

## Reservoir Sedimentation and Concerns of Stakeholders

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### Abstract

Water resource' across the world is becoming scarce element due to rising population and poor water management. The world population already crossed 700 crores and the global water deficit to an extent of 40 percent is forecast by the year 2030. For India, a deficit of 50 percent is forecast by the year 2030, with a projected annual water demand of 1500 cubic kilo- meters and water availability of 744 cubic kilo- meters. India's greatest challenge is to set in place an efficient system of river basin/ reservoir management to conserve every drop of water for useful means of mankind to meet the present and future requirements. The reservoirs which are most dependable source of storage for extraction of water depending on the priority requirements, are facing the problem of 'sedimentation' due to which they are losing their storage capacities gradually. According to a survey during the year 2012 across 122 reservoirs in India, 0.44% of reservoir storage is being replaced annually with sediment deposit. Sediment tends to accumulate at all levels(Dead and live storage) within the reservoir, with the specific accumulation pattern varying from one site to other. A wide range of sediment related problems include storage loss, delta deposition, environmental pollution, earthquake hazards etc., are to be tackled with different sediment management techniques. For sustainable development of water resources, the major stakeholders including reservoir owners, beneficiary farmers, domestic/ industrial consumers, agencies connected to tourism/ fisheries and research organizations etc., shall come together and formulate solutions to the problem of sedimentation. Various consequences due to sediment trapping and the related impact on the environment have been discussed in the present study with conclusions for sustainable long- term utilization of Reservoirs.

**Keywords:** River basin/ reservoir management, sediment deposit, storage loss, delta deposition, sediment trapping.

### Introduction

'Water resource' is becoming scarce element due to rising population and poor water management. The world population already crossed 700 crores and the global deficit in water to an extent of 40 percent is forecast by the year 2030. For India, the annual water demand is expected to increase to almost 1500 cubic kilo- meters by the year 2030, against a projected availability of 744 cubic kilo- meters, a deficit of 50 percent. Sedimentation of reservoirs is a matter of concern to all the water managers who should draft various means to make the reservoir storages useful to fight the possible deficit of water resources in the world.

### River and Reservoir Sedimentation

In India there are 12 Major river basins supported by 46 medium and innumerable minor rivers which are contributing for the distribution of surface water for different purposes besides creation of ground water potential. The major problem every river basin is facing is the urban encroachment, sedimentation, pollution etc., which necessitate suitable techniques to preserve the river basins for present and future needs. River sedimentation will change the morphological

processes while reservoir sedimentation encroaches on the useful storage.



**Figure-1**  
**Roxburgh Dam, New Zealand, Lifespan limited by sedimentation**

Sedimentation also affects the manmade water courses. Robert G. Kennedy (1895) after a close study of Sind river (Upper bar)

Doab Canal system) in Northern India showed how to design a channel in alluvium to flow with a non-silting and non-scouring velocity so that the regime is established. Subsequently Gerald Lacey through field studies and experiments along the canal systems of Ganga gave us solutions to design a channel using silt factor<sup>1</sup>.

### Effect of Sedimentation on Reservoir Storage

Sediment accumulation makes storage reservoirs the key non-sustainable component of modern water supply systems. Reservoir capacity is expressed in million cubic meters (Mm<sup>3</sup>) or relative to mean annual flow. From the stand point of sediment management the relative size, termed as hydrologic size or capacity inflow (C: I) ratio is more important than absolute size of the reservoir and is computed as the ratio of total reservoir capacity to mean annual inflow.

The reservoirs are facing the problem of 'sedimentation' due to which they are losing their storage capacities gradually. According to a survey during the year 2012 across 122 reservoirs in India, 0.44% of reservoir storage is being covered with deposition of sediment every year. In case of Srisaillam reservoir in Andhra Pradesh which was commissioned in 1976, the storage capacity is now reduced to about 79.5% of its original storage in a span of 35 years. Similarly the capacity in Nagarjuna sagar is reduced to about 80.5% of its designed capacity. The project 'Nizamsagar' in Telangana region of Andhra Pradesh has lost about 60% of its live storage even within 50 years of its existence<sup>2</sup>.

Hydrologic size is a primary factor influencing the rate of sediment accumulation (Brune, 1953) and is also a primary determinant of types of sediment management techniques that can be used. Hydrologically small reservoirs have short residence time and typically spill a significant part of the stream flow downstream during floods. They can be manipulated by encouraging release of sediments together with that part of annual discharge that is spilled. A reservoir having capacity inflow ratio exceeding 50% may be considered hydrologically large and may have significant year to year carryover storage capacity. Having a large capacity relative to runoff, these reservoirs spill little water and there is limited opportunity to periodically draw down or empty these larger reservoirs for sediment management because the associated water loss would be unacceptable<sup>3</sup>.

Reservoir pool geometry has a major influence on hydraulic behavior and the pattern of sediment transport within the impoundment. Relatively shallow reservoirs may attract less sediment deposit rather than deep reservoirs. For any reservoir, the crest elevation of un gated spillway (or) the design normal water level against the crest gate is the full reservoir level (FRL) and the higher design level during floods is termed as maximum water level (MWL). The minimum operating level is determined from requirements of particular intake design and is the

minimum at which the lowest level intake can be operated. The total storage volume created upstream of dam may be derived in to several zones as illustrated in Figure below. The dead storage is the volume that is below the lowest outlet level which cannot be drained by gravity. Active or conservation storage is the volume that can be manipulated for beneficial use, but excluding flood storage.

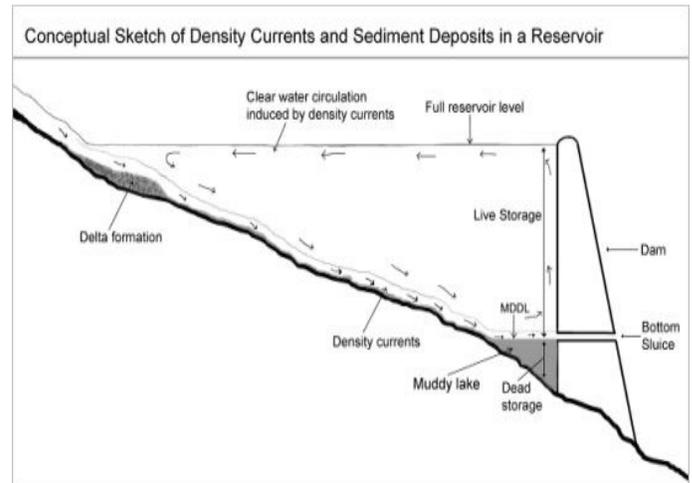


Figure-2  
Zones of storage and sediment deposit in a reservoir

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Reservoir storage characteristics are quantified using stage-storage and stage- area graphs. The accumulation of sediment displaces volume within the reservoir, causing both the storage and area curves to shift. Sediment tends to accumulate at all level within the reservoir, with the specific accumulation pattern varying from one site to other<sup>4</sup>.

### Reservoir Operation-Guidelines

A small municipal water supply reservoir will normally remain at a high level, except during drought when it will drop to low levels. A small irrigation reservoir may deliver all stored water

to farmers on an annual basis as may be emptied at the end of each irrigation season. Large reservoirs having carryover storage are characterized by water levels that gradually fluctuate over a wide range in response to series of wet and dry years. In recreation reservoirs it is normally desirable to have a continuously high and stable pool level, although some water manipulation may be desirable for control of aquatic vegetation, enhancement of fisheries etc.,. Operation for hydropower production seeks to balance two conflicting objectives. To maximize energy yield per unit of water, the pool should be maintained at the highest possible level, yet the pool elevation should be low enough to capture all inflowing flood runoff for energy generation. The resultant operation represents a compromise between high head and storage requirements and will often result in significant seasonal water level variations as water captured during the flood season is released to generate power during periods of low water inflow<sup>5</sup>

Construction of dams across rivers for water storage are creating hurdles for free transport of sediment which is a constituent of river water. However rivers carry less quantity of sediment and take much more time to fill a reservoir. The accumulated sediment can normally be ignored at the time of designing a project. Extracting of water from a reservoir is much easier but removal of sediment is becoming difficult under normal operating conditions of a reservoir.

### Sediment Related Problems

Most of the sediment related problems due to filling of reservoirs with sediment are relatively confined to the upstream side of the dams. They are listed as under.

**Loss of storage:** Storage in the reservoirs will be reduced or gradually eliminated due to deposition of sediment within the reservoir pool geometry. Thus reservoir become defunct without completing it's designed reservoir life.

**Over flowing dam at risk:** The flood storage is lost due to accumulation of sediment and the reservoir spillway which is designed for a specific flood storage may become unsafe.

**Delta deposition:** With the deposition of coarser portion of sediment from the rivers entering reservoirs, delta deposits are formed which deplete the reservoir storage and also cause channel aggradation extending many kilometers beyond reservoir pool in the upstream.

**Channel aggradation:** Common problems because of sediment transport in the channel include water logging in agricultural lands and infrastructure areas along the channel of flood plains, abnormal increase in levels of ground water, soil salinity, reduction in normal clearance below bridges effecting navigation and sediment accumulation across upstream intake structures etc.,

**Navigation:** The sediment accumulation may interfere in to the normal waterway of channel and adversely effect the navigation facilities.

**Earthquake hazard:** The sediment deposits having bigger mass density may increase the risk of additional loads on the dam that influences the earthquake forces on the structure.

**Abrasion:** Presence of sediment coarser than 0.10 mm may damage the hydropower facilities including turbine runners and wheel nozzles resulted in reduction in power generation. Sediment accumulation also blocks the intakes and low level outlets of dam head works, making them ineffective.

**Shoreline erosion:** Reservoirs may fill with land slides and debris along the shoreline and shoreline erosion may create problem of maintenance of designed reservoir capacity.

**Ecological problem:** Accumulation of sediment within the pool of reservoir adversely changes the ecology and effects the species and fish.

**Downstream consequences:** Alteration of hydro period and nutrient dynamics, reduction of sediment load, temperature changes etc., are the consequences due to flow reduction on downstream of a reservoir and creates environmental issues. Trapping of sediment by the dam also has important engineering consequences on the downstream like scouring of stream bed on account of clear water in the river channel, increase in bank height and bank erosion due to channel degradation, increase in scour depth downstream of bridges etc.,

### Sediment Management

Protection of river basins is possible by preserving the precipitation optimally without draining so that it could be percolated for recharging of ground water resource. Modern farming techniques with participatory<sup>5</sup> management of farmers is required for optimized use of water resources. Country's economic growth is possible with effective conservation of rain water.

To achieve long term benefits sediment reservoirs need to be converted as sustainable reservoirs for which adequate changes are to be initiated in the design and operation of every reservoir. Concept of reservoir life limited by sedimentation needs replacement by concept of better management of water and sediment to sustain reservoir function. Certain sediment control strategies as detailed below may be applied to achieve the goal of sustainability. i. Inflow of sediment in to the reservoir can be minimized by adopting erosion control and upstream sediment trapping techniques within the catchment. ii. Inflowing sediment either completely or partly can be routed hydraulically beyond the reservoir storage pool with techniques like drawdown operations during sediment laded floods, construction of off stream reservoirs, sediment bypass and venting of turbid density currents etc., iii. Periodical removal of deposited sediment with

techniques like dredging or excavation during dry period of the reservoir, hydraulic flushing through scour vents etc., iv. Reservoir benefits may be considered sustainable if a storage volume is provided that exceeds the volume of expected sediment supply in the turbidity watershed. The sediment storage volume may be included within the reservoir pool or in one or more upstream impoundments. v. Deposition of sediment may be in areas where its subsequent removal is facilitated or where it minimizes interference with reservoir operations.

The concept of sustainable sediment management with conversion of present sediment reservoirs into resources that will benefit future generations. The basic principle is to alleviate reservoir sedimentation by slicing density current and hyper concentrated density current and storing clear water and flushing turbid water.

## Conclusion

Greatest challenge before dam builders is to set in place an efficient system of Sediment management to conserve every drop of water for useful means of mankind to meet the present and future requirements. For a reservoir planned, certain life is assumed (say 100 years) and its capacity is designed so as to meet the storage needs of the stakeholders duly giving suitable allowance for the loss of capacity due to sedimentation. However we are failing to take adequate steps to control the encroachment of excess sediment due to the least importance being given by the stakeholders to implement different sediment management techniques. We should take precautionary measures from reservoir planning stage itself, by adopting the following measures for sustainable development of reservoirs.

**Project planning stage:** Assess the correct rate of sediment. Predict how and where the sediment to be deposited. Assess the period of time when the sediment will interfere with the useful functions of the reservoir.

**Project design stage:** Adopt designs which conserve resources, minimize environmental effects and not impact natural preserves. Make provision for reservoir sedimentation measures in the project cost and simultaneously implement along with the project construction.

**Infrastructure function:** Design and operate essential infrastructure for the delivery of services for continuous period

(or) provide for its eventual replacement with improved infrastructure at the end of its economic service life.

**Anticipation of change:** Collection of data continuously and analyze trends to anticipate change. Revise strategic plans regularly and up date design and operations to reflect better data, new technologies and evolving needs.

**Project operation stage:** Monitor reservoir- elevation- area-capacity and sedimentation status to assess the adequacy or otherwise of the sedimentation design standards adopted and implement corrective measures for extending useful life of the reservoir.

**Sustainability goals:** Integrated watershed management approach with active participation of all beneficiaries should be emphasized in the catchments of reservoirs for control of sedimentation on a sustainable basis to achieve the goals.

For sustainable development of water resources, the major stakeholders including Reservoir owners who are responsible for carving the projects, beneficiary farmers who are getting water for Irrigation, domestic/ industrial consumers benefitting from the project through water and hydro power , agencies connected to tourism/ fisheries and research organizations etc., shall come together and formulate solutions to the problem of sedimentation. Engineers associated with water resources should take a lead role in appraising all the stakeholders on the importance of implementing different sediment management techniques to tackle the future global water deficit.

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