

DOWNSTREAM GEOMORPHOLOGICAL RESPONSE OF KANO AND CHALAWA CHANNELS TO DAM CONSTRUCTION IN THE SAVANNA ZONE OF NORTHERN NIGERIA

⁺O. A. IDOWU, *E. A. OLOFIN AND ⁺O. MARTINS

⁺Department of Water Resources Management and Agrometeorology,
University of Agriculture, Abeokuta, Nigeria

*Department of Geography, Bayero University, Kano, Nigeria
E-mail of corresponding author: olufemidowu@gmail.com

ABSTRACT

An assessment of the downstream geomorphological responses of two channels to dam construction in the savanna zone of northern Nigeria reveals significant changes from pre-dam to post-dam conditions. The changes are reflected both in the post-dam channels geometrical (i.e. width, depth, cross sectional area and abandoned width) and non-geometrical variables (i.e., silt + clay percentage and mud layer thickness). Reduction in the channels effective sizes, erosion in terms of incision of post-dam depths into pre-dam channels and development of lesser and finer deposits in the post-dam channels, overbank and floodplain zones are characteristic channel changes identified to be due to dams construction. Development of abandoned tracts of land that gradually evolve into farmlands and areas of vegetation colonization are the observed consequences of the changes.

INTRODUCTION

With over 60 completed multipurpose dams and more than equal number of different forms of barrages, mainly for irrigation and water supply, Nigeria has the highest concentration of dams in the West African sub-region. Dams have gradually become popular in Nigeria as they have found relevance in the development of the people, mainly in respect of irrigation, water supply, livestock farming and hydroelectric power generation. About 70% of the dams in Nigeria are located in the northern parts of the country. The concentration of dams in the north results from the need to supply adequate water to the

major towns, and more importantly, the dependence of its agriculture on irrigation due to inadequate rainfall. Of the 70 000 Ha under formal irrigation in Nigeria, only about 4 400 Ha, i.e. about 6%, is in the south (Fatokun and Ogunlana, 1992).

The impacts of dam construction can be socio-economical and environmental (Ayoade, 1988; NEST, 1991; Martins and Olofin, 1992; Ackerman et al., 1973) and can both be positive and negative (Ruhe, 1975; Matlock, 1985; Adams, 1986). A mode of impact, however, is the development of new landforms and landforms assemblages (geomorphology) in the up-

stream and particularly downstream channels and environments. Climates, naturally, by affecting geomorphological processes, have a controlling influence on the development of unique assemblages of landforms, even taking precedence over all other ones (Peltier, 1962; Tricart, 1972; Faniran and Jeje, 1983). The focus of this study therefore, is the assessment of the downstream channel geomorphological impacts of dams in the savanna of northern Nigeria using two channels, Kano and Chalawa (on which Tiga dam and Chalawa gorge are located respectively), as case studies.

MATERIALS AND METHODS

The locations of the channels of study generally fall within the sudan savanna climatic region (Udo, 1978) which generally lies between latitudes 8^oN and 13^oN in Northern Nigeria. The locations are towards the northern extremes of the sudan savanna and therefore are in close proximity to the sahel climate (Fig.1). The areas of study fall within the Kopen's Aw savanna and Gate (1972) tropical savanna climate (Ayoade, 2004), the Budyko (1956) steppe climate (Faniran and Ojo, 1980) and the tropical continental north climatic region (Iloeje, 1976). The sudan savanna in Nigeria generally has an annual rainfall of between 500 mm and 1000 mm with single peak regime in August and between 4 and 8 dry months. The mean monthly rainfall, relative humidity at noon and maximum temperature at Kano, which is about 45 km south and southwest of Tiga dam and Chalawa gorge respectively, are presented in Table 1. The natural vegetation of the savanna in which the channels of study are located consists of grasses and scattered chumps of trees.

The Kano and Chalawa channels contain the flow of two of the headwaters of Hadeija river (Fig.1). Located on the Kano and Chalawa channels are the Tiga dam and Chalawa gorge respectively. The Tiga dam was commissioned in 1974 and has a total capacity of 1.97×10^9 m³, reservoir surface area of 178 km² and a catchment area of 6641 km². The Chalawa gorge was commissioned in 1992 after a period of partial operation. It has a total capacity of 969×10^6 m³, reservoir surface area of 101.71 km² and a catchment area of 3859 km². The hydrological influence of the dams especially in terms of upstream and downstream discharges have been reported in Martins and Olofin (1992) and Olofin and Martins (1993).

In carrying out this study, a pre-dam and post-dam approach is followed in order to isolate the effects of the operations of the two dams of interest on downstream geomorphology. The 60 km and 40 km reaches of Kano and Chalawa channels respectively, between the respective dams located on the channels and the Kano-Chalawa confluence, constitute the areas under study.

Two broad variables were observed and analysed: the channels geometrical and non-geometrical variables. The channels geometrical variables include the width, depth and cross-sectional areas, while the non-geometrical variables include the percentages of silt and clay and the layers of mud thickness. The variables are presented in terms of mean, standard deviation and coefficient of variation in order to provide broad and representative picture of the characteristics of the variables in the channels of study. Insight into the nature and

implications of the resulting geomorphological changes in northern Nigeria, particularly in the Sudan savanna climatic region as a result of dam construction, are provided by the presentation of the cross sections of Kano and Chalawa pre-dam and post-dam channels due to full dam operations in Kano channels and partial dam operations in Chalawa channels. These are enhanced by the study of the aerial photographs of Kano-Chalawa confluence pre-dam in 1963 and post-dam in 1978.

RESULTS AND DISCUSSION

Characteristic Storm Channels

The locations of study are typified by storm channels with seasonal discharges designed to evacuate the flash floods of the wet seasons. Hence, their cross sectional areas are large (Fig. 2), ebb and related to the mean wet season flood flow (i.e., mean maximum wet season discharge) rather than the wet season overall mean discharge as should be expected in the more humid climatic zones in southern Nigeria. The Kano and Chalawa channels had respective pre-dam cross sectional areas of 482 m² and 537 m² with mean annual discharge of only 37 and 22 m³/s, whereas, the wet season mean flood flows for the two rivers were 383 and 260 m³/s, respectively. The relationship between the channels sizes and stream discharges dictate the geomorphological responses of the channels to dam construction.

Impacts on Channel Geometry

The impacts of dam construction on channel geometry downstream are generally incision and reduction in the effective sizes of channels (Imevbore, 1975). Where the channels under study are lo-

cated, the incision and reduction of the effective sizes are pronounced because the channel sizes are related to the regulated post-dam wet season mean discharge which is usually less than the pre-dam mean wet season flood flow on which pre-dam channel sizes depend. The difference accounts for the reduction in the effective channel sizes. The regulated and persistent discharge over a post-dam reduced channel size, accounts for the incision. Postdam discharge can be so significantly affected that a seasonal stream can become perennial (Martins and Olofin, 1992). The geometrical responses of Kano and Chalawa (effective) channels to regulation are presented in Table 2.

Channel incision takes the form of post-dam depth cutting into the pre-dam storm channel bed (Fig. 2). Where the discharge is regulated to the extent that it varies little from the dry season flow, as in Kano channel (Fig. 3), the channel stabilizes and remains fixed (Figs. 2 and 4). Where the wet season flow is unregulated and there is no dry season flow, as in Chalawa channel (Fig. 3), the secondary channel becomes more like the pre-dam storm channel (Figs. 2 and 4).

Impacts on Non-geometrical Channel Variables

The observed pre- and post-dam non-geometrical variables differ greatly. The bed materials in the downstream reaches are usually eroded during the initial channel incision. Apparently, as a result of entrapment of river load in the reservoirs, the post-dam bed and suspended sediment load are much reduced and finer, resulting in less and finer deposits in the channel, overbank and floodplain zones (Fig. 2). The

study of Olofin (1984) has shown that in the River Kano case, the pre-dam suspended load correlates strongly in particle size distribution with post-dam mud deposits, while the post-dam suspended load was about one sixth that of the pre-dam concentration. Results of the observations made on the abandoned width, silt and clay percentages of sediments, and the mud layer thickness in the channel and overbank zones of Kano and Chalawa channels are part of Table 2. The post-dam sediment has a mean silt+clay fraction of between 40 and 50% as contrasted to that of the pre-dam mean of between 5 and 11% (Table 2). The post-dam mud layer thickness is also higher than in the pre-dam's situation; a mean of 7.3 cm as against 1.5 cm in Kano channel and a mean of 19.2 cm as against 3.4 cm in Chalawa channel.

Implications of Geomorphological Changes

The implications of the considered downstream geometrical and non-geometrical channel changes in the savanna on northern Nigeria can be significant. The significant reduction in the cross-sectional channel dimensions, with the corresponding increase in the abandoned width and stabilization of the post-dam deeply incised channel within the pre-dam channel, lead to the occurrence of tracts of abandoned lands within the pre-dam storm channel which gradually evolve into farmlands and areas of vegetation colonization. In the 60 km reach of Kano channel, between Tiga dam and Kano-Chalawa confluence, more than 1 200 Ha of new farmland evolved on parts of the pre-dam storm channel (Fig. 4). Another 500 Ha of the low terrace, usually flooded in the pre-

dam period has escaped annual floods. Similarly in the Chalawa channel, 270 Ha in 40 km reach of the channel has been abandoned in addition to the previously flooded low terrace parcels of about 200 Ha. In Jakara river basin also in northern Nigeria, Nichol (1987) estimated that a total of 65 ha of land are no longer flooded downstream of Jakara dam while Adams (1985) has reported that 77 Ha of the previously flooded land around Birmin Tudu village in northern Nigeria was no longer flooded after the establishment of Bakolori dam.

The overall effect is that the pre-dam wide, unstable alluvial storm channel which is bedload depositing, will change into a post-dam narrow and stable channel with a true floodplain where an optimum and regulated perennial discharge is maintained, like in Kano channel (Fig. 2). Otherwise, the post-dam channel, though narrower, will be unstable, like in Chalawa channel (Fig. 2).

CONCLUSION

The construction of dams have significant downstream channel geomorphological impacts in the savanna of northern Nigeria. This is revealed by Kano and Chalawa channels downstream of Tiga and Chalawa gorge respectively. The different characteristics of the pre-and post-dam channel conditions are in response to rainfall and the resultant channel discharges. What is decisive is the post-dam wet season mean discharge which is usually less than the pre-dam mean wet season flood flow on which the pre-dam channel conditions depend.

Channel erosion in terms of incision of post-dam depth into the pre-dam storm

channel, reduction in the effective channel sizes and stabilization in the case of full dam control, or mitigation of these effects in partial dam control, are characteristic. The post-dam deposits are much reduced and finer in the channels, overbank and floodplain zones. The consequence of the pre-dam changes is the occurrence of abandoned tracts of land which gradually evolve into areas of vegetation colonization.

REFERENCES

- Ackerman, W. C., White, C. F., Worthington, E.B.** (eds), 1973. Man-made Lakes; their Problems and Environmental Effects, Amer. Geophy. Union Monogram.
- Adams, W. M.** 1986. Traditional Agriculture and Water Use, Sokoto valley, Nig. Geog. Jour. 152 (1): 30-43.
- Ayoade, J. O.** 1988. Tropical Hydrology and Water Resources, Macmillan, London, 275pp.
- Ayoade, J. O.** 2004. Introduction to Climatology for the Tropics, Spectrum Books, Ibadan, 297 pp.
- Budyko, M. I** 1956. The Heat Balance of the Earth's Surface. (Translated by N. A. Stepanova), U. S. Department of Commerce, Washington.
- Faniran, A., Jeje, L. K.** 1983. Humid Tropical Geomorphology, Longman, U.S.A., 414 pp.
- Faniran, A, Ojo, O.** 1980. Man's Physical Environment, Heinemann, London, 404 pp.
- Fatokun, J., Ogunlana, F. A.** 1992. Prospects for Irrigation Development in South-Western Nigeria-In A. O. Sanda (eds.) Managing Irrigation Projects in Nigeria, Spectrum Books, Ibadan, 19-35.
- Gates, E. S.** 1972. Meteorology and Climatology for the Sixth Form and Beyond (4th edition) Harrap, London, 342 pp.
- Iloeje, N. P.** 1976. A New Geography of Nigeria, Longman, Nigeria, 221 pp.
- Imevbore, A. M. A.** 1975. The Chemistry of Kainji Lake Waters, August 1968- September 1969. In: A. M. A. and O. S. Adegoke (eds), 'Ecology of Lake Kainji. The Transition from River to Lake' University of Ife Press, 82-102.
- Martins, O., Olofin, E. A.** 1992. Environmental Impact of Man-made Lakes on River Physico-Chemical Systems: Case studies of Nigeria, Mitt. Geol.-Palaont. Inst. Univ. Hamburg, SCOPE/UNEP Sonderland 72: 113-121.
- Matlock, W. G.** 1985. The Case for Small-Scale Water Management System in Developing Countries, Mimeo. Truscan, University of Arizona.
- NEST** (Nigerian Environmental Study Team). 1991. Nigeria's Threatened Environment, A National Profile, NEST, 288 pp.
- Nichol, J. E.** 1987. Monitoring the effect of dam construction on Fadama Cultivation using SPOT satellite imagery and sequen-

tial photography, Paper presented at the National Conference of the Nigerian Society of Remote Sensing, Kano.

Ruhe, S. A. 1971. Stream regimen and man's manipulation. In *Env. Geom.*, D. R. Coates (ed) Binghamton: New York, 9-23.

Olofin, E. A. 1984. Some effects of the Tiga Dam valleyside erosion in downstream reaches of Kano River. *Applied Geography* 4 (4), 321-332.

Tricart, J. 1972. The landforms of the Humid Tropics, Forests and Savannas, trans. C.J.K. de Jonge, Longman, London, 231 pp.

Olofin, E. A., Martins, O. 1993. Dams and Reservoirs - Destabilisation of some Physical and Chemical Elements of Selected Nigerian Drainage Basins, *Nig. Jour. Wat. Res.* Vol.1, No 2, 90-105.

Udo, R. K. 1970: Geographical regions of Nigeria, Heinemann, London, 212 pp.

Udo, R. K. 1978. A Comprehensive Geography of West Africa, Heinemann, Nigeria, 304 pp.

Peltier, L.C. 1962. Areal sampling for terrain analysis, *Prof. Geog.* 14(2), 24-8.

Table 1: Some climatic indices at Kano, close to the channels studied

Climatic Indices	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Relative Humidity at noon (%)	2	16	10	17	29	41	55	68	63	41	16	17
Average Rainfall (mm)	0	0	2.5	10.2	63.5	111.8	203.2	315.0	127.0	12.7	0	0
Average Daily Max. Temp. (OF)	85.6	89.9	95.7	100.8	99.3	94.5	87.2	85.1	88.0	93.5	92.5	87.1

Source: Udo (1970)

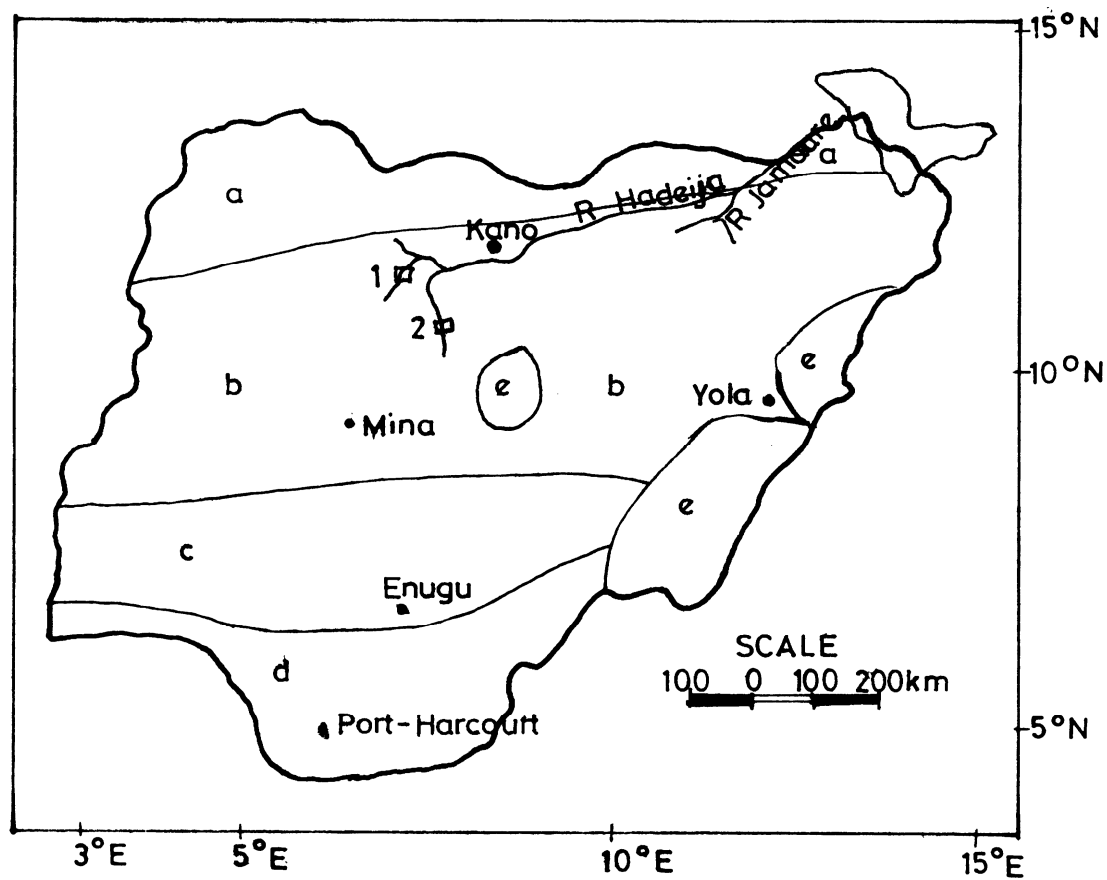
Table 2: Responses of Kano and Chalawa channels to dam construction

Channel Variables	Chalawa Channel											
	Kano Channel						Chalawa Channel					
	Pre-dam			Postdam			Pre-dam			Postdam		
	Mean	S.d	C.V %	Mean	S.d	C.V% %	Mean	S.d	C.V% %	Mean	S.d	C.V% %
Width (m)	249.0	80.2	32.2	33.7	8.4	24.8	251.0	52.9	21.0	183.0	20.8	11.4
*Depth (m)	2.01	0.32	15.9	+1.44	0.31	21.5	2.2	0.32	14.5	+1.15	0.08	7.0
Cross Sectional Area (m)	482.3	129.8	26.9	46.4	8.6	18.4	537.2	61.3	11.4	208.9	11.1	5.3
Abandoned Width (m)	-	-	-	216.3	74.2	36.0	-	-	-	68.4	34.7	50.8
Silt + Clay %	5.4	1.9	36.1	42.4	5.2	12.1	11.4	1.0	8.9	46.9	3.0	50.8
Mud Layer (cm)	3.4	0.45	13.2	19.2	13.8	71.7	1.5	0.54	36.0	7.3	1.5	20.6

* Postdam depth is incised into pre-dam storm channel bed.

S.d: Standard deviation

C.V: Coefficient of variation



KEY

- a Sahel
- b Sudan
- c Guinea
- d Sub-equatoria
- e Highland
- 1 Chalawa Dam
- 2 Tiga Dam

Fig. 1. Map showing the climatic regions of Nigeria and channels of study

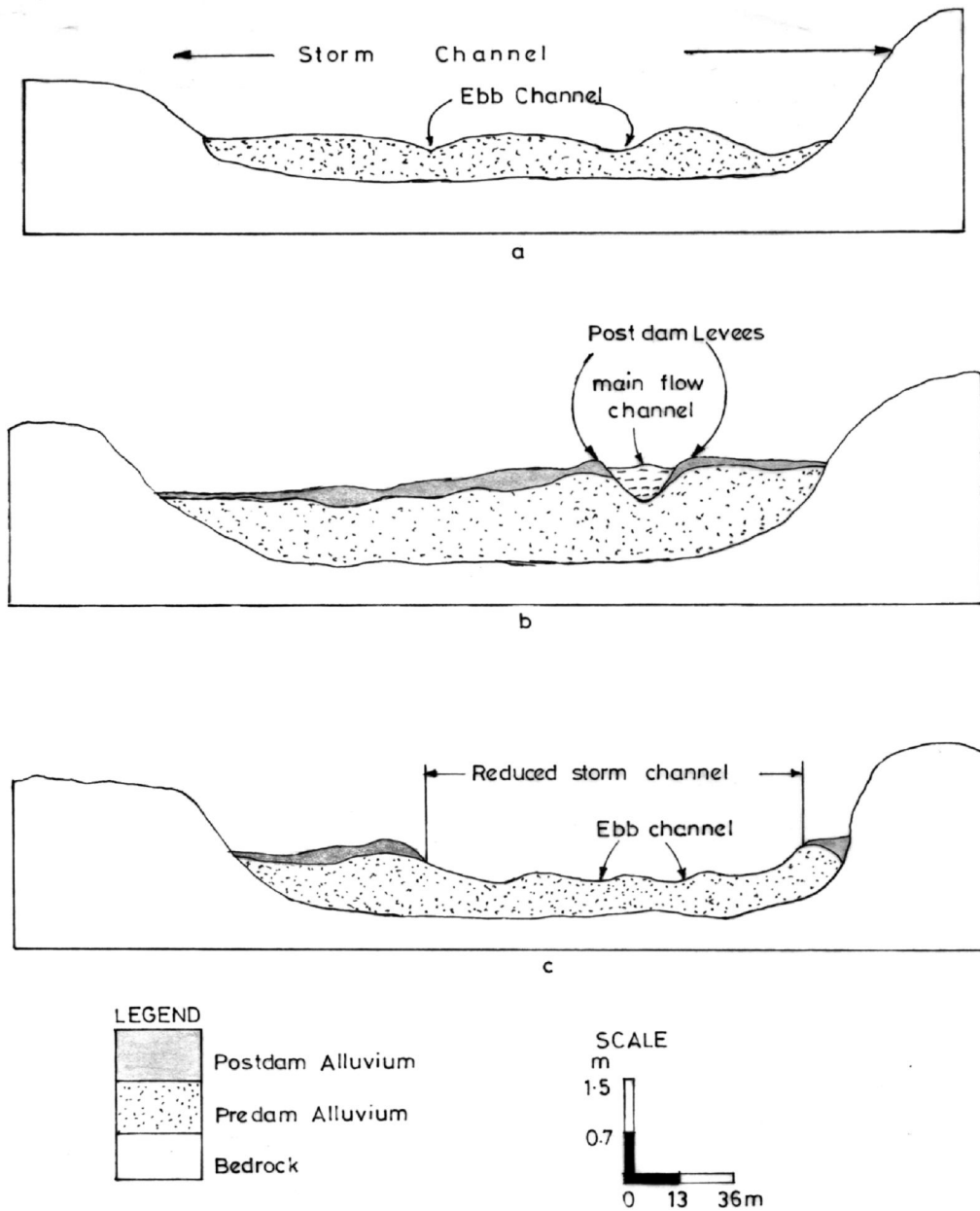


Fig. 2. Cross-section sketches of characteristics storm channels in the dry season

- (a) pre-dam (b) post-dam with full control e.g. Kano channel
- (c) post-dam with partial control e.g. Chalawa channel

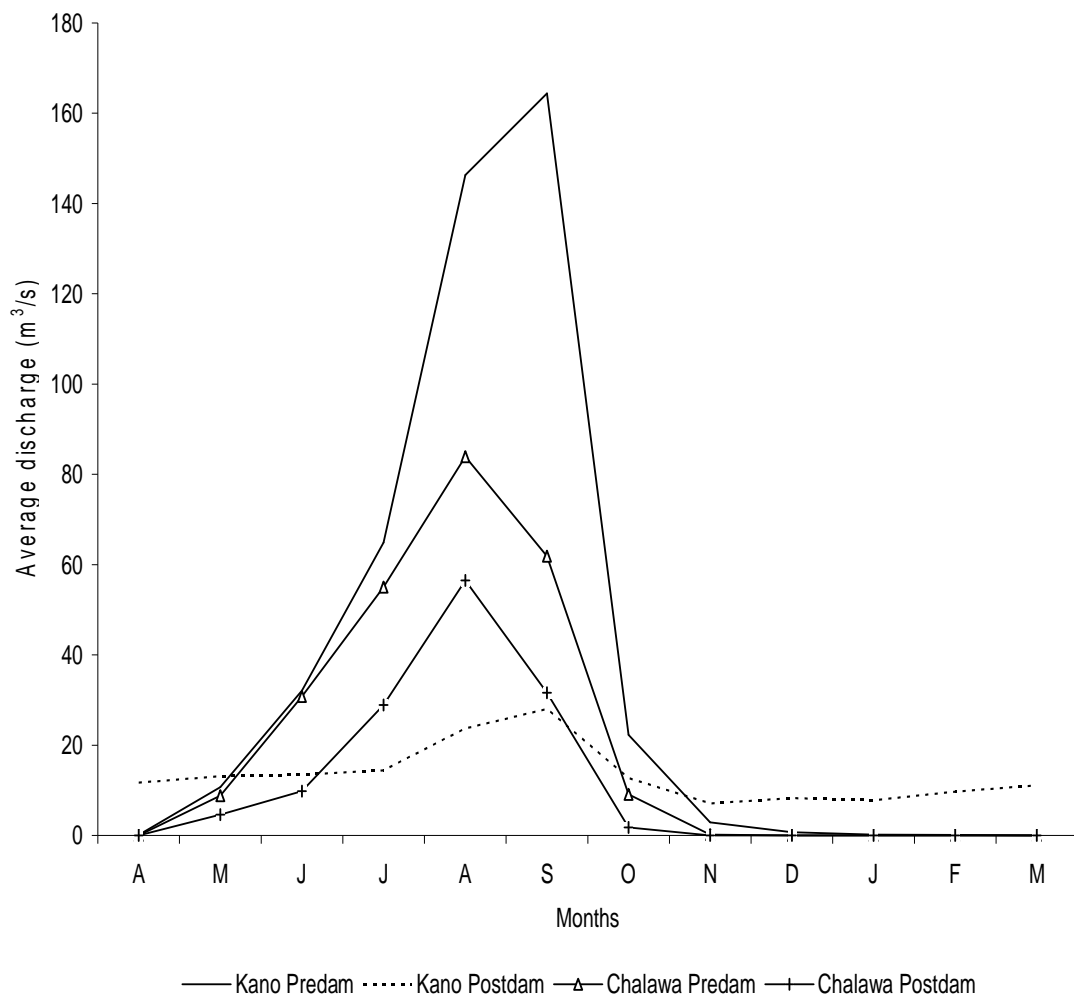


Fig. 3. Channels pre- and post-dam mean monthly discharges

(Pre-dam, 1965-70; Postdam, 1974-80)

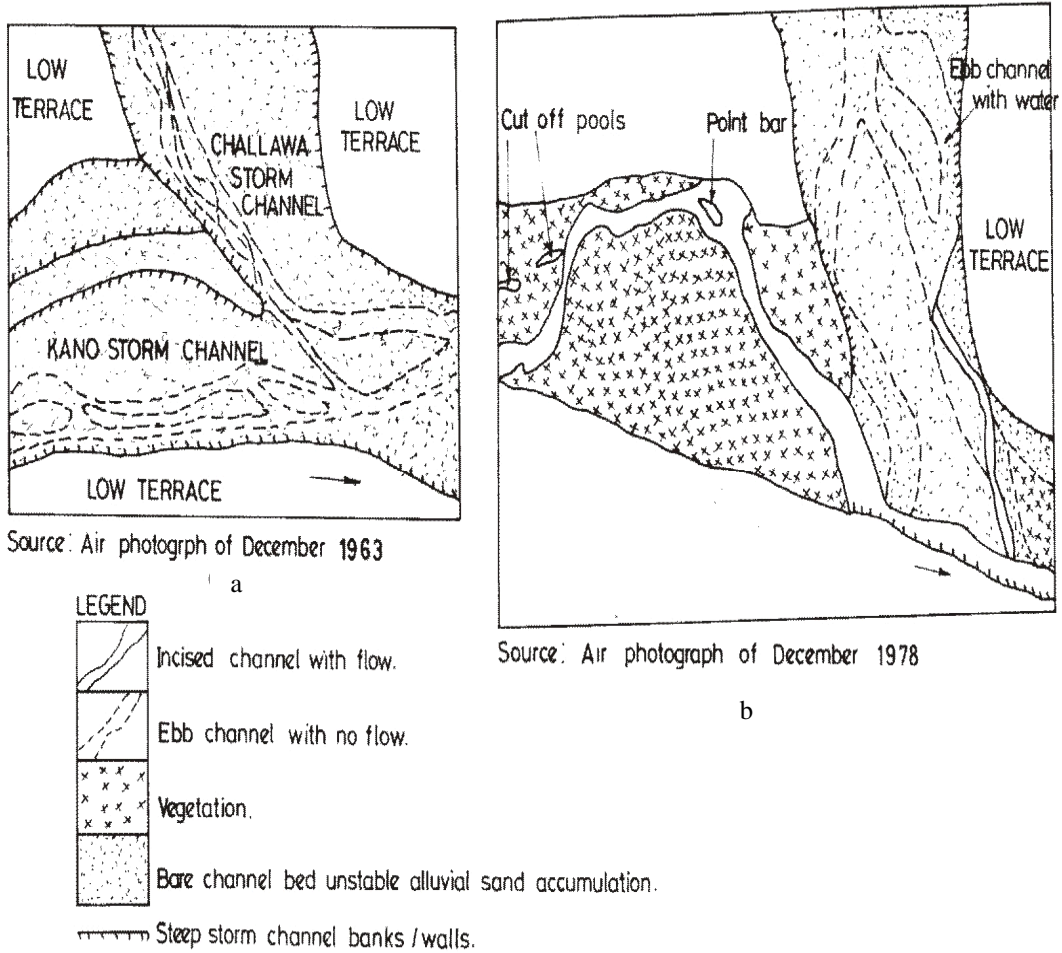


Fig. 4. Channel characteristics at Kano-Chalawa confluence due to full and partial control;

pre-dam (b) post-dam