CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

India abounds in water bodies, a preponderance of them manmade, typical of the tropics and such (artificial) water bodies are generally called Reservoirs, Ponds and Tanks (Reddy & Char 2004), depending on the place of interception in the watershed, its size and operation. A recent population projection for India (Jain 2011) indicates that water resources are one of the main components of the infrastructure sector which will be facing increasing stress on account of growing population because the demand for water for various uses largely depends on the size of the population. In the computations of water requirement for such uses, now it is implicitly assumed that water of desirable quality is available, but a review of water quality status of natural resources of India (CPCB, 2013) shows that this may not be a valid assumption. This report further states that "monitoring results obtained during 2011 (all types of water bodies) indicate that organic pollution continues to be the predominant (source of) pollution of aquatic resources measured in terms of bio-chemical oxygen demand (BOD) and Coliform bacterial count".

Research done elsewhere (Whitehead et al 2009) indicates future impacts of climate change on surface water quality is in the anvil. For example, in what ways more intense rainfall events going to affect nutrients and sediments load in to drainage systems, rivers, and lakes?; how will
climate change impact river flows, hence, the flushing of diffuse pollutants or dilution of point effluents?, which are relevant issues for future. In the half century of social and industrial development in India, the human settlements and agricultural practices are the chief factors responsible for the degradation of lakes / reservoirs (Reddy & Char 2004, Jain 2011, and CPCB 2013). The anthropogenic pressures in the catchment areas of the watershed has enhanced soil erosion and increased silt flows, which have vitiated the storage in the lakes / reservoirs immensely and its quality. In this context, the growing need for the water of required quality will be the challenges facing freshwater resources (WRSD 2014), especially the large reservoir storage created in India. Meeting the future projections of population growth, economic development and future water demands clearly means that the role of large reservoirs in meeting the demand for water supply is going to be more critical (Mukerjee et al 2008).

In this review, therefore, recent research relating to the study of reservoirs, sedimentation and their causative agents - the watershed processes and catchment characteristics responsible for water quality are presented to focus scope of the study, define the context of the research work and methodology to be undertaken.

2.2 RESERVOIR SEDIMENTATION

Sediment transport from the watershed especially from agricultural lands into rivers and reservoirs has become a major problem all over the world including India (Asthana 2007). Methods available for estimating sedimentation vary from subtraction of measured surfaces with original reservoir bottom profile to direct measurement of sediment volumes. Methods used to assess sedimentation and its impacts on the quantity and quality of water remain variable and different methodologies have been applied worldwide: United States (Ortt et al 2000, Odhiambo & Boss 2004, Snyder et

The use of multi frequency echo sounders, GPS and GIS has been proved to be an innovative and accurate recent method by many researchers (Odhiambo & Boss 2004, Goel et al 2002, Jain et al 2002) compared to conventional methods that require more onsite survey and data collection. For instance, Odhiambo and Boss (2004) conducted bathymetry and sedimentation survey using dual frequency echo sounder and GPS in two reservoirs namely Lee Creek Reservoir and Lake Shepherd Springs in north western Arkansas. Results for the projected lifetime of these two reservoirs were 500 years and 3000 years for Lee Creek Reservoir and Lake Shepherd Springs respectively. Estimated differences in projected lifetimes of these reservoirs reflected differences in initial reservoir volume and long term average annual sediment flux from the respective watersheds related to watershed area, physiography, land cover, and land use. Further, computing capacity loss and sediment volumes require comparison with previous surveys and such data may either not be always available or may not be of required accuracy. Such limitations are not present in some of the new methods and require less field work and data.

Loss of capacity of reservoir due to sedimentation has a significant impact on the water availability. A study conducted in Brazil by de Ara_ujo et al (2006) assessed the impact of reservoir siltation on water availability through stochastic modelling and now with the availability of open source
data, Alcantara et al (2010) proposed a fast and inexpensive method for estimating the bathymetry of hydroelectric reservoirs in Brazil integrating historical and Shuttle Radar Topography Mission (SRTM) data for the estimation of the bathymetry of the Itumbiara reservoir with high accuracy ($R^2 = 0.98$). For researchers who need a rapid and simple method to develop bathymetric maps of hydroelectric reservoirs, the proposed method can provide a fast alternative compared to more field data intensive methods. However, the spatial resolution of Shuttle Radar data may become a limitation in small and medium size reservoirs and may reduce the accuracy of volume estimates.

In India, systematic sedimentation surveys of reservoirs started only in 1958 when the Central Board of Irrigation and Power surveyed 28 reservoirs (Kothyari 1996). During this early period, the most common technique (hydrographic survey) adopted was direct in-situ measurement of reservoir bed profile. Later, many reservoirs were surveyed using an echo sounder along the predetermined range lines. These conventional techniques are time consuming and labour intensive. Recently, several researchers have attempted to map the bathymetry of reservoirs using remote sensing data (Goel et al 2002, Jain et al 2002, Alcantara et al 2010). The water-spread area can be determined at different reservoir levels and a revised elevation-capacity curve can be prepared. By comparing the original and revised elevation-capacity curves, the amount of capacity lost to sedimentation can be assessed. With the availability of high-resolution satellite data, capacity surveys of reservoirs by remote sensing technique are gaining recognition and acceptance. Clearly, an analysis of the data of a year that has maximum variation in the reservoir water level will be most useful. But to determine the capacity through remote sensing techniques, temporal satellite imageries can be used to extract the water spread area at different water levels and the reservoir capacities between the elevations of two consecutive water levels.
computed using prismoidal equation. The volume estimates of these studies may be reasonable for large reservoirs, however these techniques can not totally replace ground based observation methods at present.

2.3 SEDIMENT QUALITY

When there is a reduction in the capacity through sediment inflow, there is also deterioration of water quality. Many studies emphasize the importance of the sediments for water quality of reservoir uses and the danger posed by the eutrophication process. Phosphate is key element in the eutrophication process and its concentration influences the trophic state of the water body. The nature and total Phosphate load in the sediment, the reactions/mechanisms at the sediment water interface that control release of phosphate may be important factors affecting the internal loading of phosphate in reservoirs (Carter & Dzialowski 2012). Many studies are available to address this problem, but different approaches are taken by different investigators in assessing the internal load of phosphate, probably under the different field conditions that prevail.

One is the sequential extraction of different chemical forms of phosphate in sediments to study and assess the potential problem for eutrophication of the Lakes. The distribution of total as well as the different fractions of phosphate and its mobility (Fytianos & Kotzakioti 2005) appears to be important in different lakes. The chemical forms or the abundance of a specific chemical form appears to be dependent on the catchment geology, grain size, mineral content of the sediments (Kapanen 2008) as well as the enrichment by available organic matter (Beidou et al 2011). These factors are shown to be important in the flux of P from the sediments.

The pore water release and dynamics of P is another important approach in the study of phosphate release from the sediments using
microcosm studies (Steinman & Ogdahl 2010) as well as field investigations. Pore water TP is an important indicator of TP release that may be site specific (Thornton et al 2013) and need to be monitored for calculating reasonable load estimates. Phosphate turnover and circulation may be influenced by hydrological dynamics and might become the driving force has been reported from Polish reservoirs (Trojanowska & Jezierski 2011) affected also by a variety of environmental problems, such as eutrophication, humic substances content, sediment contamination with heavy metals and toxic organic pollutants. Significance of seasonal and spatial variation of Phosphate concentration in pore waters and its impact on internal loading has been reported in another Polish lake Swarz Edzkie (Kowalczewska-Madura & Goldyn 2011) and Baiyangdian Lake in North China (Dong et al 2011). These studies indicate the seasonal variability of TP release and their importance in estimating annual internal P loads.

2.4 INTERNAL PHOSPHATE LOADING

Nurnberg (1994) made the first attempt to classify the lakes based on anoxic lake sediment surfaces that are especially prone to high internal phosphate loading. She identified the morphometric, hydrological and geochemical characteristics of several lakes and used it to calculate the internal phosphate load. She calculated the internal phosphate load as the function of the area of anoxic/oxic zones of the lakes to estimate phosphate release rates. Phosphate concentrations generally increase during summer (Pettersson 1998, Graneli 1999), when external additions are minimal and due to the effects such as the fish bio manipulation on the lake and the role of sediment bacteria (Jeppesen et al 2003) and could influence annual IP loads.

Further, sediment investigations point to the importance of composition of the sediments and their impacts on nutrient loading and water quality impacts. The anoxic zone and the duration in lakes/reservoirs are
likely to affect the release of phosphate from sediments. This has been investigated through experimental as well as field studies. However, laboratory based experiments do not explicitly consider oxic/anoxic conditions, but indirectly assess the TP release and loads. Whereas direct field studies in lakes / reservoirs (Nurnberg 1994) may be more relevant and could make better estimates.

2.5 CATCHMENT SOIL EROSION

Soil and water, apart from people are among most important natural resources and their degradation by development processes, especially due to agriculture has been felt as early as 1970’s (El-Swaify et al 1982) in the tropical regions of the world including India. While soil erosion can affect agriculture itself, the sediment load of the inflow pose potential threat to the quality of receiving water bodies. Siltation and capacity loss of large (>100 Mm$^3$) and medium scale (20-100 Mm$^3$) reservoirs exceeding 25% has been noticed in the Himalayan and west flowing rivers of India even in 1980’s (Narayana & Babu 1983, Kothyari 1996). Major causes cited for soil erosion in these areas include deforestation, large scale road construction, mining and cultivation on steep slopes. Erratic and torrential rainfall, sandy and bare soils has been cited as major causes of sediment generation from arid and semiarid zones of Central India by Sharma (1996) who suggests promotion of natural vegetation and check dams can reduce it up to 94%.

Soil and water conservation (SWC) methods are often clubbed together in watershed development programs to reduce erosion of topsoil and improve the availability of water. In soil erosion assessment, SWC measures are related to the land cover / land use changes and conservation practice factors widely used in soil loss estimation methods including USLE based assessment. Several authors have tried to evaluate the watershed process

Effects of slope and land cover on sediment yield was investigated in simulation experiments in tropical field conditions by Joshi & Tambe (2010) who suggest grass cover was more effective in inducing infiltration and decreasing sediment yield compared to bare lands with steep slopes. Sharma (1996) who made a comparative study of Indian and Argentina watersheds in GIS environment also found areas with grass cover induce more infiltration and reduce sediment yield.

Jain & Kothyari (2000) identified sediment source areas and the prediction of sediment yield in Nagwa and Karso catchments in Bihar. In another study in Upper Damodar valley, Jain & Das (2010) assessed areas of soil erosion and sediment deposition for prioritizing the sub watersheds for SWC measures. Further, simulations of annual sediment yield of the catchment indicated less than 40% error. In Indian sub humid climate, intercrop based CBT (conservation bench terrace) system was found to be best alternative in sloping boarders for conserving soil and water (Sharda et al 2013) and improving crop productivity. Soil loss from mountainous areas in Western Ghats showed a close relation to degraded forests, deciduous forests and grass land areas especially in steep slopes in a study (Prasannakumar et al 2012) using RUSLE and GIS. RUSLE in GIS environment appears highly feasible spatial tool in recent erosion studies.

Application of USLE or its modified version was further extended to evaluation of Best Management Practices (BMP’s) adopted in watershed management programs. In Three Gorges area of China (Shi et al 2004) RUSLE was applied under ArcGIS environment for the entire watershed to classify soil erosion zones of the basin to evaluate existing BMP’s. Jaiswal et al (2014) suggests developing a decision support tool based on (Analytical
Hierarchy Processes) AHP of factors (morphological, topographical, climatological and management) of soil erosion and sediment yield in a basin to prioritize sub watersheds. Application of this methodology in Benisagar dam catchment area, Madhya Pradesh in India identified eight watersheds covering an area of 20.15 km$^2$ for selective conservation efforts that can substantially reduce sediment yield from the catchment.

C and P factors of RUSLE gained more attention now on their role in the study of soil erosion estimations. The SWC measures now undertaken in large scale in many countries need evaluation or analysis of their role in controlling sediment generation. Efforts at combining USLE with other models have also been attempted by many authors (Ozcan et al 2008). For example, Vemu & Udaya (2011) prioritized 15 sub watersheds for soil conservation in Upper Indravati reservoir catchment area in India, combining USLE with Watershed Erosion Response Model (WERM) in GIS environment. Outfall TSS and percentage reduction in TSS assessed in a study on Santubong River in Malaysia (Kuok et al 2013) showed effectiveness of P factors as Terracing > contour strip cropping > simple contouring > no support practice, based on the efficiency of sediment retention. A multi criteria decision model used in Yonging river basin, North West of Beijing city (Zhang et al 2010) indicated a six level grading of conservation priority areas based on erosion risk maps of 2000 and 2006. The linear (drainage network) and inverse (shape parameters) relationship of watershed morphometric parameters with soil erosion potential enabled (Nooka 2005, Thakkar & Dhiman 2007) the ranking of sub watersheds for conservation (Gajbhiye et al 2014) in Manot River catchment in Narmada valley in India. In this study, compound parameter values were calculated for each sub watershed based on rank assigned for each of the morphometric characteristic considering its relevance for erosion risk potential.
2.6 CATCHMENT LAND USE

The nature of catchment land use and its change over time also influence the sediment generation. Land use Land cover (LULC) data derived from remote sensing was used to assess sediment generation in Udaipur, Rajasthan (Machiwal et al 2010). Here GARDE model was used to assess annual runoff and sediment yield to suggest suitable sites for SWC measures. Land use changes increasing soil erosion potential was investigated in Maithon reservoir catchment, India (Sharma et al 2011) where a change in land use from forest to agriculture (2004 compared to 1989) increased mean soil erosion potential from 12.11 t/ha/yr to 13.21 t/ha/yr. Further, the location of land use categories with respect to terrain characteristics emerged as important consideration in soil erosion assessment process. In yet another approach, comparison of two sets of 51 aerial photographs taken in a span of 30 years (1975-2006), revealed improvements in land cover protective measures (Munro et al 2008) in the Central Plateau region of Tigra, Ethiopia. Landscape analysis, based on selection of homogenous land units for comparison and assigning scores on changes indicated overall improvement in vegetation cover validating SWC programs in this study.

In another long term study of stone bunds in Ethiopia, the P factor values has been verified as 0.32, produced an average increase in grain yield of 53%. More than 75% of the farmers in this watershed favoured these stone bunds made with local material as most effective and tree planting can enhance further. Evaluation of land cover on runoff and sediment yield at experimental plot scale has also been made by few investigators (Ha et al 2012). Type of fodder cover and slope length emerged as important factors in sediment export in small 1 m$^2$ experimental plots (Ha et al 2012).

In the application of LISEM model to simulate the effects of SWC programs in a study in Kenya Hessel & Tenge (2008) indicated a decrease of
28% runoff and erosion by 60%. Reforestation and mulching emerged as most effective treatment in reducing sediment yields in a simulation study of stream flow and sediment yield in Central Thailand (Phomcha et al 2012).

These studies show the wide applicability of RUSLE modeling approaches in soil erosion studies. By combing with other models or manipulating the P factor distribution, many authors have studied changes in sediment yield from water sheds. Land use changes or land cover modifications in forested terrains were also evaluated using similar approaches.

Many of the above applications help establish areas or zones of priority for SWC measures in the watersheds. This approach can further be extended to evaluate the usefulness of the SWC programs or simulations of ideal combination of such measures. This can help conserve scarce economic resources available or focus the best feasible measures in the local context. Such evaluations can be extended further using watershed scale models that can simulate future scenarios or consider evaluation of erosion control practices. Several watersheds use them as management tools in the NPS pollution abatement. The next section present the recent developments in this area.

2.7 WATERSHED MODELS

Models have been applied widely to assess stream flow, sediment yield and or predict soil erosion potential. Modeling approaches are variable: (Zhang et al 1996) statistical, process based, empirical, lumped or spatially distributed models (Merritt et al 2003, Borah & Bera 2004). While a large number of models are available to describe watershed processes, empirical and physically based models have become popular in erosion and sediment transport / yield assessment (Aksoy & Kavvas 2005). After a detailed review
of individual models, Merritt et al (2003) have concluded that in estimating at
catchment export level, physically based models are less preferred over
empirical models. This was due to the demand of spatially distributed models
for necessary input data, paucity of calibration data to define parameters, and
over dependency on experience of the user. Empirical models whereas
assume simple non event based relationships, do not attempt to model
hydrology or sensitivity to climate variability but have general physical
interpretability of modeling results.

Further, model performance and accuracy still remain a major issue
in making reliable estimates, especially in spatially distributed approaches.
Erosion and sediment transport models are in fact extensions of hydrological
models and hence erosion and sediment transport equations are coupled to
existing hydrological algorithms (Aksoy & Kavvas 2005). This means output
from the hydrological model shall become input to the erosion part of the
model and inclusion of GIS as model base permit incorporation of physical
heterogeneity in a catchment area. Such an approach become more popular in
the last decade (Borah & Bera 2003, Gassman et al 2007) and transformed the
soil erosion and non point source pollution modeling scenario. One such
model, Soil and Water Assessment Tool (SWAT) developed by Arnold et al
(1998), Arnold & Foster (2005) has gained wider applications across globe in
the areas of water, sediment assessment, predictions and agricultural chemical
yields from ungauged agriculture predominated watersheds. SWAT has many
application areas including impact of climate change, however, only some
recent applications pertaining to the area of watershed runoff and sediment
yield are reviewed below.

Many authors have used successfully SWAT for prediction of flow
and sediment yield from the watershed (Rostamian 2008, Lin et al 2010,
Pisinaras et al 2010, Nasrin et al 2013). In addition to simulation of flow and
or sediment, the efficiency of the model was tested for adaptation to field conditions and specific effects. For example, role of resolution of DEM, tested in a study (Lin et al. 2010) in China showed decreasing sensitivity with coarser resolution while the efficiency of sub division of watershed on flow, sediment and nutrient (Jha et al. 2004) concentration indicated a threshold value of 5%. The ability to predict nutrient loads has been investigated in many watersheds. In a long term study of Thur watershed in Switzerland (Abbaspour et al. 2007), SWAT provided a good flow and transport simulator for nitrogen compounds. Source areas of P generation in Buyo lake catchment in Ivory Coast has been mapped successfully (Koua et al. 2013) in a 30 year study of land cover land use change. Even a sub-daily erosion and sediment transport has been simulated by Jeong et al. (2011) in a modeling study of storm water BMP’s in experimental watersheds in Texas, USA.

Changes in land use and land cover due to developmental activities and its effect on flow and sediment delivery have been investigated (Kigira et al. 2010). Deforestation and agricultural development are main causes of land use changes besides urbanization and human settlements. Alibuyog et al. (2009) have recorded in Manupali river watershed an increase of 14% runoff volume with a decrease of 3.3% base flow, but an increase of 200 to 273% sediment yield when 50% grass lands were converted to cultivated agricultural lands. In addition, land use changes combined with climate change impacts (Molina-Navarro et al. 2014, Fan & Shibata 2015) predicted further increases of water, sediment and nutrient yields in SWAT environment in different climate zones.

In addition to prediction of impacts, evaluation of BMPs in agriculture and specifically the SWC practices adopted in watersheds have been successfully done. In Lam-Southi watershed, Central Thailand (Phomcha et al. 2012) SWAT identified 40% of watershed area as erosion
prone and further simulations recommend reforestation and mulching as most effective treatment measures to reduce sediment yield. Farm land when converted back to forests in Xiangxi river watershed in China (Liu et al 2013), SWAT predicted a reduction of NPS load with 15.9% runoff reduction, 9.16% TN and 5 to 7% of TP. In another study in central Brazilian catchment (Strauch et al 2013), SWAT predicted 40% of sediment load reduction feasible, if small retention basins and parallel terraces are constructed. Land use-soil interactive effects in a large watershed in Central Texas was simulated in SWAT (Wang et al 2010) to show the importance of wet/dry condition of soil in watersheds.

The foregoing review indicates that SWAT is applied in many watersheds around the world and has many applications in the area of watershed modeling, sediment generation and its delivery, evaluation of BMP’s and SWC measures. Further, SWAT was also successful with data scarce situations and recommended for ungauged watersheds by many investigators. SWAT can therefore be considered for use in developing countries where strong monitoring networks or comprehensive natural resources data bases are not yet available for modeling purposes.

2.8 SCOPe OF THE STUDy

India attained food security mainly due to green revolution and this was made possible by the construction of reservoirs across the Country in all the river basins, which stabilized the irrigation water supply. The past half century of development processes in catchment areas, however, are threatening now, the useful life span and water quality of reservoirs. The review of literature suggests that to protect the reservoirs and conserve the water quality, the quantitative understanding of the processes and modeling are invaluable tools.
Soil erosion is a basic catchment hydrological process, which is enhanced by the intensive irrigated agriculture and other developmental activities forming the base for nutrient load generation from the catchments. Soil erosion is a subject of study by many authors, as reviewed earlier, shows its role as a transporter of nutrients and pollutants to the reservoirs. In a compilation of (Yang et al 2003) erosion assessment across the globe, the subtropical belt has emerged as highly eroding zones of the world, which compelled the south Asia including India to initiate serious soil conservation measures. While erosion estimates of many watersheds have been made, the extension of its impact on nutrient loading of the receiving water bodies are yet to appear in detail.

Eutrophication is the enhancement in nutrient status (Nitrogen and Phosphate) of water bodies resulting in algal bloom and deterioration of quality of water for beneficial uses. This is due to the development processes taking place in catchment areas and the consequent land use changes promoting degradation of the environment. Non Point Source (NPS) load from the catchment has emerged as one important source of nutrients and pollutants in the reservoirs apart from point sources, if any. Reservoirs, in addition to input sediment loads, also act as traps accumulating nutrients/pollutants and thereby serve as internal nutrient storehouses. The implementation of remedial measures or management options for nutrient control in reservoirs requires the understanding and quantifying the processes and interactions between reservoirs and its catchment area.

More comprehensive studies incorporating these issues are required to assess the external and internal processes that control water quality in a reservoir. However, there were only fewer studies dealing with this aspect, considering the large number of storage reservoirs available in India. Many studies done in our country were on more on limnological aspects or erosion
estimates, and most of them focus on casual relations in the context of seasonal changes in water chemistry. As there has been a paucity of comprehensive studies from Indian river basins, that too still few focusing on soil loss, sediment estimations and eutrophication, studies of this nature assumes importance for the management of reservoirs, whose health is very important in sustaining the beneficial uses of water. The development of such an integrated study in a typical reservoir may be a useful comprehensive study in India and such a model can help manage the problem of eutrophication in a better way. In addition, this modelling approach, when built, may provide a methodology for application to many other reservoirs in south India, and therefore chosen for the present study.

2.9 DEFINITION OF THE PROBLEM

Comprehensive information on sedimentation, loss of capacity or sediment phosphate loads is limited from sub-tropical reservoirs. Study of catchment processes, bathymetry of the reservoir and sedimentation surveys could provide necessary information relevant for the long term planning and management of reservoirs (Thornton et al 2013). Better tools for such studies are available now like bathymetric and sedimentation surveys and provide reliable data on storage loss and water quality deterioration. A strategy to manage the problem of reservoir sedimentation effectively using latest assessment tools of quantity and quality are highly desirable to study the role of external and internal loads.

Krishnagiri Reservoir is the first dam constructed across the upper Ponnaiyar River in Tamil Nadu in 1957 to stabilize irrigation in the draught prone Dharmapuri district in northwestern part of Tamil Nadu. This project was the subject of a series of environmental investigations during the last decade. A short term pilot study on the eutrophication of the Krishnagiri reservoir (Ravichandran & Kaarmegam 2004) in Ponnaiyar river basin
provided basic information for a detailed study to be taken up. This reservoir in its lifespan of about 50 years has lost 37% of its capacity, with a permanent bloom of algae and declining water quality (Karunakaran 2004). The pilot study recommended a detailed investigation of various catchment processes responsible for the nutrient load and its impact on the reservoir water quality. Such a study was supported later by a UGC major project (Ravichandran 2006) in the Krishnagiri Reservoir Catchment area. The results of this project identified the water quality of the reservoir and the culture fishery, secondary data on water and sediment inflow and outflow, its spatial variations and produced a comprehensive environmental data base of the watershed.

Jasmine & Ravichandran (2008) made a RUSLE2 study of soil erosion in Vepanapalli, a sub watershed in the catchment area and estimated the total and spatial soil losses. Secondary data and field investigations and reports on various aspects of the reservoir and its catchment are available for this project.

This reservoir was therefore taken up for detailed investigation in this thesis. The objectives of the study are given below.

2.10 OBJECTIVES OF THE STUDY

The general objective of the study is to investigate Krishnagiri Reservoir in Tamil Nadu, south India and analyse the internal and external factors responsible for sedimentation and its impacts on the Reservoir.

The specific objectives chosen are,

1. To conduct a bathymetric study to derive the present capacity, water spread area and assess sedimentation rate

2. To investigate the physical and chemical characteristics of the sediments and calculate the internal Phosphate load
3. To estimate the soil loss and sediment yield using Revised Universal Soil Loss Equation (RUSLE) in the catchment area

4. To assess the sediment yield from the catchment area using SWAT model

5. To evaluate existing Soil and Water Conservation measures in the catchment area, based on the present study