International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

SEDIMENTATION ANALYSIS OF DAM USING GIS TECHNIQUES

Asst. Prof. Uzma Shaikh[1], Abhishek Sapkal[2], Vishal Kolage[3], Tejas Nandre[4], Ajay Madake[5]

[1]Professor, Dept. of Civil Engineering, Dr. D. Y. Patil School of Engineering, Lohegaon, Pune, India
[2-5]Student (U.G.) Dept. of Civil Engg. Dr. D. Y. Patil School of Engineering, Lohegaon, Pune, India

---

Abstract - *Reservoirs are a vital source of water supply, provide hydroelectric power, support diverse aquatic habitat, and provide flood protection. Sediment deposition has gradually reduced the effectiveness of reservoir operation over the years and decreases in storage capacity. This research presents geographic information systems (GIS) based application for investigating sediment deposits of Khadakwasla Dam. Spatial data were collected from aerial photographs, bathymetric data, and satellite images corresponding to the study area. This research was performed in many stages as survey planning, survey execution and storage, data preparation and pre-processing, spatial data and attributes data creation, database building, and the results presentation and analysis. This method for assessment of reservoir sedimentation uses the fact, that the water spread area of reservoir at various elevations keeps on decreasing due to sedimentation. GIS technique gives us directly the water-spread area of the reservoir at a particular elevation on the date of pass of the satellite. This helps us to estimate sedimentation over a period of time. Traditional methods are inconvenient, expensive and time consuming. Since applying the remote sensing technique has a greater speed and precision compared to traditional methods. The purpose of the present study is to estimate the amount of suspended sediment in the dam basin using the remote sensing facilities and satellite images of powerful sensors in the field of water studies and then comparing the results with sediment data.*

Key Words: Geographical Information System (GIS), Sediment Deposition in dam, ARC-GIS software, Satellite Remote Sensing (SRS)

1. INTRODUCTION

A reservoir will generally be located towards the end of a large watershed and receive inflows from major rivers. On the other hand, reservoirs have a shorter residence time but a much larger watershed which can be more difficult to control. Therefore, capacity surveys are important for proper allocation and management of water in a reservoir. Knowledge about the quantum of sediment and its deposition pattern in various zones of a reservoir is very essential to assess the balance life of reservoir. In view of this, systematic capacity surveys of a reservoir should be conducted periodically. Using the Remote Sensing techniques, it has become very efficient and convenient to quantify the sedimentation in a reservoir and to assess its distribution and deposition pattern. Remote Sensing technology, offering data acquisition over a long period of time and broad spectral range, can provide synoptic, repetitive and timely information regarding the sedimentation characteristics in a reservoir. Reservoir water spread area for a particular elevation can be obtained very accurately from the satellite data. Reduction if any, in the water spread area for a particular elevation indicates deposition of sediment at that level. This when integrated over a range of elevations using multi-date satellite data enables in computing volume of storage lost due to sedimentation.

The flow of river brought sediment particles originate from soil erosion processes in catchment. When this flow of water is stored in reservoir, sediment settles in reservoir which results in the reduction of storage capacity, cover fish spawning grounds, clog drainage canals and passage and reduce downstream water quality. Hence estimation of sediment deposition becomes very important for river morphology, conservation planning of water and soil, design of erosion control structure and proper management and working of reservoirs. Certain Conventional methods such as, hydrographic surveys, inflow and outflow approaches, are used for estimation of reservoir sedimentation. But these methods are inconvenient, expensive and time consuming. So simple methods should be developed, which is less time consuming and economical.

Reservoirs offer many benefits to the communities including flood control, water supply, fish, and hydropower. Determining the impacts of sediment on the reservoir operations is critical to maintaining current operations and planning for future needs. Sedimentation within the reservoirs is the main problem that could reduce the reservoir capacity and therefore affecting its economic life. Proper management of the reservoir requires that current reservoir volumes and sedimentation rates be determined. Current trend towards a more efficient management of reservoir is using the application of Geographical Information System (GIS). The geographic information system (GIS) is used for importing, analysing, modelling, visualizing, and reporting information for the reservoir and gives functionalities of spatial data management, mapping and analysis to assist decision- making.

1.1 Area of Study

Pune is the ninth popular city in India and the second largest in the state of Maharashtra after the state capital Mumbai. The district covered geographical area is 16642sq.km. It is located in the west part of the State and East bank of the Mutha River. Khadakwasla is the village

situated near to Khadakwasla dam. It is the main source of water for Pune and its suburbs. Total capacity of dam is 374 million cubic metre. The height of dam is 31.79 m. It lies between latitude 18.750 N and longitude 73.440 E. The climate is tropical in Khadakwasla. The summers are much rainier than the winters in Khadakwasla. The average annual temperature in Khadakwasla is 24.7⁰ C. The average annual precipitation is 1083 mm. Now-a-Days, Pune city has been become an auto web, host to IT and Automotive companies, large Industrial region and highly ranked an Educational Institutes. Migration of people is too large for various purposes in Pune city. Therefore, city requires all facilities with their population demand including water. Due to high demand, there is water scarcity in Pune city, so it is need to recharge a surface below the ground thus, by increasing the storage capacity of reservoir.

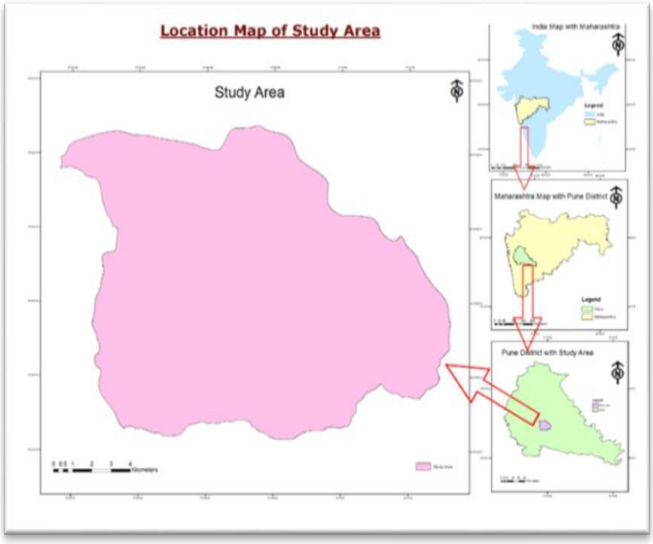

Fig -1: Location of Study Area – Khadakwasla Dam

2. LITERATURE REVIEW

Reservoir is the very important and valuable hydraulic structure for storage of water so that this resource can be used for vast area of society and different aspects. And the capacity of reservoir is continuously reducing due to entering of eroded soil carried by water, wind, ice and movement of particles due to gravity force. A huge quantity of sediment is deposited annually by Indian rivers in lakes, reservoirs, estuaries, bays and oceans. Loss of storage capacity due to reservoir sedimentation affects both obtains ability of water and operation schedules.

The study concluded that there is a possibility that the satellite images are prepared in different climatic conditions and different days of the year, given that the land has its own conditions in various conditions, different reflectance is reflected from the land. As a result, there is a possibility of change in the average reflectance of Landsat bands. So different situation should be considered; in this thesis the 10 and 15% of applied coefficients for sensitivity analysis are applied on the average value of the Landsat reflectance band and then analyze the changes that had occurred in sediment values. The analysis of sensitivity analysis by applying the coefficient of 10 and 15% of increase and decrease in the average reflectance of Landsat band 7. [1]

Research study gives and confirmed Geographical Information System (GIS) based technique for the determination of sediment source areas and the estimation of sediment yield from catchments. The Integrated Land and Water Information System (ILWIS) GIS package and Earth Resources Data Analysis System (ERDAS) Imagine image processor has used for geographic analyses and the digital analysis of satellite data for deriving the land cover and characteristics of the catchments soil. Using this study to determine soil erosion and sediment yield in a reservoir watershed using GIS technique. The spatial disaggregation of catchment area into uniform cells is done to get the sedimentation by using USLE along with determination of sediment delivery ratio and various parameters. The effect of DEM resolution on sediment yield is analyzed using two different resolutions of DEM. [2]

After analyzation, the data from Liss III images and google earth images from 1990 to 2020 has been carried out using GIS technology, Superimposition of the bank lines on these images have indicated that river is migrating within and adjacent flood plain in the study area. In the central part of the river more erosion has been observed. In this part, erosion is mainly confined in the northern side and deposition in the southern side that is on right and left bank. More erosion and less deposition indicate that sediments flow in the river from upstream to downstream is being checked in the reservoir of successive dams constructed in the catchment area. Probably it is due to checking of the sediments by the dams located in the upstream. Erosion is more pronounced on both banks than the sedimentation. A large part of agricultural land as well as plantation and rural settlements are affected by erosion every year. [3]

While working on catchment area, gives a method for estimation of sedimentation yield from catchment area by using GIS method. In this method, they uses spatial Disaggregate of the catchment into cells having monotonous soil erosion properties. The erosion from surface of each discretized cells is routed to the catchment outlet using the help of sediment delivery ratio, which is defined as a ratio of sediment yield to total surface erosion. The total sediment yield of catchment is a sum of individual sediment given by each cell. The spatial disintegration of catchment and essential properties of erosion from each cell is computed by GIS technique by using the Integrated Land and Water Information Systems (ILWIS) package. [4]

Research on a GIS based model, Soil and Water Assessment Tool (SWAT) which is used to determine sediment transport from the 17 sq.km watershed located. This has property of mixed land use and on on-stream sediment control structures called check dam. By simply comparing observed data and measured data, a calibration (1996) and validation (1997-2001) of surface runoff and sediment yield is performed with SWAT model on both a daily and monthly basis. Calibration and validation of the SWAT model is performed with and

without check dams to test its ability in visualizing the impacts of sediment control structures in the watershed. The model shows that loss of sediment from the watershed could be decreased more than 64% by acquiring check dams as a barrier for sediment. [5]

This techniques can be used to model bathymetry and the spatial distribution of sediments. The use of Remote Sensing technique to estimate suspended sediment has been reported by several investigators determined siltation in the dam reservoir by comparing reflectance values in the green and red portions of the spectrum. Research findings indicate that siltation during the flood period was largely confined to the main river channel of the reservoir and large embankments. Areas of extensive siltation were identified and the amounts of deposition were determined through ground surveys. This information was used to predict the distribution of silt deposits in the reservoir. It uses a visual interpretation technique on large scale imagery of Landsat-MSS to estimate the water-spread area at different levels to evaluate the capacity of the reservoir and concluded that the results are comparable with hydrographic survey observations and similar to the curves obtained from the conventional methods. A digital technique in which density slicing of Landsat-MSS Near-infrared (NIR) data was performed for extracting the water-spread area and correlated computed reservoir capacity based on the surface area obtained using cone formulae. [6]

The sedimentation survey for the high dam reservoir to determine the amount and distribution of sediment deposition through the reservoir. Since year, 1973 the bathymetric surveys were conducted for only few known cross sections because of the reservoir size to investigate the reservoir sedimentation progress by using the traditional survey method. However, from year, 1999, it was proposed an alternate method of mapping the reservoir bottoms by using a hydro acoustics system with a Differential Global Positioning System (DGPS) and Echo sounder to collect depth measurements and locations. The new technology provides the bathymetry data in suitable format that can be used to create digital maps. The work focuses on the using of geographic information system (GIS) technique to perform the analysis and process the bathymetric data to produce sedimentation maps for the bottom of the reservoir in different years. In addition, it was discussed the benefits of using GIS approach over the traditional methods for determination of the sedimentation locations and thickness of it, in the reservoir. [7]

3. METHODOLOGY

At the first use of ENVI for atmospheric and geometric correction. Removing the influence of the atmosphere is a critical pre-processing step in analyzing images of surface reflectance. Properties such as the amount of water vapor, distribution of aerosols, and scene visibility must be known. Because direct measurements of these atmospheric properties are rarely available, they must be inferred from the image pixels. Hyper spectral images in particular provide enough spectral information within a pixel to independently measure atmospheric water vapors absorption bands. Atmospheric properties are then used to constrain highly accurate models of atmospheric radiation transfer to produce an estimate of the true surface reflectance.

A GIS represents both features and surfaces. Features are geographic objects with well-defined shapes (such as political boundaries). Surfaces are geographic phenomena with values at every point across their extent. Elevation is a common example, but surfaces can also represent temperature, chemical concentrations, and many other things.

Surfaces are usually modeled with raster datasets. A raster is a matrix of cells, also called pixels, organized in rows and columns and covering some part of the world (or even the whole world). Each cell in the matrix represents a square unit of area and contains a numeric value that is a measurement or estimate for that location. Before continuing GIS for pixel values in this step we can use digital elevation.

Satellite images include pixels or the components of image that in this pixel the reflectance values are recorded. In this study, using ARCGIS Software we calculated the reflectance values in each Landsat band and number of repetitions. Then the mean of the reflectance values for each band were calculated in the basin.

The calculation of sediment based on the samples measured at the hydrometric stations. Due to the lack of accurate statistics of the erosion and deposition of sediment at the watershed in most cases the sediment measurement curve prepared by discharge and sediment concentration data or sediment discharge are used. At the hydrometric stations sampling suspended sediment concentration is performed at the base discharges or in low flood discharges. However, the variability of flow and sediment relationships in flood discharges is much higher due to changes in rainfall and catchment (soil moisture, presence of sediment and subcortical water content) and thus, the efficiency of rating curve depends on the accuracy of the obtained data.

Considering the different reservoir levels between dead storage level (D.S.L) and Full storage level (F.S.L) on various dates in between 2013 to 2020 for covering full range of live storage of reservoir. The original elevation-area capacity curve/table and the reservoir level of year 2014 to 2020 have also been used in the analysis.

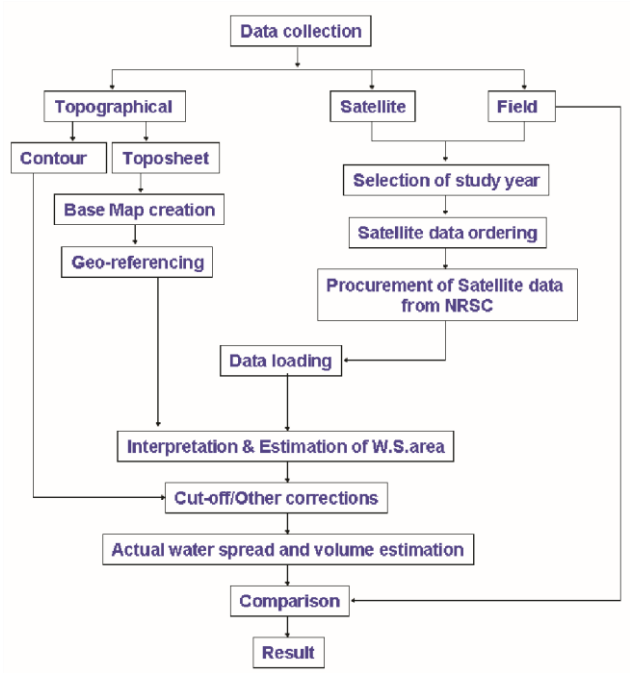

Chart -1: Methodology flow chart

3.1 Procedure for Sedimentation Analysis

1). For analysis of sedimentation in water of a region required data is collected by year wise such as contour maps & rainfall from Department of Meteorological Department, groundwater levels in during monsoon, pre monsoon and post monsoon from Ground Survey and Development Agency.

2). Annually rainfall data for the period of some years has collected from Meteorological Department. Many rainfall stations take into consideration for analyzing annual rainfall pattern and seasonal rainfall pattern has been calculated. The collected data has processed and analyzed by preparing various graphs, maps and figures using GIS software.

3). For assessment of sediments some thematic maps are created by using following:

- Digitization of scanned toposheets
- Editing for elimination of errors
- Topology Building

Above three steps are involved in ArcGIS which are basic operations required for mapping.

4). ArcGIS software has been used for digitization, editing, and topology creation. Integration of multi-thematic information and delineation of groundwater prospect map created through GIS processing. The groundwater prospect map is created through this technique has been verified with field data. Thus, sedimentation map is prepared.

5). Various favorable sedimentation thematic maps have been integrated into a single groundwater prospect zone with the application of GIS techniques. This required four steps, which are as follow:

- Spatial database building
- Spatial database analysis
- Data integration through GIS
- Generation of groundwater potential zones map

The require data is collected from different department as per their requirements. From IMD (Indian Meteorological Department) rainfall data is collected, Ground levels are collected from GSDA (Ground Survey and Development Agency).

3.2 Analysis

Thematic map will be created by using ArcGIS. The main aim of maps is to shows the location of a place and distribution of variables. Some maps are prepared with special themes. Such maps are called thematic maps. Through such maps, distribution of various variables in a region is shown below. Distribution of sedimentation, soil, slope, land cover and water depth is shown on the map according to the data of these variables.

GIS Data Gridding: Gridded depths were used in all analysis and presentation for the research. The gridded data were chosen because the GIS process used to identify change from each subsequent survey required gridded data. ArcGIS software was used to create the difference grids for the bathymetric survey of the reservoir. Difference grids were created using the Raster Calculator function in software. Grid extent, cell size and the horizontal position of the grid nodes were consistent between surveys to ensure accuracy in the output grids. The values of the difference grid nodes were created by subtracting the grid of 1999 data from the grid of 2001, and 2019 data.

Sediment Deposition Mapping: The sediment deposition maps from the different surveys years 1999, 2001, and 2019 covering the same geographic area were produced and compared to identify changes in the reservoir bed elevations and illustrate the sediment deposition in the reservoir. The presentation of this analysis was images color coded by the amount of change. Areas of sediment deposition & areas of no overlapping data or erosion are indicated with different colors for the significance change. It is detected that more than 80 percent of the deposition thickness was more than 2.50 meters. The larger changes from year 1999 to year 2019 occurred in the wider entrance of the reservoir. These maps were generated volumes are based on a more accurate method that uses data for the entire reservoir and not just data from along a few cross sections. The accuracy of these maps may be affected by the density of the data coverage. Ideally, data should be collected in a grid pattern dense enough to allow the maps to identify all of the bottom features. The results from the analysis of these maps are being used to track sediment migration pattern with high resolution than can be modeled.

4. RESULTS AND DISCUSSIONS

Analysis of data from satellite images and google earth images from 1990 to 2020 has been carried out using GIS technology, Superimposition of the bank lines on these images have indicated that river is migrating within and adjacent flood plain in the study area. In the central part of the river more erosion has been observed. In this part, erosion is mainly confined in the northern side and deposition in the southern side that is on right and left bank, respectively. Since there is a possibility that the satellite images are prepared in different climatic conditions and different days of the year, given that the land has its own conditions in various conditions, different reflectance is reflected from the land. As a result, there is a possibility of change in the average reflectance of bands received by sensor. So different situation should be considered; in this thesis the 10% and 15% of applied coefficients for sensitivity analysis are applied on the average value of the reflectance band and then analyze the changes that had occurred in sediment values.

5. CONCLUSION

This study indicated that the combination of hydro acoustics, GPS, and GIS are capable of producing bed elevations maps comparable in accuracy and quality to traditional surveying method. A key difference between the traditional and GIS analysis approaches is that the GIS approach calculates sediment volumes over the entire reservoir area by comparing digital surfaces, whereas the traditional approach applies an average area method to calculate volumes based on a limited number of cross sections. A future benefit of the GIS analysis approach will be the ability to view time perspective of sediment change and support automated sedimentation analysis. However, certain issues and problems were recognized during this study.

6. REFERENCES

[1] Kasra Hossein Mostofi et al. "River Sediment Monitoring using Remote Sensing and GIS" (2019), By Civil Engineering Department, University of Aveiro, ISSN (e): 2250-3021, ISSN (p): 2278-8719, Vol. 09||S (I) || PP 23-30.

[2] R. K. Jaiswal "Assessment of Reservoir Sedimentation in Chhattisgarh State using Remote Sensing and GIS" (2017), By National Institute of Hydrology, Bhopal, pp. 526–534 Article ID: IJCIET_08_04_059 ISSN Print: 0976-6308 and ISSN Online: 0976-6316.

[3] Rahul Panchal et al "Change Analysis of Bank Line Migration, Erosion and Sedimentation Patterns at lower reaches of Mahi River, Gujarat using Remote Sensing And GIS" (2017), By Department of Civil Engineering, L.D. College of Engineering, Ahmedabad, India, Volume 4, Issue 5 e-ISSN (O): 2348-4470 p-ISSN (P): 2348-6406.

[4] Deependra Dadoria, H. L. Tiwari "Assessment of Sedimentation by GIS" (2016), By International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869 (O) 2454-4698 (P), Volume-5, Issue-3, July 2016.

[5] C. Todosi et al "Reservoir Sedimentation Analysis using GIS Techniques in the Bahluiet Catchment in the Perspective of Sustainable Agricultural Development" (2016), By Department, Geography and Geology Faculty, 'Alexandru Ioan Cuza' University of Iasi, 20A Carol I Street, 700 505 Iasi, Romania, Journal of Environmental Protection and Ecology 17, No 3, 1095–1104 (2016).

[6] Kamuju Narasayya et al "Assessment of Reservoir Sedimentation using Remote Sensing Satellite Imageries, A Geographical Information System (GIS)" (2012), By Central Water and Power Research Station, P.O. Khadakwasla, Pune.

[7] Dr. Hossam El-Sersawy "Sediment Deposition Mapping in Reservoir Using Geographic Information System (GIS)" (2003), By Researcher, Nile Research Institute (NRI), National Water Research Center (NWRC),P.O. Box 13621, Egypt.