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Towards effective Hydrological Measurements downstream of Oyan dam

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Abstract

In 2011 the National Water Resources Institute (NWRI), Kaduna developed a Concept Note on Reservoir Sedimentation Study for Bakolori, Goronyo and Oyan dams. The study thrust is in five areas: Reservoir depth sounding, Downstream Studies, Hydrological Studies, Remote Sensing/GIS Applications and Environmental/ Socio-economic impacts assessments. A focus group on each area of the Reservoir Sedimentation study was constituted. NWRI held collaborative meetings with participating staff of selected organizations in Nigeria that are to implement the study. NWRI Management had undertaken a planning visit to these dams and the supports of the River Basin organizations that own the dams was secured. On 24th – 27th. May, 2011, the author participated in the Downstream Study group planning visit to Oyan Dam. During the visit, the downstream study group had a meeting with the Management of the Ogun-Oshun River Basin Development Authority (OORBDA) to discuss the study and obtain relevant documents like rating curves of existing gauging stations, maps etc. Also there was a visit to Oyan Dam reservoir, the GPS readings of benchmarks at the dam site were taken and the Oyan river system downstream of the dam was explored to determine along the main channel suitable sections for discharge measurement and Sediment sampling for onsite determination of sediment concentrations. Ten sites on the Oyan and Ogun rivers system were visited noting their hydro-environmental peculiarities. A brief overview of some of the sites is highlighted in the paper. Five locations were identified as suitable for discharge measurement and sediment sampling.

Key words: Oyan dam reservoir, Downstream, Flooding, Gauging Stations, Stage- discharge.

Introduction

In 2011 the National Water Resources Institute (NWRI), Kaduna developed a Concept Note on Reservoir Sedimentation Study for Bakolori, Goronyo and Oyan dams. The study thrust is in five areas: Reservoir depth sounding, Downstream Studies, Hydrological Studies, Remote Sensing/GIS Applications and Environmental/ Socio-economic impacts assessments. A focus group on each area of the Reservoir Sedimentation study was constituted. NWRI held collaborative meetings with participating staff of selected organizations in Nigeria that are to implement the study. This paper captures the outcome of the Downstream studies.

Floodplains are the preferred areas for habitation since time immemorial for their various advantages. Many people depend for their livelihoods on the various services provided by the river and its corridor ecosystem. At the same time the floodplains are occasionally flooded thereby adversely impacting the economic activities and resulting in loss of property and life. An example where these realities play out is in the downstream of Oyan dam.

Oyan Dam is in Abeokuta North Local Government Area of Ogun State at about 20 km northwest of the State Capital, Abeokuta. It was constructed in 1978. The dam crosses the Oyan River, a tributary of the Ogun River. It is used primarily to supply raw water to Lagos and Abeokuta, but has potential for use in irrigation and power generation. The Oyan dam is owned by the Ogun-Osun River Basin Development Authority (OORBDA), which is a parastatal of the Federal Ministry of Water Resources. The Oyan dam, located at latitude 7˚ 15′ and longitude 3˚ 15′ has a capacity of 270 million m^3. A location map of Oyan dam is as shown in Figure 1

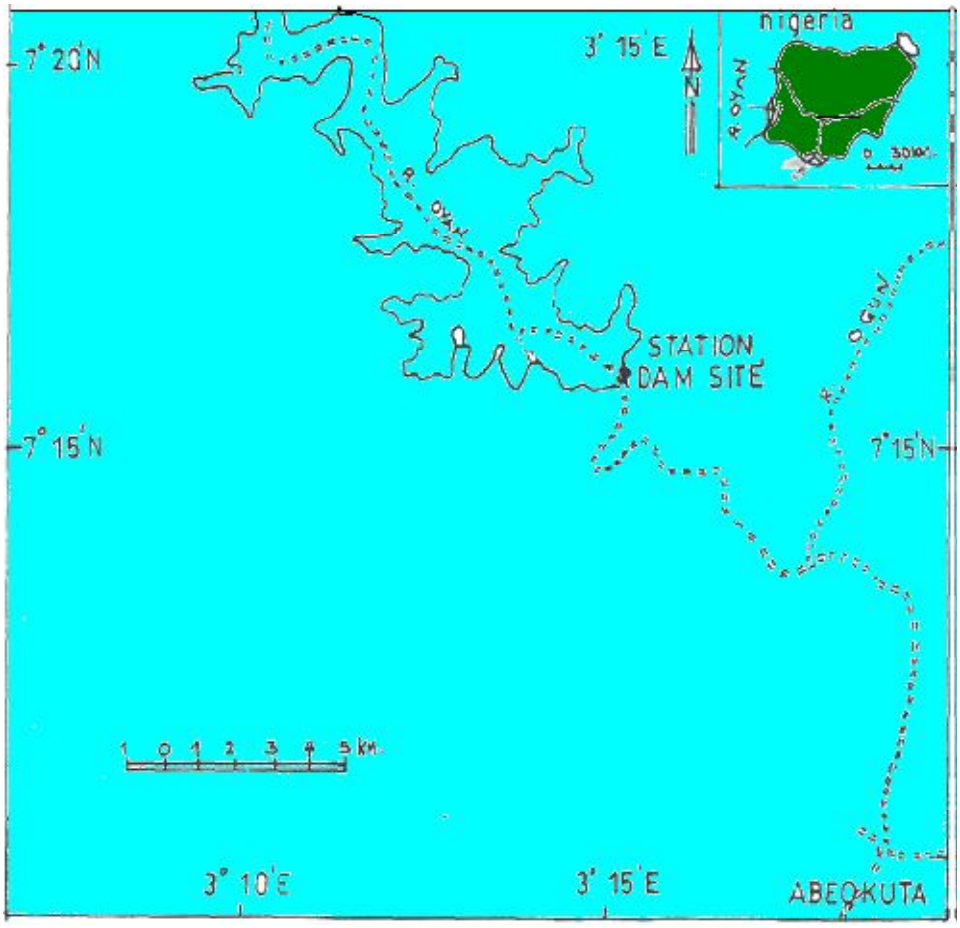

Figure 1: Location map of Oyan Dam (. Ufoegbune et al. 2011)

Wikipedia(2010) documented that the Oyan River Dam was designed to supply raw water to Lagos and Abeokuta which are the immediate downstream urban cities, and to support the 3,000 hectare Lower Ogun Irrigation Project. Three turbines of 3 megawatts each were installed in 1983. Over the years, there had been cases of downstream flooding attributed to releases from the Oyan Dam. Other operational problems have also led to conflicts over the adequacy of water released for downstream uses: irrigation, fisheries and raw water supply for water treatment in Lagos state. The Oyan dam has a power house shown in Figure 2 for generating 9 MW of electricity and the Oyan reservoir also functions to control flood through safe releases downstream.

Figure 2: Power station at Oyan dam

Objectives of Study

The objectives of the downstream study of the Oyan Dam reservoir include the following:

- To determine accessible and suitable sites along the river course where discharge measurements can be taken.
- To compile a database of river sections identified in (i) for risk assessment of flood.
- Sediment sampling and onsite determination of sediment concentrations at river cross-sections
- Identify and recommend ten suitable sites on the river course for the installation of manual gauges with two automatic gauges to be established at the dam site.

The goal of the Oyan downstream study is to improve upon hydrological measurements with a view to mitigating the effects of frequent flood in the area. Daily Trust Newspaper, (2010) in a report titled, "River Basin Authority warns of impending release of water from Oyan Dam" written on Monday, 23 August 2010 underscores the need for improved hydrological measurements for the management of Oyan and Ogun rivers floodplain. The Daily Trust Newspaper reported as follows:

"The Ogun-Oshun River Basin Development Authority, Abeokuta, has warned of impending rise in the water level of Ogun River as it prepares to release water from Oyan Dam. Mr Femi Dokunmu, the Assistant Director (Public Relations) in the authority, said in a statement yesterday that the dam commenced gradual release of water on Saturday."The heavy rainfall in the last few days has raised the water level in the dam to a point where its gradual release has become imperative. All residents and estate developers on the banks of River Oyan and Ogun River in Ogun and Lagos States are implored to note this development and take precautionary measures" .

Dokunmu told newsmen on telephone that the water level in the dam had risen to an alarming 63 centimetres, necessitating the release of water to avoid its collapse. He warned that if the water was not released gradually, the collapse of the dam might lead to heavy flood and destruction along the banks of Ogun River in both Ogun and Lagos States. It

would be recalled that the release of water from the dam after heavy rainfall in 2007 led to flooding and destruction of farms and homes in Abeokuta and Isheri in Lagos State.

A report similar to the above was carried by the Compass Newspaper on Friday 17 th February 2012. The report illustrates the varied positions of stakeholders regarding flooding attributed to releases from Oyan Dam. The report states: "The management of Ogun- Osun River Basin Development Authority (OORBDA) has said water from the Oyan Dam would not be released until May, this year. OORBDA also declared that water from the dam's reservoir was not the sole cause of flooding in some communities in Lagos and Ogun States. The agency's Assistant Director, Public Relations, Mr. Femi Dokunmu, disclosed this in Abeokuta when residents of Riverview Estate, Isheri, Ogun State visited the Oyan Dam to demand the early release of water from the reservoir to forestall flooding in their area during the rainy season. Addressing the residents, Dokunmu said the dam was the major source of water supply to Lagos and Ogun during the dry season... He, however, contended that water from the dam was not the only cause of flooding in Isheri and other flood-prone areas in the State. Dokunmu explained further that Isheri and some of the flood-prone areas were originally designated as green belt zone on which people should not have constructed buildings. He urged people living along floodplains to always take necessary precautions as OORBDA intensified efforts to combat incidence of flooding. Speaking earlier, however, the Chairman, Riverview Residents Association, Mr. Abayomi Akinde, blamed government for the worrisome situation in the area. Akinde, who was accompanied by the Principal, Nigerian Turkish International College, Isheri, Mr. Fatih Keskin, lamented the devastating effects of incessant flooding in the area. He explained that most property owners in the area were not aware of the situation of the land before investing there.

Methodology of Study

A Downstream Study group was constituted by NWRI for the study. NWRI held collaborative meetings with participating staff of selected organizations in Nigeria that are members of the study group. NWRI Management had undertaken a planning visit to these dams and the supports of the River Basin organizations that own the dams was secured. On 24th– 27th. May, 2011, the Downstream Study group visited Oyan Dam. During the visit, a meeting was held with the Management of the Ogun-Oshun River Basin Development Authority (OORBDA) to discuss the study and obtain relevant documents like rating curves of existing gauging stations, maps etc. There was also a visit to Oyan Dam reservoir. The GPS readings of benchmarks at the dam site were taken and the Oyan river system downstream of the dam was explored to determine, along the main channel, suitable sections for discharge measurement and sediment sampling for onsite determination of sediment concentrations. Ten sites on the Oyan and Ogun rivers system were visited noting their hydro-environmental peculiarities. A brief overview of some of the sites are highlighted in the paper

Brief Overview of Field Visits

River Oyan at Oyan Dam site

The Bench mark at the security gate of Oyan dam is located at 31 N 0528592 , E 0802661. The dam site elevation at this Bench mark was 85 m above mean sea level. Reservoir water level as at the time of visit at the Dam was 60.3 m. The downstream channel at the dam site was filled with water hyacinth and rock outcrops. The downstream flow was at the mercy of

the dam reservoir releases controlled by four (4) functional radial gates (Figure 3). Greenish vegetation was observed around the dam. The dam site was accessible but there was no suitable point for measurement along the river course before Alamutu Village. Upstream of the dam, land use activity was observed at left bank, while on the right bank evidence of some work done on a proposed irrigation scheme was noticeable.

Figure 3: Spillway section at Oyan dam.

River Oyan at Alamutu Village, Abeokuta

Here, the construction of housing for equipment on Early Flood Warning System was on-going (Figures 4 and 5). The elevation observed at this site (near the bridge on Abeokuta – Sokoto road) was 48 m. GPS positioning was (31 N 0532756 , E 0797800) Rock outcrops was observed within the channel. There was no existing hydrological station to record water level and none was being proposed, which if done may complement downstream observation. It was observed that the floodplain was very steep and soil surface bare, which may encourage soil erosion vis-à-vis sediment inflow to the river channel. It was discovered that installation of a new hydro station was being proposed by the OORBDA. The site was accessible and suitable for discharge and sediment sampling measurement.

Figure 4: Early Flood warning equipment housing under construction

Figure 5: Downstream Study Group at Oyan river below Early Flood warning equipment housing.

River Ogun at Mokoliki bridge (Owode-Papanlato Road)

On a side of the bridge railings, the GPS positioning are (31 N 0541285, E 0760610) at an elevation 23 m. An ungated rectangular weir (Figure 6) with auxillary side channel spillway was built on the river channel. Sandy bed was observed downstream of the bridge with attendant on-going sand mining activity both on the river channel and the floodplain. The ingenious miners created some secondary currents in the river by putting some obstructions under the bridge. This arrangement constrained the flow to go forward and turn back in a section of the river. In the process of turning back, the velocity reduces and more sediment settles in the river bed increasing the available sand to be mined.The reservoir behind the weir and the channel was infested with water hyacinth. Floodplain was dotted with green vegetation such as trees, plantain plantation and palm trees. There was no water level recorder at this site. Floodplain soil characteristic was clayey in nature, which could encourage mud turbidity during high runoff. Site accessibility was okay but would required bush clearing during the project execution. The site was suitable for measurement at downstream or upstream of the weir.

Figure 6: River Ogun at the bridge close to Mokoliki weir.

River Owiwi at Owiwi Village, Abeokuta

River Owiwi is a tributary of Ogun River. At Owiwi dam site (Figure 7), the study group visited water treatment site which supplies water to Owiwi communities and settlements near Abeokuta. The owiwi reservoir irrigates about 45 ha of land. Water level at the time of visit was 38.6 m. Bench mark was at 42.29 m. GPS readings were 31 N 0529551 , 0780599

Figure 7: Spilway section of Owiwi dam

Owiwi Bridge on Abeokuta - Lagos Road

The site is shown in Figure 8. . At this site accessibility was okay but the river width was very narrow. It was envisaged that suitable location for measurement could be found a little

further down of the bridge. No gauging station was seen, but BM of Owiwi dam site could be transferred to this site. The river channel was bushy and needed clearing. GPS readings were31 N 0530874, 0779546, with an elevation of 40 m

Figure 8: River Owiwi at the bridge on Abeokuta – Lagos road

River Ogun at Iberekodo Waterworks - downstream of Oyan Dam

Iberekodo Water works was established in 1962 and equipped with five (5) vertical gates (Figure 9), supplying water to Abeokuta metropolis and its environs. Water level of reservoir as at the time of visit was 5.27 m. However, the visiting team was informed that the minimum operating tolerable level is 4.27 m. Anything below this level would hinder the water supply regimentation. This rather informed the frequent complaints of Lagos community of inadequate raw water supply at this critical water level at Iberekodo Waterworks. The channel downstream was dotted with rock outcrops which may hinder discharge measurement. Discharge measurements could be done further downstream or upstream of the waterworks. GPS readings were31 N 0536617, 0794632 at an elevation of 48 m.

Figure 9: Weir at Iberekodo waterworks in Abeokuta

Stream Discharge Monitoring

According to US Geological survey (2004), gauging stations are facilities used by hydrologists to automatically monitor streams, wells, lakes, canals, reservoirs and or other water bodies. Instruments at these stations collect information such as water height, discharge, water chemistry and water temperature. Figure 10 shows a schematic diagram of stilling well and shelter at a stream gauging station.

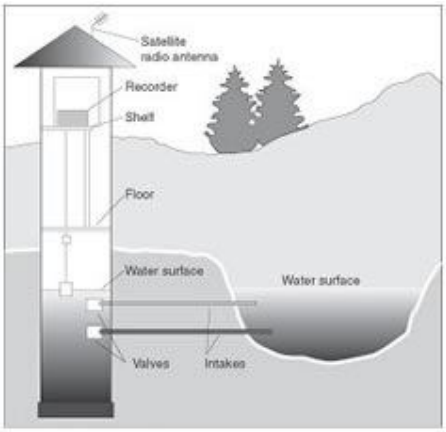

Figure 10: Schematic of a stilling well and shelter at a stream gauging station (USGS and NOAA, 2004).

Stream gauging provides water quantity information for (Tasmania Bureau of Meteorology, 2011):

- The design of water supplies, dams and other engineering works;
- Monitoring the sustainability of water allocation and water management;
- Implementing water restrictions;

- Flood mitigation and drainage;
- Monitoring climate change and drought; and
- Assessment of changes in water yields resulting from altered land use.

The flow rate or discharge of a river is the volume of water flowing through a cross-section in a unit of time and is usually expressed as m^3/s.
The Chezy Manning equation which, although developed for conditions of uniform flow in open channels, may give an adequate estimate of the non-uniform flow which Is usual in natural channels. The Manning equation states that:

$$Q = 1/n\ AR^{2/3}S^{1/2} \quad (1)$$

where
Q = discharge (m^3/s)
A = cross-sectional area (m^2)
R = hydraulic radius (m) and = A/P
P = wetted perimeter (m)
S = slope of gradient of the stream bed
n = roughness coefficient
More accurate values for discharge can be obtained when a permanent gauging station has been established on a stretch of a river where there is a stable relationship between stage (water level) and discharge, and this has been measured and recorded. Once this relationship is established, readings need only be taken of stage, because the discharge may then be read from a stage-discharge curve.
The stage-discharge relationship, or rating curve, usually includes the extremes of discharge encountered in a normal year. The rating curve should be checked periodically, ideally once a year, since minor adjustments may be necessary to take account of changes in the cross section of the stream or instability in the flow characteristics, or to eliminate errors in previous measurements (Kuusisto,1996).
Stream gauging using the Velocity – Area method is made up of two phases: the first has to do with measurement of the physical parameters (width, depth, speed); the second is the calculation of the discharge as a function of the recorded measurements.

Choosing the Measuring Section

It is important to take enough time in choosing a measuring section. A badly chosen section will never yield a high quality gauging. The geometric dimensions of the measuring section should be clearly defined to cover all the stream flow. This measuring section should be as rectilinear as possible. Its location should be far from natural or artificial obstacles or bends in the streambed. The measuring section should be perpendicular to the flow of the stream. When this is not possible, the widths of the biased section can be adjusted for correction.
The flow must be as regular as possible. Effort should be made to avoid taking measurements in converging or diverging flow areas that are oblique to the direction of the flow or that are in backwash or dead flow areas. The depth of the water should be sufficient that the equipment can be properly submerged. The measuring section itself should not present any disproportionate vertical or horizontal variation. In order to limit uncertainties,

the best compromise between sufficient depth and measurable water speed, including low flow conditions, should be made.
The location of the section should not be obstructed by any obstacles immediately upstream or downstream (immersed tree trunks or branches, rocks, plant growths, etc.) which would affect the measurement.

Conclusion

Floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss. Timely warnings and forecasts save lives and aid disaster preparedness. An improvement in the stream gauges installations and monitoring can significantly help mitigate the impacts of flood in the Oyan Dam downstream communities. With timely warnings, people in flood prone areas can plan to move to high grounds should persistent heavy rains occur.
As far as gauging goes, there are no fixed, unchangeable rules. The main objective is to get as close as possible to the existing realities of the field.
Ten sites were visited by the Oyan dam downstream study group. Five of the ten sites are suitable for the proposed downstream study of Oyan dam. On the whole the planning visit undertaken by the downstream study group is useful and the cooperation received from the Management of the Ogun - Oshun River Basin development Authority was commendable and heart-warming.

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