CONSTRUCTION AND RESERVOIR OPERATION OF OBUDU DAM IN CROSS RIVER BASIN DEVELOPMENT AUTHORITY, NIGERIA

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ABSTRACT

Obudu dam is located on River Abeb in Okwel Obudu, Obudu Local Government Area and approximately between longitude 7°50'-9° 27E and latitude 4°30'-6° 55N in northern senatorial district of Cross River State. The area has rainfall of about 2000mm per annum, about 80 percent of this is concentrated in the wet season, high seasonal rainfall period.

The dam is multi-purpose with about 80% of its storage devoted to water supply. Other benefits include small irrigation, fisheries, tourism and flood control. Obudu dam15m high is a zoned earth fill dam with vertical and horizontal drainage blanket, impermeable blanket, upstream and foundation cut off. The total storage capacity is 5.25mcm. The dam instrumentation includes amongst others, surface monuments, relief wells, piezometers etc.

Opened for operations in 1999, a massive rainstorm in July, 2003 combined with release of excess water from the Lagdo Dam in Cameroons damaged the spillway and caused flooding that destroyed over 200 houses downstream the dam. This incidence necessitated the World Bank rehabilitation and reconstruction of the Dam in 2012 to improve on the resilience of the dam to take care of flood/preservation of Life and property.

Even with the reconstruction of the Dam, because of the high rainfall intensity, run-off from surrounding mountains and obvious challenges of climate change, a careful reservoir operation schedule had to be modelled to ensure dam safety.

1. INTRODUCTION

Efficient reservoir operation in a dam generally attempts to achieve the following objectives; to enhance flood management and flood control, maximize water storage capacity upstream, address dam safety issues and improve the aesthetics of the environment.

Accordingly, reservoir operators commonly manage downstream flooding using a set of operating rules which determine releases during, before and after a storm to achieve these objectives. During a storm, operators try to store the surge of inflows in available reservoir storage space to capture the storm's peak flow and delay its release until a less damaging time. Reservoir operators are presented with the challenge of knowing when to begin storing water for a flood, how long to retain it, and whether to make releases in anticipation of a storm to make more storage capacity available. Reservoir operation rules help optimize the system and control flooding.

Many reservoir variables can affect downstream flood frequency. Several studies have explored the effects of reservoir operations on regulated flood frequency.

Ayalew et al. [1] as well as Bradley and Porter [2] has at several times used a stochastic method of generating flood hydrographs and considered the effects of reservoir stage on outflow due to flood wave dissipation as it travels from the inlet to the outlet. Both studies demonstrated that greater reservoir storage decreases the unit effectiveness in reducing

downstream flood peaks. Theoretical analysis and real applications of various flood operation rules have also been implemented for single reservoirs and reservoir systems by Goldman and Ji [3]. This paper provides a careful reservoir operation schedule modelled to ensure dam safety and mitigate the incidences of flooding aggravated by increased precipitation as a result of climate change at the Obudu Dam.

2. PROJECT LOCATION AND TECHNICAL DATA

2.1 Project Location

Figures 1 &2 show the location of Obudu dam.

Obudu dam is located on the River Abeb in the northern part of Cross River State, Nigeria, approximately between longitude 7°50'-9° 27E and latitude 4°30'-6° 55N West Africa, about 3km to the east of Obudu town. It lies in the lowland area to the western side of the Obudu Plateau which rises to approximately 2300m above sea level. The dam site is around 200m above sea level where the topography is gently undulating in contrast to the surrounding mountain.

The dam is in an area of low seismic activity. The nearest known activity is along the Cameroon volcanic line some 200km away. Shallow earthquakes of magnitudes between 1 and 4 are associated with this line. The area is tectonically stable.

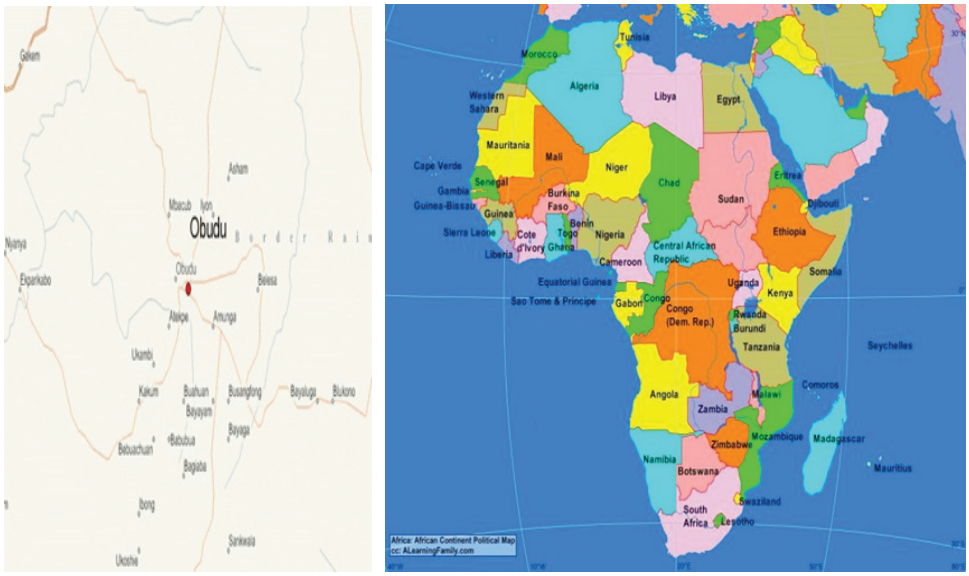

Figure 1 : Map showing location of Obudu

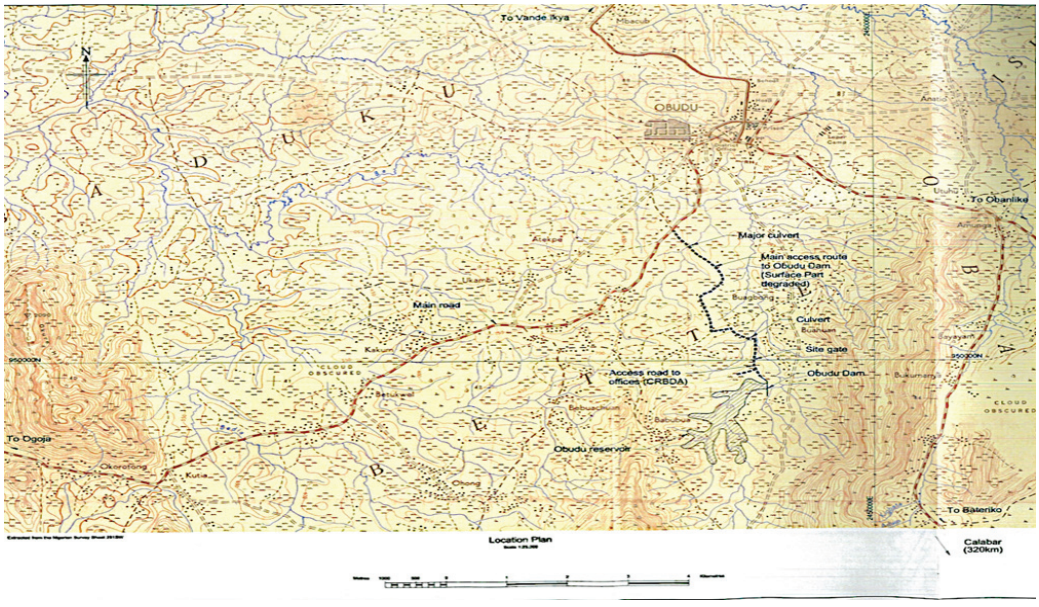

Figure 2 : Topographical map of obudu dam location

2.2 Technical data in Obudu dam

Dam type	Earth filled embankment dam
Height	15m
Top crest width	6m
Crest length	425m
Reservoir	
Reservoir surface area at elev, 113m	0.92km^2
Total Storage Capacity	5.25mcm
Catchment Area	20km^2
Spillway	
Spillway type	0gee/Stone pitched/ Grassed Trapezoidal Channel
Upstream protection	Riprap
Downstream protection	Grassing
Upstream slope	1:4
Downstream slope	1:2

Instrumentation

- Surface Monument
- Relief Wells
- Piezometers
- Weirs

The spillway with design discharge of 174m^3 /s at elevation 113Masl is located on the right abutment of the dam, approximately 60m from the southern end of the embankment. The structure comprises: upstream approach channel of 50m wide unlined section excavated in weathered rock: overflow section of 50m wide broad crested weir formed from hand placed rocks embedded in mass concrete: partially lined downstream channel with hand placed rocks embedded in mass concrete.

3. METEOROLOGICAL AND HYDROLOGICAL DATA

3.1 Average Weather in Obudu

In Obudu, the wet season is warm, oppressive, and overcast and the dry season is hot, muggy, and partly cloudy. Over the course of the year, the temperature typically varies from 65°F to 89°F and is rarely below 60°F or above 93°F.

3.2 Temperature

The hot season lasts for 2.1 months, from January 28 to March 31, with an average daily high temperature above 88°F. The hottest day of the year is February 23, with an average high of 89°F and low of 70°F.

3.3 Rainfall

Figure 3 shows the rainfall accumulated over a sliding 31-day period centered around each day of the year. Obudu experiences extreme seasonal variation in monthly rainfall.

The rainy period of the year lasts for 9.6 months, from February 13 to December 1, with a sliding 31-day rainfall of at least 0.5 inches. The most rain falls during the 31 days centered around September 25, with an average total accumulation of 11.4 inches.

The rainless period of the year lasts for 2.4 months, from December 1 to February 13. The least rain falls around December 29, with an average total accumulation of 0.1 inches.

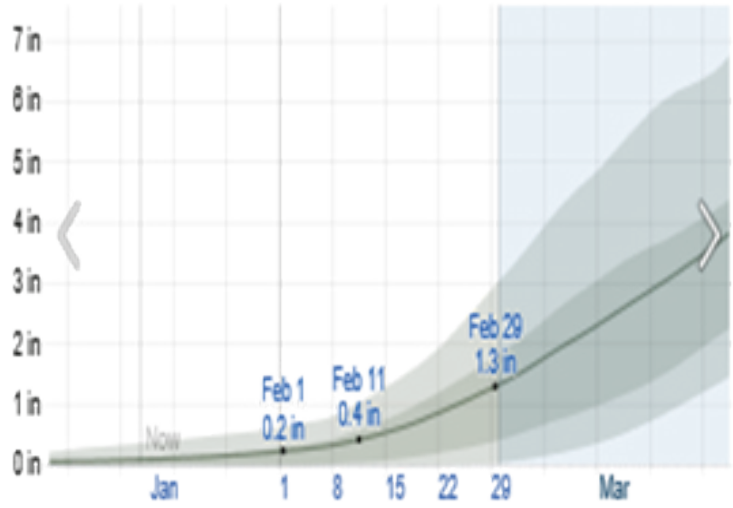

Figure 3 : Average monthly rainfall

4. FLOOD EVENTS THAT LED TO UPGRADE AND RECONSTRUCTION OF DAM

A flood event passed through Obudu Reservoir resulting from a rainfall event on the 19 and 20 July, 2003. The spillway suffered major damage during the flood in 2003 when 315mm of rainfall were recorded in a period of approximately 16hours on 19 July. The concrete/rock protection layer to the channel bed and side slopes were badly eroded from a distance of 10m downstream of the weir. Scour holes up to 4m deep were formed during the flood discharge that also led to destruction of over 200 houses and displacement of communities downstream. The maximum water level recorded at the flood event was 114.3mOD.

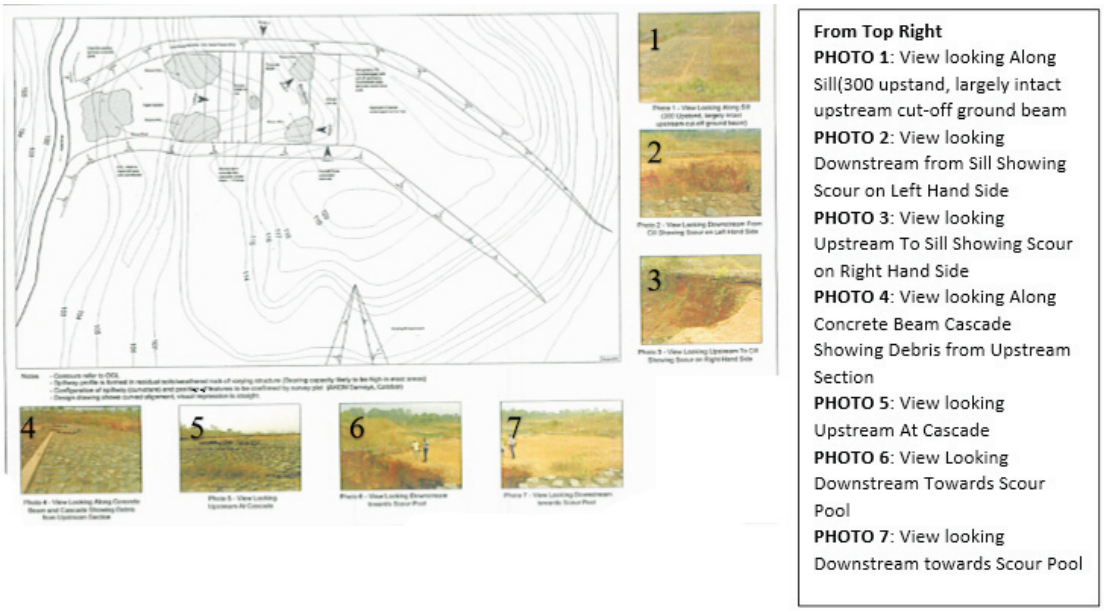

Figure 4 : Plan and picture showing details of damaged spillway

4.1 Summary of upgrade/reconstruction works of the dam in 2012

The Federal Government of Nigeria, in collaboration with the World Bank, implemented "The Rehabilitation of Obudu Dam" under the 2nd National Urban Water Sector Reform Project (2NUWRP) aimed at guaranteeing the safety and integrity of the reservoir for enhanced urban water supply.

The works focused on how to establish a draw-off point and an effective spillway as well as to provide efficient and sustainable operation of the various dam components and facilities.

In accomplishing these objectives, the task was to construct an approach channel, spillway structure, draw-off structure (at elevation 110mOD) and rehabilitation of the dam crest re-profiling, control chamber (inclusive of the inlet and outlet facilities) including all other ancillary works. Details shown in Fig 5.

At the completion of the reconstruction works, the reservoir capacity was enhanced from 4.5MCM to 5.25MCM. The spillway capacity was increased to safely pass a flood flow of 236m^3/s at elevation 113mOD (see figure 6 below).

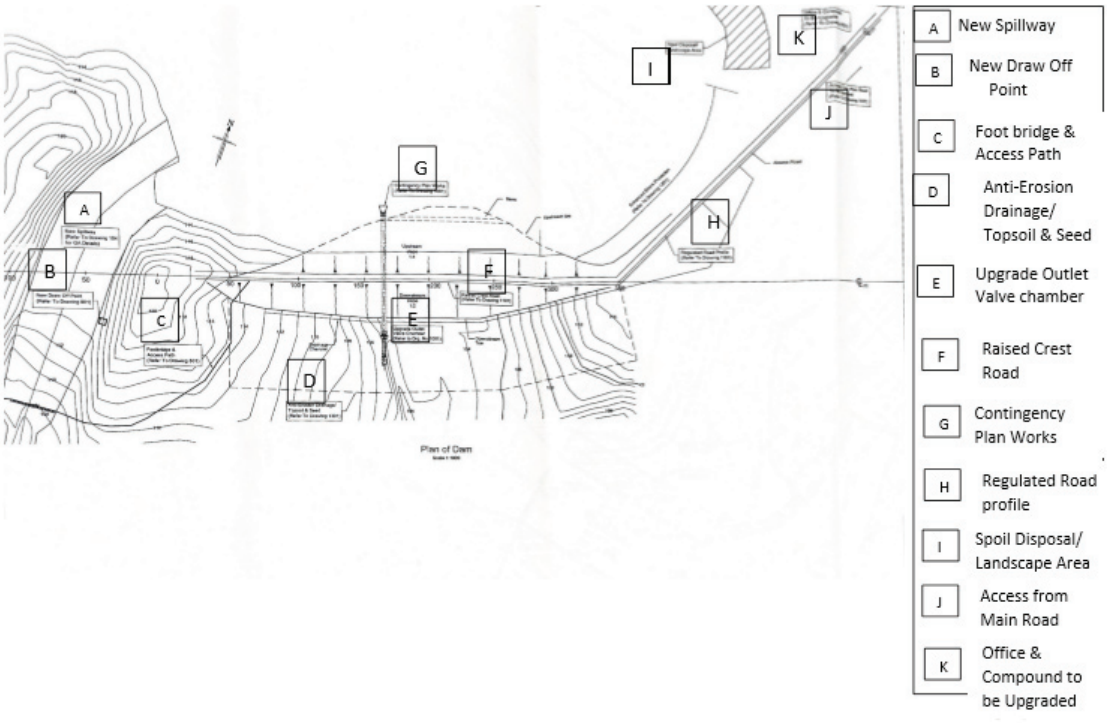

Figure 5 : Plan of dam showing details of new work for reconstruction and upgrade

Figure 6 : Plan of new spillway showing improved capacity

4.2 Hydropower

Following the rehabilitation and upgrade of the dam facilities including the reservoir, the Obudu dam now holds a potential for small hydropower of about 3MW. This power potential, when installed will be very useful to serve new and emerging Agro based industries within the catchment of the dam. This is indeed the period of Renewable Energy Development and boosting of Nigeria energy mix.

5. RESERVOIR OPERATION AND SUSTAINABLE FLOOD MANAGEMENT

5.1 Reservoir Operation Objectives (Planning Stage): In the operation of the Obudu

Dam Reservoir, the following principles were applied:

- Determining temporal changes in storage volume, reservoir water levels, actual supplies, shortages, spills, evaporation losses, over life of dam for given inflows.

- Sizing of storage keeping in view the water demands.
- Fixation of maximum conservation level.
- Defining the optimum rules of operation

5.2 Obudu dam reservoir operation in wet hydrological year

Table 1. Obudu dam reservoir operation hydrological data (wet year)

Resevoir Levels		INFLOWS		OUTFLOWS	
Month	Levels(masl)	Month	m3/s	Month	m3/s
Jan	112.95	Jan	68	Jan	72
Feb	112.4	Feb	67	Feb	72
Mar	111.9	Mar	66	Mar	72
Apr	111	Apr	65.2	Apr	72
May	110	May	65.1	May	72
Jun	111	Jun	70	Jun	72
Jul	110	Jul	74	Jul	72
Aug	113	Aug	105	Aug	72
Sep	113	Sep	110	Sep	103
Oct	113	Oct	-	Oct	80
Nov	113	Nov	-	Nov	73
Dec	112.8	Dec	-	Dec	72

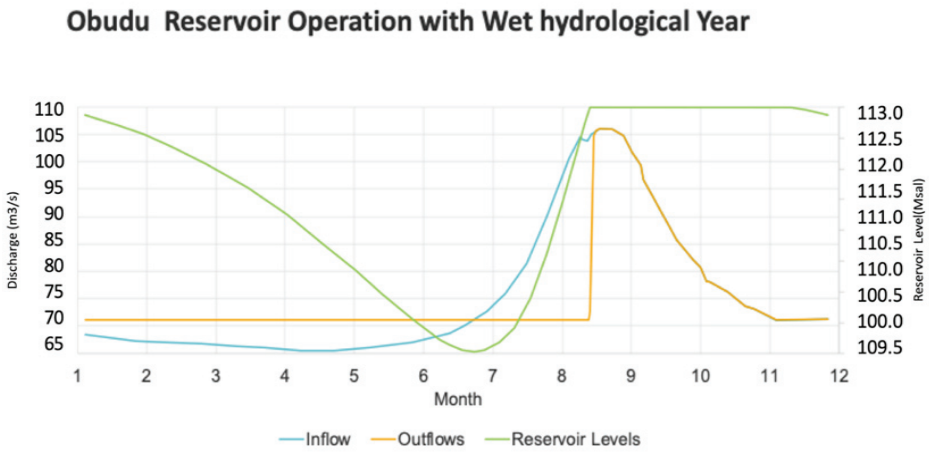

Figure 8 : Obudu dam reservoir operation with wet hydrological year

5.3 Model for reservoir operation of Obudu dam

After the reconstruction of the Dam, the above model was adopted for the careful operation of the reservoir to address flood menace and ensure dam safety (See Figure 8 above).

(i) The inflow in the reservoir is constant from the month of February to May. As the precipitation increases, the inflow rises in the month of June to peak inflow in August and September.

(ii) To absorb the inflows and maintain the maximum conservation level to ensure availability of water for its various uses at Obudu dam as well as forestall flooding, the releases are kept constant from the month of January to August. To ensure dam safety, the releases are up scaled during the peak inflow.

(iii) In our model for operating our reservoir, there is a careful drawdown of the reservoir level from January to the minimum storage level in June to allow sufficient storage of expected flood waters during the peak storm in July - September (as a flood control measure). During the upcoming dry months (falling limb of the outflow hydrograph) our reservoir level is kept constant at the highest water level.

(iv) Variation in weather accentuated by climate change have recently impacted both negatively and positively on water resource availability and environmental challenges.

6. RECOMMENDATIONS

Following our model for the reservoir operation of Obudu Dam as shown in the fiqure above, the following recommendations are necessary:

I Reservoir operations of the dams in the sub basin should be tailored along the set of operating rules which determine releases during, before and after a storm to optimize the system, manage downstream flooding and ensure dam safety.

II There is need to maintain and upgrade the hydro meteorological station in the dam vicinity. There are computer programs now in use to simulate river and reservoir system operation. This is now the global practice.

7. CONCLUSION

In implementing the construction of the new works at the Obudu dam, there were a number of different approaches to improving the flood handling capacity at the dam. The optimum solution was a careful balance of hydraulic efficiency, safety margins and construction economics.

In doing this, the combination of discharge with flood storage was increased from 50m to 80m; improved discharge hydraulics, high initial energy dissipation plus channel outlet, progressive energy dissipation over the length of the discharge chute: stilling basin arrangement at junction with the Abeb River, re-aligned channel and maintenance of steady flow.

Also deepening the approach channel by 3m and re-profiled the dam crest from 15m to 15.6m to accommodate more flood and improve reservoir capacity.

The hydraulic efficiency of the new works and our model for reservoir management has safely passed floods of the past 8 years even in the reality of increased precipitation in the current climate change scenario to keep the dam safe.

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