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Examining Sediment Accumulation in Goronyo Reservoir, Sokoto State, Nigeria

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ABSTRACT: Goronyo Reservoir was impounded in 1984 on the Rima River and it has a storage capacity of 942,000,000 m^3 and a catchment area of 21,445 km^2. Construction of dams and reservoirs lead to modification of the hydro-morphological river regime which facilitate sediment deposition in the reservoirs. Reservoirs eventually becomes as sediment traps. The aim of this study was to examine the extent of sediment accumulated in Goronyo reservoir from 1984 to 2013. The research was carried out using bathymetric survey method. Geo-referenced depth data were collected with an echo sounder. The current water volume in the Reservoir was computed from the collected bathymetric data using Surfer 11 software. The study revealed that the volume of sediment accumulated in the Reservoir from 1984 to 2013 was 24,490,315 m^3. It is concluded that low volume of sediment was deposited during the 29 year age of the Reservoir. Recommendations of the study include repeated bathymetric surveys in the future and monitoring of both catchment erosion and sediment transport.

Keywords: Sediment, reservoir, sedimentation, bathymetric survey, Dam, Goronyo

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I. INTRODUCTION

The average annual inflow of sediments into a reservoir, the total sediment volume accumulated in the reservoir and the distribution of the sediments within the reservoir are important attributes of any reservoir (Imanshoa*et al*., 2014). Sediments in reservoirs are mixtures of soil particles and rock fragments, detached from the earth's crust, transported and deposited in the reservoir basin (De Villiers, 2006). The sediments undergo a series of processes in their downstream journey: erosion, entrainment, transportation and deposition (Mahmoud, 1987). Sediments that are transported and deposited in reservoirs are derived from catchment erosion (Hassanzadeh, 1995). This means that the deposition of sediments in lakes and reservoirs is an off-site consequence of accelerated erosion (Adediji, 2004; Adewubi*et al*., 2009).

Construction of Dams and Reservoirs causes changes in the fluvial system (Radoane and Radoane, 2005) because they form an artificial interruption in the hydro-morphological river regime which normally leads to deposition of sediments in reservoirs (Basson and Rooseboom, 1999). This is the main reason that makes the reservoirs to serve as sediment traps and also to change water flow and sediment flow in the downstream direction (Julien, 2010; Zhide and Yuqian, 2003). Dams and reservoirs also reduce flow velocity (Mahmoud, 1987) and allow a relatively clean water to pass downstream (Heidarnejad, 2006). The final fate of all reservoirs is to be filled up with sediments after long period of time (Haregeweyn*et al*., 2012).

Many dams and reservoirs were constructed in Nigeria. There is need for collection of data on the dams and reservoirs of Nigeria. In reality, there is poor tradition on research of dams in Nigeria. This study on sediment volume of Goronyo Reservoir was carried out to address part of this problem. Therefore, information on sediment volume of Goronyo Reservoir is needed for sediment management and reservoir operation in the Sokoto-Rima River Basin. In addition, the occurrence of flood from Goronyo Reservoir in September 2010 was one of the motivating reasons for this research.

Goronyo Reservoir was impounded in 1984 on the Rima River and it has a storage capacity of 942,000,000 m^3 (ImpresitBakolori Nigeria Limited, 1979). The main purposes for this Reservoir are farmland irrigation, water supply and flood regulation. The construction of this Reservoir was at the instance of the FAO Report (1969) which advised that some reservoirs should be constructed in the Sokoto Rima Basin including the one near Katsira (Kachera) to control River Rima (ImpresitBakolori Nigeria Limited, 1979). The Katsira Reservoir was renamed Goronyo Reservoir and later constructed by ImpresitBakolori Nigeria Limited. The aim of this study was to find out the volume of sediment deposited in the Goronyo Reservoir from 1984 to 2013.

II. MATERIALS AND METHODS

2.1. The Study Area

The study area, Goronyo Reservoir, is located between latitudes 13°30'N to 14°N and longitudes 5°30'E to 6°E (Ita*et al*., 1982). The Reservoir has a length of about 20km with a width of about 10km and an area of about 200km^2 with a storage capacity of 942 million cubic metres (Ita*et al*., 1982). The study area is located in Goronyo Local Government Area, Sokoto State, Northwest Nigeria. The study area is part of the Sokoto-Rima basin, which has a total catchment area of about 193,000km^2 distributed in Nigeria and the Niger Republic (Gill, 1974).

The Sokoto-Rima basin has a semi-arid tropical climate with a prolonged dry season from October-May and a short wet season from end of May to early October (Udo, 1970; Ogheneakpobo, 1988; Adeniyi, 1993). Temperatures depict both seasonal and diurnal variations in the area (Davis, 1982 a). Two temperature maxima of over 35°C are common between April-May and between October-November (Gill, 1974; Adeniyi, 1993). Two minimum temperature periods below 20°C are also common between December-January and in August (Gill, 1974; Adeniyi, 1993). During the rainy season, the diurnal range of temperature in the area is low but during the dry season it is high (Davis, 1982 a). Rainfall in the area shows both spatial and temporal variations (Udo, 1970; Adeniyi, 1993). The mean annual rainfall varies from about 700mm in the northern part of the Rima basin to about 1,100mm in the south (Gill, 1974; Davis, 1982 a; Adeniyi, 1993). The duration of the rainy season is also longer in the southern part (Davis, 1982 a) since it begins earlier and ends later than in the north (Gill, 1974).The study area has mostly sandy soils which have low organic matter and nutrients –nitrogen, phosphorus, and potassium (Swindell, 1986; Yelwa and Eniolorunda, 2012).

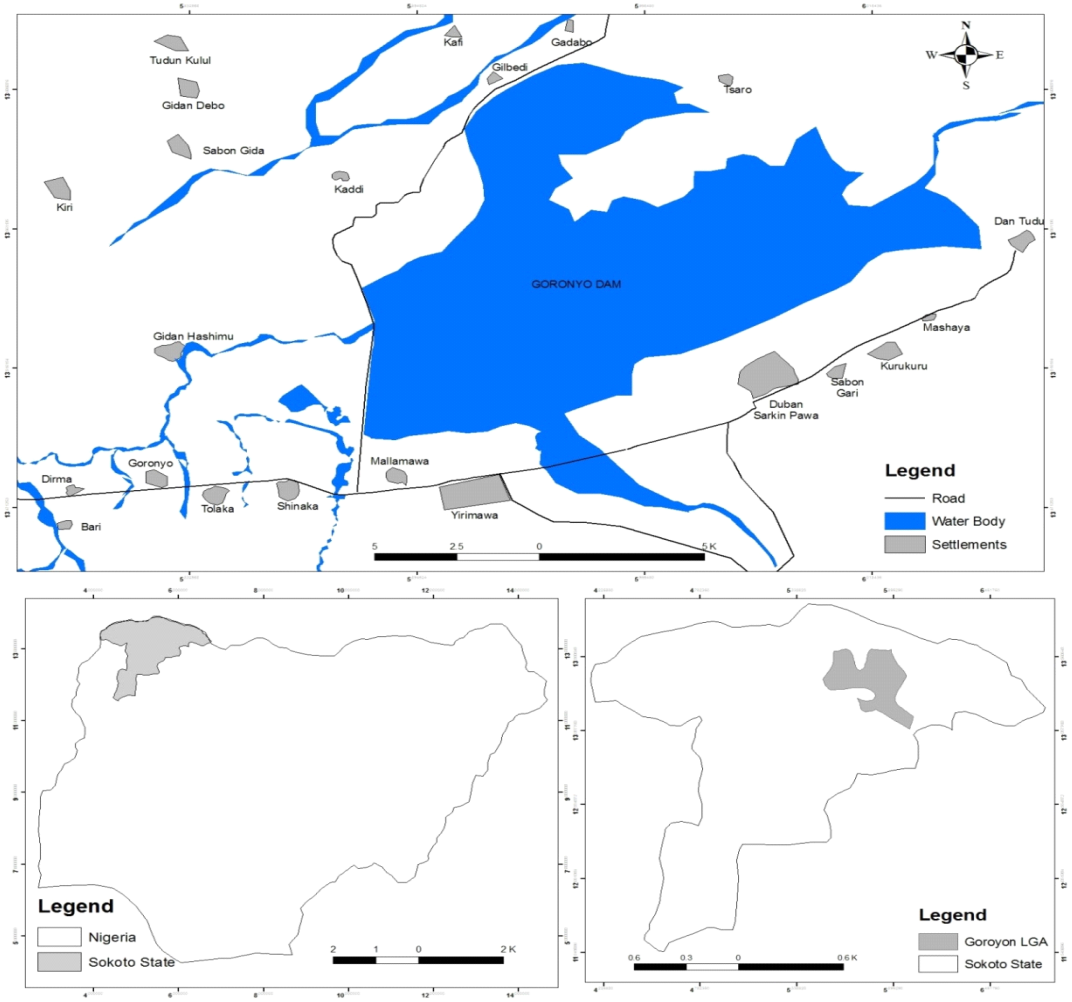

Figure 1: The Study Area (Goronyo Reservoir) ;**Source:** NASRDA, 2012

The sandy soils are associated with uplands or *tudu* and they may be ferruginous soils or ferralitic (kaolinitic) soils (FAO, 1969; Udo, 1970; Swindell, 1986). The flood plain or *fadama* soils are in contrast to the upland sandy soils (Udo, 1970; Swindell, 1986). The *fadama* soils are mostly hydromorphic soils which are

clayey and loamy with grey or black colour (Swindell, 1986). They are also highly fertile due to high nutrient contents and high cation exchange capacities (FAO, 1969; Udo, 1970; Swindell, 1986). The vegetation is the sudan savanna type with short grasses and trees (Udo, 1970; Davis, 1982 b). The sudan savanna is influenced by many physical and human factors (Davis, 1982 b). The categories are woodland, savanna woodland, tree savanna, shrub savanna, farmed parkland, riverine woodland, and semi-aquatic non-tree vegetation (FAO, 1969; Davis, 1982 b).

2.2 Reservoir Bathymetric Survey

Bathymetric survey is concerned with collection of depth data from the underwater portion of the study area (Ferrari and Collins, 2006). The type of bathymetric method used in this research is the contour method. This is a type of bathymetric survey in which the results of the survey are used to generate contour maps at different elevation intervals which can be used to calculate volumes (Ferrari and Collins, 2006). The contour method demands complete survey of the reservoir and the production of bathymetric map of the reservoir (Morris *et al*., 2008).The bathymetric survey of Goronyo Reservoir was conducted from 28 August to 2 October 2013. The survey was conducted with a canoe and A.YITE Technology Group's model GE-103G GPS Ultrasonic Depth Meter echo sounder. The echo sounder measured the depth of the reservoir (z) while the accompanying GPS recorded the geographic position of the canoe in form of longitude (x) and latitude (y). Each x, y, z data constitute a single three-dimensional point which was manually recorded during the course of the survey. The canoe was maneuvered along the periphery of the reservoir and along random transects from bank to bank of the reservoir until the whole reservoir was covered. As the survey progressed, the x, y, z data were collected and recorded. By the end of the survey, about 6,119 data points covering the reservoir surface area were collected by the echo sounder. After the bathymetric survey, the data were compiled and assembled with the Microsoft Excel 2007 spreadsheet software.The surface elevation of Goronyo reservoir during this bathymetric survey was measured at 286.4 m. This water level was used as the reference elevation and all water depths were adjusted to conform to it.

2.3 Calculation of Water and Sediment Volume

Bathymetric survey is based on comparing volume of reservoir water storage capacity at different periods (Tamene*et al.*, 2006). In this case, information on the original reservoir capacity was required as a benchmark against which the current water storage capacity can be compared (Tamene*et al.*, 2006 and Adwubi, *et al.*, 2009). Information on the original storage capacity of the Goronyo Reservoir is based on the initial topographic map of the Reservoir and the corresponding geotechnical report by ImpresitBakolori Nigeria Limited (1979).

Two stages were followed to determine the volume of sediment deposited in the Reservoir. The first stage is the calculation of the current total volume of water in the Reservoir. The second stage involves subtracting the current total volume of water in the Reservoir from the initial Reservoir storage capacity to find the volume of deposited sediment (Adediji, 2005; Adwubi*et al*., 2009).

The 6,119 water-depth points and the corresponding GPS coordinates collected during the bathymetric survey of Goronyo Reservoir were processed and analysed by Surfer 11 software. Current Reservoir water storage capacity and surface area of the Goronyo Reservoir were calculated using the collected data and the grid-volume function of the Surfer 11 software. After getting the current total volume of water in the Reservoir, it was then subtracted from the original reservoir storage capacity to obtain the volume of sediment deposited in the Reservoir (cf. Adediji, 2005; Adwubi*et al.*, 2009). This is calculated as follows:

SV = Initial Reservoir Storage Capacity – Current Total Water Volume in Reservoir

where, SV is the sediment volume (m^3).

III. RESULTS AND DISCUSSION

3.1 Capacity of the Reservoir

At 288 m elevation, the original capacity of Goronyo Reservoir is 942,000,000 m^3. The 2013 bathymetric survey was carried out when the elevation of the reservoir was at 286.4 m. The stage-capacity curve based on the initial topographic contour map was used to obtain the original storage capacity of the Reservoir that corresponds to 286.4 m. The stage-capacity curve is a graph of water level (y-axis) plotted against reservoir volume (x-axis). The design stage-capacity curve of Goronyo Reservoir is shown in figure 2. From the stage-capacity curve of Goronyo reservoir, the volume of water in the reservoir corresponding to 286.4 m elevation is 650,000,000 m^3. This is the original capacity that was used for comparison with the current volume of water in the Reservoir.

3.2 Water and Sediment Volume

Bathymetric surveys facilitate the computation of water and sediment volumes of reservoirs. The original capacity of the Goronyo Reservoir at 286.4 m is estimated from the stage-capacity curve to be 650,000,000 m^3. The current water volume of Goronyo Reservoir was computed using the Surfer 11 grid-volume function as 625,509,685 m^3. The current total surface area of Goronyo Reservoir was computed by Surfer 11 as 151,363,742 m^2. The sediment volume of Goronyo Reservoir was computed as the difference between the original and current capacity of the Reservoir.

The sediment volume of Goronyo Reservoir was calculated thus:

SV = Initial Reservoir Storage Capacity – Total Water Volume in Reservoir

= (650,000,000 – 625,509,685) m^3

= 24,490,315 m^3

where, SV is the sediment volume.

Therefore, the sediment volume of Goronyo Reservoir is 24,490,315 m^3. The water volume at 286.5 m elevation is 625,509,685 m^3. Sediment volume represents loss of storage capacity of the reservoir. The total storage loss due to sediment deposition in 29 years of operation of Goronyo Reservoir is 2.6 % of total storage.

Sediment volume or loss of storage capacity has implications on the dead storage capacity of reservoirs. Dead storage is the volume of the reservoir that is allocated for sediment storage to allow the reservoir to function at optimum level. Dead storage cannot be emptied by gravity and it prevents complete emptying of the reservoir. The dead storage capacity of Goronyo Reservoir is 21,500,000 m^3. The loss of storage (24,490,315 m^3) is slightly above the dead storage. The difference between sediment volume and dead storage is 2,990,315 m^3 of sediments. This means that Goronyo reservoir has lost storage capacity at about its dead storage with an excess of 2,990,315m^3 of sediments. It is to be noted that only part of the incoming sediment is actually deposited in the dead storage zone of most reservoirs. Sediments accumulate at all elevations within the reservoir and the mode of sediment accumulation show variation pattern due to particular site condition of each reservoir (Morris and Fan, 1998). The data obtained from Goronyo Reservoir was also used to generate bathymetric contour map of the Reservoir. The bathymetric map is shown in figure 3.

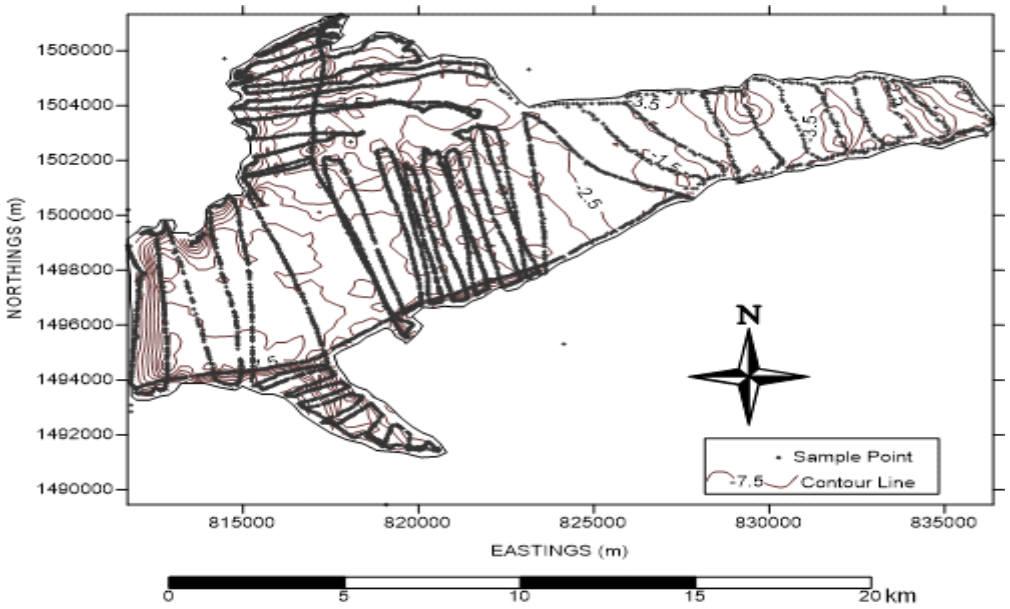

Figure 3: Current Bathymetric Map of Goronyo Reservoir Generated by Surfer 11

Source: (Authors,Field Work, 2013)

IV. CONCLUSION AND RECOMMENDATIONS

Accumulated volume of sediment deposited in the Goronyo Reservoir in 29 years was computed using bathymetric survey method. The volume of sediment accumulated within the Reservoir in its 29 years of operation was 24,490,315 m^3. This is equivalent to 2.6 percent of the total storage capacity of the Reservoir. This means that relatively low volume of sediment was deposited in the Goronyo Reservoir from 1984 to 2013.

Based on the findings of this study, some recommendations are forwarded. First, there is need for repeated bathymetric surveys in the future to provide sediment data on the Reservoir. Second, there is need for continuous monitoring of catchment erosion and sediment transport in the reservoir catchment. Third, there must be implementation of watershed management interventions such as afforestation and control of farming near the Reservoir.

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REFERENCES

[1] Adediji, A. (2005). Reservoir Sedimentation: The case of Opa Reservoir catchment, Southwestern Nigeria. South African Geographical Journal 87 (2): 123 – 128.
[2] Adeniyi, P.O. (1993). Integration of remote sensing and GIS for agricultural resource management in Nigeria.EARSel Advances in Remote Sensing 2(3): 6 – 21.
[3] Adewubi, A., Amegashie, B.K., Agyare, W.A., Tamene, L., Odai, S.N., Quansah, C. and Vlek, P. (2009).Assessing sediment inputs to small reservoirs in Upper East Region, Ghana.Lakes and Reservoirs: Research and Management 14 (4): 279 -287.
[4] Basson, G.R. and Rooseboom, A. (1999).Dealing with Reservoir Sedimentation –Dredging (Report No. TT 110/99). Pretoria: South African Water Research Commission.
[5] Bello, K. (2002). Agricutural land degradation in Goronyo local government area of Sokoto state(B.Sc. Project). Department of Geography, UsmanuDanfodiyo University, Sokoto.
[6] Davis, G. (1982a). Rainfall and Temperature. In: Abdu, P.S. and Swindell, K. (Eds.) Sokoto State in Maps: An Atlas of Physical and Human Resources. Ibadan: Ibadan University Press.
[7] Davis, G. (1982b). Vegetation. In: Abdu, P.S. and Swindell, K. (Eds.) Sokoto State in Maps: An Atlas of Physical and Human Resources. Ibadan: Ibadan University Press.
[8] De Villiers, J.W.L. (2006). 2D Modelling of turbulent transport of cohesive sediments in shallow reservoirs(M.Sc. Thesis).Department of Civil Engineering, University of Stellenbosch, South Africa.Retrieved from http://scholar.sun.ac.za on 15/09/2011.
[9] FAO, Food and Agriculture Organization (1969).Soil and Water Resources survey of the Sokoto Valley, Nigeria. Final Report, Volume V, Rome.
[10] Ferrari, R. and Collins, K. (2006).Reservoir survey and data analysis. In: Erosion and Sedimentation Manual. Bureau of Reclamation, Sedimentation and River Hydraulics Group, U.S. Department of the Interior, Denver, Colorado.Retrieved from http://www.usbr.gov/pmts/sediment/kb.
[11] Gill, M.A. (1974).Hydrological characteristics of the Sokoto-Rima basin.Savanna 3(1): 61 – 76.
[12] Haregeweyn, N., Melesse, B., Tsunekawa, A., Tsubo, M., Meshesha, D., and Balana, B.B. (2012) Reservoir sedimentation and its mitigation strategies: A case study of Angereb reservoir (NW Ethiopia).Journal of Soils and Sediments 12: 291-305.
[13] Hassanzadeh, Y. (1995). The removal of reservoir sediment.Water International 20 (3): 151 – 154.
[14] Heidarnejad, M., Golamee, S.H., Mosaedi, A. and Ahmadi, M.Z. (2006).Estimation of sediment volume in Karaj Dam reservoir (Iran) by hydrometry method and a comparison with hydrography method.Lake and Reservoir Management 22 (3): 233 -239.
[15] Imanshoar, F., Jahangirzadeh, A., Basser, H., Akib, S., Kamali, B., Tabatabaei, M.R.M., and Kakouei, M. (2014) Reservoir sedimentation based on uncertainty analysis.Abstract and Applied Analysis, Vol. 2014, article ID 367627, pp. 1-6.
[16] ImpresitBakolori Nigeria Limited (1979). Goronyo dam project: Second phase of the Sokoto-Rima river basin development. Final Report, Engineering B, volume 2 – Hydrology.
[17] Ita, E.O., Balogun, J.K. and Adimula, O.A. (1982) Preliminary report of pre-impoundment fisheries survey ofGoronyoreservoir. A report submitted to the Sokoto Rima River Basin Development Authority, Sokoto, Nigeria.
[18] Julien, P.Y. (2010) Erosion and Sedimentation, 2nd.ed. Cambridge: Cambridge University Press.
[19] Mahmoud, K. (1987). Reservoir sedimentation: impacts, extent and mitigation(World Bank Technical Paper No. 71). Washington DC: World Bank.
[20] Morris, G. L., Annandale, G. and Hotchkiss, R. (2008) Reservoir sedimentation. In: Garcia, M.H. (ed.) Sedimentation Engineering: Processes, management, modelling, and practice. American Society of Civil Engineers, Manual and Reoport on Engineering Practice No. 110, Virginia.
[21] NASRDA, National Agency for Space Research Development Authority (2012) Nigerian Imagery.
[22] Ogheneakpobo, E.M. (1988). Landuse changes as a result of the Goronyo dam construction(B.Sc. Project). Department of Geography, University of Sokoto, Sokoto.
[23] Radoane, M. and Radoane, N. (2005).Dams, sediment sources and reservoir silting in Romania.Geomorphology 71, 112 -125.

[24] Olofin, E. A. (1994). Dam construction and Fadama Development. In: Strategies for the Sustainable use of Fadama Lands in Northern Nigeria, Kolawole, A., Scoones, I., Awogbade, M. O. and Voh, J. P. (eds.), pp. 113-117. Isola Ola and Sons, Zaria.
[25] Swindell, K. (1986). Population and agriculture in the Sokoto Rima basin of north-west Nigeria: A study of political intervention, adaptation and change, 1800 – 1980. Cahiers d'etudesAfricaines26 (101 – 102): 75 – 111.
[26] Tamene, L., Park, S.J., Dikau, R. and Vlek, P.L.G. (2006). Reservoir siltation in the semi-arid highlands of northern Ethiopia: sediment yield-catchment area relationship and a semi-quantitative approach for predicting sediment yield. Earth Surface Processes and Landforms 31, 1364 -1383.
[27] Udo, R.K. (1970).Geographical Regions of Nigeria. London: Heinemann.
[28] Yelwa, S.A. and Eniolorunda, N.B. (2012). Simulating the movement of desertification in Sokoto and its environs, Nigeria using 1km SPOT-NDVI data.Environmental Research Journal 6(3), 175 – 181.
[29] Zhide, Z. and Yuqian, L. (2003).Reservoir sedimentation and impact on river processes. In: Xiaoqing, Y. (Ed.) Manual on Sediment Management and Measurement(Operational Hydrology Report No. 47).Geneva, Switzerland: World Meteorological Organization.

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