A REVIEW ON RESERVOIR SEDIMENTATION STUDIES USING SATELLITE REMOTE SENSING TECHNIQUE

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ABSTRACT

Sedimentation in the reservoir gradually reduces its storage capacity. By keeping a check on the sedimentation and by providing control measures for the same, the reservoir life can be maintained. Ujjani dam was constructed for irrigation, water supply and power generation schemes. It lies in Solapur district which is a drought prone area. This makes Ujjani a socially and economically significant project for the state. In the present study, reservoir sedimentation for Ujjani reservoir is assessed for monitoring purpose. Two techniques namely Satellite Remote Sensing Technique (SRST) and mathematical modeling using HEC RAS, were used in the study for estimating sedimentation. Owing to advantages like low cost, time saving, less manpower requirement, accuracy in estimation and capability of carrying out past surveys, the Satellite Remote Sensing Technique is gaining importance over the time consuming and high cost conventional hydrographic surveys. The water spread areas for different reservoir levels were delineated from the satellite images of Ujjain Reservoir using ARC GIS software. Volume between two water levels was calculated using prismoidul formula. The present volume of reservoir was compared with the initial volume during impoundment of reservoir. This gave the loss of volume which was due to sedimentation.

KEYWORDS: Sedimentation, Ujjain reservoir, Satellite Remote Sensing technique,

INTRODUCTION

Water in streams and lakes is a source of civilization and industrial development. Advancement of technology has enabled us to manage and control the water resources in order to maximize the benefits gained through water. This is done by making dams, barrages and man-made streams. But this type of development also imbalances the different natural systems, eventually disturbing the sediment transport equilibrium which affects the system efficiency, reducing benefits derived from the dam construction. Bed aggradations on upstream of dams are seen as a result of such disturbance.

Sediment particles in the river are in form of sand, silt, gravel and even larger boulders. Water flowing in the river, scours its bed and banks, detaching these sediment panicles from the surface and carries them to the downstream. If a dam is constructed on this river, the velocity of the flowing water is reduced due to obstruction, thereby helping the sediment panicles to settle down in the reservoir formed. This phenomenon is called Reservoir Sedimentation". It results in loss of storage capacity of Reservoir (Bowonder 1985).

This problem can be addressed in planning stage itself by predicting the sedimentation in future. Also, proper management of dam operations can be planned for avoiding sedimentation. Reservoir sedimentation studies are essential for keeping a cheek on siltation over the years after closure of dam. These efforts cannot be achieved unless a detailed case specific sediment transport analysis and reliable future predictions are made. Despite advancement of science and technology, sediment transport being a complex natural phenomenon, still remains a branch of science and engineering fully not explored. Although many theories have been presented to explain the phenomenon, all of them satisfy sediment transport behaviour only under certain conditions to a specific level of accuracy. These theories in form of empirical and semi-empirical expressions, however, are the only scientific and reliable foundations to analyze and study the sediment transport behavior for any particular case. This project will throw light on two soft computing techniques which use few empirical theories to study sedimentation phenomenon. Satellite Remote Sensing Technique is a Remote Sensing application which considers the two dimensional grid of the satellite imagery consisting of reservoir, to find its area. Mathematical Modeling is problem solving using softwares. In this study, mathematical model used is HEC RAS, which solves continuity and momentum equations.

SATELLITE REMOTE SENSING TECHNIQUE

Remote sensing is defined as the measurement of object properties on the earth's surface using data acquired from aircraft and satellites. It is therefore an attempt to measure something at a distance, rather than in situ (Schowengerdt. 2007). Sedimentation assessment is important, but requires lot of data, which is mostly not available. Satellite remote sensing can contribute by providing spatial data to such assessments. Conventional hydrographical surveys are time consuming, laborious, require lot of manpower, weather/ site conditions dependable and expensive. These drawbacks compelled to look for new technologies which can be used as a tool to carry out capacity surveys rapidly, frequently and economically. As physical model studies of these processes associated with river dynamics are also expensive and lime consuming, Remote Sensing can be a good alternative, as it provides many functions and tools which facilitate in the evaluation of problems associated with remote areas on a broader scale. The advantage of satellite data over conventional sampling procedures include repetitive coverage of a given area every three to four days, availability of synoptic view which is unobtainable by conventional methods, and almost instantaneous spatial data over the areas of interest. More accurate data about water spread area of reservoir on a given date could be collected instantaneously which is practically impossible even withih high-tech survey systems. These advantages have led to development of Remote Sensing Technique in study of reservoir sedimentation (Barodiya 2009)

Satellite Remote sensing technique (SRST) uses the phenomenon of Satellite Imageries representing a two dimensional water spread area of the reservoir, which changes through the years due to sedimentation. By comparing the decrease in water spread area with time, the sediment distribution and deposition pattern in a reservoir can be determined. The Reservoir (water body) portion appearing in Satellite Imageries of series of years can be delineated in remote sensing softwares like ARC-GIS (Geographical Information System) to get the reservoir area. This can be converted into volume of reservoir using reservoir water level by means of prismoidal formula. Change in this volume of reservoir over the years gives an estimate of Reservoir Sedimentation.

LITERATURE REVIEW

Following papers were reviewed for the present study. They discuss the methods to be used i.e. SRST and HEC RAS. They discuss about the situations where these methods were used, and how they analyzed a particular problem of sedimentation.

Martin J. Teal, Marc A. Schulte, David T. Williams, and John I. Remus II (2004) presented paper on **Sediment Modeling of Big Bend Reservoir, South Dakota.** Closure of Big Bend Dam in 1963 resulted in changes in the hydraulic regime of the Missouri River and the formation of a delta in the headwaters of Big Bend Reservoir (also known as Lake Sharpe) in South Dakota. The U.S. Army Corps of Engineers, Omaha District commissioned a study of sedimentation in the headwaters of Lake Sharpe as part of operation and maintenance activities associated with the Missouri River mainstream dams and reservoirs. Questions about

the current and future development of the sediment delta in the lake were addressed by developing a calibrated HEC-6T sediment transport model of the Missouri River and Big Bend Reservoir. Cross section geometry was developed using survey data collected by the Corps since dam closure (1968-1997). Sediment inflow from the Bad River, the largest single contributor of sediment to Big Bend Reservoir was developed from data collected by the U.S. Geological Survey (USGS). A sediment budget was developed for the reservoir, taking into account not only Bad River inflows but also minor tributaries and bank erosion. Both cumulative depositional volumes and average bed elevation statistics were used as criteria in the calibration process. The calibrated model was then used to predict river conditions fifty years into the future. This paper focuses on the sediment transport modeling of Lake Sharpe (Big Bend Reservoir) in South Dakota. Hydraulic and sediment transport models were prepared to (1) calibrate a sediment transport model for the period 1968-1997 and (2) use the calibrated mode! to predict bed conditions and water surface profiles for the period 1997-2047. Innovative methods were used during model construction and calibration to develop missing cross sections and estimate inflowing sediment loads from tributaries.
Cumulative sediment volume and average bed elevation comparisons, a calibration of the HEC-61 model was obtained. Because of the differences in calculation methods and problems with the measured cumulative sediment volume data, it is more important to compare trends rather than specific magnitudes of sediment deposition. Sediment deposition was most -affected by the wash load (clay-silt) apportionment of the sediment inflow from the Bad River and tributaries as well as the clay and silt erosional and depositional thresholds.

M.S. Mundhe, V. B. Pandhare, M.B. Nakil, S.S. Pande (2009) presented paper on **Analysis of Remote Sensing based Sedimentation Surveys in Maharashtra.** Remote Sensing application being easy, economical method thus was used for 28 reservoirs for Sedimentation Surveys. The capacity range of reservoirs was found between 27.476-2677 Mm^3. Assumed Sedimentation rate was 3.57-7.15 ha $m/100km^2/yr$ and observed Sedimentation rate was 0.9-38.33 ha $m/100km^2/yr$ i.e. (Actual > Designed). 4 major factors affecting sedimentation rate were listed as Rainfall Quantity, Size of Catchment, Sedimentation Period, and Reach of Reservoir. Methodology which was used comprised of digitalization of images and data, estimation of water spread area, comparison with previous survey and subsequent estimation of live capacity loss. Data was analysed and grouped on basis of :

1) Basin wise data
2) Sedimentation period as effecting factor
3) Rainfall of Reservoir as Governing factor
4) Rench of Reservoir as Governing factor
5) Catchment Area with dense forest

It was observed that young reservoir < 15 yrs. showed higher rates of sedimentation compared to older, rainfall > 2000 mm had higher sedimentation, d/s situated reservoirs with catchment area > 10000 km^2 showed stabilized sedimentation, small catchments < 500 km^2 have sedimentation rates higher than large catchments. Grouping of reservoirs & basin wise approach gave better understanding of sedimentation rates, which can be used for reservoir operation & further designing reservoirs.

Brian G. Wardman, P.E.; Brad R. Hall, P.E.; and Casey M. Kramer (2009) presented on **One-Dimensional Modeling of Sedimentation processes on the Puyallup River.** One-dimensional sediment transport capabilities of HEC-RAS 4.0 were used to quantify sedimentation processes in the lower Puyallup River, WA. The HEC-RAS 4.0 model used in this study was calibrated using USGS measured sediment transport rates and verified by producing the observed deposition of the reach between 2001 and 2007. Results of the model show the bed elevations are expected to increase by as much as 5 feet over the next 50 years. The results provide estimates of future channel geometry, which when input into the HEC-RAS hydraulic model will reveal how flood profiles arc likely to be affected by sediment deposition 50-years in the future.

Pradeep K. Mishra, Zhi-Qiang (2009) presented paper on **Sediment TMDL (Total Maximum Daily Load) development for the Amite River.** Amite River was recognized as one of the 15 water bodies impaired by sediments in Louisiana, USA. Based on US TMDL development is conducted for the Amite River. The TMDL development consists of four components:

1. Development of a new model for cohesive sediment transport
2. Estimation of sediment loads (sources) due to watershed erosion,
3. River flow computation and
4. Determination of sediment TMDL for the Amite River.

Reynolds transport 1-D model was developed for computation of suspended cohesive sediment transport. Sediment erosion in the Amite River is calculated by combining the USLE (Universal Soil Loss Equation) model. The calculated average annual rate of soil erosion in the Amite River Basin is 13.368 tons per ha, producing a nonpoint sediment load of 103 mg/L. The flow computation is performed using the HEC-RAS Software. The computed sediment concentration in the Amite River varies in the range of 3-114 mg/L and sediment TMDL is 281.219 tons/day.

Stanford Gibson, US Army Corps of Engineers, Chris Nygaard and Paul Selafani (2010) presented paper on **Mobile Bed Modeling of the Cowlitz River using HEC-RAS: Assessing Flooding Risk and Impact due to System Sediment.** A one dimensional sediment transport model of the lower 20 miles of the Cowlitz River was developed to calculate long term sediment impacts on flood risk. Mobile boundary capabilities in HEC-RAS 4.2 were used to model sediment dynamics. The model was calibrated to bed change measurements for an observed 5 year timeframe by adjusting the parameters of the transport function selected. Several novel approaches employed to achieve this result and new features were added to HEC-RAS for the analysis.
Longitudinal cumulative deposition displays simulated and measured deposition. Observed and simulated bed changes are summed from the upstream to downstream end of the reach. The plot can be used to evaluated the calibration on the criteria of total deposited mass and the longitudinal trends of the deposition or the "shape" of the curve.

Amor Hamzeh Haghiabi and Ehsan Zaredehdasht (2012) presented paper on **Evaluation of HEC-RAS Ability in Erosion and Sediment Transport Forecasting.** One of the main objectives of river engineering is river training which is defined as controlling and predicting river behaviours. It is taking effective measurements to eliminate any associated threats and consequently improving river system. River training is mainly consisted of the control erosion and sedimentation in a river. In some rivers, the riverbed continues to erode and degrade; thus never reaching to balance. Generally, analysis of geometric characteristics of river and bed erosion is one of the most complicated, yet key topics in river engineering and sediment hydraulics. The advent of new computer technologies has enabled engineers to resolve equations of sediment transports and hydraulic issues via computer simulations and modeling. The selection of proper model and its calibration remained as a difficult, sensitive task to field engineers. The latest version of HEC-RAS model, called HEC-RAS 4.0, is utilized in this paper. The study area was reachable between Mollasani station (upstream) and Farsiat station (Downstream) with a length of 110 km. This reach includes 113 sections all of which were introduced into the model. The results obtained from simulations of river bed, were compared to those model reported in the literature. This paper primarily focused upon identifying critical erodible points and areas with potential sediment aggradation along Karun River.

Kamuju Narasayya, U.C. Roman, S. Sreekanth and Sunneta Jatwa (2012) presented paper on **Assessment of Reservoir Sedimentation using Remote Sensing Satellite Imageries.** The water spread area through the years keep changing due to sedimentation in reservoir which can be assessed using SRST. This paper describes assessment of sedimentation carried out for the Srisailam Reservoir using

Remote Sensing satellite imageries. The area capacity curve of year the 1976, when actual impoundment was started, is used as a base for sedimentation assessment for the year 2004. The results of Remote sensing survey for the period 2001-04 are compared with the deposition pattern of Srisailam Reservoir with the standard types of deposition pattern as per Area Reduction Method suggested by Borland and Miller. Deposition pattern compared with that by Area reduction technique and found that Srisailam Reservoir followed Type-I in 2004. The sediment index computed considering total sediment deposition since 1976 to 2004 was found to be 543.84 T/km^2/year, which is lower than the rates suggested by Garde & Kothyari. The Methodology used, comprises of digitalization of images and data, estimation of water spread area, comparison with previous surveys and subsequent estimation of live capacity loss. AEC curve developed and compared for old and new capacity of reservoir was found. The gross, dead and live storage capacities of Srisailam Reservoir for the year 1976 were 8724.88 Mm^3, 1557.68 Mm^3 and 7167.2 Mm^3 respectively. Storage capacity of 7167.20 Mm^3 was reduced to 5467.54 Mm^3 i.e. by 23.714% in 28 years. Sediment yield worked out to be 543 .84 T/km^2/year which is close to value of 600 to 700 km^2/year found comparable with that estimated by Garde and Kothyari.

SUMMARY

In the reviewed papers it was seen how Remote Sensing was used to study the different parameters of reservoir sedimentation by delineating the water spread areas of satellite images and how it was used to analyze the sedimentation rate by interpreting the governing factors of sedimentation for various reservoirs in a region. The papers also discussed about sediment transport features of HEC RAS, how it was used in determination of Total daily Maximum load, in finding the future geometry, the flood profiles and how it was used in river training by assessing the locations and approximate magnitude of sedimentation and erosion. Similarly in the study. Remote Sensing and HEC RAS will be used to estimate the total present sedimentation in Ujjani reservoir.

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