Hydraulics Research
Wallingford

TRAPPING EFFICIENCY OF RESERVOIRS

Contract Completion Report

(Contract PECD 7/6/126 "Reservoir Sedimentation")

Report SR 220
October 1989

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This report describes work funded by the Department of the Environment under contract PECD 7/6/124, Reservoir Sedimentation. It is being carried out in the River Engineering Department.

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ABSTRACT

Because of the change in flow conditions that they create the construction of dams and the resulting reservoirs tend to trap a large proportion of the fluvial sediments that enter the reservoir. Knowledge of the trapping efficiency of reservoirs is important in assessing locations for new reservoirs as well as estimating the active life of existing reservoirs.

A study was carried out using a numerical reservoir sedimentation model to analyse the factors which affect reservoir trapping efficiency. The effect of altering variable which represent the reservoir geometry, flow and sediment conditions were investigated. This report is a brief summary report of the study. the technical details are described in full in HR Report SR 212.

CONTENTS

1 INTRODUCTION

It is the nature of reservoirs to cause a reduction in both the velocity of flow in a river and the water surface slope. This reduces the capacity of the river to transport sediment and encourages the deposition of sediment in the reservoir. The accumulation of sediment reduces the amount of water storage available and hence the utility of the reservoir. In extreme cases effectively all the useful storage may be lost due to sedimentation. The rate at which sediment accumulates has a major impact on the useful life of a reservoir and so is significant in assessing the economics of a proposed reservoir. There is, therefore, the need to be able to assess sedimentation when a reservoir is being planned.

In considering the impact of sedimentation on a storage scheme it is important to know the loss of available storage after a given time period as this directly affects the yield of the reservoir. The distribution of the sediment deposits affects the stage/storage curve and so may have an impact on the operating rules of the reservoir. For the designer, therefore, there is a need to be able to predict both the amount and distribution of sedimentation.

2 IMPACT OF RESERVOIR SEDIMENTATION

Reservoir sedimentation is a major problem world-wide. In 20 large reservoirs in China 7.7 billion cubic metres of sediment have accumulated resulting in a 90% loss of storage in 20 years. In India 21 reservoirs of more than 1,000 million cubic metres capacity are losing storage at a rate of between 0.5 and 1% per year. In the USA 1,200 million tonnes of sediment are deposited in reservoirs annually costing in excess of US $ 100 million.

The adverse effects caused by reservoir sedimentation may include :

(a) a reduction in the storage available and hence a reduction in the yield provided by the reservoir,

(b) degradation downstream of the dam. This may threaten structures associated with the dam and lead to problems at structures further downstream such as bridges and intakes,

(c) deposition at the head of the reservoir leading to an increase in flood levels in the contributing streams upstream,

(d) increased evaporation losses for a given storage volume.

Until recently reservoir sedimentation could only be assessed using simple, empirical methods. To estimate the volume of deposited material the notion of trapping efficiency was introduced. The trapping efficiency of a reservoir is defined as a ratio of the quantity of deposited sediment to the total sediment inflow.

Gottschalk (1948), Churchill (1948) and Brune (1953) provided simple graphical means to determine trapping efficiency and these have been used extensively. Since, however, the trapping efficiency must depend upon the sediment size, the flow through the reservoir, the distribution of flows into the reservoir and the way that the reservoir is operated, it follows that such estimates of trapping efficiency can only provide approximate values which may, on occasions, be seriously in error.

More recently, however, numerical models of sedimentation in reservoirs have been developed and these have provided a means of studying reservoir sedimentation in much greater detail. Unfortunately such models are complicated to use and expensive to apply.

It is common in the initial planning stages of a storage project to consider a number of possible dam locations and heights. It would be impractical to study each possible alternative using a detailed numerical model. What is required is a simple method which will give an approximate estimate of the sedimentation rate but is more accurate than the existing empirical techniques.

3 PRESENT PROJECT

The present project was aimed at using the existing numerical model of reservoir sedimentation to derive a simple method to provide a quick reliable technique for estimating the trapping efficiency of reservoirs so that the rate of sedimentation can be predicted. In the study the numerical reservoir sedimentation model was used to investigate the trapping efficiencies of a number of reservoirs with a range of geometries and characteristics in order to improve the understanding of the factors determining trapping efficiency. This involved changing a number of variables such as reservoir length, width, depth, discharge and determining the corresponding trapping efficiencies. From this information a procedure was developed to determine the instantaneous trapping efficiency of a reservoir. This procedure can then be used to consider the trapping efficiency of a reservoir at a number of different instants during the year so that the average yearly trapping efficiency could be determined. The method was tested on the data from a number of reservoirs in Zimbabwe. The

details of the analysis and procedure are described in HR Report SR 212 (Hydraulics Research, 1989).

The settling characteristics of sediments depends, among the factors, and the size of the sediment particles. In the HR Report SR 212 it is detailed how the settling velocity depends upon sediment diameter. The sediment that is deposited in any reservoir reflects the whole range of sediment sizes that are transported by the river immediately entering the reservoir. Typically the sediments range from fine silts and clays up to sands or gravels depending upon the nature of the river. The coarser sediments are normally found at the head of the reservoir while the finer sediments are transported further into the body of the reservoir. Depending upon the nature of the sediments the procedure can be used for a range of sediment sizes to take full account of the differences in behaviour of the range of sediment sizes.

By utilising this procedure the engineer will be able to quickly estimate the trapping efficiency, and thus active life, of existing reservoirs. The procedure will also be of use when assessing sites for new reservoirs. Using the procedure the trapping efficiencies of reservoirs at different sites can be rapidly assessed. Once a particular site and reservoir has been selected, a numerical reservoir sedimentation model can be used to identify the location of deposition together with subsequent changes in bed level and loss of storage.

4 DISSEMINATION OF RESULTS

It is the intention of Hydraulics Research to produce a paper for a suitable journal which summarises the findings and method described in HR Report SR 212. Using its own funds HR has also incorporated the

method into a simple computer program. It is the intention of HR to market this software in the future to the civil engineering industry.

5 CONCLUSIONS

1) There are a number of empirical approaches to estimating the trapping efficiency of reservoirs but these have not proved particularly accurate in the past.

2) Numerical reservoir sedimentation models exist but are impractical to use at the earliest stages of design when a large number of possible alternatives need to be compared.

3) In this study the results from a numerical reservoir sedimentation for a number of reservoirswith a range of geometries and characteristics have been studied in order to develop a simple, quick method for analysing the trapping efficiency of reservoirs.

4) By utilising this procedure the engineer will be able to quickly estimate the trapping efficiency, and thus active life, of existing reservoirs. The procedure will also be of use when assessing sites for new reservoirs. Using the procedure the trapping efficiencies of reservoirs at different sites can be rapidly assessed. Once a particular site and reservoir has been selected, a numerical reservoir sedimentation model can be used to identify the location of deposition together with subsequent changes in bed level and loss of storage.

5) Using Hydraulics Research own resources the method has been incorporated into a computer program. It is the intention of HR to market this software to

the civil engineering industry and to publish the results of the study as a paper in an appropriate journal.

6 REFERENCES

Brune G M : 1953, Trapping efficiency of reservoirs. Trans AGU. Vol. 34. No 3.

Churchill M A : 1948, Discussion of Gottschalk's paper an Analysis and Use of reservoir sedimentaiton data. Proc. FIASC, USDA (Washington).

Gottschalk L C : 1948, Analysis and use of reservoir sedimentation data. Proc. FIASC, USDA (Washington).

Hydraulics Research, 1989, Trapping efficiency of reservoirs, Hydraulics Research, Report SR 212.

APPENDIX.

APPENDIX 1

Executive Summary of HR Report SR 212

This report describes a study undertaken by Hydraulics Research to investigate the factors which affect the trapping efficiency of reservoirs.

A numerical reservoir sedimentation model is used to investigate the effect of altering variables which represent the reservoir geometry, flow and sediment conditions.

The critical factors in determining reservoir trapping efficiency are the discharge, mean depth, width and shear velocity, and the sediment fall velocity.

The trapping efficiency of a reservoir is dependent on the mean depth to length ratio.

When assessing the trapping efficiency of a reservoir only the active length of the reservoir should be considered.

Two graphical procedures are developed for estimating reservoir trapping efficiency. In the first a backwater calculation is required to give the variation of shear velocity along the reservoir. In the second the active length of the reservoir is estimated from a plot of non-dimensional variables and then the mean shear velocity calculated. In both procedures the trapping efficiency is calculated from a plot giving trapping efficiency as a function of non-dimensional variables.

Both procedures give good agreement with the numerical model results except under extreme conditions such as very shallow reservoir or very high discharge.

When applied to a typical yearly cycle of reservoir inflows the procedures give good agreement with both the numerical model and Brune curves.