Bathymetry Study of the Siltation Level in Ayede Dam Reservoir in Ekiti State, Nigeria.

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Abstract

Siltation can either be gradual or fast depending on the rate and provenance of sediments which can adversely affect a dam reservoir capacity. Measuring and determination of siltation level in a dam reservoir is not always an easy task but requires systematic approach because of the environment. Bathymetry survey is one the method that can be used to measure the amount of siltation in a dam reservoir and was carried out at Ayede Dam to determine the level of siltation at the dam reservoir. It is a small dam with a height of 13 meters, crest length of 326m, and a holding reservoir capacity of 1.5 million cubic meters of water at completion in 1979. Results obtained from the investigation indicated a heavily silted dam reservoir as the reservoir capacity has shrunk from original designed capacity of 1,500,000 m^3 to 191, 270.59m^3. About 87% of the designed capacity have been lost to siltation which may have been gradual. Sedimentary infilling of the dam reservoir has reached advance stage. The highest water depth recorded from the bathymetry survey is 3.52m as against 11.5m at completion. The result clearly shows a heavily silted reservoir and hence the urgent need to de-silt the reservoir and improve its capacity for socio-economic development.

Keywords: *Ayede dam, siltation, bathymetric survey, reservoir.*

INTRODUCTION

Ayede dam which was conceived and constructed for the purpose of irrigation and water supply to Ayede community and environs in Ekiti State. It is a small dam with a height of 13 meters, crest length of 326m, and a holding reservoir capacity of 1.5 million cubic meters of water at completion about 43 years ago.

The dam is located on the Oye stream southwest of Ayede Town and the stream is characterized by seasonal flow regime pattern with a peak discharge averaging 48.6m^3/hour but dries up during the dry season. The contribution of base flow is quite low when compared to the contribution of the huge runoff which could serve as a conveyor of silt / sediment to the dam. The area is characterized by undulating topography with weathering characterizing rock exposure in the area.

Ayede Town and environs is underlain by basement complex rock which is most times characterized by low groundwater potential owing to the geology, deforestation and topography which supports high runoff and little infiltration. The town is still struggling with the problem of potable water supply and the dam is contributing next to absolutely nothing to potable water supply to the area due to long abandonment despite the huge capital investment. Several scholarly works have been carried out in the area with the

purpose of establishing the groundwater potential and quality in the area. Evaluation of the groundwater potential and quality in Ayede town have been done by (Ige et al. 2021). Their work revealed a deeply weathered and moderately fractured terrain and recommended drilling depth greater than 90 meters in the area.

The Benin-Owena River Basin Development Authority installed a 50 Ha Central Pivot Irrigation System (CPIS) facility in their farm land located adjacent to the dam with the aim of using the impounded water for irrigation purposes and thereby boosting agricultural activities through dry season farming with the believe that the reservoir can successfully serve the irrigation facility and providing the needed impetus for small scale Agro allied industrial development of the area.

Dam siltation is a major problem that could reduce a dam reservoir capacity and with increasing population and urbanization occasioned by anthropogenic activities, it is expected that the long abandoned Ayede Dam may have been heavily silted up because of construction works and agricultural activities upstream of the area and hence the need to for this study to establish the current reservoir capacity of the dam.

Location of study area

The dam area is located southwest of Ayede town covering an estimated area of about 54,338.24m^2 and bounded by latitude $7^0$52'47.49", $7^0$52'56.91" N and longitude $5^0$18'25.61", $5^0$18'44.09" E with a mean elevation of about 550 meters above mean sea level at the dam area. The elevation North-East of the dam area is well over 655 meters above mean sea level wherein the source of the river lies. The dam is located within the woody savannah forest belt of the southwestern Nigeria with an average annual rainfall of 1,694.97mm (1,743.8mm in 2019, 1,481.9mm in 2020 and 1,343.7mm in 2021) (NIMET, 2021) and (NIMET, 2022). The declining trend of rainfall pattern may have related to climate change. Runoff is usually high owing to the rock type, land use and topography. Over the last 35 years, rainfall data show a decreasing rainfall pattern. The area is covered by woody savannah vegetation with farming and trading as the main activities of the inhabitants. The dam is easily accessible through a 3,942 meters long earth road off Itaji - Ayede road at Ayede town.

Geology of the study Area

The study area is underlain by basement complex rocks characterized by Granite Gneiss, Migmatite Gneiss, and Charnokites belonging to Precambrian age (Rahaman, 1988). The area is characterized by undulating topography with isolated hills defining the rock outcrops while the low land denotes the weathered rocks forming overburden. Overburden thickness in the area varies considerably with about 10m as maximum recorded so far from borehole logs (Ademilua, 1997). Granite Gneiss, Migmatite Gneiss, and Charnokites generally undergo disintegration forming clay and quartz (Eluwole, et al. 2019). Groundwater occurs in the overburden, weathered, partially weathered / fractured rocks. Depth of groundwater ranges from 40 - 50 meters and 80 – 90 (Ige, et al. 2019).

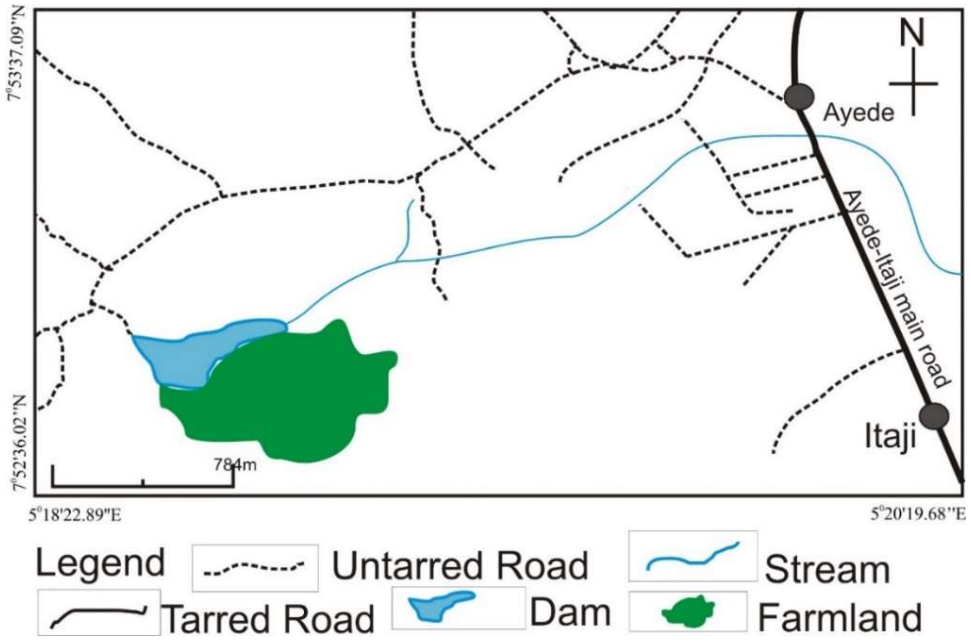

Figure 1: Sketch map of Ayede town showing dam location.

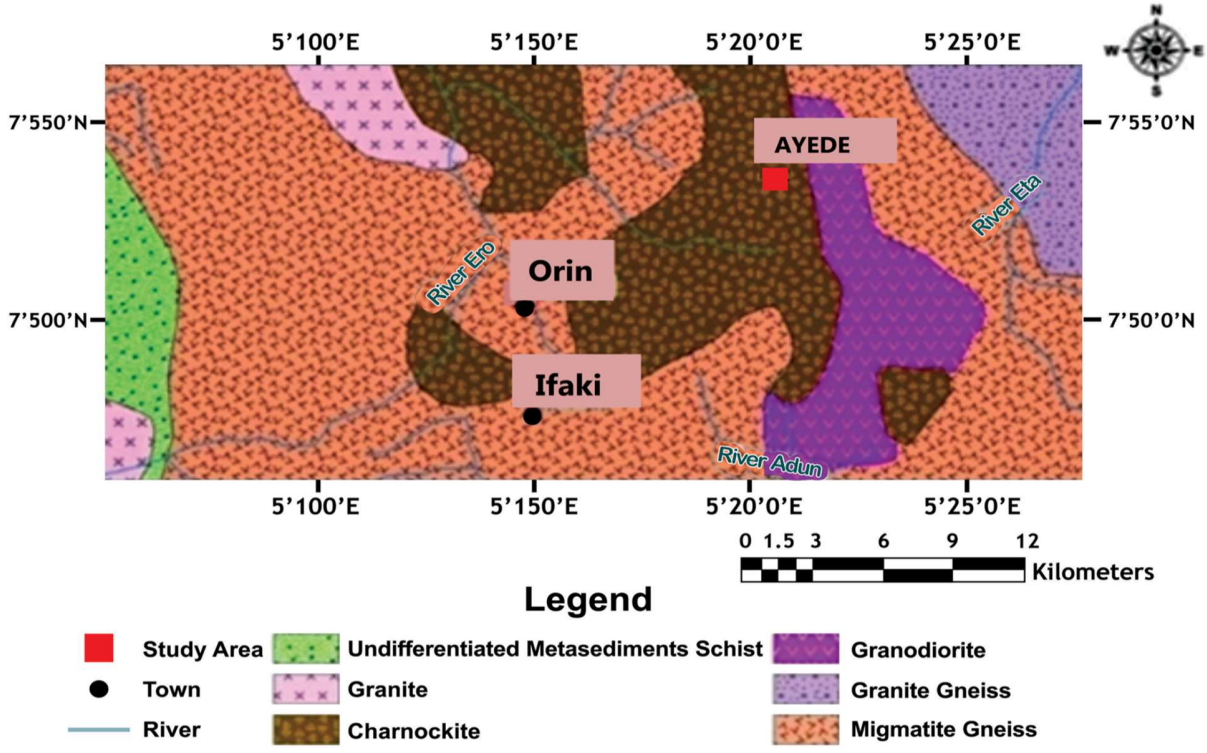

Figure 2: Geological map of part of Ekiti State showing the study area (adapted from Eluwole, et al., 2019)

MATERIALS AND METHODS

Direct measurement of siltation in a dam reservoir is not always easy and attainable (Naima et al., 2014). Bathymetric approach is based on a simple comparison of reservoirs morphology at two different time periods, first at the time of the construction of the dam and second at the time of the survey. Bathymetric map involves two types of necessary measures: the position and depth measurements (Ghorbel & Claude, 1982). Conducting a bathymetry is often not an easy task because of the nature of the environment. It involves measuring depth of water column with the aim of establishing the geometry of the reservoir floor. Different methods and equipment can be used in conducting bathymetry survey, but the equipment used in conducting Ayede Dam bathymetry survey is the Apache 5 which uses the principle of echo sounding techniques. An Echo Sounder is a type of SONAR (Sound Navigation and Ranging) device used to determine the depth of water by transmitting sound pulses into water (Ortt, et al. 2000) and (Erena, et al. 2020). It relies on the principle of transmitting sound waves from equipment's and then measuring the time taken for the echo to be returned from reservoir bed (Calder & Mayer, 2003). If the velocity of sound in water is known the time will be proportional to the distance travelled. The time taken by the waves to travel to and from the reservoir bed is measured and depth can be determined, by the formula Distance=Velocity x Time/2 (Al-Taiee, 2005) and (Ayadi & Abida, 2012).

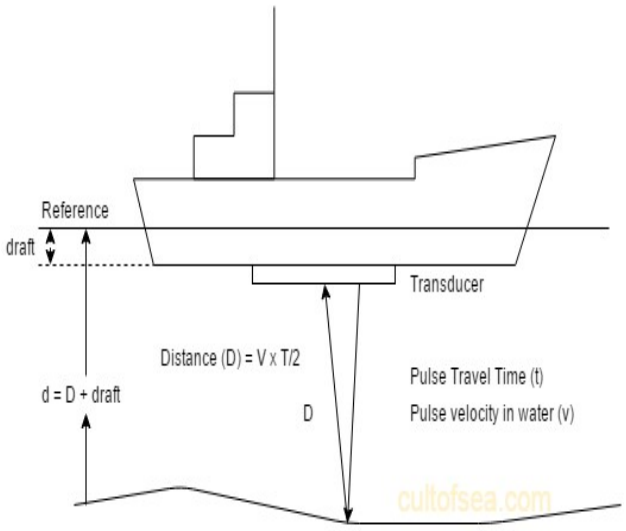

Figure 3: Sketch of echo sounding principle.

It is a perfect solution for hydrographic survey and mapping, channel survey and underwater geological exploration (Anaton, et al. 2016) and (Shanghai Huace Navigation Technology, 2018). The equipment was remotely controlled through an established parallel lines 5 meters apart and depth recorded at 5 meters interval within the reservoir area. Observed field data was used to calculate volume of water in the reservoir. Contour for the reservoir area was developed by joining places of equal depth within the reservoir area for the purpose of determining reservoir capacity and the level of siltation. There are several methods for calculating volume of siltation in a dam reservoir (Adediji, 2005).

The Kolmogorov Method which is based on the average between two sections survey profiles Pa, Pb and a fictitious profile Pc (Ghorbel & Claude, 1982).

Average Height method is based on the average silted heights on surveys profiles Pa

and Pb and the surface that separates them Sab (Ghorbel & Claude, 1982).

General Method based on silted sections on the surveys profiles but also takes into account the inclination of sections Pa and Pb (Camus, et al. 1995).

Plate 1: Preparing the equipment for deployment.

Plate 2: Equipment about to be deployed.

Plate 3: Apache 5 equipment deployed at the dam.

RESULTS AND DISCUSSION

Empirical result obtained from the bathymetric survey of Ayede dam shows a heavily silted dam reservoir and hence there is the urgent need to de-silt the Ayede dam. The current volume of water at the dam can barely serve the Central Pivot
Irrigation System facility installed by the Benin-Owena River Basin Development Authority for the entire dry season farming purpose. A gradual accumulation of silt over the years which have taken over 87% of the reservoir may have been from construction upstream of the area.

Interpretation of contour showing underwater geometry of the reservoir area shows a tight contour at the northern end of the reservoir area but shows a contracting difference at the NE / SE end of the reservoir area. This obviously indicate a gradual transgression of siltation at the dam. Though it is believed that the dam is old, a gradual drop in the gradient of the floor of the reservoir area but no empirical information has been provided to indicate the rate of siltation from this study (see figure 4).

The maximum depth recorded is 3.52m at the middle of the reservoir close to the dam axis indicating a pro-grading siltation. Minimum depth recorded at the reservoir is 0.4 meters restricted to the upstream of the reservoir area. The calculated reservoir volume from the investigation is 191, 270.59m^3 covering a reservoir spread area of 54,338.24m^2 as against 1,500,000m^3 at completion, indicating siltation of about 87.25% of the reservoir at completion.

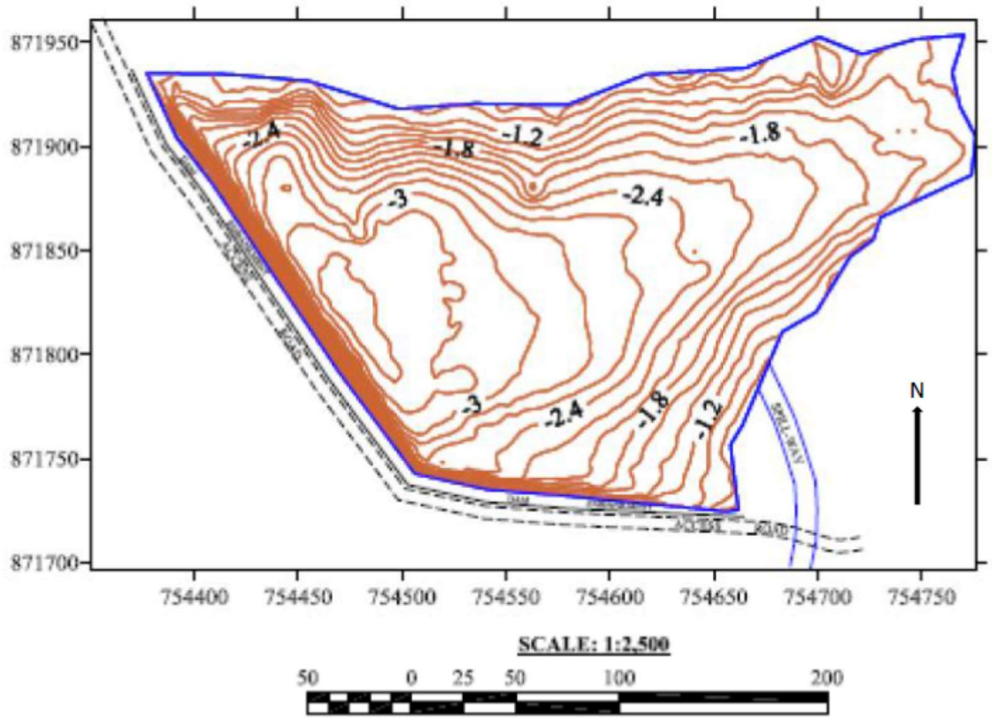

Figure 4: Contour showing underwater geometry of Ayede dam reservoir.

CONCLUSION

The bathymetric survey of Ayede dam reservoir shows that the reservoir capacity has shrunk from original designed capacity of 1,500,000 m^3 to 191, 270.59m^3. About 87% of the designed capacity have been lost to siltation which may have been gradual since completion in 1979 by the then Ondo State Government. The dam reservoir is housing 1,308,729.41m^3 of sediments indicating an advance stage of siltation. The active reservoir capacity is 191, 270.59m^3 with highest water depth recorded from the bathymetry survey standing at 3.52m as against 11.5m at completion. The result clearly shows a heavily silted reservoir and hence the urgent need to de-silt the reservoir through dredging and improve its capacity for socio-economic development.

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