332

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# Sedimentological assessment of the Tucuruí Reservoir (Tocantins River, Brazil)

## NEWTON DE OLIVEIRA CARVALHO[1], ANTÔNIO RAIMUNDO SANTOS RIBEIRO COIMBRA[2], BRUNO LEONEL PAYOLLA[2], TARCÍSIO LUIZ COELHO DE CASTRO[3] & ANDERSON BRAGA MENDES[4]

1 *Sedimentology and Water Resources Adviser, Rua Conde de Baependi, 112 ap. 904, Flamengo, Cep 22231-140, Rio de Janeiro,RJ; Brazil*
newtonoc@openlink.com.br

2 *Centrais Elétricas do Norte do Brasil, ELETRONORTE. SCN, Quadra 6, Bloco, C Sala 501, Ed. Venêncio 3000, Cep 70716-900, Brasília, DF, Brazil*

3 *Engevix Engenharia S/A, SCN Q. 04, Bloco B, 13º andar, Pétala D, Centro Empresarial Varig, Brazil*

4 *Engevix Engenharia S/A, Rua José Rodrigues dos Santos, 117, Bela Vista, Duque de Caxias, RJ, Brazil*

**Abstract** The results of a study on the sedimentation in Tucuruí Reservoir, located in the lower reaches of the Tocantins River, Brazil, are presented. Morphological information on reservoir sediment deposits and sediment transport data collected since dam closure in 1984 were utilized. These data were used to construct an empiricial model of reservoir sedimentation that allowed an assessment of the impact of land use change upstream Tucuruí Dam. Results of the model show there is not any short or medium-term problem regarding the development of sediment deposits at the water intake sill of the reservoir. Future work on topographic surveys in the river and sedimentological studies in the reservoir are recommended.

**Key words** Brazil; deposit heights at dam toe; erosion; reservoir; sediment; sediment distribution; Tocantins River; useful life

## INTRODUCTION

Reservoir sedimentation is an important issue facing many water resource managers. Assessment of reservoir sedimentation requires information on discharges of sediment to the dam, calculation of sedimentation rates within the reservoir, and therefore computation of the time to reach the sill of water intakes—a computation of the useful life of water supply reservoirs. There are many large dams in Brazil and this paper reports on a study of sedimentation in the Tucuruí Reservoir, one of the largest artificial lakes in Brazil.

## PRELIMINARY COMPUTATION

The Tucuruí Reservoir is located in the lower reaches of the Tocantins River, downstream from its confluence with the Araguaia River. It has a drainage area of 758 000 $km^2$, which represents 98.8% of the Tocantins River catchment. Thus, the dam has the capacity to trap most of the sediment load of the Tocantins River. The Tucuruí Reservoir began filling in September 1984 and since then there have been other reservoirs built upstream, namely: Serra da Mesa built in 1996 and Lajeado built in 2001, on the Tocantins River. Several other

dams are planned for construction. All these structures will have an effect on the sediment load to the main Tucuruí Reservoir.

The first stage of the project was to evaluate the total sediment load to the reservoir. This involved the construction of sediment transport algorithms that related sediment discharge to river flows and therefore enabled the calculation of long term sediment loads to the reservoir. These data were then used to determine rates of sedimentation in the reservoir. The fundamental equations for reservoir sedimentation were:

$$S = D_{st} E_r / \gamma_{ap} = 356 \, Q_{st} E_r / \gamma_{ap} \quad \text{and} \quad T = V_{res} / S \qquad (1)$$

where $S$ is sediment volume retained by the reservoir (m$^3$ year$^{-1}$); $D_{st}$ is annual average sediment discharge to the reservoir (t year$^{-1}$); $E_r$ is sediment trapping efficiency in a reservoir (dimensionless); $\gamma_{ap}$ is the gravity weight of the deposits (t m$^{-3}$); $Q_{st}$ is average sediment discharge from the reservoir (t year$^{-1}$); $T$ is sedimentation time (years); $V_{res}$ is reservoir capacity (m$^3$).

It is pertinent to note that $Q_{st}$, $D_{st}$, $E_r$ and $\gamma_{ap}$ vary with time and sediment yields will also change over time because of increases in erosion potential in the reservoir catchment. The sediment trapping efficiency of the reservoir will decrease as sediment deposits increase and the gravity weight of the sediment deposits changes as a result of its compaction overtime. As the deposits become more significant, $V_{res}$ decreases. The sediment trapping efficiency of the reservoir ($E_r$) was obtained through the Brune curve, whilst the gravity weight of the sediment deposits was computed via the Lara and Pemberton procedure (see Strand, 1974; ICOLD, 1989; Carvalho, 1994, 2000).

## INCREASE IN THE SEDIMENT DISCHARGE

There has been significant land use changes in the Tocantins–Araguaia catchment associated with population increases between 3.5 and 8% per year. Land use changes have included increases in agricultural areas, deforestation, road and general construction. This has all contributed to a substantial increase in sediment yield from the catchment and subsequent increases in sediment discharges in the receiving rivers. Anecdotal evidence suggests commensurate in-channel and reservoir sedimentation causing drawbacks (severe flow events, etc). The rainfall runoff coefficients have increased over a longer time period at five out of seven monitoring stations in the catchment. It was also observed that the river flow at the dam site became greater, with the long-term average discharge between 1931 and 2000 increasing from 3.62 to 250 m$^3$ s$^{-1}$.

For this study, sediment discharge data for three stations in the catchment, with a record of about 20 years, were used. These data were assembled in 5-year periods, and from the flow and average yearly sediment discharge data, mass curves were traced (Fig. 1). Sediment yield rates were computed by using the angular coefficients of the straight lines. The coefficient of the first line of the mass curve provides $r_1$, whereas the second line gives $r_2$. $E_c$ represents the increase/decrease of the phenomenon within a period, whereas $R$ means the annual rate, according to the following equations:

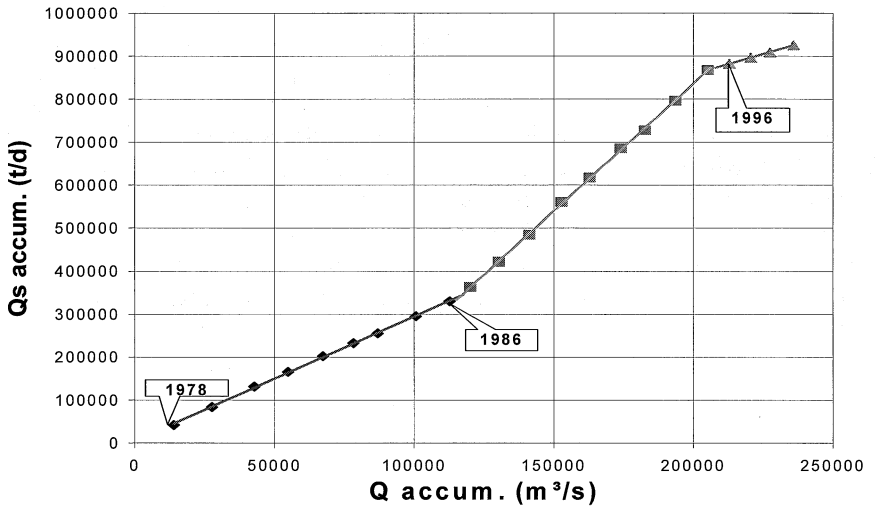$$E_c = (r_1 - r_2) / r_1 \quad \text{and} \quad (1 + R)^n = 1 + E_c \qquad (2)$$

**Fig. 1** Mass curve for the period between 1978–1999 (Tocantins River at Marabá station).

**Table 1** Sediment discharge increase rate at stations on the Araguaia and Tocantins Rivers.

| Code | Station | Period | Sediment yield rate ($R$) per year (%) | Drainage area ($km^2$) |
|------|---------|--------|----------------------------------------|------------------------|
| 2410 0000 | Araguaia River at Cachoeira Grande | 1977–1986 | 2.14 | 4504 |
|  |  | 1982–1989 | 6.77 |  |
|  |  | 1987–1991 | −10.95 |  |
|  |  | 1977–1991 | 1.04 |  |
| 2905 0000 | Tocantins River at Marabá | 1978–1995 | 3.44 | 690 920 |
|  |  | 1996–1999 | 2.85 |  |
| 2910 0000 | Itacaiúnas River at Fazenda Alegria | 1979–1994 | 2.59 | 37 600 |



—— Hypothesis I – – Hypothesis II ------ Hypothesis III – - – Hypothesis IV
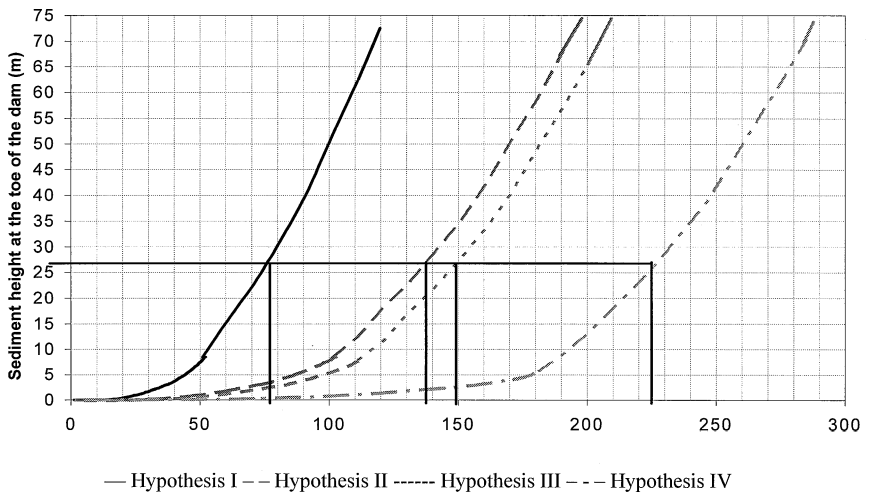
**Fig. 2** Useful life of the plant for the four hypotheses. The horizontal line indicates the elevation of the sill of the water intake (27 m).

The results of the studies made for the three stations are presented in Table 1. The resultant reservoir sedimentation was assessed for four different scenarios—hypothesis I, not considering other reservoirs upstream; hypothesis II, considering the construction of Serra da Mesa dam upstream; hypothesis III, considering the existence of Serra da Mesa and Lajeado dams upstream; and hypothesis IV, considering Serra da Mesa, Lajeado, Santa Isabel and Serra Quebrada dams upstream Tucuruí dam (Fig. 2). From these scenarios it appears that there will be neither short nor medium-term sediment problems in the Tucuruí Reservoir if the sediment yield remains unchanged or presents the same rate through the years. However, it is necessary that sediment studies are made approximately every 10 years. Such studies include sediment discharge sampling, re-evaluation of the phenomena, topographic surveys, study on erosive processes of river banks and downstream from the dam, besides other studies aiming to verify the validation of the scenarios exhibited here.

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