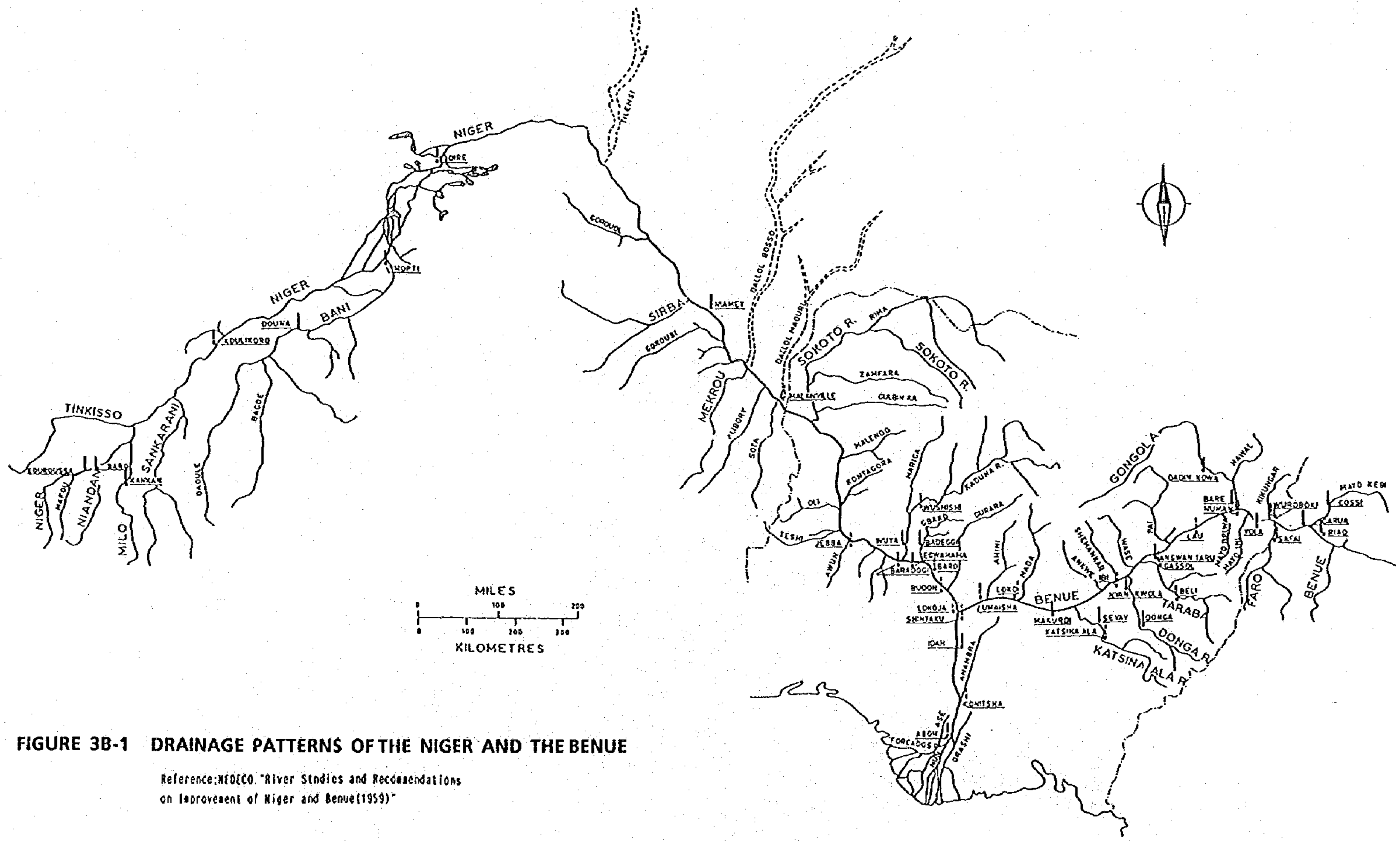
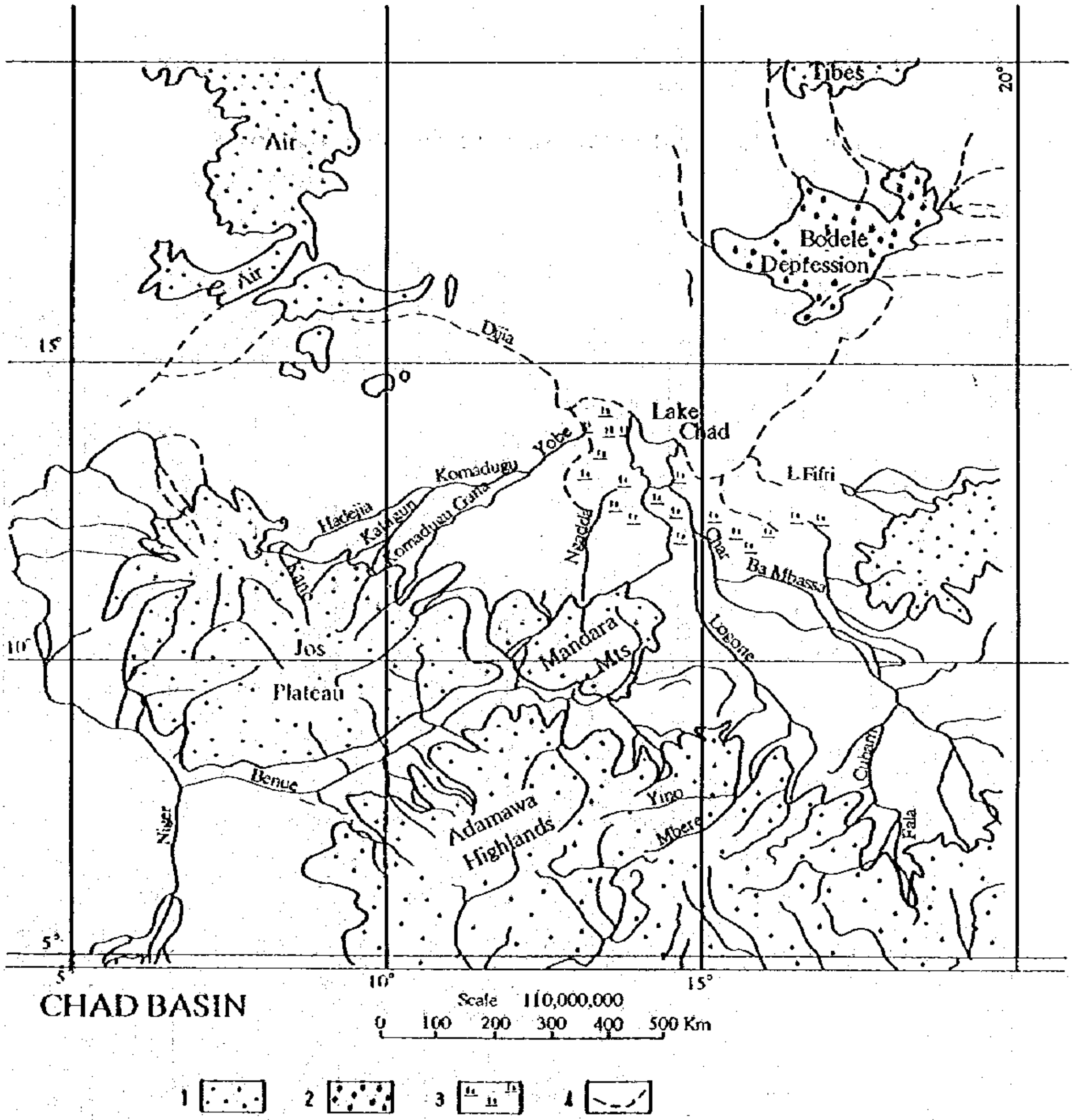


FIGURE 3B-1 DRAINAGE PATTERNS OF THE NIGER AND THE BENUE

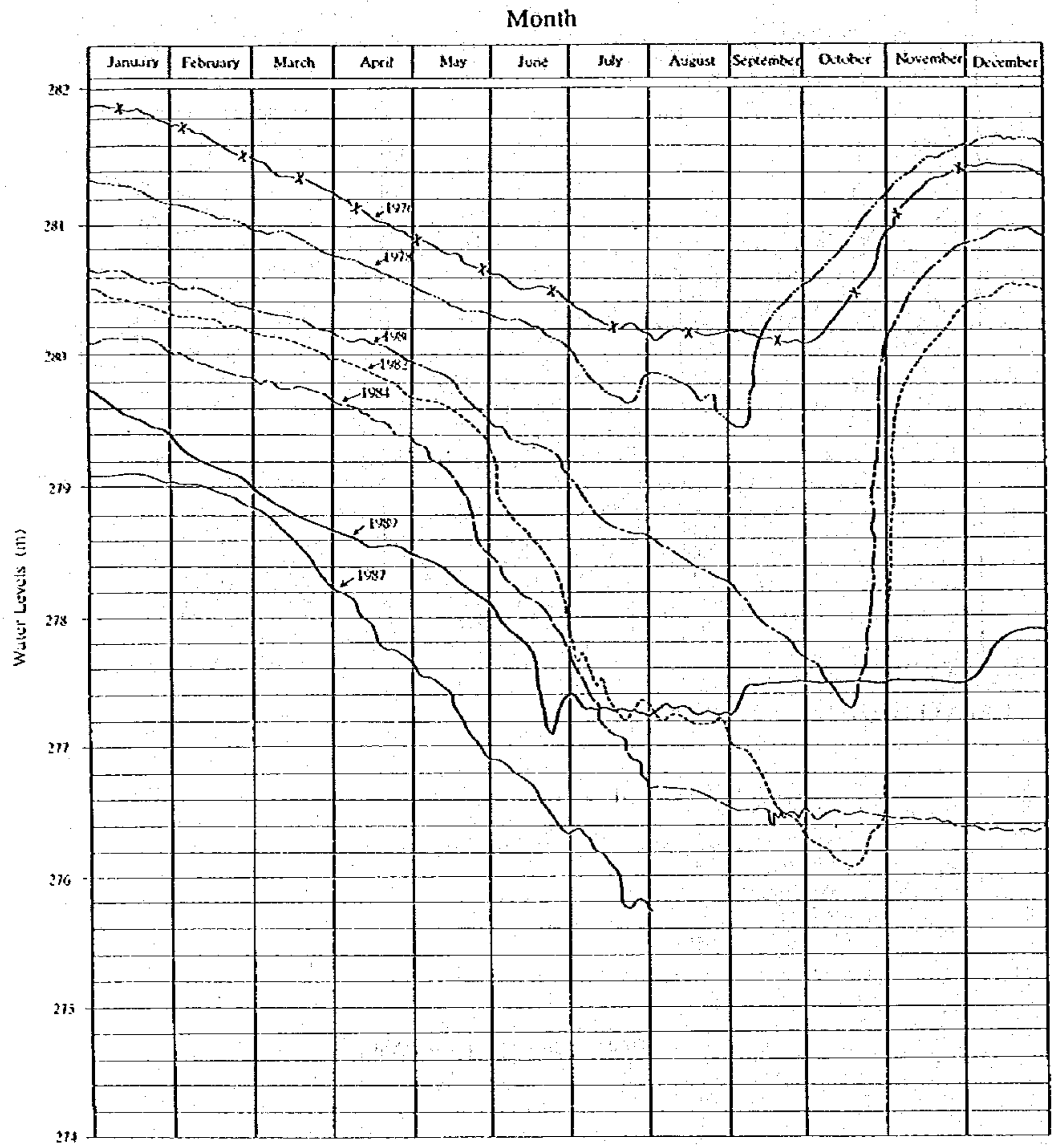
Reference:NEDECO."River Studies and Recommendations on Improvement of Niger and Benue(1959)"



Note: palaco-water courses and sources of Lake Chad in flows
1. Land over 500 El-m
2. Bodele Depression
3. Swamps
4 Palaco-Watercourses

FIGURE 3B-2 CHAD BASIN

FIGURE 3B-3 WATER LEVEL OF LAKE CHAD AT KIRENOWA



PART 3C. SURFACE WATER RESOURCES

3C. 1 JICA-NWRIS

The principal Ministry responsible for water resources policy formulation and development in Nigeria is the Federal Ministry of Water Resources and Rural Development (FMWRRD). The Federal Department of Hydrology and Hydrogeology (FDHH) is the operational department in the Ministry with the following main functions:

- Establishment, operation and maintenance of hydrological stations for basic data collection, analysis, storage and dissemination through periodic publications for real-time forecasting of hydrological phenomena,
- Groundwater exploration, evaluation, development and monitoring, and
- Policy formulation on hydrological and hydrogeological codes of practice.

Under the control of the FMWRRD, Zonal Offices and River Basin Development Authorities (RBDAs) are involved in water resources development. There are three other agencies which collect hydrological data. These are:

- State Water Agencies,
- The Federal Inland Waterways Department (FIWD), and
- The Nigerian Electric Power Plc. (NEPA).

The State Water Agencies are mainly involved in establishing river gaging stations at selected locations and collecting data which they intend to use for studying conceived projects. The Hydrological Division of FIWD located in Lokoja is charged with the task of collection, processing and analysis of water stages and discharge data along the River Niger, Benue river, Cross river and their tributaries such as Gongola, Donga, Taraba and others. The NEPA generates data on reservoir operation for hydropower purpose including Kainji, Jebba, Shiroro and others. The NEPA also has river gaging stations where the inflows are monitored. Furthermore, the NEPA maintains hydrological gaging stations at strategic locations along the River Niger.

It was estimated that there were in the region of 700 locations where stage and/or discharge measurement have been made on a routine basis (Draft Report "Sub-Sahara Africa, Hydrological Assessment : West Africa", January 1992). There is currently no comprehensive inventory of hydrological monitoring stations. According to data and information obtained from the FDHH, 627 river gauging stations were listed in 1987. Of 627 stations, 213 stations were reported to be discharge measurement stations; however, rating curves of most stations were not renovated, resulting in recording of river stage only.

During the Field Work period of this study, 358 river gaging stations have been identified through the inventory survey. The organizations maintaining river gaging stations are listed below:

Organizations Maintaining Stations

Organizations	Nos. of Stations	%
State Water Agencies	148	41
RBDAs	89	25
FDWR	59	16
FIWD	44	12
NEPA	14	5
Others	4	1
Total	358	100

Of 358 river gaging stations, 48 stations have automatic water stage gaging instruments and 310 stations are staff gaging stations. The following table gives the functional status of river gaging stations:

Functional Status of Stations

Status	Nos. of Stations	%
Good	173	48
Intermittent	111	31
Poor	74	21
Total	358	100

Discharge records are available at 119 stations for 83 rivers so far, and the data from these stations have been collected through the inventory survey for a 20 year period from 1970 to 1989. The long term discharge records are available at major stations on the River Niger, being maintained by the FIWD and NEPA, and the rivers of Yobe basin to drain into the Lake Chad.

65 river gaging stations with discharge records of more than five years in the 1980s have been selected for the study purpose, covering 33 rivers of Niger, Benue and other 31. Distribution of the selected stations by the HA is given below:

Selected Stations and Rivers

Nos. of:	Niger	Benue	Hydrological Area (HA)								Total
			I	II	III	IV	V	VI	VII	VIII	
Stations	7	4	7	3	11	2	-	7	11	13	65
Rivers	1	1	5	2	5	1	-	5	4	9	33

Locations and monthly runoff of the above 65 stations and other 25 stations which have discharge records in the 1970s are tabulated in the Water Resources Inventory Survey of this report under separate volume.

3C. 2 RIVER RUNOFF

3C. 2. 1 Long Term Trend of Niger River Runoff

Figure 3C.1 shows the fluctuation of yearly runoff of the River Niger at selected stations where long term discharge data are available. The fluctuation of the yearly runoff of the Benue river at two stations of Yola and Makurdi is given in Figure 3C.2 together with the yearly runoff at Lokoja on the River Niger. The runoff in MCM for the period from 1914 to 1957 is estimated based on the discharge data presented in the NEDECO report published in 1959.

As can be seen from the figures, the runoff of the River Niger has a tendency to decrease between 1925 to 1945, and in 1955 it marked the maximum ever recorded since 1914 (261,800 MCM). Since then the runoff has a downward trend to record the minimum annual runoff of 89,800 MCM in

1984. The fluctuation of the yearly runoff of the Benue river in the 1960s is not clear because of lacking of discharge data; however, it is obviously observed that the annual runoff is decreasing since 1969. The mean annual runoff of the River Niger at Lokoja over the period of 75 years is 183,000 MCM. The mean annual runoff of the River Niger is summarized as follows:

Mean Annual Runoff of River Niger

(Unit: $10^9 m^3$)

Year	Niger Main at Baro (730,300 km²)	Benue at Makurdi (305,500 km²)	Niger Main at Lokoja (1,089,000 km²)
1915 - 19	75	104	190
1920 - 29	89	n.a.	206
1930 - 39	80	104	186
1940 - 49	65	95	173
1950 - 59	n.a.	99	205
1960 - 69	78	111	204
1970 - 79	57	84	166
1980 - 89	42	72	138

3C.2.2 Runoff by HA

The mean annual runoff in the 1980s has been estimated for 65 runoff stations (Table 3C-1). For such runoff stations as have intermittent observation data, the sum of mean monthly runoff is deemed as the mean annual runoff. The general pattern of normal annual runoff is similar to that of the rainfall, but modified by soil and geological characteristics and other factors. The characteristics of runoff by the HA are summarized as follows:

HA - I : All rivers have a seasonal flow regime. About 95 percent of the annual runoff are concentrated in five months from June to October with the peak runoff in August. The mean annual runoff of the Rima river at Wamako is 1,141 MCM; however, according to the periodical discharge data at the downstream reaches in 1988 - 1989 observed by the Sokoto-Rima RBDA, the runoff of the river decreases toward downstream from Wamako. This is due to heavy evaporation and infiltration over the alluvial plains extending widely along the river.

HA - II : The rivers of Kaduna and Gongola, largest two rivers in this area, have perennial flows. 80 - 90 percent of the annual runoff are concentrated in five months from June to October with the peak in September.

HA - III : The area may be divided into two sub-areas with respect to river runoff being bordered by the Benue river. In the right bank of the Benue river, the Gongola river yields 102 mm/year of water at the confluence with the Benue, whereas in the left bank of the Benue river, the major rivers of Taraba and Donga that originate in the Cameroon highlands have the runoff yields of 535 mm at Tela and 1,200 mm at Manya respectively. Around 90 percent of the annual runoff of the rivers concentrated in five months from June to October with the peak in August in the north and in September in the south.

HA - IV : Discharge data are available only for the Katsina-Ala river at Katsina-Ala and Sevav that receive the runoff from the Cameroon highlands where annual rainfall in the headwaters exceeds 4,000 mm. The Katsins-Ala river has the runoff yield of 1,000 mm at Sevav and the peak occurs in September.

HA - V : No discharge data of tributary are available for the HA-V where the area lies along the lower reaches of the River Niger between Lokoja and the river mouth.

HA - VI : Many dams have been built on the rivers of the western littoral including the Oyan dam on the Oyan river. The runoff of the Oshun river is regulated by the operation of the Asejire dam. Peak flow occurs in September - October.

HA - VII: The important river in this area is the Cross that rises in the Cameroon highlands covered with dense rain forest. The runoff yield of the Cross river at Ikom is 1,590 mm. About 85 percent of the annual runoff are concentrated in five months from June to October with the peak in September, whereas about 70 percent of the annual runoff of the Imo river with the runoff yield of 650 mm at the river mouth concentrate in five months with the peak in September.

HA - VIII: In the HA-VIII, which constitutes parts of the Chad Lake basin, all rivers have a seasonal flow regime except the rivers of Kano, Hadejia and Yobe of which runoff is under the influence of the operation of dams including the Tiga dam on the Kano river. The largest river system in the area is the Hadejia-Yobe river system. The variation of annual runoff of this river system is marked by the fact that the annual runoff at Hadejia with the catchment area of 25,900 km^2 is lower than that at Wudil with the catchment area of 16,380 km^2 in 14 years in the 17-year period from 1972 to 1988, and in many years the annual runoff at Gashua with the catchment area of 55,700 km^2 is lower than that at Hadejia. River water is lost by evaporation and infiltration over the flood plains along the river as can be seen from the following table.

Yearly Runoff of Hadejia-Yobe River System

(Unit: MCM)

Year	Hadejia River at Wudil	Hadejia River at Hadejia	Yobe River at Gashua
1972	1,304	508	771
1973	882	456	642
1974	1,062	914	1,091
1975	1,077	757	1,137
1976	544	419	766
1977	2,122	790	788
1978	2,179	1,199	979
1979	2,502	950	926
1980	2,448	963	845
1981	3,042	1,185	872
1982	4,732	985	667
1983	318	751	469
1984	438	544	381
1985	799	848	599
1986	886	830	1,289
1987	971	909	464
1988	1,266	1,234	1,360

The fluctuation of the monthly discharge at the selected stations is given in Table 3C-2.

3C.2.3 Rainfall-Runoff Relation

The portion of rainfall does not contribute to stream flow; the water is lost by interception, depression storage and soil moisture. The annual runoff coefficients have been estimated at selected stations. Of 65 major stations, 38 stations were excluded; 19 stations receive runoff from the Cameroon highlands; 19 stations are lacking in continuous runoff data, leading to the selection of 27 stations. One or two representative rainfall stations are selected for each runoff station, and in case of two representative rainfall stations the arithmetic average depth of rainfall is used as the areal rainfall over the catchment area. The estimated annual runoff coefficients are presented in Table 3C-3. The annual runoff coefficients by the HA are summarized as follows:

HA - I : Excepting the two stations of Goronyo dam and Wamako on the Rima river which have relatively large catchment area, the annual runoff coefficients at five stations range from 0.13 to 0.18. The annual runoff coefficient of the Rima river is as small as 0.05.

HA - II : The continuous runoff data enough to estimate the annual runoff coefficient are not available in this area; the annual runoff coefficients of the Kaduna and Gurara rivers, two largest rivers in this area, are roughly estimated. The mean runoff field in the 1980s of the Kaduna river at the river mouth is 217 mm, whereas the areal rainfall over the catchment in the same decade is 1,140 mm, resulting in the annual runoff coefficient of 0.19. The monthly runoff data of the Gurara river is available for six years from 1974 - 79 at Izom station with the catchment area of 7,950 km^2, based on which the annual runoff coefficient is assumed to be 0.30.

HA - III : Being located on the right bank of the Benue river, the annual runoff coefficients of the Gongola river vary from 0.15 at Gombe Abba with the catchment area of 17,650 km^2 to 0.08 at Dadin Kowa with the catchment area of 32,700 km^2. On the left bank of the Benue river, the runoff yields of the Taraba and Donga rivers are as high as more than 500 mm as the rivers receive the high runoff from the Cameroon highlands. The annual runoff coefficient of the Jigawal river, one of the tributaries of the Taraba river, at Maisamari is 0.23.

HA - VI : Available data are not enough to estimate the annual runoff coefficients. The coefficients in this area may be in the order of

0.20 to 0.35 according to the runoff analysis of the Oshun and Oba rivers.

HA - VII: Runoff data are available only for the Imo river, the annual runoff coefficients of which range from 0.3 to 0.35.

HA - VIII: In the upstream areas of the Kano-Hadejia-Yobe river system, the annual runoff coefficients range between 0.13 and 0.15, and decrease toward the downstream: 0.06 at the Hadejia station and 0.03 at the Gashua station on the Yobe river.

Runoff will occur only when the rate of rainfall exceeds the rate at which water may infiltrate into the soil. After the infiltration rate is satisfied, water begins to fill the depressions on the soil surface. As the depressions are filled, overland flow begins. The rainfall-loss water correlation is drawn by plotting the accumulated rainfall and accumulated losses on the monthly basis for 14 stations in the Northern region (HA-1 and VIII). Typically the relation is slightly curved, indicating a decreasing percentage of loss water as rainfall increase; however, loss water increases straight as rainfall increases for four stations of Goronyo dam and Wamako on the Rima river, Kari station on the Misau river and Chai Chai station on the Gaya river. The estimated initial losses vary from 120 mm to 350 mm as shown below:

Initial Losses at Selected Stations

HA	River	Station	Catchment Area (km^2)	Initial Losses (mm)	
				Mean	Range
I	Sokoto	Gusau	2,570	160	141 - 197
		Bakoroli Dam	4,800	160	141 - 198
	Rima	Goronyo Dam	21,450	320	237 - 487
		Wamako	40,160	270	193 - 334
	Zamfara	Anka	4,140	130	68 - 178
	Gulbinka	Banaga Dam	3,170	230	187 - 276
	Malendo	Malendo Bridge	9,954	210	146 - 332
VIII	Kano	Tiga Dam	6,553	130	104 - 169
	Challawa	Challawa Gorge	3,859	120	44 - 190
		Challawa Bridge	6,889	120	51 - 188
	Jama'are	Bunga Bridge	7,380	140	96 - 186
	Misau	Kari	5,865	350	213 - 594
	Gaya	Chai Chai	1,710	310	244 - 434
	Watari	Gwarzo Road	1,450	160	129 - 183

3C.3 SEDIMENT AND WATER QUALITY

The only available records of sediment and water quality data are of short term, usually collected for studies, design and construction of major projects. Various feasibility reports collected so far did not yield much information. There is no national program for the monitoring of the quality of surface water. The Federal Environment Protection Agency (FEPA) is mainly concerned with the pollution of water by industry. The quality of water, whether surface or groundwater, being utilized by the rural population is largely unmonitored.

3C.4 CURRENT PROBLEMS AND NEEDS

3C.4.1 Observation Network

It is reported that there are more than 1,000 rainfall stations and more than 600 river gaging stations; however, many of these stations have been abandoned or poorly maintained. The JICA-NWRIS has identified 358 river gaging stations, of which the monthly data with the data length of more than five years in the decades of the 1970s and 1980s have been collected at 119 river gaging stations, with a network density of 1.3 river gaging stations per 10^4 km^2. The problems of the present observation network are sparse network density of functioning stations for river discharge and evaporation, uneven distribution of the stations, and lack of stations at important locations.

To obtain more reliable data and information on surface water, data collection needs to be intensified, and the observation network density of meteorological and hydrological observations needs to be increased to the level recommended by UNESCO/WMO in 1988. Data on rainfall, river runoff and evaporation are closely related to the effective operation of the water resources development projects, especially in the northern regions of the country which are under the influence of the recent Sahelian drought. The observation network shall cover the existing and proposed water resources development projects.

3C. 4. 2 Continuous Observation

As mentioned above, the continuous observation data are not available at all stations. Excepting principal stations located close to the main towns or water resources development projects and the river gaging stations on the main rivers, data are lacking, in many cases for about three to four months in a year and some cases for many years. This is mainly due to breakdown and/or lack of equipment, lack of vehicles, lack of staff training, and insufficient funds to maintain observation works. Rehabilitation/renovation of the existing stations should be implemented and provision of equipment and vehicles are needed to maintain the continuous observation with reliability.

3C. 4. 3 Coordination in Observation

Many government agencies are involved in the hydrological observations, and data and information are stocked in the respective offices of the agencies concerned. Not all data and information are available in the FMWRRD, the principal Ministry responsible for water resources development. Better coordination with government agencies concerned is needed to prepare improvement plans of the present observation networks. Data and information should be exchanged among the government agencies concerned.

3C. 4. 4 Data Stock, Analysis and Training

Under the framework of the UNDP Project, the Water Resources Databank Center was initiated in 1990 with the main objective of establishing a computer-based water resources management information system at the Federal Department of Water Resources Headquarters and two zonal offices, and data entry has started. A comprehensive data collection and collation system should be established, and all data and information observed at sites be sent to the Federal Department of Hydrology and Hydrogeology (FDHH) through zonal offices for data collation and stock. The FDHH shall stock meteorological and hydrological data recorded by other government agencies.

Making better use of the Databank Center, all data shall be compiled in yearbooks for studies on water resources development. The National Water

Resources Institute (NWRI) in Kaduna would be charged with hydrological analyses that are beyond engineering capacities of the RBDAs, the State Water Agencies and other government agencies related to design and construction of water resources development projects. The NWRI would provide training courses of engineering staff from water agencies for maintaining the observation networks, and knowledge and experiences gained through the training course will be transferred to staff working at the sites.

3C.5 POTENTIAL SURFACE WATER RESOURCES

3C.5.1 General

Available runoff data during the period of 1970-1989 collected and reviewed by JICA-NWRIS reveal a downward trend of the river runoff in Nigeria due to Sahelian Drought since late 1960s. Keeping this in mind, the potential surface water resources in Nigeria have been evaluated by taking 1980-1989 average rainfall-runoff patterns. The potential surface water resources at each Sub-Hydrological Area (SHA) is estimated based on the mean runoff yield (mm) in the 1980-89 as explained hereinafter.

3C.5.2 Data Arrangement for Mean Annual Runoff

Although continuous discharge measurement data during 1970 - 1989 are available at limited stations, the data gathered from 90 stations are considered reliable and thus selected for estimation of the potential surface water resources. The monthly and annual mean runoff (MCM) at 90 stations is first prepared as shown in the Water Resources Inventory Survey. In addition, the rainfall isohyetal map as shown in the Water Resources Database Maps is prepared based on the rainfall in the 1980s. The potential surface water resources are evaluated in the following manner:

- Mean monthly rainfall and runoff in the 1970s and 1980s are first estimated based on the observed data gathered at the gaging stations. Since many gaging stations have no continuous observed data during the past 20 years, the monthly mean data are reconstructed based on the observed data.

- Mean annual rainfall and runoff in the 1970s and 1980s are estimated by totaling the above observed or reconstructed monthly data.
- Mean annual runoff is converted into the river yield in terms of millimeter by dividing the runoff volume (MCM) by the respective catchment area.
- When the observed data in the 1980s are not available, the runoff yield in the 1980s is assumed based on the 1970s data.
- When the runoff yield data at the gaging station and the SHA can not be estimated due to unavailability of data in the 1970s and 1980s, the yield is assumed taking into account the areal rainfall, scale and condition of catchment area, river condition of the adjoining catchment area, etc.
- Potential surface water resources at each SHA and gaging station are estimated by multiplying the yield by the scale of a catchment area.

3C. 5. 3 Evaluation of Potential Surface Water Resources

The potential surface water resources at each SHA and gaging stations are estimated in the manner mentioned above, the result of which is presented in the Database Maps.

In the Niger, Benue, Sokoto-Rima and Lake Chad basin, the potential surface water resources decrease toward downstream due to seepage and evaporation losses taking place along the river courses and reservoir losses from two large dams of Kainji and Jebba built on the River Niger. The potential surface water resources is therefore re-evaluated taking into account the above-mentioned water losses.

The potential surface water resources over the country have been estimated to be about 267,300 MCM p.a. as presented in Table 3C-4, and is summarized as below:

Summary of Potential Surface Water Resources

River System	Catchment Area (km^2)	Potential Surface Water (MCM)	Runoff Yield (mm)
River Niger	1,143,400	158,000	138
South West Region	100,500	35,400	352
South East Region	73,200	65,700	898
Lake Chad	188,000	8,200	43
Total	1,505,100	267,300	178

The estimated potential surface water resources for the Hydrological Area (HA) are outlined below:

(1) HA-I: International Border to Kainji Dam

(a) Jiddere Bode Station on the River Niger

The runoff data of the River Niger at Jiddere Bode are completely recorded covering the period 1970-1989. The mean annual runoff at the station is 34,100 MCM in the 1970s and 25,100 MCM in the 1980s. The runoff during the period of October to May is considered to be mostly the black flood, which comes across the international border between Nigeria and Niger, because the rivers in the Nigerian territory have less runoff in this period. The black flood, which originates during the rainy season in Mali and Niger, flows down to Nigeria with a long flow time lag and arrives at the international border during the dry season in Nigeria. The runoff at the station in the period of June to September, the rainy season in Nigeria, is deemed to be mostly the white flood originating in the Sokoto-Rima river basin in Nigeria.

In the evaluation of the potential surface water resources at the Jiddere Bode station, it is assumed that 10 percent of seasonal runoff during the period of June to September is contributed by the black flood. The mean annual runoff of the River Niger at Jiddere Bode is classified into the black and white flood as given below:

Mean Annual Runoff of River Niger at Jiddere Bode

(Unit : MCM)

Item	1970s	1980s	Decrease (%)
1) Black Flood			
Runoff of Oct. to May	26,900	17,500	
10% runoff of Jun. to Sep.	1,000	900	
Sub-total	26,900	18,400	32
2) White Flood			
90% runoff of Jun. to Sep.	7,200	6,700	7
Total	34,100	25,100	26

The annual mean of black flood passing through the international border is estimated at 26,900 MCM in the 1970s and 18,400 MCM in the 1980s. The remarkable decrease in black flood may be caused by not only the influence of Sahelian Drought but also by the development of water resources in Mali and Niger.

(b) Sokoto - Rima River System

The Sokoto - Rima river which empties into the River Niger is the largest river in HA-I; major tributaries are Gada, Bunsuru, Gagere and Sokoto in its northern basin and Gawon Gulki, Zamafara and Gulbinka in the southern basin, covering a total catchment area of 88,300 km^2. Runoff data were available only at Goronyo dam on the Rima, Gusau and Bakolori dam on Sokoto river and Anka on Zamfara river. Basing on the observed runoff data and estimated areal rainfall for each river basins, the runoff yield of this river system is estimated at 70 to 100 mm for the northern basin and 120 to 130 mm for the southern basin.

The potential surface water resources of the northern basin with a catchment area of 21,200 km^2 is estimated at 1,580 MCM; however, this potential decreases to 720 MCM at Goronyo dam with a catchment area of 21,450 km^2, because, in addition to storage in Goronyo dam, a part of runoff is lost by seepage and evaporation in the large alluvia plains developed along the tributaries.

The catchment of Wamako on the Sokoto-Rima collects runoff from Goronyo dam with a potential runoff of 720 MCM and tributaries of the

Sokoto with a potential runoff of 1,100 MCM. However, the potential runoff at Wamako is estimated at 1,250 MCM according to observed runoff data. This decrease in runoff is due to seepage losses and consumption for irrigation in large wetlands expanding along the river reaches between Goronyo dam and the Wamako station.

The potential runoff yields of the southern basin with a catchment area of 46,000 km^2 fall within 120 to 130 mm, a little higher than that of the northern basin in reflection of rainfall intensities, and the potential runoff is estimated at 5,000 MCM. This river runoff flows down to the River Niger without significant water losses.

As a result, the potential surface water resources of the Sokoto - Rima system at the confluence with the River Niger is estimated at about 6,000 MCM.

(c) Kainji Damsite

The outflow from Kainji dam is recorded by National Electric Power PLC. (NEPA) as the sum of water release through hydropower plants and spilled water from spillways. The mean annual runoff from Kainji dam is 34,000 MCM and 22,400 MCM in the 1970s and 1980s respectively, showing a remarkable decrease from the 1970s to 1980s.

The operation of Kainji reservoir was initiated in 1969 for hydropower generation. Kainji reservoir with its active storage capacity of 12,000 MCM was designed to store 1/4 of the total average runoff of 45,000 MCM. According to the reservoir operation data obtained from the NEPA, the reservoir water level in the 1970s was maintained near the designed full water level during eight months from July to next February, and the spilled water during the period from August to October in the 1970s reached about 11,100 MCM p. a. on an average.

In the 1980s, the reservoir water level did not reach the designed full water level during the continuous seven years from 1981 to 1987 and no spillage water was recorded. Most inflow to the reservoir was stored to recover water levels for power generation causing loss water of evaporation and seepage through the large reservoir area of about 1,270 km^2. The mean annual outflow of the River Niger at Kainji dam was 22,400 MCM in the 1980s, whereas the mean annual runoff at Jiddere Bode was 25,100 MCM in the 1980s as mentioned earlier.

(2) HA-II: Kainji Dam to Lokoja Station

(a) Jebba Damsite

The mean annual outflow from Jebba dam with catchment area of 631,800 km^2 and a storage capacity of 1,000 MCM was observed by the NEPA at about 24,300 MCM as the average in the 1980s, while the mean annual inflow to Jibba reservoir in the same decade was estimated at about 26,000 MCM by adding local runoff from tributaries between Kainji dam and Jebba dam to the outflow of 22,400MCM from Kainji dam with the balance of 1,700 MCM.

(b) Kaduna River System

The Kaduna river system might be divided into two basins for the study purpose: the upper and lower. The main rivers are Gurara, Kaduna, Mando, Tubo and Sarikin in the upper basin with catchment area of 36,000 km^2, and Esse, Koringa, Kojin, Maringo and Ebba in the lower basin with catchment area of 28,000 km^2. The runoff yield of Kaduna river system is estimated at 150 to 200 mm in the upper basin, and increases toward downstream, resulting in 200 to 250 mm in the lower basin, because of high rainfall in the lower basin.

Hydrology of Shiroro reservoir located on the border of upper and lower basin is observed by the NEPA since 1984, based on which the mean annual runoff of Kaduna river at Shiroro is estimated to be 8,000 MCM in the 1980s, or equivalent to the runoff yield of 200 mm. The annual mean runoff of Kaduna river at its river mouth amounts to 14,900 MCM. The potential surface water resources of the River Niger increases from 24,000 MCM at Jebba damsite to 40,500 MCM at the confluence of the River Niger and Kaduna river.

(c) Baro Station

Baro station with catchment area of 730,700 km^2 is located about 80 km downstream of the confluence of the River Niger and Kaduna river. Gbako and Kampe river are main tributaries which flow into the River Niger between the River Niger and Kaduna confluence and Baro station, having catchment area of 21,600 km^2. These rivers present the mean annual runoff of 4,800 MCM. Accordingly, the potential surface water resources of the River Niger at Baro station reaches about 45,500 MCM.

(d) Lokoja Station

Lokoja station is located at the junction of the River Niger and Benue river with catchment area of 1,089,000 km^2, including 751,000 km^2 of the River Niger basin and 338,000 km^2 of Benue river basin. The Gurara river, which has catchment area of 18,000 km^2, empties into the River Niger between Baro and Lokaja station. This river basin with steep topography is covered with forest, and receives annual rainfall of around 1,200 mm. The mean annual runoff of the Gurara is estimated to be 8,600 MCM, or equivalent to river yield of 480 mm. The potential surface water resources of the River Niger at Lokoja reach 55,000 MCM.

(3) HA-III and IV: Benue River System

(a) Yola Station

Yola station with catchment area of 108,400 km^2 is located near the international border of Nigeria and Cameroon, about 60 km downstream from the border. The mean annual runoff of the Benue river at Yola station is 22,000 MCM and 14,200 MCM in the 1970s and 1980s respectively. The decrease in runoff in the 1980s was mainly caused by water storage of large Lagbo reservoir constructed in the upper Benue river basin in Cameroon. The decreasing runoff of the upper Benue river basin, however, does not give much influence to the total runoff of the Benue river, because the river receives abundant runoff from the large tributaries of Gongola, Taraba, Donga and Katsina-Ala.

(b) Numan Station

Numan station with catchment area of 168,000 km^2 is located just downstream of the confluence of the Gongola river and Benue river, 60 km downstream from Yola station. The Gongola river originates in the Jos Plateau with high rainfall intensity, runs through large alluvial plains and empties into the Benue river at Numan. The river runoff of the Gongola in the upper basin in the 1980s is 120 mm, while it decreases to less than 100 mm in the lower basin due to seepage, evaporation, irrigation in the large alluvial plains and wetlands developed along the river. The potential surface water resources of the Gongola the river at the river mouth with catchment area of 53,800 km^2 is estimated at 5,500 MCM.

Another important tributary which contributes to runoff of the Benue river between Yola and Numan is Mayo Ine river with catchment area of 8,000 km^2. The catchment of the river is covered with dense forests with annual rainfall of around 1,500 mm, so that the estimated mean annual runoff of the river is as large as 2,000 MCM, or 250 mm of runoff yield.

The potential surface water resources of the Benue river at Numan station amount to 22,000 MCM by adding the river runoff of the Gongola, Mayo Ine and other small tributaries.

(c) Benue - Taraba Confluence

The Taraba river and other small tributaries of Belwa, Ramurde, Fan, Pai, Duchi, etc. drain into the Benue river between Numan station and the confluence of the Benue river and Taraba river, having total catchment area of 68,000 km^2 including the Taraba river area of 22,400 km^2. Small tributaries on the left bank of the Benue river have a little higher runoff yield of 200 to 300 mm compared to those on the right bank, because the watershed covered with forests receives relatively high annual rainfall of 1,200 to 1,500 mm.

The upper basin of the Taraba river, which originates in the mountain regions, receives the annual rainfall of 1,500 to 2,000 mm, thus resulting in the relatively high runoff yield of 700 to 800 mm; however, the yield decreases to 300 to 500 mm in the lower basin.

The potential surface water resources of the Taraba river with catchment area of 22,400 km^2 is estimated at 12,000 MCM. The potential surface water resources of the Benue river at the confluence of the Benue and Taraba come to 38,000 MCM including the runoff from the Taraba river and other small tributaries.

(d) Makurdi Station

The rivers of Donga with catchment area of 21,200 km^2 and Katsina - Ala with catchment area of 22,800 km^2, two largest tributaries of the Benue river in Nigeria, join in the Benue river within the river reach between Taraba confluence and Makurdi. Other tributaries which empty into the Benue river are Shemankar, Ankwe and Gume with the total catchment area of about 70,000 km^2; 50,000 km^2 on the left bank and 20,000 km^2 on the right bank of the Benue river.

The characteristics of the catchments of Donga and Katsina - Ala river are similar to that of the Taraba river catchment covered with dense forests with high rainfall intensity. The mean annual runoff is estimated at 19,400 MCM for Donga river and 23,000 MCM for Katsina - Ala river. The runoff yield in the headwaters of both rivers is as high as 1,000 to 1,200 mm in reflection of high rainfall of more than 2,000 mm.

A part of runoff of the Benue river is lost within the long river reach of 260 km between the Taraba confluence and Makurdi station due to evaporation, seepage and irrigation water use, and the potential surface water resources of the Benue river decrease to about 80,000 MCM at Makurdi according to discharge data observed by the Inland Waterways Department (IWD).

(e) Benue and Lokoja Confluence

The Benue river joins with the River Niger at Lokoja about 240 km downstream of Makurdi station on the Benue river. Mada river and other small tributaries empty into the Benue river between Makurdi and Lokoja station, and the total runoff yield of these rivers with the total catchment area of 32,000 km^2 is estimated at 125 mm, or 4,000 MCM of annual runoff.

The potential surface water resources of the Benue river at the Lokoja confluence are estimated at 83,000 MCM according to discharge data observed by the IWD. About 1,000 MCM of water might be lost in the long river reach of about 240 km between Makurdi station and the Lokoja confluence.

(4) HA-V: The Niger Delta

The HA-V is the collection point of the vast drainage system of the Niger main and Benue rivers. After the confluence with Benue river at Lokoja, the River Niger flows straight south down to Aboh, via Onitsha, before draining into the ocean through the Niger Delta where many rivers are ramified. The distance from Lokoja station is 210 km for Onitsha station and 300 km for Aboh station.

According to discharge data observed by the IWD, the mean annual runoff in the 1980s is 142,000 MCM at Onitsha with catchment area of 1,100,800 km^2 and 162,000 MCM at Aboh station with catchment area of 1,112,800 km^2. The runoff yield of 146 mm as observed by the IWD at Aboh seems to be a little high when compared with the runoff yield of 127 mm at Lokoja and 129 mm at Onitsha. Anambra river with catchment area of 12,000 km^2, the largest tributary in HA-V, joins the River Niger at the just upstream of Onitsha station, and below this station there is no river system to drain into the River Niger.

Accordingly, the mean annual runoff of the River Niger at Aboh station is estimated at about 148,000 MCM, or equivalent to 133 mm of runoff yield, on the assumption that about 500 mm of water may be drained from the catchment of 12,000 km^2 between Onitsha and Aboh station. The potential surface water of the River Niger at its river mouth is estimated at 158,000 MCM.

(5) HA-VI: The South - West Region

The HA-VI contains those north - south flowing rivers discharging into the western Lagoons and the Gulf of Guinea. The rivers originate in the northern plateau with annual rainfall of 1,200 to 1,500 mm, whereas the annual rainfall over the Lagoons varies from 1,500 mm to 2,000 mm. Continuous discharge measurements are seldom available in this area. Therefore, the potential surface water resources are estimated mostly by applying areal rainfall and runoff coefficient in consideration of topographical conditions of the river basins.

The runoff yield is estimated at 150 to 200 mm in the upper basins and 300 to 400 mm in the lower basins. The total potential surface water resources may amount to 35,400 MCM or 350 mm for the total catchment area of 100,500 km^2.

(6) HA - VII: The South - East Region

The HA-VII is formed with the Cross river basin, Imo river basin and some smaller catchments. The Cross river originates in the mountains in Cameroon, runs southward through Nigeria and drains into the Gulf of Guinea. The catchment area of the Cross river is 56,200 km^2, of which 13,400 km^2 of catchment lies in Cameroon covered with dense forest with the annual rainfall of 2,500 to 3,000 mm. The mean annual runoff of the Cross river at Ikom station located close to the international border of Nigeria and Cameroon is as large as 27,000 MCM, or 1,600 mm of the runoff yield, whereas the yield of the Cross within Nigeria is about 800 mm. The potential surface water resources of the Cross at its river mouth with catchment area of 56,300 km^2 is estimated at 53,500 MCM, or equivalent to 950 mm of the runoff yield.

The total runoff of other rivers in this area is estimated at 12,000 MCM for the total catchment area of 17,000 km^2 including Imo, Achacha and other small river basins. The potential surface water resources in the HA-VII amount to 65,700 MCM.

(7) HA-VIII: The Lake Chad Basin

(a) Komadugu Yobe River System

The Komadugu Yobe river system includes the Hadejia, Jama'are and Komadugu Gana river on the left flank of the Lake Chad basin. Discharge data are available since mid-1960s at the rivers of Challawa and Kano in the Hadejia river basin and Bunga in Jama'are river basin. The rivers of Jama'are and Hadejia, which originate in the Jos plateau and Challawa plateau respectively, run eastward to join in the wetlands, and the river is named Komadugu Yobe. The Hadejia river collects runoff of the Challawa and Kano river basin which contain the largest number of dams in any basin in the country. The observed runoff records of the Komadugu Yobe river system at selected stations are given as follows:

Mean Annual Runoff of K. Yobe River Basin at Selected Stations

River	Station	Catchment Area(km^2)	Mean Annual Runoff 1970s	1980s	Decrease (%)
Challawa	Challawa Dam	3,860	480	340	30
Challawa	Challawa	6,890	830	600	28
Kano	Tiga Dam	6,650	920	700	24
Hadejia	Wudil	16,400	1,560	1,640	-
Gaya	Chai Chai	1,700	57	44	23
Hadejia	Hadejia	25,900	750	940	-
Jama'are	Bunga	7,400	1,830	1,270	30
K. Yobe	Gashua	55,700	1,000	810	29
K. Yobe	Geidam	58,500	660	600	9

There is a tendency for the mean annual runoff of the Komadudgu Yobe river system to decrease mainly due to the Sahelian Drought, as can be seen from the above table, except two stations of Wudil and Hadejia on the Hadejia river. The increase in runoff of the Hadejia river at the above two stations may be affected by the operation of Tiga dam that impoundment of water was started in 1974 to fill the reservoir with a total capacity of 1,968 MCM and water release to downstream was in 1977. Tiga dam with catchment area of 6,553km^2 controls runoff of about 40 percent of catchment area above Wudil station and 25 percent above Hadejia station.

The mean annual runoff of the Hadejia river remarkably decreases toward downstream from 1,640 MCM at Wudil station to 940 MCM at Hadejia station located about 140 km downstream of Wudil station. The major losses of water are due to surface evaporation, irrigation use and infiltration from the vast area of wetlands stretching form Wudil station to Hadejia station. The same is observed in the Jama' are river between Bunga station and the confluence with the Hadejia river. The potential surface water resources of the above two river basins are evaluated to be 1,640 MCM for the Hadejia river, 1,270 MCM for the Jama'are river and 960 MCM for Iggi river which is one of the tributaries running through the headwaters of the Jama' are river.

The mean annual runoff of Misau river, upstream reaches of the Komadugu Gana river, is estimated at 180 MCM, or the runoff yield of 31 mm for the catchment area of 5,870km^2. The runoff of Komadugu Yobe river tends to decrease toward further downstream, after collecting the runoff of the rivers of Hadejia, Jama'are and Komadugu Yobe, and the mean runoff yield at Damusak station with catchment area of 82,600km^2 where discharge records in the 1980s are not available is estimated at 6.5 mm, resulting in 540 MCM of annual runoff.

(b) Yedseram and Other River Systems

The Yedseram and other rivers on the right flank of the Lake Chad basin is another important river system. Main rivers are Yedseram, Dingaiya, Ngaddo and Komadugu Gama, all of which originate in the southern plateau and empty into the Lake Chad. The mean annual runoff in the headwaters of these rivers totals to 1,200 MCM; however, the runoff decreases toward downstream to almost negligible amount. In this study, the runoff of 1,200 MCM is considered to be the potential surface water resources of this river system.

(c) Rivers along the Border with Niger

In the northeast of the Lake Chad basin, there are several rivers flowing northward into Niger; they are Tagwai, Gari, Jakara and other small rivers. In the upper reaches of these rivers within Nigeria, the mean annual runoff is estimated at 1,600MCM for the total catchment area of 24,000km^2, which is considered to be the potential surface water resources of the Lake Chad basin.

(d) Total Potential Surface Water Resources of the Lake Chad Basin

In the evaluation of the potential water resources in this basin, HA-VIII, a difficulty arises from the hydrological phenomenon that most of rivers collect moderate water in their upper basins but the river discharge tends to decrease toward lower basins. The potential surface water resources in this basin, therefore, are estimated as the sum of available water at important locations as mentioned above, and it amounts to 8,200 MCM (refer to Table 3C. 4).

3C. 5. 4 Water Balance and Water Use Rate

(1) Climatic Water Balance

Evapotranspiration (ET), sometimes called consumptive use, describes the total water removed from an area by transpiration and by evaporation from soil, snow and water surface. In order to grasp the general situation of climatic water balance over the country between rainfall and ET, two representative climatic parameters, an attempt to calculate potential ET by the Modified Penman Method has been made. As a first step, climatic data and information of 30 stations were collected; however, at many stations data on wind speed and sunshine hours are lacking, and finally 10 stations are selected. Calculations cover only five year periods from 1986 to 1990 under the limited time schedule of JICA-NWRIS. In addition to the above 10 stations, potential ET at Jos and Kaduna are referred to the Final Report, Detailed Engineering Design, Gurara Interbasin Water Transfer Scheme, May 1992. The report presents the calculated potential ET by Penman Method on a yearly basis; 29 years from 1951 to 1979 for Jos and 15 years from 1966 to 1980 for Kaduna.

The calculated mean monthly ET is compared with the mean monthly rainfall, in which the monthly rainfall at Jos and Kaduna is the mean monthly rainfall in the 1980s (Table 3C-5) as summarized below:

Climatic Water Balance at Selected 12 Stations

Station	North Latitude	Potential ET (mm)	Mean Rainfall (mm)
Sokoto	12°55'	2,026	534
Kano	12°13'	1,816	713
Maiduguri	10°51'	2,407	498
Kaduna	10°41'	2,318	1,102
Bauch	10°17'	2,046	865
Minna	09°39	2,058	1,093
Jos	09°38	2,248	1,299
Yola	09°14	1,946	886
Ilorin	08°29	1,749	1,024
Makurdi	07°41	1,864	1,102
Enugu	06°28	1,724	1,618
Calabar	04°58	1,298	2,763

As can be seen from the above table, the potential ET decreases towards south, whereas rainfall increases towards south; surplus of rainfall over ET is found south of around latitude 7°C, the delta and southeastern coast where perennial crops are grown. Most of Nigeria's perennial rivers in the northern parts carry less water and are easily depleted during the dry season.

Figure 3C-3 gives the variation of mean monthly rainfall and ET at 12 stations, implying the importance of irrigation water supply for the promotion of agricultural crop production in most regions of the country. Monthly ET is greater than monthly rainfall in ten months at four stations of Sokoto, Kano, Maiduguri and Bauch, nine months at two stations of Yola and Makurdi, eight months at four stations of Kaduna, Jos, Minna and Ilorin, six months at Enugu, and three months at Calabar.

(2) Basin Water Balance and Water Use Rate

The water demand on irrigation and water supply is estimated with the target year of 2020, based on which water balance study has been carried out on the SHA basis to examine whether surface water availability can meet the demand or not. The estimate of river runoff in a SHA is based on the evaluation of potential surface water resources in the 1980s as mentioned in 3C.5.3 of this chapter. In the study, river runoff from the neighboring countries is not counted.

Water demand consists of irrigation, water supply and downstream release. The irrigation demand includes water losses and effective rainfall for irrigation. The water supply demand presented in this study is the water to rely on surface water resources; details of water demand for irrigation and water supply is presented in the respective sector report. Water for downstream release to maintain river ecology is estimated by applying rates of water release to annual river runoff. For the time being, release rates are arbitrarily determined between zero to 30 percent in consideration of land use, topography, status of rural development and others related to water resources of the adjacent downstream SHA.

Water balance is examined for 90 SHAs (Table 3C.6) and is summarized at the HA level as given below:

Summary of Water Balance

HA	River Runoff	Irrigation	Water Supply	Downstream Release	Total	Surplus	Water Use Rate (%)
I	12,110	1,843	167	1,269	3,279	8,831	27
II	34,660	3,782	638	2,567	6,987	27,673	20
III	49,940	2,381	138	5,415	7,934	42,006	16
IV	27,810	1,852	183	2,676	4,711	23,099	17
V	23,690	1,019	130	1,187	2,336	21,354	10
VI	35,550	1,745	1,687	2,110	5,542	30,008	16
VII	66,080	1,604	276	3,305	5,085	60,995	8
VIII	8,281	2,624	485	0	3,109	5,172	38
Total	258,121	16,750	3,704	18,529	38,983	219,138	15

The water balance study has clarified the availability of surface water on the HA basis to meet the projected water demand when any of water source facilities like dams and reservoirs, diversion dams and pumping stations are provided at appropriate locations. As is expected from the climatic characteristics in Nigeria that whereas rainfall generally increases southwards, the tendency of ET is to increase northwards, values of water surplus are greater in the south than in the north.

The overall water use rate of the country will amount to 15 percent of the potential surface water resources, ranging between eight to 38 percent depending on the HA. Being located in the north of the country, the HA-I and VIII will have high water use rate of 27 percent and 38 percent respectively to meet the projected water demand. The estimated water use rates of the HA-VI and other three HAs of II, III and IV which are situated in the middle belt of the country fall within 16 to 20 percent, while two HAs of V and VII in the south of the country will not exceed 10 percent. Surface water resources, though ample in sum total, are subject to large yearly and seasonal variations. To attain these water use rates in order to meet the future water demand, the introduction of integrated water management on the river basin basis is a major promise, especially in the HA-VIII where many reservoirs are in operation.

With respect to water balance at the SHA level, shortage of water resources will occur at three SHAs of SHA-105 (Rima river basin), SHA-809 (Katagun river basin) and SHA-812 (along Lake Chad) as shown in Table 3C.6 when surplus water resources at upstream basins are not considered. In other words, in other SHAs than the above mentioned three SHAs, enough water is supplied by potential surface water resources from respective SHAs. To meet the water demand of the three SHAs, surplus water of the upstream SHAs has to be released; they are SHA-102 (Bunshur river basin) and SHA-103 (Gagere river basin) for SHA-105, SHA-813 (Ngaddo river basin) for SHA-812, and SHA-805 (Bunga and Jama'are river basins) and SHA-806 (Iggi river basin) for SHA-809. In the planning of Kafin Zaki dam project on the Bunga river which is conceived by the Nigerian Government, potentiality of irrigation development in the downstream areas should be carefully taken into account.

3C.6 NWRMP TOWARDS THE YEAR 2020

3C.6.1 General Strategies

A comprehensive hydro-meteorological monitoring system covering the whole country shall be established in order to provide the continuous data with accuracy for input to the river basin management plan and the hydraulic works operations. The design of storage dams, irrigation systems, water supply works and others related to water resources development and management must ensure that the structures are sound. In the absence of information and data for rainfall and river flow, the structures may be designed with extra safety factors. Consequently, these structures would be more costly than to collect necessary data and information on rainfall and river flow.

The primary role of a national hydrological services unit or the like is, in principle, to provide the information to decision-makers on the status and trend of water resources (WMO, 1990). To this end, it is necessary to intensify the network system density of hydro-meteorological stations and to continue the observation with sufficient accuracy and quick data processing.

3C. 6. 2 Network Design

(1) Minimum Network Density Recommended by UNESCO/WMO

The UNESCO and the WMO give recommendations on the minimum acceptable levels of activities including network densities. The recommended activity levels depend on climate, geology and whether the location is in a temperate or tropical region. Two climate categories of arid and humid are generally identified depending on the balance of mean potential evaporation and mean rainfall on an annual basis in line with the definition that annual rainfall is less or more than annual potential evaporation. Geological sub-division is also made into sedimentary and non-sedimentary.

According to the recommendation by UNESCO/WMO in 1988, the minimum network density of hydro-meteorological observation by the HA can be designed. Geological sub-division is made as presented in para. 3D.3.4 "Groundwater Potential Map". In the identification of arid and humid, reference is made to the study on characteristics of precipitation and potential evapo-transpiration (D. O. Adefolalu, 1985). The following table gives the minimum numbers of hydro-meteorological stations by the HA as recommended by the UNESCO/WMO:

Minimum Number of Hydro-Meteorological Stations by HA

HA	Area (km^2)	Rainfall	Evaporation	River Flow	Sediment
I	131,600	96	5	39	8
II	158,100	114	6	52	8
III	158,900	116	6	45	9
IV	73,000	54	3	21	5
V	53,900	94	2	52	17
VI	100,500	129	5	71	19
VII	59,800	128	5	74	24
VIII	188,000	140	6	46	12
Total	923,800	871	38	400	102

(2) Objectives of Monitoring Network

The monitoring network should be established based on two main conditions; (1) the monitoring objectives; and (2) the physical aspects of the system to be monitored. In order to permit an optimal design of network, the hydro-meteorological stations in the NWRMP are classified into the following four types with their objectives;

- Basic Reference Control Points (BRCPs) with the objective of detecting river flow of main rivers in terms of quantity and quality for integrated river basin management over the country,
- Stations attached to existing reservoirs with the objective of monitoring hydro-meteorological data and information for effective OM and management of the projects,
- Stations built on proposed dam and irrigation project sites in a Sub-Hydrological Area (SHA) to discuss where priority of water resources development is given, with the objective of collecting hydro-meteorological data and information for specified watersheds for subsequent project planning and management, and
- Stations built in specified river basins with the objective of interpolating the monitoring of BRCP and other stations to determine the characteristics of the basic hydro-meteorological elements anywhere in the river basins.

(3) Installation of BRCP

The establishment of a network of BRCPs is imperative to monitor the general status and trend of water resources and proper overall management of important river basins over the country. The proposed network is composed of 23 stations on 14 main rivers: (1) 20 new stations; and (2) three existing stations at Kainji, Jebba and Shiroro. The locations have been selected to cover the country in consideration of the size of catchment areas, the spatial distribution and the importance of data and information requirements to be monitored with respect to hydro-meteolorogy for the water resources management. The BRCPs are scheduled to observe water levels, river flow discharge, sediment discharge, rainfall and evaporation, and water quality. The list of proposed BRCPs is given in Table 3C-7, and their distribution is as follows:

Distribution of BRCPs by HA

HA	Nos. of Stations	HA	Nos. of Stations
I	4	VI	2
II	4	VII	2
III	6	VIII	1
IV	2		
V	2	Total	23

(4) Installation of New Stations at Existing Reservoirs and Priority SHAs

For effective water management and planning, 214 new hydro-meteorological stations will be newly installed under the NWRMP; 130 stations at the existing reservoirs and 84 stations in the priority SHAs.

Of 130 stations at the existing reservoirs, 20 stations at the total storage capacity of more than 50 MCM will observe river inflow to the reservoirs, sediment discharge, reservoir water levels, water release from the reservoirs, rainfall and evaporation. At the remaining 110 reservoirs with the total storage capacity of less than 50 MCM, the reservoir water levels and water release from the reservoirs will be recorded. The distribution of existing reservoirs for which gauging stations are to be installed are given below (Details of the existing reservoirs are presented in Chapter 4 "Water Source Works" of this Sector Report):

Distribution of New Stations at Existing Reservoirs by HA

HA	≥ 50MCM	< 50 MCM	Total	HA	≥ 50MCM	< 50 MCM	Total
I	5	10	15	VI	3	23	26
II	5	20	25	VII	-	10	10
III	3	13	16	VIII	4	15	19
IV	-	10	10				
V	-	9	9	Total	20	110	130

In the priority SHAs, there are 35 of topographically possible construction sites of dams (refer to Table 3C-8) and 49 of possible irrigation project areas. Details of the projects are given in Chapter 4 "Water Source Works" and Chapter 5 "Irrigation and Drainage", respectively. For use for planning and designing of the water resources development projects, gaging stations will be newly installed; 35 gaging stations at the proposed damsites for observation of river water levels, river flow discharge, sediment discharge and rainfall; 49 gaging stations at the proposed irrigation project areas for observation of river water levels and river flow discharge. Distribution of the gaging stations is given below:

Distribution of New Stations at Proposed Project Sites by HA

HA	Dam	Irrigation	Total	HA	Dam	Irrigation	Total
I	2	7	9	VI	5	5	10
II	9	11	20	VII	3	5	8
III	7	9	16	VIII	1	-	1
IV	4	8	12				
V	4	4	8	Total	35	49	84

(5) Supplemental Gaging Stations

A total number of the gaging stations to be newly installed as mentioned above for the observation of hydro-meteorological parameters at the basic Reference Control Points, existing reservoirs and priority SHAs, amounts to 78 stations for rainfall, 63 stations for evaporation, 237 stations for river flow and 78 stations for sediment. The proposed national hydro-meteorological network needs the installation of supplemental stations in order to meet the minimum requirements recommended by UNESCO/WMO. The following table presents the number of the supplemental stations by HA:

Distribution of Supplemental Stations by HA

HA	I	II	III	IV	V	VI	VII	VIII	Total
Rainfall									
- Rehabilitation	106	190	122	78	107	252	71	145	1,071
Evaporation									
- Rehabilitation	2	3	5	2	1	5	3	2	23
River Discharge									
- New Station	-	-	-	-	15	20	27	-	62
- Rehabilitation	11	3	7	-	29	23	37	25	135
Total	11	3	7	-	44	43	64	25	197
Sediment Discharge									
- New Station	-	-	-	-	11	9	19	6	45

(6) Overall Density of Proposed National Hydro-Meteorological Network

The NWRMP on hydro-meteorology has proposed to establish the monitoring network composed of 1,149 rainfall stations, 66 evaporation stations, 434 river discharge stations and 123 sediment discharge stations, totaling 1,772 of hydro-meteorological gaging stations (refer to Table 3C-9). The number and density of monitoring network by HA is summarized below:

Number of Hydro - Meteorological Stations by HA

HA	I	II	III	IV	V	VI	VII	VIII	Total
Rainfall	117	208	138	84	113	262	76	151	1,149
Evaporation	11	12	14	4	3	10	5	7	66
River Flow	39	52	45	24	63	81	84	46	434
Sediment	11	18	16	6	17	19	24	12	123
Total	178	290	213	118	196	372	189	216	1,772

Density of Hydro-Meteorological Stations by HA

Unit: Number per 10^3 km^2

HA	I	II	III	IV	V	VI	VII	VIII	Total or Average
HA Area (10^3 km^2)	131.6	158.1	158.9	73.0	53.9	100.5	59.8	188.0	923.8
Rainfall	0.89	1.32	0.87	1.15	2.10	2.61	1.27	0.80	1.24
Evaporation	0.08	0.08	0.09	0.05	0.06	0.10	0.08	0.04	0.07
River Flow	0.30	0.33	0.28	0.33	1.17	0.81	1.40	0.24	0.47
Sediment	0.08	0.11	0.10	0.08	0.32	0.19	0.40	0.06	0.13

3C. 6. 3 Integrated Operations of Hydro-Meteorological Network

Water management in Nigeria is operated by various agencies related to water resources development under the Federal and State Governments. The Federal agencies such as the Inland Waterways Department and the Nigeria Electric Power Plc. also established the hydrological data collection systems relating to water transport and power generation, respectively.

For the integrated operation of hydro-meteorological networks that may enable effective water resources development and management, the FMWRRD as the principal Ministry responsible for water resources management should play a decisive role in maintaining the national hydro-meteorological observation network systems. In this context, it was proposed to transfer the monitoring of the BRCP on the rivers of Niger and Benue except two stations at Kainji and Jebba from the Federal Inland Waterways Department (FIWD) to the FMWRRD in the National Workshop for NWRMP held in December 1993; to this end, a concurrence was obtained between the FIWD so that the official procedures required should be started for early realization.

As for the meteorological observation, the Federal Department of Meteorological Services (FDMS) should be responsible for maintaining the monitoring networks under the present organizational structure. The proposed rainfall and evaporation stations under the NWRMP will function to provide data and information on rainfall and evaporation to supplement the networks of the synoptic stations to be maintained by the FDMS.

The Department of Water Administration which should be newly established in the FMWRRD as is examined in para. 12.3.3 of Chapter 12, would be responsible for the unitary administration in terms of the quantity and quality of the nation's water resources as required for their proper management and sound development as the apex Federal body, while the NWRI will be entrusted with the responsibility of technical coordination and development for all of the hydro-meteorological observation work and subsequent data processing and dissemination. Fundamentally, the hydrological monitoring stations may be divided into two: (1) those required for OM of existing projects and schemes which would be managed by the project executing agencies such as the RBDAs; and (2) those other than (1) which would be managed by the four Regional Water Administration Offices under the Department of Water Administration.

All of the observed data by the FDMS, RBDAs, Regional Water Administration Offices and others will be sent to the NWRI for subsequent processing, and then such processed data in a well-arranged and data-banked form will be promptly utilized by the agencies for project planning and management under the coordination and direction of the Federal Department of Water Administration, FMWRRD.

3C. 6. 4 Plan Implementation Program

The NWRMP on the national hydro-meteorological network will provide 1,772 gaging stations: new installation of 509 stations and rehabilitation of 1,263 existing stations. New stations are installed at the BRCPs, the existing reservoirs, the priority SHA and the supplemental locations as mentioned earlier.

Installation of Gaging Stations

- Unit: Number -

Station	New Installation	Rehabilitation	Total
Rainfall	78	1,071	1,149
Evaporation	43	23	66
River Discharge	265	169	434
Sediment Discharge	123	-	123
Total	509	1,263	1,772

The NWRMP on the establishment of the national hydro-meteorological network will be implemented over the 25-year period from 1996 to 2020. New gaging stations are the BRCPs (23 locations) and existing reservoirs (130 locations) is scheduled to complete during the five year period from 1996 to 2000 and the 10 year period from 1996 to 2005, respectively. The implementation schedule is given in Table 3C-10 and summarized as follows:

Implementation Schedule

- Unit: Nos. of Stations -

Station	Total Quantity	1996 - 2000	2001 - 2005	2006 - 2010	2011 - 2015	2016 - 2020
Rainfall	1,149	63	285	270	270	261
Evaporation	66	43	23	-	-	-
River Discharge	434	63	178	68	67	58
Sediment Discharge	123	63	27	12	12	9
Total	1,772	232	513	350	349	328

In addition to the measuring instruments to be provided at the stations such as rainfall recorders, evaporation pans, water level recorders and meteorological recorders for the use at the reservoirs with the total storage capacity of more than 50 MCM, the project will provide current meters, 4WD and pick-up vehicles, boats and water samplers for the use of field survey teams, and sediment analysis equipment and micro computers for the use at field offices. The number of field survey teams, current meters and sediment analysis equipment is estimated at the rates recommended by UNESCO/WMO in 1988.

The total project costs will amount to 1,073.9 million Naira including the costs for erection of gaging stations, procurement of monitoring equipment and operation and maintenance of the project. The cost of the erection of gaging stations includes procurement of gaging equipment, and the operation and maintenance cost includes observation, analysis of data, report preparation and maintenance of the stations. The project cost by the HA is given below:

Project Cost by HA

- Unit: Million Naira -

HA	Installation of Stations	Monitoring Equipment	Operation and Maintenance	Total
I	52.6	14.3	58.7	125.6
II	70.7	21.5	79.6	171.8
III	52.0	20.1	66.7	138.8
IV	21.1	8.9	32.0	62.0
V	36.6	22.8	59.7	119.1
VI	77.7	23.7	94.4	195.8
VII	37.7	23.8	70.3	131.8
VIII	53.7	15.7	59.6	129.0
Total	402.1	150.8	521.0	1,073.9