CHAPTER FOUR

ANALYSIS AND RESULTS

4.0 Introduction

For a particular type of recurrent climatic or meteorological phenomenon, it is possible to construct local or national-level indicators of existing hazards from data relating to frequency and severity of the type of event in question (Adger *et al.*, 2004). For example, one can construct a flood index based on the historical frequency of notable floods in a particular country or region. In this chapter, analysis and results of flood events in Shiroro LGA are presented using meteorological (e.g. rainfall), hydrological (flood flow), and historical data (flood events derived from the community), to examine the vulnerability and adaptive capacity of the communities residing on the River Kaduna floodplain to flood hazards.

4.1 Climate of Nigeria

Nigeria has a tropical climate with variable rainy and dry seasons depending on location. It is hot and wet most of the year in the southeast but dry in the southwest and farther inland (Oguntoyinbo, 1985). A savannah climate, with marked wet and dry seasons, exists in the north and west, while a steppe climate with little precipitation is found in the far north (Oguntoyinbo, 1985). In general, the length of the rainy season decreases from south to north (Fig.4.1). In the south the rainy season lasts from March to November, whereas in the far north it lasts only from mid-May to September. A marked interruption in the rains occurs during August in the south, resulting in a short dry season often referred to as the "August break" (Kowal and Kassam, 1975). Precipitation is heavier in the south, especially in the southeast, which receives more than 120 inches (3,000 mm) of rain a year, as compared with about 70 inches (1,800 mm) in the southwest. Rainfall decreases progressively away from the coast; the far north receives no more than 20 inches (500 mm) a year (Kowal and Kassam, 1975).

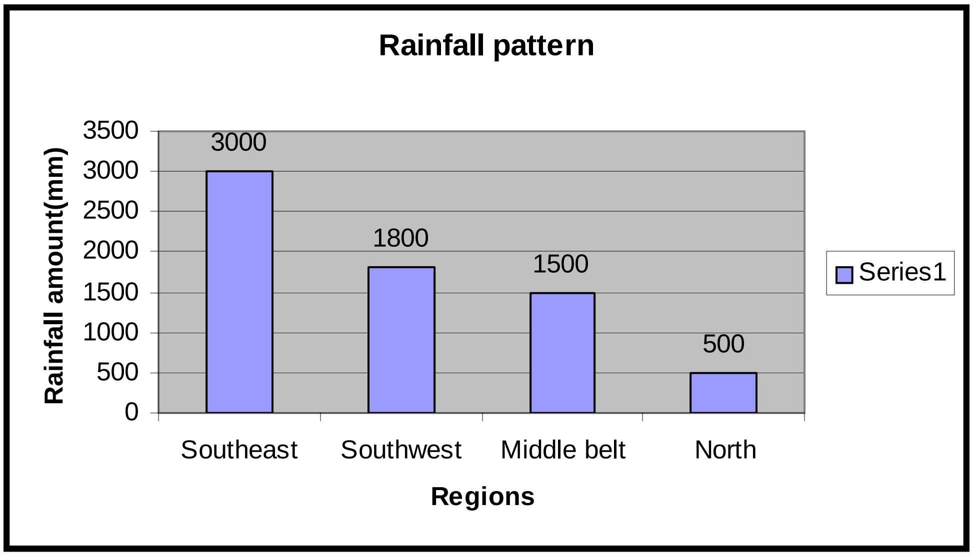

Figure 4.1: Rainfall Pattern over Nigeria (Source: Kowal and Kassm, 1975).

Temperature and humidity remain relatively constant throughout the year in the south, while the seasons vary considerably in the north. During the northern dry season, the daily temperature range becomes great as well (Oguntoyinbo, 1985). On the coast the mean monthly maximum temperatures are steady throughout the year, remaining at about 90 °F (32 °C) at Lagos and at about 91 °F (33 °C) at Port Harcourt. The mean monthly minimum temperatures are approximately 72 °F (22 °C) for Lagos and 68 °F (20 °C) for Port Harcourt (Oguntoyinbo, 1985). In general, mean maximum temperatures are higher in the north, as well as the mean minimum temperatures. In the north-eastern city of Maiduguri, for example, the mean monthly maximum temperature may exceed100 °F (38 °C) during the hot months of April and May, while in the same season frosts may also occur at night (Oguntoyinbo, 1985). The humidity generally is high in the north, but it falls during the harmattan (the hot, dry, northeast trade wind), which blows for more than three months in the north but rarely for more than two weeks along the coast (Iloeje, 1982).

The amount of rainfall over a river catchment such as the Kaduna River is a significant index of its climatic state, which could be expressed as either wet or dry. Of greater significance is the regularity, amount and the duration of rainfall events that act in concert to determine the trend of hydrological events such as the magnitude of flood flow, its duration and recession. For a successful exploitation of water resources, for instance assessment of flood impacts, vulnerability and its adaptability, relevant facts about rainfall and runoff for the whole basin must be continuously known.

4.2 RAINFALL VARIABILITY IN NIGER STATE AND FLOOD FLOW VARIABILITY OF KADUNA RIVER

4.2.1 Annual Rainfall Pattern

Raw data of seasonal variation of rainfall over the Kaduna River catchment (Minna, Bida, Kaduna South and Kainji) was gathered (Table 4.1). Rainfall generally begins in March/April, increases till the month of September and decreases thereafter until cessation takes place almost completely in November. About 60% of the annual rainfall total accumulates in the three heaviest rainy months of July, August and September and lowest in the months of December, January and February (Fig.4.2).

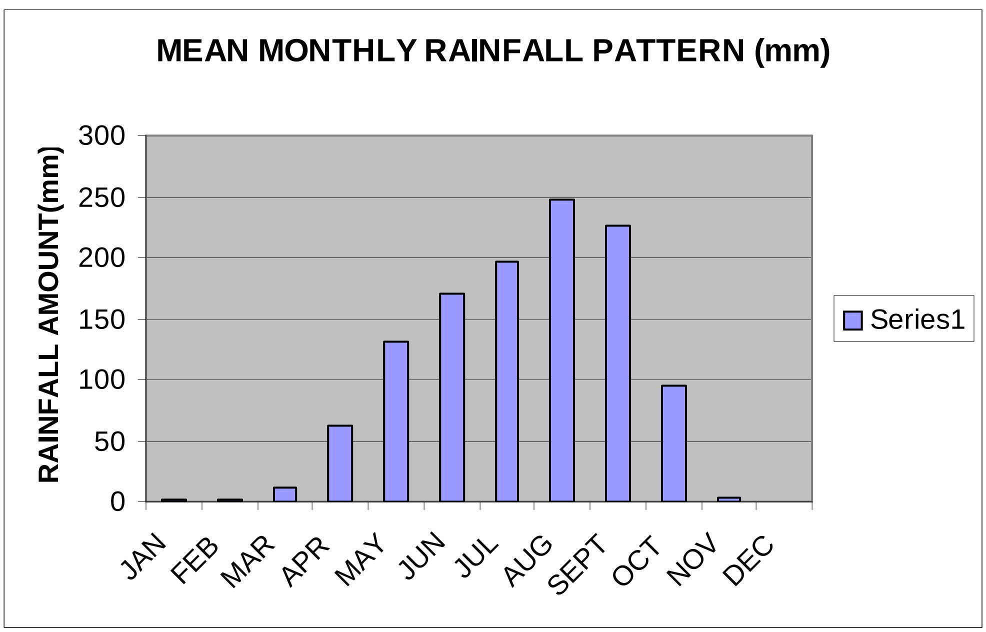

Figure 4.2: Mean monthly rainfall pattern over River Kaduna catchment areas (Source: Nigerian Meteorological Station Oshiodi).

There are thus marked dry and rainy seasons. The former generally lasts for about five months, while the latter lasts for about six to seven months. The month of September/early October marks the peak of the flood-inflow into Shiroro reservoir. The flood-peak inflow immediately following accumulated peak rainfall period may be attributed to the time lag factor between rainfall and peak flow. The annual pattern of rainfall shows a very irregular pattern (Fig. 4.3). It could be as high as 1240 mm, as recorded in the year 1991, and as low as 766 mm as recorded in the year 1983 (Nigerian Meteorological Record Oshodi).

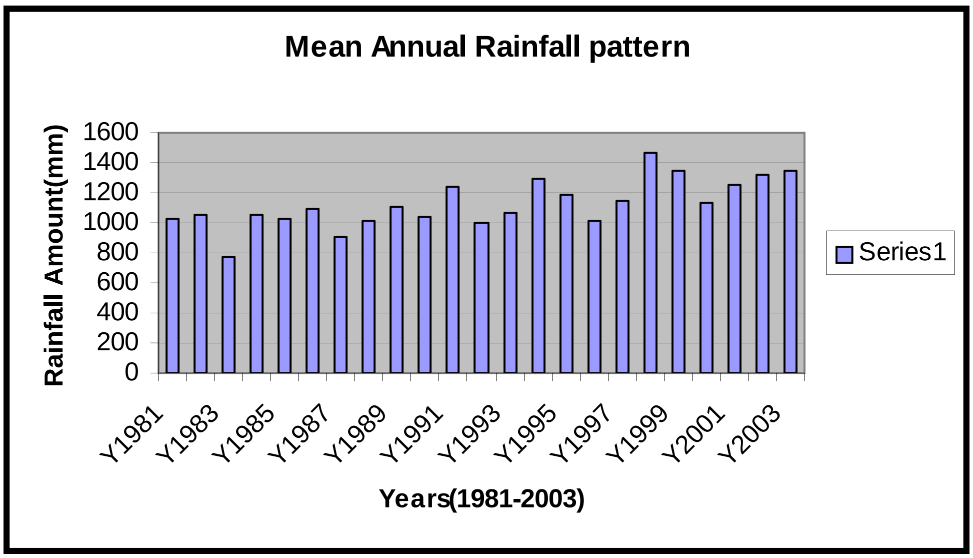

Figure 4.3: Mean Annual Rainfall Pattern over the River Kaduna Catchment Areas for 23 years (*Source: Nigerian Meteorological Station Oshiodi).*

Figure 4.3, also shows that rainfall amount over Niger State for 23 years are constantly above 1000 mm except in the 1983 and 1987 with 766 mm and 908 mm of rainfall amount respectively. These are the cases in the 1983 and 1987 when annual rainfall deficit in the Kaduna River decreased to as low as 766 mm and 908 mm respectively which are below the annual average value of 1143 mm for 23 years (Table 4.2). The inverse case of rainfall deficit occurred in the 1990s when annual rainfall totals improved and sustained till the 1998. The rainfall amount decreased slightly from the 1999 till 2000 and then increased again till the 2003. This is particularly noticeable where annual rainfall totals measured 1465 mm, 1344 mm, 1328 mm, 1247 mm, 1321 mm and 1348 mm respectively in the 1998, 1999, 2000, 2001, 2002 and 2003 thus making the six years the wettest in the recent decades. Interestingly enough, the 1990s with abundant rainfall harvest coincide with the period of abundant flood flow in the Kaduna System and very significant runoff into Kaduna reservoir. The 1990s wetness (Fig. 4.3) shows that annual rainfall totals in the 1991, 1994, 1998, 1999, 2000, 2001 2002 and 2003 as recorded are generally high. There is a significant wet period observed in the 1990s. The significant wet periods generated an excessive surface runoff in the Kaduna River system. Excessive runoff normally involves a river bursting its banks and inundating the land of its floodplain (Byrne, 1997). Spillways and other reservoir outlet facilities are designed to handle a pre-determined probable maximum flood (PMF).

The probable maximum flood (PMF) is the hypothetical flood considered to be the most severe reasonably possible flood, based on the comprehensive hydro-meteorological application of maximum precipitation and other hydrological factors favourable for maximum flood runoff (Enzel, *et al.,* 1993). It is usually several times larger than the maximum-recorded flood (Enzel, *et al.,* 1993). PMF is a direct result of the probable maximum precipitation (PMP). PMP is the greatest amount of precipitation, for a given storm duration, that is theoretically possible for a particular area and geographic location (Costa, 1987). Drainage areas with the same PMP, however, may have different PMFs. This is possible because the amount of flooding which results from a given rainfall amount depends upon the characteristics of the drainage basin (Costa, 1987). Therefore, if the pre-determined PMF is exceeded or there are inadequate flood routing facilities, the dam may be overtopped or the flood may escape through another route. Either of the two events can lead to flooding, however, damaging to the dam structures, loss of lives, properties and general ecological damages. Having examined the rainfall variability for the River Kaduna catchment Areas, attention now focuses on the River Kaduna floods and flow variability.

Table 4.1: Mean monthly and annual rainfall totals over Niger State (mm).

RAINFALL STATIONS	MINNA	BIDA	KADUNA SOUTH	KAINJI	MEAN
January	0.54	3.10	0.62	1.00	0.68
February	0.40	4.00	0.00	1.20	0.5
March	9.20	17.70	10.66	9.50	9.64
April	71.20	66.00	66.42	45.00	63.46
May	153.20	137.00	105.16	130.30	135.47
June	177	178.00	167.84	157.80	169.91
July	189.40	208.00	213.00	176.10	192
August	253.90	219.00	304.60	226.60	259.8
September	223.20	206.00	288.40	185.80	230.15
October	173	82.40	53.38	69.30	117.17
November	4.40	2.30	6.90	0.70	4.1
December	0.00	0.00	0.00	0.00	0
Mean	1255.44	1123.5	1216.98	1003.3	1182.88
Length of record	23years	23years	23years	23years	

Source: Adapted from the meteorological station Oshiodi Lagos.

Table 4.2: Annual Rainfall Records (mm) for the River Kaduna Catchment Area for twenty-three years.

YEARS	MINNA	BIDA	KADUNA SOUTH	KAINJI	MEAN
1981	1175	1085.5	869	963	1023.12
1982	1097.5	994.4	1072	1035	1049.72
1983	942.8	879.7	604	640	766.62
1984	877.1	1345	971	1048	1060.27
1985	1191.4	1157	793	980	1030.35
1986	1229.9	1096.2	1008	1027	1090.28
1987	823.4	1112.7	747	949	908.03
1988	1302	1145.8	1342	1059	1212.2
1989	1181.5	1163.6	906	1179	1107.52
1990	1109.5	1132	752	1181	1043.63
1991	1316.7	1252.5	1107	1285	1240.3
1992	1241.9	967.9	1046	753	1002.2
1993	1069.4	1240.6	916	1016	1060.5
1994	1482.3	944.7	1537	1228	1298
1995	1279.3	1210.3	1162	1098	1187.4
1996	1274.3	1128.9	820	823	1011.55
1997	1245.1	1147.9	1055	1117	1141.25
1998	2632.7	905.4	974	1350	1465.53
1999	1249.5	1268.4	1565	1295	1344.48
2000	1274.5	1257.6	1208	975	1328.78
2001	1233	1298	1191	1267	1247.25
2002	1294	1265	1441	1286	1321.5
2003	1314	1391	1402	1288	1348.5

Source: Adapted from the meteorological station Oshiodi Lagos.

4.3 RIVER KADUNA FLOODS AND FLOW VARIABILITY.

4.3.1 Introduction

Water constitutes an important factor in hydrology and climatology as well as in such diverse fields as agriculture, forestry and reservoir management. Water is the main fuel for power generation activities at Shiroro hydro power station. Since hydrology is highly data dependent, continuous assessment of the available water is an essential pre-requisite to the water that can be depended upon under various conditions and probabilities. This is more so in agricultural studies, river flow studies and dam-reservoir water quality management. Dependable water utilisation in hydropower generation at Shiroro dam is very much tied to adequate data from across the River Kaduna catchments at upper and lower reaches. In this section, the seasonal and annual flood variability of the Kaduna River is examined.

4.3.2 Annual and seasonal flood variability

River Kaduna has a distinctive demarcation between the wet and the dry seasons as indicated by the rainfall regime represented in tables 4.1 and 4.2. These rainfall characteristics correspond to that of wet and dry season in Nigeria. The resultant effect is that the Kaduna River is characterized with high average monthly flow of 1874 m^3/sec. as recorded in the 1999 and low minimum flow of 16 m^3/sec. as recorded in the 1984 (Table 4.3). About 50% of the annual discharge is received at Shiroro during the flood season of July to October and the remainder is distributed over the rest of the year. The average annual yield of the Kaduna, as being measured at Shiroro over a period of 20 years is approximately 15.75 billion Cubic meters of water and historical maximum of 24.65 billion cubic meters of water and historical minimum of 8.6 billion cubic meters of water.

4.3.3 Seasonal flood variability

The mean monthly discharges of 20 years have been computed to obtain the seasonal variability of the flow pattern on the River Kaduna regime (Fig. 4.4). The figure 4.4 indicates that the highest average discharge occurs in September and minimum average discharge occurs in the month of May. There is a striking resemblance to the seasonal rainfall induced floods with a distinct peak. The highest peak, which ranges from 1000 to 1874 cubic metres per second, corresponds to the floods generated during the wet season experienced between July and October (Fig. 4.2).

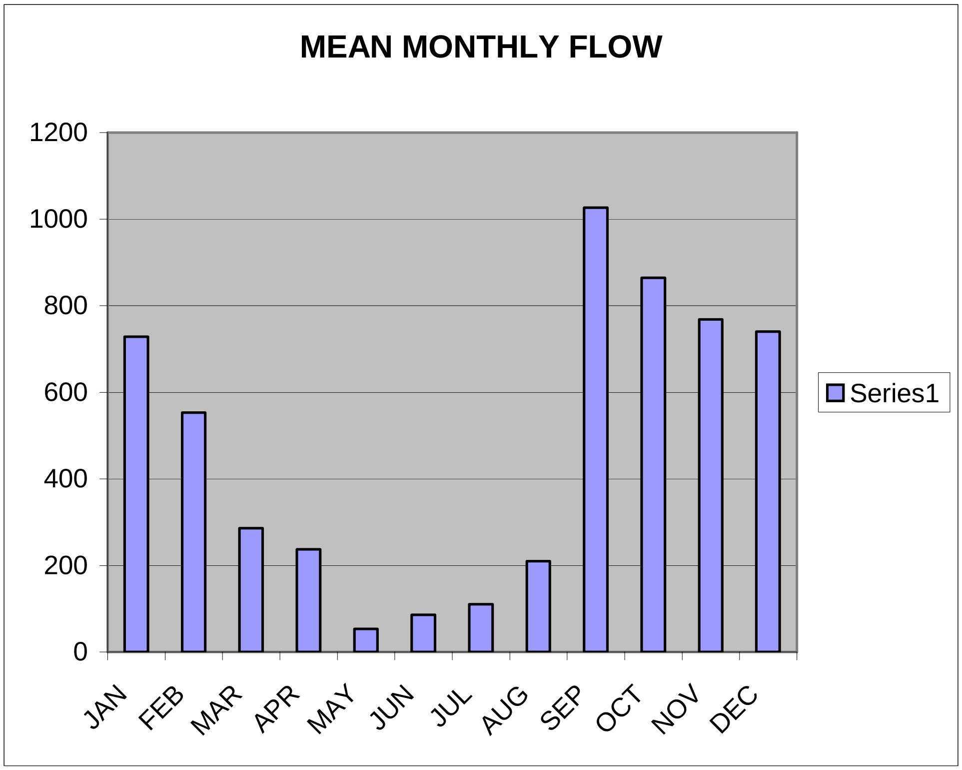

Figure 4.4: Mean monthly water flow (m^3/sec) of the River Kaduna into Shiroro reservoir (Source: Adapted from NEPA Shiroro Hydrological Records).

4.3.4 Annual flood variability

The pattern of discharge variation of the Kaduna River, for alternate years over a period of 20 years is summarized in figure 4.5 that shows that there are both wet and dry years occurring over different periods. It also shows that a sequence of wet years is followed by sequence of dry years. The first phase reflects the period when the Sahelian drought struck in the year 1972 and a dry phase was begun and lingered for several years and up to the early 1990s. Annual discharge within this dry phase was generally below 15 billion cubic meters, although wetter years, such as 1988, are observed.

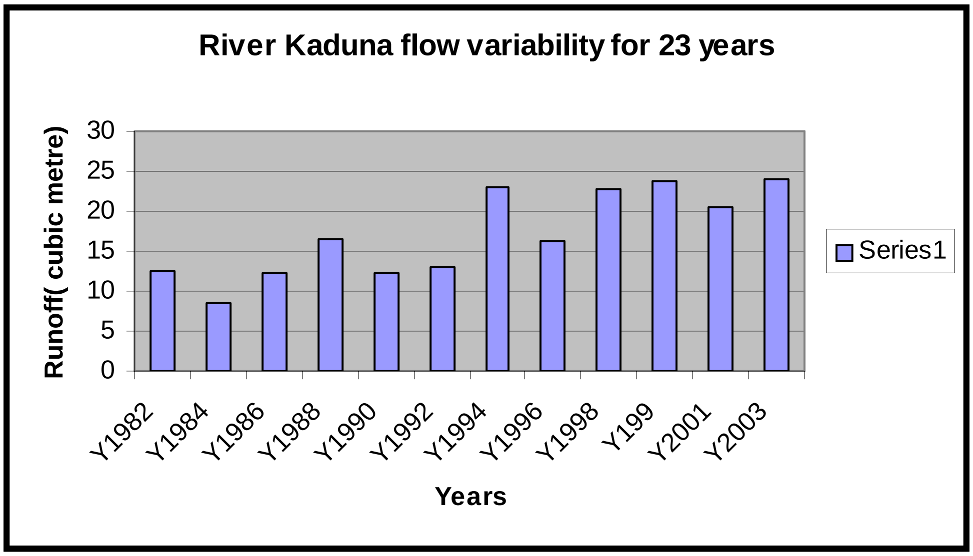

Figure 4.5: River Kaduna runoff variation for 23 years (Source: Adapted from NEPA Shiroro Hydrological Records).

The second wet phase that started in the year 1994 lasted until the year 1999. This phase is characterized by high inflow as recorded in 1994, 1998 and 1999 with periods of copious annual runoff (Table 4.3). Rainfall amounts and the River Kaduna runoff variation as shown in figures 4.3 and 4.5 respectively indicate that increases in rainfall increases the amount of river runoff and also the frequency of flood occurrences.

Table 4.3: Monthly average inflow into Shiroro reservoir in m^3/sec.

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL ($\times 10^9$ M^3)
1982	847	755.5	223.5	72.5	39.5	71.5	153	639	1646	823	699.	705	12.9034
1984	450.5	216	86	22	16	56	72.5	269	544	674	583	539	8.6188
1986	615	295.5	126	30	27.5	51	252	463.5	781	700	671	663	12.2543
1988	481	2335	185	40	92	85	252.5	745	1449	1078	772	777	16.4104
1990	496.5	231	95	36.5	26	28	131	523	797	641	657	650	12.16755
1992	604	312	135	49	35	42	189	588	1117	709	670	673	12.91175
1994	531.5	286	104	31	16	91.5	228	1052	1684	1332	853	839	23.0079
1996	842.5	770	337	141	94	136	170	591	1083	880	743	765	16.23315
1998	732.5	469	164	73	125	222	51	1284	1547	1381	834	847	22.6563
1999	876.5	722.5	315.5	129.5	125	91.5	329.5	1103.5	1874	1322	867	860	23.8419
2001	901	432	172	44	32	112	145	538	1088	1348	1167	1079	20.4532
2003	993	462	190	73	52	56	262	10461	1594	1283	1315	1301	23.9001

Source: Adapted from NEPA Shiroro Hydrological Records.

Table 4.4: Summary of historical inflows into Shiroro reservoir for 13 years (1991-2004).

MONTH	MEAN MONTHLY FLOW (m^3 /sec)	AVERAGE HISTORICAL MAX. FLOW (m^3 /sec)	AVERAGE HISTORICAL MIN. FLOW (m^3 /sec)	AVERAGE HISTORICAL RUNOFF ($\times 10^9 m^3$
JAN	822.875	927	741.5	1.5372
FEB	653.435	786.5	522.5	1.35405
MAR	286.03	446.5	186	0.76605
APR	236.5	193.5	64.5	0.30015
MAY	52.88	124	30.5	0.15465
JUNE	85.565	207	43.5	0.22615
JUL	209.835	479	88	0.56215
AUG	110.03	1040	302	1.63015
SEPT	1026.02	1254.5	828.5	2.65575
OCT	864.065	1042	751	2.3138
NOV	740.215	783.5	718.5	2.04795
DEC	767.645	788.5	709.5	1.92155

Source: Adapted from Hydrological Records Shiroro Power Station.

Table 4.5: Variation in start duration and peak discharge of flood inflow into Kaduna reservoir.

HYDROLOGICAL YEAR	START OF FLOOD	END OF FLOOD	DURATION OF DAYS	PEAK DISCHARGE (m^3/sec)	PEAK DATE
1990/91	19/6/90	1/11/90	135	1035	15/10/90
1991/92	12/5/91	22/11/91	194	1366	9/9/91
1992/93	29/6/92	24/10/92	117	1598	15/9/92
1993/94	6/6/93	2/11/93	149	935	11/9/93
1994/95	7/6/94	15/12/94	191	2447	25/9/94
1995/96	27/6/95	31/10/95	126	1027	3/10/95
1996/97	1/6/96	5/11/96	157	1646	17/9/96
1997/98	28/5/97	29/10/97	154	1144	20/9/97
1998/99	18/5/98	22/11/98	188	3119	28/9/98
1999/2000	1/6/99	29/11/99	180	2671	14/9/99
2000/2001	28/5/2000	21/11/2000	-	-	-

Source: Adapted from the Federal Ministry of Water Resources Abuja.

Table 4.5, presents variations in the start, end, duration and maximum discharge of flood inflow into Shiroro reservoir from the year 1990 – 2000. It should be noted at the onset that the River Kaduna flow rate is usually lower than inflow into Shiroro reservoir, which includes contributions from lateral feeder channels such as Rivers Dinya, Sarkin Pawa, Erena and Muyi.

The flood is usually initiated in the month of June but becomes prominent in July. However, there are isolated cases as indicated in table 4.5, when the flood starts much earlier in month of May. These are the cases in the 1991/92 and 1998/99 hydrological seasons. The duration of the flood from the start to termination varies from minimum of 110 days in the 1989/90 to maximum of 194 days in the 1991/92, with a mean variation in the magnitude of the peak discharge rates of the flood (Fig. 4.6). The highest peak occurred in the 1998/99 with a flow rate of 3119 m^3/sec, while the lowest peak of 935 m^3/sec occurred in the 1993/94 hydrological seasons.

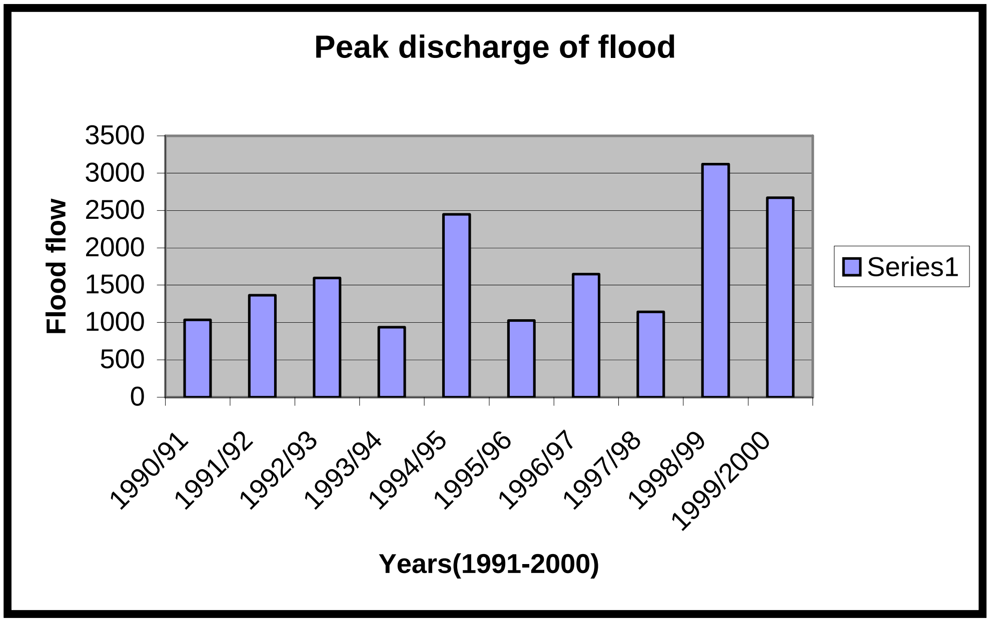

Figure 4.6: Peak discharge of flood into Shiroro reservoir from the year 1991-2000 *(Source: Adapted from the Federal Ministry of Water Resources Abuja).*

Table 4.6: Statistics of significant flood events down stream of Shiroro dam.

YEAR	PEAK FLOW (m^3/sec)	DATE OF OCCURRENCE	TOTAL INFLOW (billion m^3)	TOTAL SPILLAGE (billion m^3)
1994	1074	22nd Sept.	35.6	5.8
1998	2931	28th Sept.	43.2	2.5
1999	4041	17th Sept.	45.0	17.1
2000	1738	24th Aug.	37.2	6.9
2003	3711	5th Sept		

Source: Adapted from the Federal Ministry of Water Resources Abuja.

Table 4.6 shows that all the significant flood events except that of the year 2000 occurred in September (rainy season) and the three highest flood peaks in the series occurred in the

1990s with the 1999 value of 4041m^3/sec (Fig. 4.7), the highest flood peak since Shiroro Dam came on-stream in the 1990.

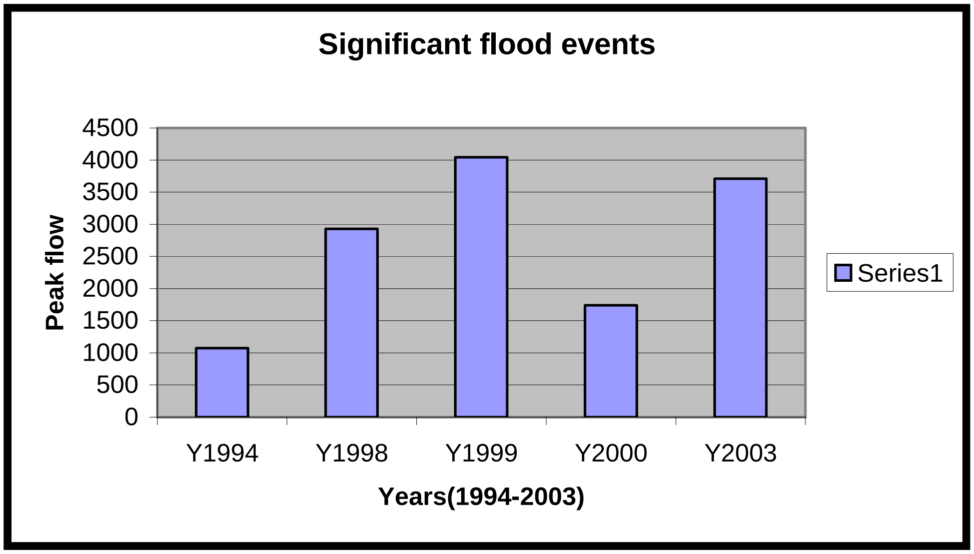

Figure 4.7: The significant flood events between the year1994-2003 (Source: Adapted from the Federal Ministry of Water Resources Abuja).

According to the dam management at Shiroro, spillways and other reservoir outlet facilities are designed to handle a pre-determined probable maximum flood (PMF) of 10,000 m^3/sec. This is because flood problems at a dam site and the environmental consequences can be very severe, if the pre-determined PMF is exceeded. Although the estimated probable maximum flood of 10,000 m^3/sec has never occurred, it appears however, that the hydrological responses of the range of significant floods presented in figure 4.7 above has indicated conditions of increasing magnitudes and or severity over varying timescales particularly from the year 1994 to 2003. The 1994 flood peak of 1074 m^3/sec is the lowest on records with the least annual runoff. This 1994 low flood peak value, however, increased to 2931 m^3/sec in the year 1998 and 4041 m^3/sec in the year 1999. It drops to another low value of 1738 m^3/sec in the year 2000 and increased again to 3711 m^3/sec in 2003. Interestingly, the entire high magnitude flood peaks recorded in the 1994, 1998, 1999 and 2003 are associated with high annual rainfall totals (Table 4.2). Having examined the seasonal and annual flood variability of the Kaduna River, attention now turns to examine the impacts of some of the significant floods on the communities at Shiroro LGA.

4.4 IMPACTS OF SOME OF THE SIGNIFICANT FLOOD EVENTS ON THE COMMUNITIES ALONG THE KADUNA RIVER AT SHIRORO LOCAL GOVERNMENT AREA OF NIGER STATE

4.4.1 Introduction

Floods are the most common natural disaster in both developed and developing countries and they are occasionally of devastating impacts (Ahern, *et al.,* 2005). Such floods as the 1959 floods in China, the 1969 floods in Bristol, United Kingdom, Bangladesh in the 1974, the 1988 floods in Khartoum, Sudan, the 1998 floods in Bangladesh, the tsunami in Southeast Asia in December 2004 can result in devastating consequences for the environment and communities. Their impacts on health, livelihood, and infrastructures vary between populations for reasons relating to population vulnerability and the type of flood event (Ahern, *et al.,* 2005). Flood-related mortality has been studied in both high and low-income countries (Ahern, *et al.,* 2005). The most readily identified flood deaths are those that occur acutely from drowning or trauma, such as being hit by objects in fast-flowing waters (Ahern, *et al.,* 2005). The number of such deaths is determined by the characteristics of the flood, including its speed of onset (e.g. flash floods are more hazardous than slow-onset ones), depth, and extent (Malilay, 1997). Many drownings occur when vehicles are swept away by floodwaters (Dietz *et al.,* 1990; Staes, *et al.,* 1994).

Information on risk factors for flood-related death remains limited, but men appear more at risk than women (Jonkman, 2005). A number of compound or additional impacts can arise. Those drowning in their own homes, for example, are largely the elderly (Jonkman, 2005). Surveillance data also showed an apparent increase of mortality from diarrhoea following the year 1988 floods in Khartoum, Sudan, but a similar rise was also apparent in the same period (May–July) of the preceding year (Woodruff, 1990). Routine surveillance data and hospital admissions records similarly showed diarrhoea to be the most frequent (27%) cause of death following the severe 1988 Bangladesh floods, but again the effect of the flood was not separately quantified from seasonal influences (Siddique, 1991).

In Nigeria, there are many flood prone areas, such as, Lagos Island in the west, Niger State in the Middle Belt, and most States in the North especially those lying on the lowlands and floodplains. Floods have impacted negatively on people's socio-economic lives, especially among the villagers along the River Kaduna, in Niger State. Table 4.7 by way of example, below shows the year 1988 flood event and its impacts.

Table 4.7: Flood Data 1988.

Location	**Detailed Location**	**River(s)**	**Began**	**Ended**
Northern Nigeria	Niger State	River Kaduna	14th Spet.1988	26th Sept.
Duration	**No. Dead**	**No. Displaced**	**Damage (USD)**	**Main cause**
13 days	7 people	136000	NA	Brief torrential rainfall
Secondary cause	**Recurrence interval**	**Severity**	**Hectares flooded**	**Haden code**
NA	NA	1	30000	Tpz (major flooding)
Affected region (sq.km)	**Flood magnitude**			
71960	6.9			

Source: Adapted from the Dartmouth Flood Observatory (www.dartmouth.edu).

Table 4.7 shows that the Kaduna River overflowed its bank as a result of brief torrential rainfall in 1988. The flood flow lasted for 13 days. About 45 houses along the River

Kaduna were destroyed. Eight communities along the River Kaduna in Shiroro LGA were submerged in floods. Seven persons were recorded dead, while 136000 were rendered homeless. About 30,000 hectares of farmland were flooded. The Hayden code is a classification system for flood due to climate variability developed by Bruce Hayden. The Hayden Code (Tpz) measures the magnitude of a flood .i.e. indicates that the flood is a major flooding.

Table 4.8. 1999 Flood Data.

Location	**River**	**Began / Ended**	**Duration**	**No. Dead**
States of Niger, Sokoto, Kwara and Adamawa. One of the most affected area was Shiroro LGA	Rivers Kaduna, Niger and Benue	15th Sept.1999. And ended on 11th Oct. 1999	It lasted for 27 days	85
No. Displaced	**Damage (USD)**	**Main cause**	**Secondary cause**	**Recurrence interval**
396748	$21000000	Heavy rain. Unusually heavy seasonal rains in September.	Hydroelectric dams opened their gates	Worst flooding in 30 years
Severity	**Hectares flooded**	**Hayden code**	**Affected region (sq.km)**	**Flood magnitude**
1	9010000	Tpz (major flooding)	8000	NA

Source: Adapted from the Dartmouth Flood Observatory (www.dartmouth.edu).

Table 4.8 above, shows that the Kaduna River overflowed its bank as a result of unusually heavy seasonal rainfall in September 1999. The flood flow lasted for 27 days. The hydroelectric dam, however, opened the gates inundating many villages downstream. About 1200 houses along the River Kaduna were destroyed. 24 communities along the River Kaduna in Shiroro LGA were submerged in floods. 85 persons were recorded dead, while 396,748 were rendered homeless. Over nine hundred hectares of farmland were flooded and property worth of 21 000 000 USD destroyed. The year 1999 was recorded the worst flooding in 30 years.

Table 4.9: 2003 flood data.

Location	**River**	***Began / Ended***	***Duration***	***No. Dead***
Niger State - Borgu, Kede, Mokwa, Azza, Katcha, Baro, Shiroro, Wushishi, Age, Lakpma, Gbako and Edati. 100 villages downstream of Shiroro dam.	River Kaduna	Started on 5th Sept.2003 And ended on 28th October 2003	It lasted for 54 days	16 people
No Displaced	**Damage (USD)**	***Main cause***	**Secondary cause**	**Recurrence interval (anecdotal)**
210000	2570000	Heavy rain	September 13-15 - Shiroro hydroelectric dam opened to release water. Floodwaters from Kaduna river, inundating 100 villages in Niger State.	20
Severity	**Hectares flooded**	**Hayden code**	**Affected region (sq.km)**	**Flood magnitude**
1	177600	Tpz (major flooding)	134900	14.7

Source: Adapted from the Dartmouth Flood Observatory (www.dartmouth.edu).

Table 4.9 shows that the Kaduna River overflowed its bank as a result of a long period of heavy rainfall in the year 2003, which lasted for 54 days. About 500 houses along the

River Kaduna were destroyed. Floodwater only began subsiding on the 9th of September. During the 13th to 15th September the Shiroro hydroelectric dam opened to release floodwater from the Kaduna River, inundating over twenty villages in Shiroro Local Government Area. In October 12-14, 14 communities along the River Kaduna in Shiroro LGA were submerged in floods. Over one hundred houses were destroyed. Sixteen persons were recorded dead, while 210,000 were rendered homeless. 177,600 hectares of farmland were flooded and property worth of 2,570,000 destroyed. The Severity Class of the entire flood event so far along the Kaduna River is class 1 type. This means that the magnitude assessment shows large flood events that have significant damage to structures or agriculture with some records of fatalities, and must have repeated itself within1-2 decades.

Recent catastrophic floods all over the world have raised new questions as to traditional approaches in dealing with such extreme events (e.g. Pelling and Uitto, 2001; Vlachos, 1995; Blaikie, *et al.*, 1994). Many societies have accepted floods as inevitable natural phenomena to be endured. In modern times, however, a changing attitude has emerged as control over the physical environment has increased and technology and social organization have made it possible successful manipulation of natural resources (Blaikie, *et al.*, 1994). The increasing occupation of floodplains, and competing and conflicting developmental demands have exacerbated the impacts of floods on society and the environment (Smith, 1990). Having briefly examined the impacts of some of the significant floods on the communities along the Kaduna River, the next section reviews some of the significant flood events that occurred along the River Kaduna.

4.5 REVIEW OF SOME OF THE SINGIFICANT FLOOD EVENTS ALONG THE KADUNA RIVER AT SHIRORO LOCAL GOVERNMENT AREA

In view of their unprecedented nature and successive years of occurrence, the 1988, 1998, 1999 and 2003 flood events deserve a review. From rainfall data available, particularly on the Kaduna River Basin, the years 1988, 1998, 1999 and 2003 were very wet (Table 4.2). The year 1988 annual rainfall total as monitored at Minna, Bida, Kainji and Kaduna South, is the highest in the decade. Similarly, the 1998 rainfall event has the highest amount of annual rainfall total in the 1990s. Available records, for Shiroro Power Station (e.g. Hydrology log book, 1998) indicate that the year 1998 rainfall event was early in arrival, high in frequency and copious in the amount of rainfall. The same records also show that a single day's downpour in the month of July measured 120.27 mm. In an Interview with the Shiroro dam management the rainfall events as described above, and the Shiroro dam reservoir inflows in the 1999 and 2003 flood years were noted as being unprecedented and in fact the highest since the dam was constructed in the year 1990.

In terms of discharge, Shiroro power Station Annual Report (1998) shows that the Kaduna River discharged copiously into the Shiroro reservoir, as monitored at Shiroro dam to upstream of the Kaduna River. Apart from the main flow of the Kaduna River, the contributory effect of the major tributaries discharging into the Kaduna River upstream of the Shiroro dam thereby increasing flow magnitude were very significant. Available data extracted from the Shiroro Power Station Annual report (1998) also indicates that rivers Dinya, Sarkin Pawa, Erena and Muyi contributed 4.882 x 10^9 m^3 or 20.9 percent of runoff into Shiroro reservoir. Table 4.7, 4.8 and 4.9 show the observed flood events that occurred along the River Kaduna, specifically at down stream.

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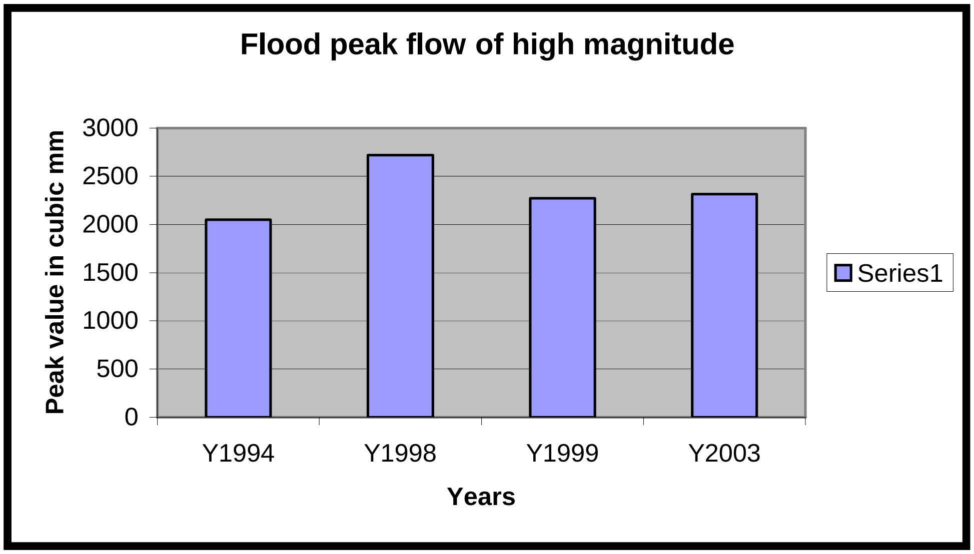

Figure 4.8: River Kaduna peak flow of high magnitude (Source: Adapted from Shiroro dam management through the Federal Ministry of Water Resources Abuja).

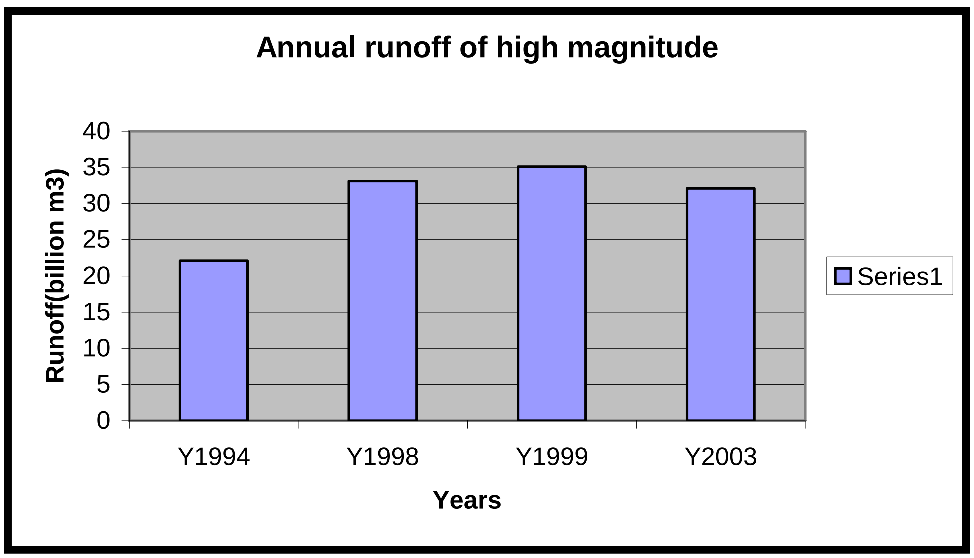

Figure 4.9: Annual runoff of high magnitude into Shiroro reservoir (Source: Adapted from Shiroro dam management through the Federal Ministry of Water Resources Abuja).

The main cause of the flooding is heavy rain with the secondary cause, dam management practices, including the opening of the hydroelectric dam. Figures 4.8 and 4.9 represent the River Kaduna flood peak flows of high magnitude and corresponding annual runoff into Shiroro reservoir for the 1994, 1998, 1999 and 2003. The graphs show that rarely have two significant floods occurred in quick succession that is the 1998 and 1999 floods.

In total, the 1998 and 1999 flood events accounted for 68.2 x109 m^3 runoff and heavy spillway releases by the dam on the surrounding communities (Table 4.10).

Table 4.10: River Kaduna flood peak flows of high magnitude and corresponding annual run off into Shiroro reservoir for some selected years.

YEAR	PEAK FLOW (M^3)	PEAK DATE	ANNUAL RUN OFF (BILLION M^3)
1994	2047	25/9/94	22.1
1998	2719	28/9/98	33.1
1999	2271	14/9/999	35.1
2003	2315	5/9/2003	32.1

Source: Adapted from Shiroro dam management through the Federal Ministry of Water Resources Abuja.

These inflows and spillway releases undoubtedly must have stressed the dam structures, made reservoir operation hectic and unleashed serious ecological implications on the Kaduna flood plains and environment in general, especially on the socio-economic life of people living on the flood plain in Shiroro Local Government Area of Niger State. Indeed, the 1988, 1998, 1999 and 2003, the Kaduna River flood events heralded the worst series of flood flows for the Shiroro communities.

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The flooding occurring along the Kaduna River floodplain at Shiroro LGA could be described as normal. This is because the difference in rainfall amount is not much. Although there is an irregular rainfall pattern over the Kaduna River catchment areas, the data show a slight increase in rainfall amounts. The average annual rainfall amount from the year 198-1989 is 1028 mm while from the year 1990-2003 is 1217 mm, therefore, there is only 189 mm rainfall difference between the two decades. About 60% of the annual rainfall total accumulates in the three heaviest rainy months of July, August and September. The flood-peak inflow immediately following the accumulated peak rainfall period may be attributed to the lag factor between rainfall and peak flow. A slight increase in rainfall therefore, increases the amount of river runoff and discharge of flood waters into the Shiroro reservoir. This research report shows that flooding of the Shiroro communities along the Kaduna River occurs primarily when heavy rain increases the magnitude of discharge of flood into the Shiroro reservoir.

Dam management also compounds the flood events. Dam management opens the dam gate to release the excess flood in the reservoir. The release of the excess water from the dam reservoir downstream has forced thousands from their homes along the floodplain of the Kaduna River. The 1994, 1998, 1999, and 2003 flood events were attributed to opening of the dam gates to release the excess water in the reservoir as a result of heavy rainfall. The flood event of the year 1988 occurred before the Shiroro dam started its operation in 1990, which was caused by torrential rainfall. The Shiroro dam, therefore, makes the floodwater accumulate. Upon release, the magnitude of the flood flow into the surrounding communities on the floodplain is high, causing greater damages. In the next chapter, the socio-economic and physical factors also increasing vulnerability of the communities on the floodplain to flood events are examined.