ESTIMATION OF TOTAL VOLUME OF SEDIMENTS IN SALAULIM RESERVOIR USING ANN MODEL

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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MASTER OF TECHNOLOGY

IN

HYDRAULICS AND WATER RESOURCES ENGINEERING

Submitted by

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CANDIDATE'S DECLERATION

I, Shailesh Kumar Gupta, Roll No. 2K17/HFE/13, student of M.Tech (Hydraulics and Water Resources), hereby declare that the project Dissertation "Estimation of Total Volume of Sediments in a Salaulim Reservoir Using ANN model" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirements for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for award of any Degree, Diploma Associates, Fellowship or other similar title or recognition.

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Date:

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CERTIFICATE

I hereby certify that the project Dissertation titled "Estimation of Total Volume of Sediments in a Salaulim Reservoir Using ANN Model" which is submitted by Shailesh Kumar Gupta, Roll No. 2K17/HFE/13, Department of Civil Engineering, Delhi Technological university, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by him under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Reservoir sedimentation has become a critical issue these days. The life of reservoir at planning is not the same after construction. There is a loss of storage capacity because of volume of sediments deposited and evaporation taking place throughout the area of reservoir. Thus, reduction in capacity of reservoirs also decreasing the useful life of the reservoirs. Volume of sediments deposited in a reservoir is the major role that reduces the storage capacity of reservoir.

In my present study, volume of total sediments deposited in the Salaulim reservoir is estimated using different methods such as siltation rates and ANN model. The results of these methods have been compared with the results got from equation ($V_s = KT^{0.66}$) given in report of Salaulim Reservoir, Goa provided by CWC.

In the present study, 21 years data of Salaulim Reservoir is used. Volume of sediments deposited in a Salaulim Reservoir was estimated using siltation rate. The annual siltation rate of Salaulim Reservoir was found to be 6.75 mm/year in 21 years. Volume of total sediments deposited was also estimated by the equation. The results of both methods were compared. The regression coefficient was found to be 0.976.

Again the results from the equation were compared with the estimated value of volume of total sediments deposited in a Salaulim Reservoir by ANN model. The regression coefficient was found to be 0.998. A feed forward three layered ANN model with back propagation algorithm was developed. The data was trained using Levenberg Marquardt process. The training was stopped when MSE was 0.01.

In the present study, ANN model performed better than the method of siltation rates. It is fast and can solve complex problems. The volume of sediments deposited in Salaulim Reservoir estimated in 21 years was 29.61 M.Cu.m. The estimated life of the Salaulim Reservoir was 150 years.

ACKNOWLEDGEMENT

I am grateful to the vice chancellor of Delhi Technological University, Prof. Yogesh Singh and Prof. Nirendra Dev (Head of Department, Civil Engineering, DTU.) for made available all the necessary equipments and facilities in lab to finish my undertaking. I am exceptionally appreciative to my administrator Associate Prof. Dr. T. Vijay Kumar, Civil Engineering Department, Delhi Technological University, New Delhi for his interminable direction and backing. He constantly roused me and has regulated in every single troublesome time. He has constantly urged me to improve his remarks. He has constantly pointed my missteps so I can be better. I need to express gratitude toward Executive Engineer Sudhanshu, CWC, Bhikaji Kama Place, New Delhi for helping me to get the information of Salaulim Reservoir located at Sangeum (Salaulim or Guleli River) in Goa.

I would like to thank all the faculties and professors of Civil Engineering Department, Delhi Technological University, for their kind gratitude. I also want thank my friends and family who helped me overcome every obstacle and to be better.

PLACE SHAILESH KUMAR GUPTA

DATE 2K17/HFE/13

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LIST OF ABBREVIATION

CWC	Central Water Commission
BBMB	Bhakra Beas Management Board
ANN	Artificial Neural Network
E	Error
Y	output vector
X	input vector
W	weight vector
b_{ij}	bias
SMR	Summer Monsoon Rainfall
HSDM	Homogeneous Surface Diffusion Model
GANN	Geomorphological Based ANN model
NANN	Non- geomorphological Based ANN model
MLD	Million Litre Per Day
M.Cu.m	Million Cubic meter
FRL	Full Reservoir Level
MDDL	Minimum Draw Down Level
LM	Levenberg Marquardt
V_s	Volume of total sediments deposited
K	coefficient observed By EAL
T	Time period (years)
EAL	Elevation-Area-Capacity
USGS	United States Geological Survey
WEPP	Water Erosion Prediction Project

CHAPTER 1

INNTRODUCTION

1.1 Background

The deposition of sediments with time in the reservoir is known as sedimentation. From studies it is very clear that performance and economics of reservoir decreases with time. It is the time to study about the sediments depositing every year in the reservoir. It has been already proven that due to construction of dam across the river decreases the surface gradient. This is the reason of reduction of velocity of flow at dam. Reduction in velocity of flow is the reason for the deposition of sediments in the reservoir. Dam behaves like the obstruction to the velocity of flow. Deposition of sediments also decreases the capacity of reservoir. Hence, also decreases the life of reservoir. The capacity that is lost annually varies 1-2% of the total storage capacity (Mahmood 1987; Yoon 1992; Yang 2003).

As we have realized that India is a rural nation and its populace is around 1 billion. As horticulture is the biggest financial part of India. All the horticultural grounds must be saddled by water that is being provided by in excess of 4000 dams and a great many little dams [Central Water Commission (CWC) 2001; Durbude and Purandara 2005]. For instance, Nizam Sagar Reservoir which is arranged in Andhra Pradesh, was built in 1930 and had an underlying limit of 841.18 * 106 m^3. It has lost its 60.74% limit by 1992 (CWC 2001). CWC in 2001 revealed that the sedimentation rate in Indian Reservoirs is higher than the structure rate taken at the phase of designing. Numerous reservoirs out of these reservoir are losing their ability at a rate of 0.2 – 1.0% yearly (CWC 2001). Shangle (1991) has done the examination of 43 reservoirs. There were major, medium and minor reservoir. The examination reasoned that the rate of sedimentation of significant reservoir fluctuate between 0.34 – 27.85 ha.m/100 km2/year. The rate of sedimentation of medium reservoir differ between 0.15 – 10.65 ha.m/100 km2/year. In like manner the rate of sedimentation of minor reservoir differ between 1.0 – 2.3 ha.m/100 km2/year.

1.2 Reservoir Sedimentation

Sedimentation happens in every reservoir and diminishes the limit of reservoir. As the limit of reservoir is diminished henceforth, it influences the life of reservoir and life of reservoir is diminished. Actual life of reservoir vary from the life of reservoir at the planning stage because of sedimentation. Siltation in reservoir can be in charge of numerous unsafe issues. It is extremely important to learn about sedimentation and siltation rate with the goal that these unsafe issues can be give drastic damage. There was practice in vogue before eighties was that a dead stockpiling ought to be given to oblige 100 years of sedimentation. Agreeing this it was expected that dregs are just kept in dead stockpiling at the base of reservoir. Afterward, it was discovered that it was invalid and investigation of studies demonstrated that sedimentation occurred all through the supply.

Siltation rates can be defined as the rate of deposition of sediments with time in a reservoir. CWC (Central Water Commission) is surveying the reservoirs and studying their siltation rates and reduction in capacity of reservoir. They are trying to compare the reservoirs of all zones. CWC is biggest organization of Central Government looking after water resources. According to the report provided to me, the siltation rate is the crucial factor of sediments to study. Siltation rate is the factor that gives the percentage of sediments depositing in the reservoir.

Table 1.1 Rate of sedimentation of few Reservoirs of India

Reservoir	River	Catchment Area (Km^2)	Initial Storage Capacity (10^6 m^3)	Average Sedimentation Rates (ha.m/100 km^2/year)
Linganamakki	Sharavathi	2176	4435.35	24.00
Ramganga	Ramganga	3134	2449.60	22.94
Pong	Beas	12562	8578.99	21.10
Malaprabha	Malaprabha	2176	1064.04	19.00
Konar	Konar	997	281.23	17.50
Idukki	Periyar	649	1998.57	15.92
Gandhisagar	Chambal	23025	7740.00	8.96
Aliyar	Aliyar	195	109.40	8.48
Ukai	Tapi	62224	8510.00	8.13
Hirakud	Mahanadi	83395	8105.00	6.35
Bhakra	Satluj	56980	9868.00	6.10
Jayakwadi	Godavari	21774	2909.04	4.78
Matatila	Matatila	20720	1132.70	4.69
Sriram Sagar	Godavari	91751	3171.94	2.80

Note – Data from CWC

Above table 1.1 gives the average siltation rates of different reservoirs. Average siltation rates are calculated from Elevation-area-capacity curve. Elevation-area-capacity curves are prepared from hydrographic survey done by CWC. Elevation-area-capacity curve gives the capacity of reservoir at a particular area and at a particular elevation.

1.3 Elevation-area-capacity

Elevation-area-capacity tables can be generated using grid generated from XYZ file. Geosoft utilities, GRIDVOL and GRIDSTAT have been used to compute capacities and areas at various levels from the lowest bed level at. Loss of storage can be estimated based on elevation-area-capacity curve. The difference in pre-impound survey and present survey gives the total sediments depositing in the reservoir. The volume of sediments deposited can give us the loss of storage.

1.4 Effect of Sedimentation on the Life of reservoir

Reservoir sedimentation diminishes the storage capacity and available water storage and damage the sustainable water resource management. Reservoir is like an artificial lake that is constructed by us. All of these reservoirs are going through severe problem of loss of storage capacity due to deposition of sediments. The capacity of reservoir is diminishing daily without any instant damage. The damage can be there but it would happen after a long time. As we can observe, reduction in capacity of reservoir is also affecting the life of reservoir. The reservoir would be not useful as designed.

Loss of storage is mainly due to the deposition of sediments and the evaporation that is taking place in the reservoir. The percentage of loss of storage will keep on increasing over the years. A time will come, when reservoir would become inefficient. Jothiprakash and Garg (2008) concluded from their study that the useful life of Gobind Sagar Reservoir (Bhakra Dam) on Satluj River in Bilaspur district Himachal Pradesh is reduced by 3/4th of the period estimated by BBMB.

It has become very necessary to put a check on reservoir sedimentation rates. Reservoir should be observed and should be noted on monthly basis. Analysis should be done using all the data and remedial steps should be taken as it is a severe problem for all of us. As it will not satisfy the demand for which it was designed.

1.5 Different steps used to control sediments

There are different basic remedies that can be used to control the sediments depositing in the reservoir. The different steps that are used to control sediments are given below.

- Vegetation should to grown along the river.
- Degraded areas should be treated upstream of the catchment.
- Check dams should be built.
- Bypass should be constructed for the diversion of water containing silt.
- Regularly dredging should be done to remove silt.
- Waste lands should be developed which are coming in between the catchment areas.

1.6 ANN modeling

ANN model works same as human cerebrum. Like as human mind ANN likewise has neurons to take input. Synapsis in ANN model exchanges the sign and furthermore yield neuron which gives us yield. An ANN is gigantic parallel appropriated data preparing framework which has a few working highlights looking like natural neural systems of the human mind (Haykin, 1994). ANN models are the scientific portrayal of neural science.

Development of ANN is based on following rules.

- The processing of information occurs at nodes known as unit cells or neurons.
- Nodes pass the signals between them through connection link.
- Each connection link is associated with weights that represents the strength of connection.
- A non linear transformation known as activation function is applied to its net input to get the output signal.

A neural system is described by its engineering which demonstrates the example of association between hubs, its technique for deciding the association loads and enactment work (Fausett, 1994). Neural Networks can be arranged by the quantity of layers: single (Hopfield nets); bilayer (Carpenter/Grossberg versatile reverberation systems); and multilayer (back proliferation systems). There are distinctive different approaches to order neural systems. One of these is the grouping as per the bearing of stream of data. Feed forward system is a sort of it. In feed forward system there are a few layers in succession beginning from information layer and consummation at yield layer. The succession can have concealed layers moreover. Each layer can have at least one number of neurons. Information layer passes the data to the concealed layer and from shrouded layer to the yield layer. Every neuron is associated with the neuron of other layer with the related loads. Neuron in a layer can't be associated with the other neuron in a similar layer. Related weight speaks to the quality of association. The quantity of neurons in concealed layer is discovered by experimentation strategy. Fig. 1.1 shows the demonstration of ANN network.

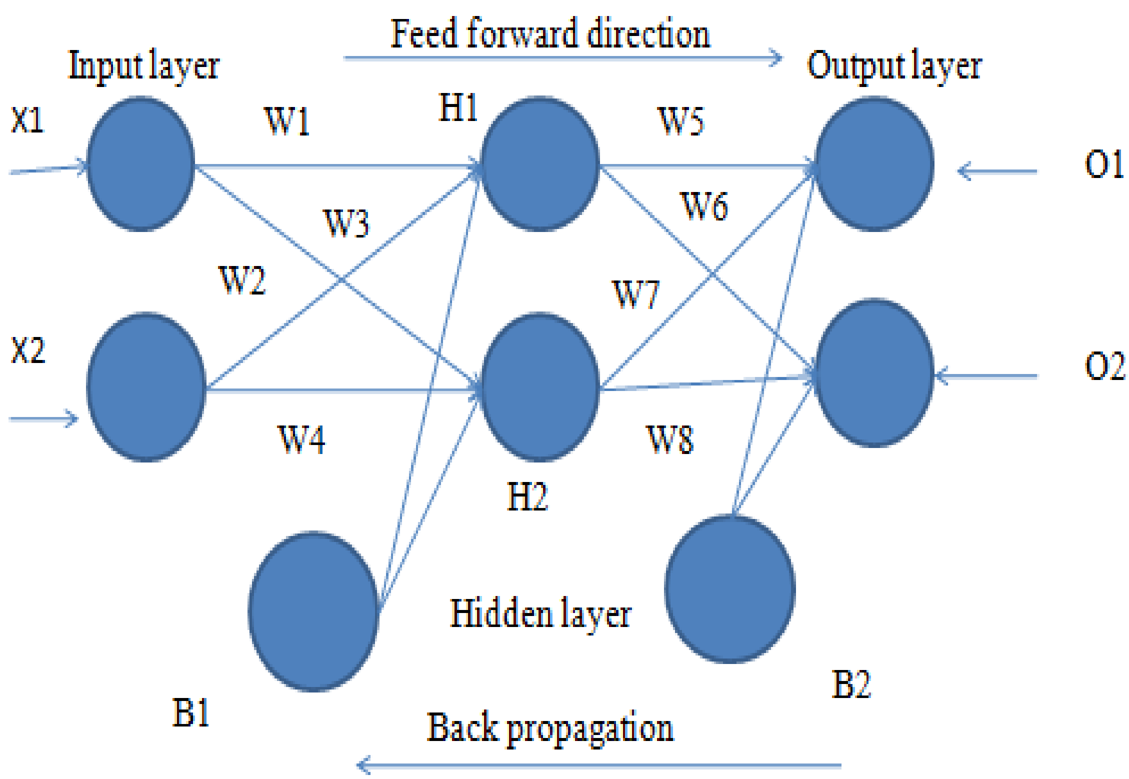

Fig 1.1 Demontration of ANN modeling

Fig. 1.2 shows a schematic diagram of a *m*th node. mth node get the inputs from the set input layer. All the inputs are in the form of vector i.e vector X = (X_1, X_2, X_3 ....X_n). The sets of associated weights to each input are shown by W vector i.e vector W_m = (W_{1m}, W_{2m}, W_{3m}..........................W_{im}). W_{im} is a vector which shows the strength of connection from this node to each input.

The inner product of vectors weights and inputs are multiplied by activation function f(t) to get the output Y_m. b_j in above figure is known as bias. The sigmoid function gives the non linear response. The function is nondecreasing. The sigmoid function is given below.

( ) ——— ....(1.1)

The output is given by below equation:

$Y_t = f\,(X * W_m - b_j)$..(1.2)

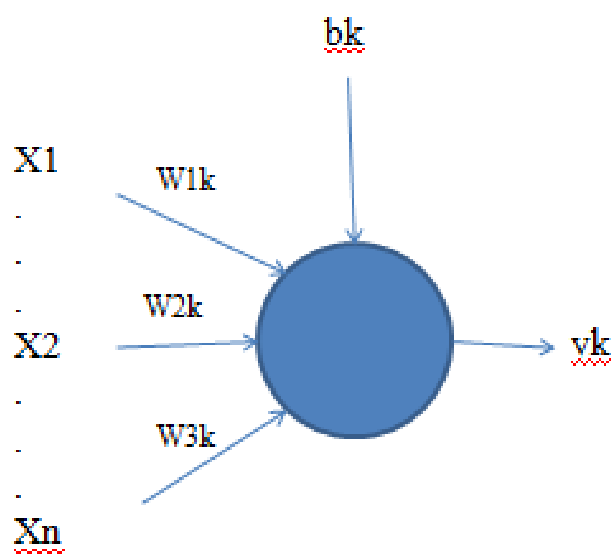

Fig 1.2 Schematic diagram of node m

1.6.1 Network Training

A preparation procedure is finished by ANN known as figuring out how to produce a output or yield vector Y = (y1, y2… yn) which is near wanted target vector T = (t1, t2,… … tn). A preparation procedure is done to discover upgraded weight grid and predisposition work V, with limited error. Other layer with the related weights. Neuron in a layer can't be associated with the other neuron in a similar layer. Related weight speaks to the quality of association. The quantity of neurons in concealed layer is discovered by experimentation method.

$$\sum \sum (\ ) (\ ) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{......}(1.3)$$

Here, t_t is yield wanted segment; y_t is in correspondence with ANN yield; q = number of yield hubs; Q = number of preparing designs. During the time spent preparing, the association weights are naturally reenacted through nonstop procedure by the condition the system is inserted. The primary objective of preparing is to advance the weights and decrease the blunder so the output or yield by ANN ought to be equivalent to or extremely near the objective worth. These are essentially two sorts supervised and unsupervised. A managed preparing procedure requires a guide. In this sort of preparing process, an enormous number of informational indexes are required for testing and approving of information. In this procedure of preparing, the outcomes are iterated and changed in accordance with get the advanced loads and edge an incentive for every hub. In unsupervised preparing process, no outside guide is required. A lot of info is given to ANN, it naturally bunch the arrangement of information into class of same properties and improves the loads. When preparing is finished, presently ANN model can be given arrangement of information which will furnish us with yield.

1.7 ANN modeling applications

There are different number of application of ANN modeling such as rainfall runoff modeling, stream flows modeling, water quality modeling, estimation of precipitation, etc. There are many researchers who have already done so much using ANN modeling. Some application based on researches done so far are given below.

1.7.1 Estimation of precipitation

It is very difficult to estimate the precipitation because of the spatial and temporal variation that is caused by it. French et al. (1992) developed three layer feed forward ANN network to estimate the rainfall intensity at a lead time of I hour. He used back propagation algorithm with the ANN network. He used current field as input. He compared the mathematical modeling results and ANN results. He concluded ANN gave slightly better results.

Navone and Ceccatto (1994) developed ANN model to predict Summer Monsoon Rainfall (SMR) over India. SMR could be a deterministic or stochastic process from studies done till now. Therefore, ANN models were developed for deterministic as well as stochastic framework. Firstly, an ANN model was developed and trained to correlate predictors (two indices related to El Nino-Southern Oscillations) with SMR. Another model was developed and trained to learn the dynamics of the time series. There were seven inputs that were chosen from the reconstructed phase using time delayed of SMR. The result of both hybrid structure perform 40% more accurately than the best linear statistical method. The data used was same for both linear statistical method and ANN model.

1.7.2 Ground Water ANN Modeling

Aziz and Wong (1992) showed the usage of ANN to estimate the aquifer parameters from drawdown data observed from pumping test. This examination drew on the example acknowledgment capacity of an ANN dependent on aquifer test information. Utilizing estimated drawdowns as information sources, neural systems were prepared to yield transmissivity T, stockpiling coefficient S, and the proportion r/B, where r speaks to the separation to the perception well and B is the aquifer thickness. Both confined and leaky-confined aquifers were considered. The information layer contained 16 nodes speaking to the confined aquifer information and 12 nodes speaking to the leaky-confined aquifer inputs. In the event that the ANN was to be utilized for a carefully bound aquifer, at that point contributions to the last 12 hubs were set to zero, and the other way around. A three layer ANN model was prepared with information produced from the Theis and Hantush-Jacob solutions. In the wake of preparing, the ANNs were tried on two arrangements of field information. The estimations of aquifer parameters anticipated by the ANN contrasted well and results utilizing customary techniques.

1.7.3 Water Quality Modeling

ANN is getting very popular these days. It has been found number of applications in the area of water quality modeling. Flow rate, contaminated load, medium of transport, water levels, initial conditions and other factors are the factors that affect the quality of water. Using manual or conventional methods make the estimation of such variables very complex. ANN modeling tool makes the work easier and remove the complexity.

Basheer and Najjar (1995) developed three layered ANN model to predict the break through time in a fixed-bed adsorption system. Training and validating data was taken from HSDM model. There were three inputs that were used in this ANN model. The inputs taken were influent concentration, adsorbent specific weight, diameter of particle of the porous bed material. There were 10 hidden layers that was set by trial and error process. They found that ANN model gave reliable results within the range of data sets.

1.7.4 Stream Flows Modeling

Stream flows are never treated separately. They are treated as the estimates of combined runoff from watershed and runoff due to rainfall. Here, the application dealt with stream flows separately without involving precipitation. Kang et al. (1993) developed different three layered ANN architectures to predict daily and hourly stream flows in Pyung Chang River basin in China. After the study, according to the conclusion ANN are the beneficial tools for forecasting stream flows.

Muttiah et al. (1997) developed ANN architecture to compare cascade correlation algorithm and standard techniques of regression analysis proposed by USGS. They used all these methods for the prediction peak discharge of two year from watersheds in US. The input data for ANN model was made available through GIS database. There were three inputs namely drainage basin area, elevation, average slope, and average annual precipitation.

1.7.5 Other Miscellaneous application of ANN

Raman and Sunil Kumar (1995) developed a three layer feed forward ANN model with back propagation algorithm. They modeled a multivariate water resource time series. The input used in ANN model was the reservoir data of previous two months. These inputs were used to estimate current month input as output. The results were compared with the statistical method. ANN model gave a very close result to the statistical method.

Raman and Chandramouli (1996) developed ANN model to estimate the reservoir operating policy. They also developed MLP ANN model which was feed forward and algorithm used was back propagation. The inputs taken were initial storage, inflow, demand during each fortnight period. The results were compared with the results got from dynamic programming. There were 4 hidden nodes that were taken by trial and error process. ANN model performed better than other three regression models.

CHAPTER 2

LITERATURE REVIEW

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ASCE task committee (2000a) deals with the introduction and working of ANN model. This paper also deals with the suitability and algorithms used in the ANN model. They have tried to give a brief idea to the applicability of ANN model in hydrology. They have given a description about how an ANN model works. They have tried to explain the main function of ANN model. The paper also shows the increment in the usage of ANN model these days.

ASCE task committee (2000b) provided a series of two papers. First paper gives us the brief idea and introduction of ANN model. Second paper gives us the application of ANN model. The paper showed a variety of application of ANN model such as estimation of precipitation, water quality modeling, Rainfall-runoff modeling etc. It gave us the other different application where ANN can be used. It gave us an idea to use ANN modeling in different field of Hydrology.

H. K. Cigizoglu (2000) developed a multilayer feed forward model to estimate suspended sediments in the river. He compared the results of ANN model with sediments rating curve. He had taken the two rivers which had same catchment area and properties in the North of England to estimate the suspended sediments. The data from one river was utilized to estimate the sediments concentration and the data from other river was used to estimate flux. In ANN model split sample approach was used for training, testing and validation of data from site. ANN model results of sediment concentration and flux are highlighted and ANN can also give the information about the structure of events which is not possible with sediment rating curves.

H. K. Cigizoglu (2000) again developed an ANN model for the forecasting and estimation of suspended sediments. As sediment concentration estimation from regression model is complex and time consuming. The results of previously forecasted and estimated value of suspended sediments were compared from ANN model developed. ANN model gave the superior results than other regression models.'

P. Licznar and M. A. Nearing (2002) developed an ANN model and compared the results with WEPP model. This study was to estimate the quantitative prediction of soil loss and check the applicability of neural networks in prediction of soil loss. 2879 erosion events were used from eight location in the US. The models of ANN model were for each individual with eight inputs. The results concluded that the ANN model worked superior than WEPP model. This also concluded that ANN model can be used to estimate the soil loss.

A. Sarangi and A. K. Bhattacharya (2005) developed two ANN model namely GANN and NGANN to predict sediment yield. These two models were validated from data of hydrographs and silt load (1995-1998) for the Banha Watershed in the upper Damodar valley in Jharkhand state in India. The results of sediment yield from GANN and NGANN models were compared with the regression models developed earlier to estimate sediment yield. Both ANN models gave better results than regression models. GANN predicted better results than NGANN with R^2=0.98 and R^2=0.94 respectively.

N. S. Raghuwanshi et al. (200) developed five ANN models to predict both runoff and sediment yield on daily and weekly basis. Out of five, three models were developed to predict runoff and sediment yield on daily basis. Remaining two models were developed to predict runoff and sediment yield on weekly basis. There were one or two hidden layers in all models developed. There was different number of hidden neurons in all five models developed. The data of five years (1991-1995) of monsoon season (June-October) was used to train the architecture developed. The trained data was tested with data of two years (1996-1997) of rainfall and temperature of monsoon season (June-October). Regression models were also developed using the same above data. ANN performed superior in all cases.

2.1Objectives of the present study

- To determine the siltation rate of Salaulim Reservoir.
- To estimate reservoir capacity of Salaulim Resevoir elevation-area-capacity curve.
- To estimate total amount of deposition of sediments in Salaulim Reservoir.
- To estimate the total amount of sediments deposited in Salaulim Reservoir using ANN modeling.
- To compare the results of manually estimated sediments and ANN estimated sediments.
- To compare which is better and more efficient in estimating the total amount of sediments.

CHAPTER 3

METHODOLOGY

3.1 Study Area

The location of Salaulim Dam is at Sangeum (Salaulim or Guleli River). It is a tributary of the Zuari River in Goa. This Dam is the part of Salaulim Irrigation Project. It was constructed for the benefits of irrigation and drinking water supply to South Goa. The catchment area Salaulim Reservoir is shown in Fig 2.1.

This project site is located at Pajimol-Xelpen in the Zuari River Basin. It is drained by the Zuari River. The location of Salaulim Dam is on the Sangeum River which is situated in Sangeum Taluk near Sangeum town. The river covers 209 sq. km of area.

The Dam is earth cum masonry type which has 42.50 m height above the deepest foundation level. 1003.83 m is the length of the Dam at crest and water spread area that is covered by reservoir is 29.64 sq. km. The volume of Dam is 2.714 M.Cu.m. The total storage capacity of the reservoir is 234.36 M.Cu.m. The Live Storage capacity of reservoir is 227.16 M.Cu.m.

The Spill has a length of 44 m. It is an ungated structure locate in the gorge section. It is a Duckbill type (Morning Glory Type).

The project was planned to irrigate the lands in Sangeum, Quepum, Salceto taluks. The water available for the domestic and industrial use is 220 MLD. The water that was provided originally was 160 MLD.

The water spread area covered by the reservoir at FRL is 29.64 sq. km. The gross storage capacity at FRL is 234.36 M.Cu.m. The Dead Storage is 7.20 M.Cu.m. Therefore, the effective Live Storage is 227.17 M.Cu.m. The catchment area and location of the map is shown in the Fig 3.1 and Fig 3.2 (a) and Fig 3.2 (b).

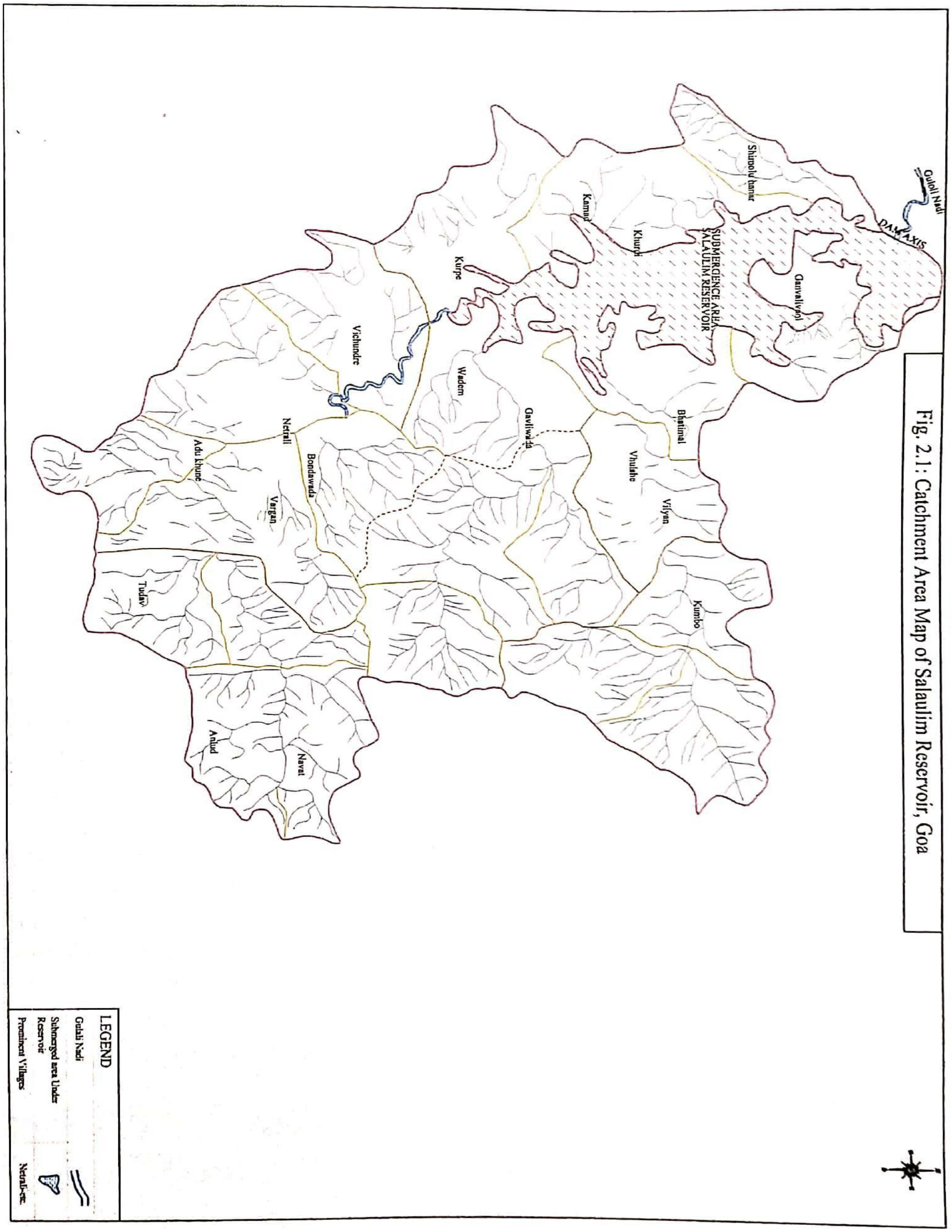

Fig 3.1 Catchment Area of Salaulim Reservoir, Goa

(Report of Capacity Survey of Salaulim Reservoir, CWC)

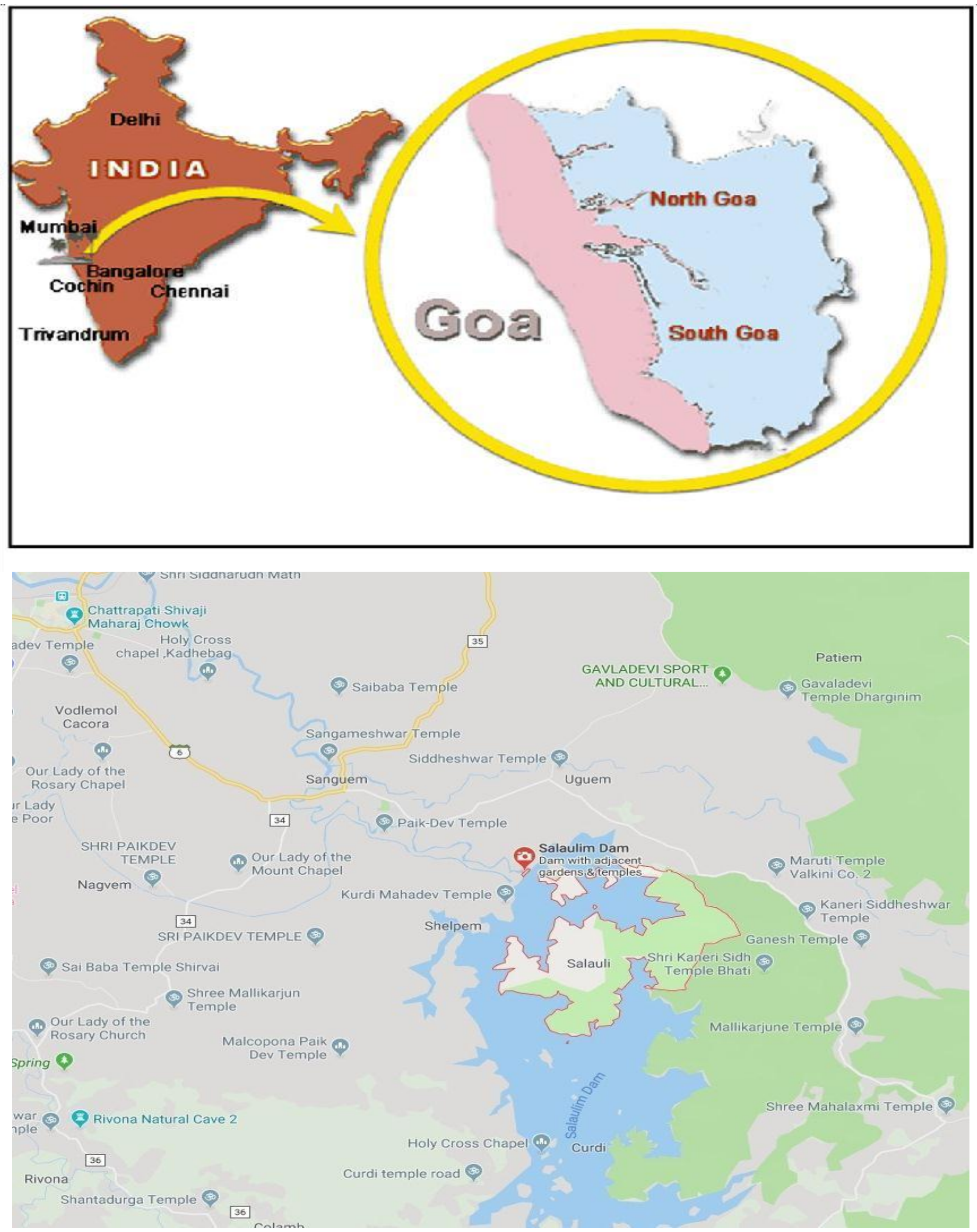

Fig 3.2 (a) Location of Salaulim Reservoir

(Report of Capacity Survey of Salaulim Reservoir, CWC)

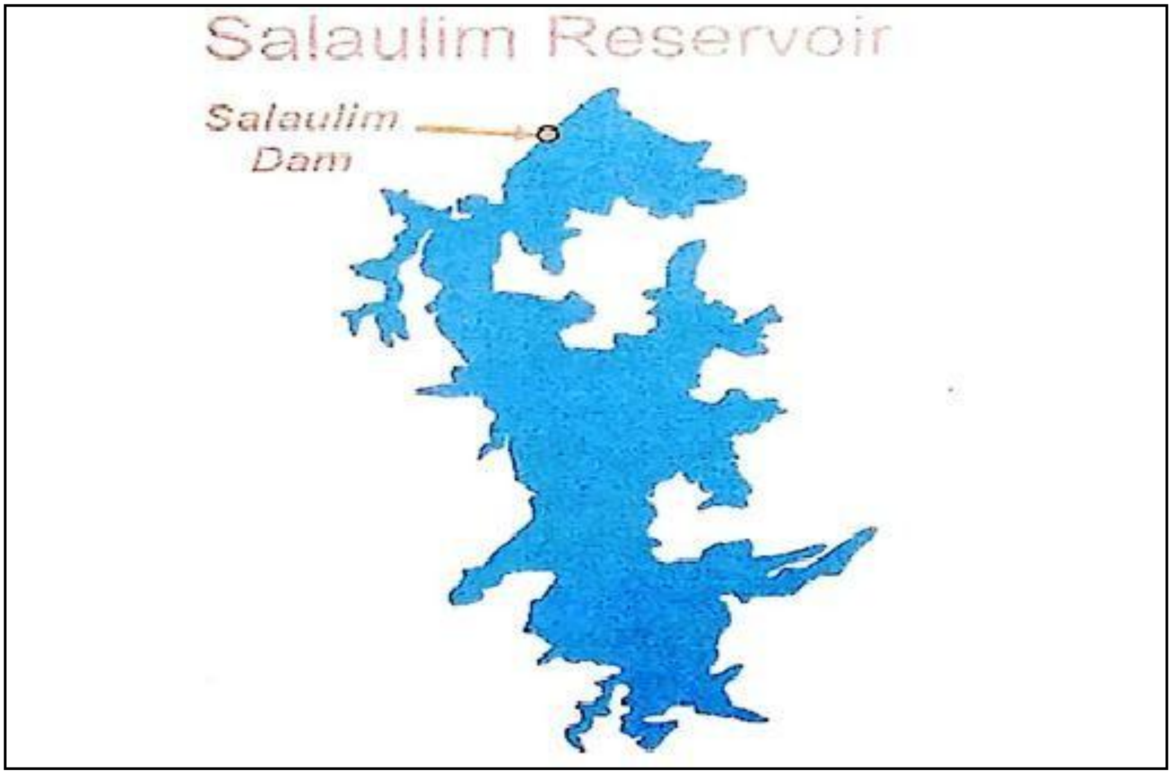

Fig 3.2 (b) Reservoir Location

Fig 3.2 (c) Salaulim Dam

(Report of Capacity Survey of Salaulim Reservoir, CWC)

3.2 Elevation-Area-Capacity Curve

The capacity surveys are done to have a check on reduction in the reservoir storage capacity. There were two capacity surveys done by CWC. The first survey was done in 1990 which is Pre-impoundment survey of Salaulim Reservoir. The elevation-capacity curves were prepared. Second capacity survey was done in 2011 and the elevation-area-capacity curve was prepared. Comparing the capacity survey of 1990 and 2011 the loss in storage of reservoir was found out. Elevation-Area-Capacity curve give us the Capacity of reservoir and area of reservoir at a particular elevation. Using elevation-area-capacity curve the siltation rate can be calculated. Using siltation rate, deposition of sediments in a year can be found out. The following table 3.1 (a) shows us the elevation area and table 3.1 (b) shows us the elevation capacity.

Table 3.1 (a) Elevation Area as per 2011 survey

Sq.km.

Elevation (m)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
14	0.000	0.004	0.008	0.012	0.016	0.020	0.024	0.029	0.033	0.037
15	0.041	0.050	0.060	0.069	0.078	0.088	0.097	0.106	0.116	0.125
16	0.135	0.144	0.153	0.163	0.172	0.182	0.191	0.200	0.210	0.219
17	0.228	0.238	0.247	0.257	0.266	0.275	0.285	0.294	0.304	0.313
18	0.322	0.336	0.349	0.363	0.376	0.390	0.403	0.417	0.430	0.443
19	0.457	0.476	0.494	0.513	0.531	0.550	0.568	0.587	0.605	0.624
20	0.643	0.665	0.687	0.710	0.732	0.755	0.777	0.800	0.822	0.845

21	0.867	0.898	0.928	0.959	0.989	1.020	1.051	1.081	1.112	1.142
22	1.173	1.209	1.245	1.281	1.317	1.354	1.390	1.426	1.462	1.498
23	1.534	1.572	1.610	1.648	1.686	1.724	1.762	1.800	1.838	1.876
24	1.914	1.967	2.020	2.074	2.127	2.181	2.234	2.288	2.341	2.395
25	2.448	2.503	2.588	2.613	2.668	2.723	2.778	2.834	2.889	2.944
26	2.999	3.057	3.115	3.174	3.232	3.291	3.349	3.407	3.466	3.524
27	3.582	3.641	3.700	3.759	3.818	3.877	3.936	3.995	4.054	4.113
28	4.172	4.235	4.298	4.362	4.425	4.488	4.551	4.614	4.678	4.471
29	4.804	4.888	4.971	5.055	5.139	5.222	5.306	5.390	5.473	5.557
30	5.641	5.752	5.864	5.976	6.087	6.199	6.311	6.422	6.534	6.646
31	6.758	6.904	7.051	7.198	7.345	7.492	7.639	7.786	7.933	8.080
32	8.227	8.412	8.596	8.781	8.965	9.150	9.334	9.519	9.703	9.888
33	10.073	10.277	10.481	10.685	10.889	11.093	11.297	11.501	11.705	11.909
34	12.113	12.310	12.507	12.705	12.902	13.099	13.297	13.494	13.691	13.889
35	14.086	14.246	14.405	14.565	14.725	14.884	15.044	15.204	15.363	15.523

36	15.683	15.855	16.027	16.200	16.372	16.545	16.717	16.890	17.062	17.235
37	17.407	17.566	17.725	17.884	18.043	18.202	18.361	18.520	18.679	18.838
38	18.998	19.164	19.331	19.498	19.665	19.832	19.999	22.166	20.333	20.500
39	20.667	20.836	21.005	21.175	21.344	21.513	21.682	21.851	22.020	22.189
40	22.358	22.481	22.604	22.727	22.850	22.973	23.096	23.219	23.342	23.465
41	23.588	23.712	23.951	24.064	24.177	24.291	24.404	24.517	24.631	24.744
42	24.857	24.985	25.112	25.240	25.367	25.495	25.622	25.750	25.877	26.005
43	26.132	26.258	26.383	26.509	26.634	26.760	26.885	27.011	27.136	27.262
44	27.387	27.495	27.603	27.711	27.819	27.928	28.036	28.144	28.252	28.360
45	28.468	28.592	28.716	28.839	28.963	29.087	29.210	29.334	29.458	
Area at MDDL of 20.42 m = 0.737 sq. km Area at FRL of 41.15 m = 23.84 sq. km										

Table 3.1 (b) Elevation-capacity as per 2011 survey

Unit : M.Cu.m

Elevation (m)	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
14	0.000	0.000	0.001	0.002	0.003	0.005	0.007	0.010	0.013	0.017
15	0.020	0.025	0.030	0.037	0.044	0.053	0.062	0.720	0.083	0.095
16	0.108	0.122	0.137	0.153	0.169	0.187	0.206	0.225	0.246	0.267
17	0.290	0.313	0.337	0.362	0.389	0.146	0.444	0.473	0.502	0.533
18	0.565	0.598	0.632	0.668	0.705	0.743	0.783	0.824	0.866	0.910
19	0.955	1.001	1.050	1.100	1.152	1.206	1.262	1.320	1.380	1.441
20	1.505	1.570	1.638	1.707	1.779	1.854	1.930	2.009	2.090	2.174
21	2.259	2.348	2.439	2.533	2.631	2.731	2.835	2.941	3.051	3.164
22	3.279	3.398	3.521	3.647	3.777	3.911	4.048	4.189	4.333	4.481
23	4.633	4.788	4.947	5.110	5.277	5.447	5.622	5.800	5.982	6.167
24	6.357	6.551	6.750	6.955	7.165	7.380	7.601	7.827	8.058	8.295
25	8.537	8.785	9.038	9.297	9.561	9.830	10.105	10.386	10.672	10.964
26	11.261	11.564	11.872	12.187	12.507	12.833	13.165	13.503	13.847	14.196
27	14.551	14.912	15.280	15.653	16.031	16.416	16.807	17.203	17.606	18.014
28	18.428	18.849	19.275	19.708	20.148	20.593	21.045	21.504	21.968	22.439
29	22.916	23.401	23.894	24.395	24.905	25.423	25.949	26.484	27.027	27.579
30	28.139	28.708	29.289	29.881	30.484	31.099	31.724	32.461	33.009	33.668
31	34.338	35.021	35.719	36.431	37.158	37.900	38.657	39.428	40.214	41.015

32	41.830	42.662	43.513	44.381	45.269	46.175	47.099	48.041	49.003	49.982
33	50.980	51.998	53.035	54.094	55.172	56.271	57.391	58.531	59.691	60.872
34	62.073	63.294	64.535	65.795	67.076	68.376	69.695	71.035	72.394	73.773
35	75.172	76.589	78.021	79.470	80.934	82.415	83.911	85.423	86.952	88.496
36	90.056	91.633	93.227	94.839	96.467	98.113	99.776	101.457	103.154	104.869
37	106.601	108.350	110.114	111.895	113.691	115.504	117.332	119.176	121.036	122.912
38	124.804	126.712	128.637	130.578	132.536	134.511	136.503	138.511	140.536	142.578
39	144.636	146.711	148.803	150.912	153.038	155.181	157.341	159.517	161.711	163.921
40	166.149	168.391	170.645	172.912	175.191	177.482	179.785	182.101	184.429	186.769
41	189.122	191.487	193.870	196.271	198.683	201.106	203.541	205.987	208.445	210.193
42	213.393	215.886	218.390	220.908	223.438	225.982	228.537	231.106	233.687	236.282
43	238.888	241.508	244.140	246.785	249.442	252.111	254.794	257.488	260.196	262.916
44	265.648	268.392	271.147	273.913	276.689	279.477	282.275	285.084	287.904	290.734
45	293.576	296.429	299.294	302.172	305.062	307.964	310.879	313.806	316.746	

Capacity at MDDL of 20.42 m = 1.822M.Cu.m
Capacity at FRL of 41.15 m = 192.67 M.Cu.m

Note – data from CWC

The above tables 3.1 (a) and 3.2 (b) shows the area and capacity at a particular elevation. These values have taken from the hydrographic survey of reservoir. Geosoft utilities, GRIDVOL and GRIDSTAT have been used to compute capacities and areas at various levels. The elevation- area-capacity curve is drawn from given above two tables 3.1 (a) and 3.2 (b). The following table

2.2 given below shows the elevation-area-capacity values. The table shows the elevation-area- capacity of both Pre-impoundment survey (1990) and other survey (2011).

Table 3.2 Elevation-Area-Capacity

Elevation (m)	Pre-impoundment table supplied by project		Corrected pre-impoundment table		2011 survey	
	Area (sq.km)	Capacity (M.Cu.m)	Area (sq.km)	Capacity (M.Cu.m)	Area (sq.km)	Capacity (M.Cu.m)
10		0.00	0.00	0.00	0.00	0.00
14		0.60	0.078	0.16	0.00	0.00
15	0.098	1.54	0.098	0.25	0.04	0.02
16		1.65	0.18	038	0.14	0.11
17		1.80	0.25	0.60	0.23	0.29
18		3.00	0.45	0.95	0.32	0.57
19		4.20	0.80	1.57	0.46	0.96
20	1.214	6.48	1.21	2.50	0.64	1.51
21		7.80	1.65	3.85	0.87	2.26
22		10.80	2.20	5.77	1.17	3.28
22.50	2.430	12.30				
23		13.80	2.80	8.27	1.53	4.63

24		17.40	3.45	11.40	1.91	6.36
25	4.250	21.89	4.25	15.22	2.45	8.54
26		26.40	5.05	19.85	3.00	11.26
27		32.40	5.85	25.30	3.58	14.55
28		38.40	6.65	31.55	4.17	18.43
29		46.80	7.60	38.67	4.80	22.92
30		54.89	8.60	46.77	5.64	28.14
31		65.40	9.60	55.87	6.76	34.34
32		78.00	10.80	66.07	8.23	41.83
33		91.80	12.00	77.47	10.07	50.98
34		106.80	13.20	90.07	12.11	62.07
35	14.340	116.57	14.34	103.87	14.09	75.17
36		138.00	15.80	118.97	15.68	90.06
37		156.00	17.40	135.57	17.41	106.60
37.50	18.210	165.29				
38		174.60	19.20	153.87	19.00	124.80
39		193.20	20.60	173.77	20.67	144.64
40	22.610	212.15	22.61	195.27	22.36	166.15
41		231.60	24.30	218.62	23.59	189.12
41.15		234.36	24.50	222.28	23.84	192.68

The graph in fig 3.3 given below shows the elevation-area-capacity curve of the above given table 3.2. This graph helps us to find the siltation rate in the reservoir. The capacity at FRL is 192.67 M.Cu.m. The capacity at MDDL of 20.42 m = 1.822 M.Cu.m. From the silt rates calculated from the above curve can be used to estimate the volume of sediments deposited every year in the reservoir. The siltation rate will be in mm/year. The graph in Fig 3.3 shows the elevation-area-capacity curve. The empirical formula provided by CWC is $V_s = KT^{0.66}$. here V_s = total volume sediments deposited in a reservoir, K is the coefficient that was worked out by observing Elevation-Area-Capacity curve and T is the time in years.

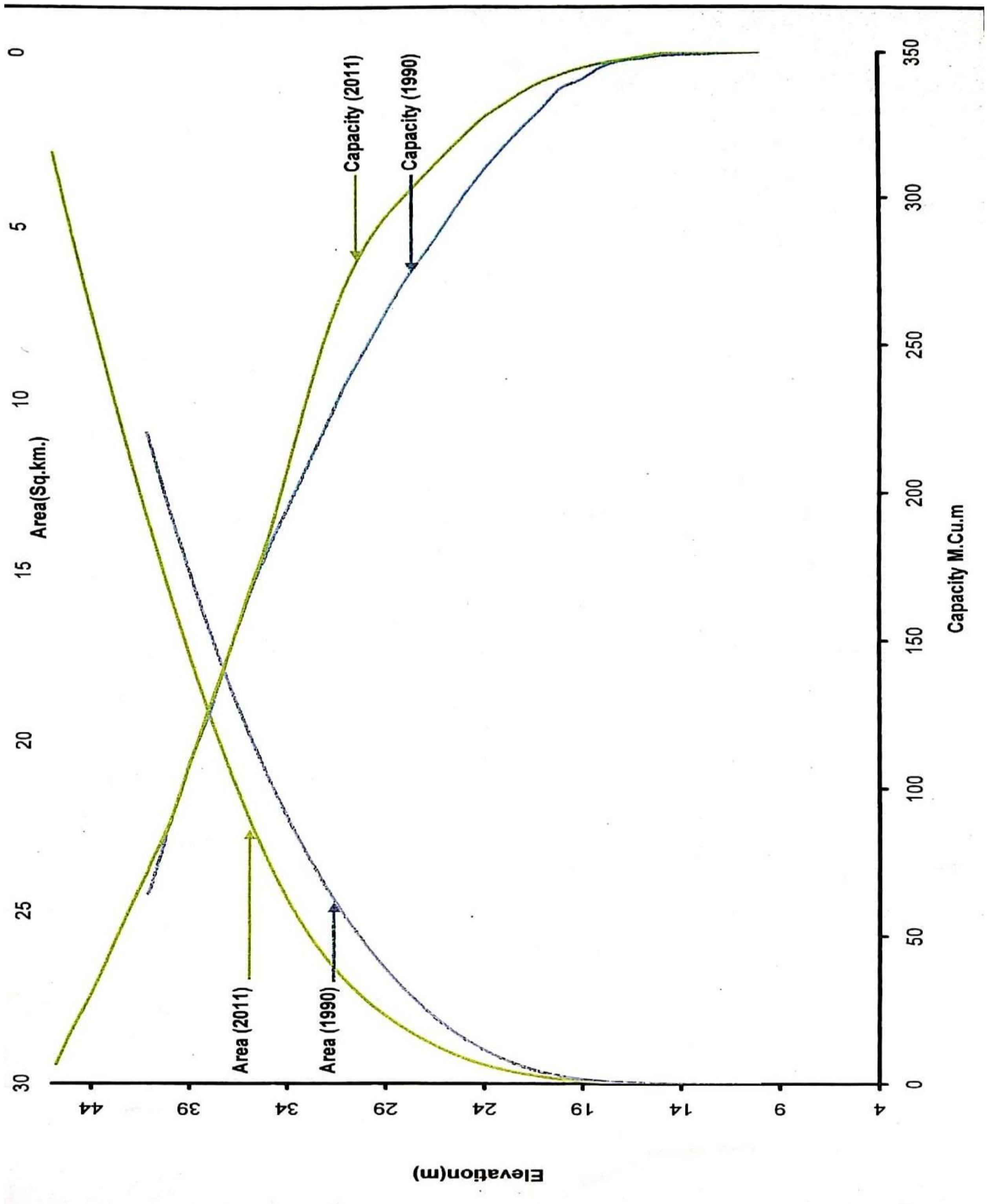

Fig 3.3 elevation-area-capacity curve

(Report of Capacity Survey of Salaulim Reservoir, CWC)

From the above figure 3.3 Elevation-Area-Capacity,

The Capacity at FRL as per pre-impoundment survey 1990	= 222.28 M.Cu.m.
The Capacity at FRL as per 2011 survey	= 192.68 M.Cu.m.
Siltation in 21 years (1990-2011)	= 222.28 – 192.68
	= 29.6 M.Cu.m.
Average Annual Siltation	= 29.6 / 21
	= 1.41 M.Cu.m.
Siltation Rate	= 1.41 * 1000 / 209
	= 6.75 Th. Cu.m/Sq.km/year
	= 6.75 mm/year

Loss of gross storage capacity at FRL in 21 years	= 29.6 M.Cu.m
Percentage loss of Storage Capacity	= 29.6*100 / 222.38
	= 13.32 %
Average percentage loss per year	= 13.32 / 21
	= 0.63 %

3.3 ANN model

ANN modeling is a tool that is widely used in Water Resources in today's world. It works in a similar manner like biological neural system. ANN goes through a learning process. Input layer is connected with weights which resembles strength of connection. Pattern recognition tool is used to generate the input-output relationship that is very useful in water resource. The application of ANN in water resource are rainfall-runoff relationship, precipitation estimation etc. ANN model is a network of neurons which receives one or more inputs and gives the output.

In the present study, a three layered feed forward ANN model was developed. The model uses back propagation algorithm in it. The input layer has 2 inputs name, capacity of reservoir, age of reservoir. There is one hidden layer which has 10 neurons. The neurons in hidden layer are estimated by trial and error procedure. The data of estimated total sediments using formula provided by CWC was taken as target. The ANN architecture developed is shown in Fig. 3.4.

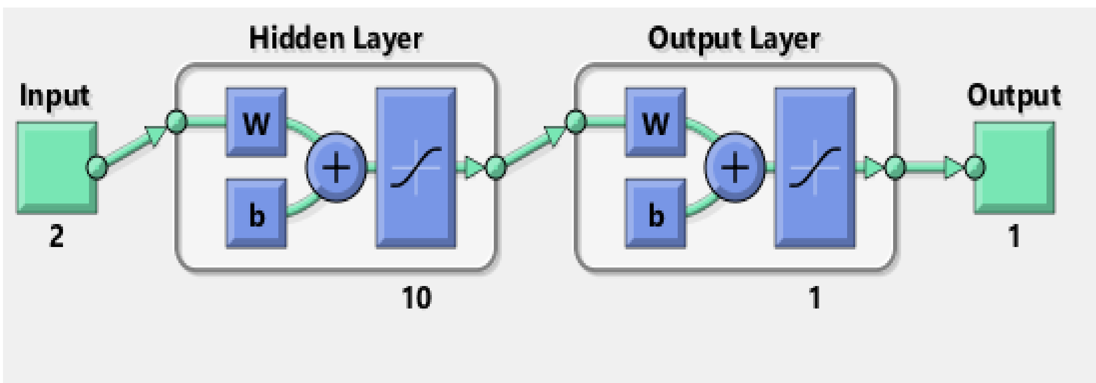

Fig. 3.4 ANN architecture

The data sets were trained using LM training process. Spit sample approach was used to train, test and validate the data sets. In this approach 70 % of data sets are used for training and remaining 30 % data sets are used in testing and validating. The training process stops when MSE error is 0.01. The transfer function that is used in this ANN model developed is sigmoid function. The results of ANN model is discussed in next chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results from above methodology

The table 4.1 given below gives us the results of volume of sediments deposited in the Salaulim Reservoir in each year. There are results of total sediments deposited in a reservoir estimated with the help of siltation rates calculated in Chapter 3. Table 4.1 shows the total sediments deposited in the reservoir using the empirical formula given in the report of Salaulim Reservoir provided by CWC. Table 4.1 shows the results got from ANN model.

Table 4.1 Results of Total sediments deposited in each year

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Time (year)	Age of reservoir (Year)	Reservoir Capacity (M.Cu.m)	Estimated Total sediments deposited (Siltation rates) (M.Cu.m)	Estimated total sediments deposited ($V_s= KT^{0.66}$) (M.Cu.m)	Estimated Total sediments deposited (ANN model) (M.Cu.m)
1990	00	222.28	0.00	0.00	0.0000
1991	01	220.87	1.41	3.97	5.0975
1992	02	219.46	2.82	6.27	6.5764
1993	03	218.05	4.23	8.20	8.2180
1994	04	216.64	5.64	9.91	9.6911
1995	05	215.23	7.05	11.48	11.1737
1996	06	213.82	8.46	12.95	12.7259
1997	07	212.41	9.87	14.34	14.1603

1998	08	211.00	11.28	15.66	15.4654
1999	09	209.59	12.69	16.93	16.7324
2000	10	208.18	14.10	18.15	18.0281
2001	11	206.77	15.51	19.23	19.2722
2002	12	205.36	16.92	20.47	20.4483
2003	13	203.95	18.33	21.58	21.5927
2004	14	202.54	19.74	22.66	22.6945
2005	15	201.13	21.15	23.71	23.6997
2006	16	199.72	22.56	24.75	24.6351
2007	17	198.31	23.97	25.76	25.7530
2008	18	197.00	25.28	26.75	26.9778
2009	19	195.49	26.79	27.72	28.0211
2010	20	194.08	28.20	28.67	28.6753
2011	21	192.67	29.61	29.61	29.0390

The above table 4.1 shows the total amount of sediments deposited in the Salaulim Reservoir. There are different methods and formulas used to estimate the Sediment deposition. In table 4.1 column 4 shows the total amount sediments estimated with the help of average siltation rates in 20 years of Salaulim reservoir. Column 5 shows the amount of e total sediments deposited in the Salaulim Reservoir estimated by the formula provided in the Salaulim Reservoir project report. Column 6 shows the amount of total sediments deposited in the Salaulim reservoir estimated using ANN model developed.

4.2 Regression analysis in Column 3, 4 and 5

Comparison of results from all the methods and formulae given above is done using regression analysis. ANN model results are compared with results got from formulae $V_s = KT^{0.66}$. Results of this formulae are compared with the results got from siltation rates. The analysis is shown with the help of the graph in fig. 4.1 and Fig 4.2.

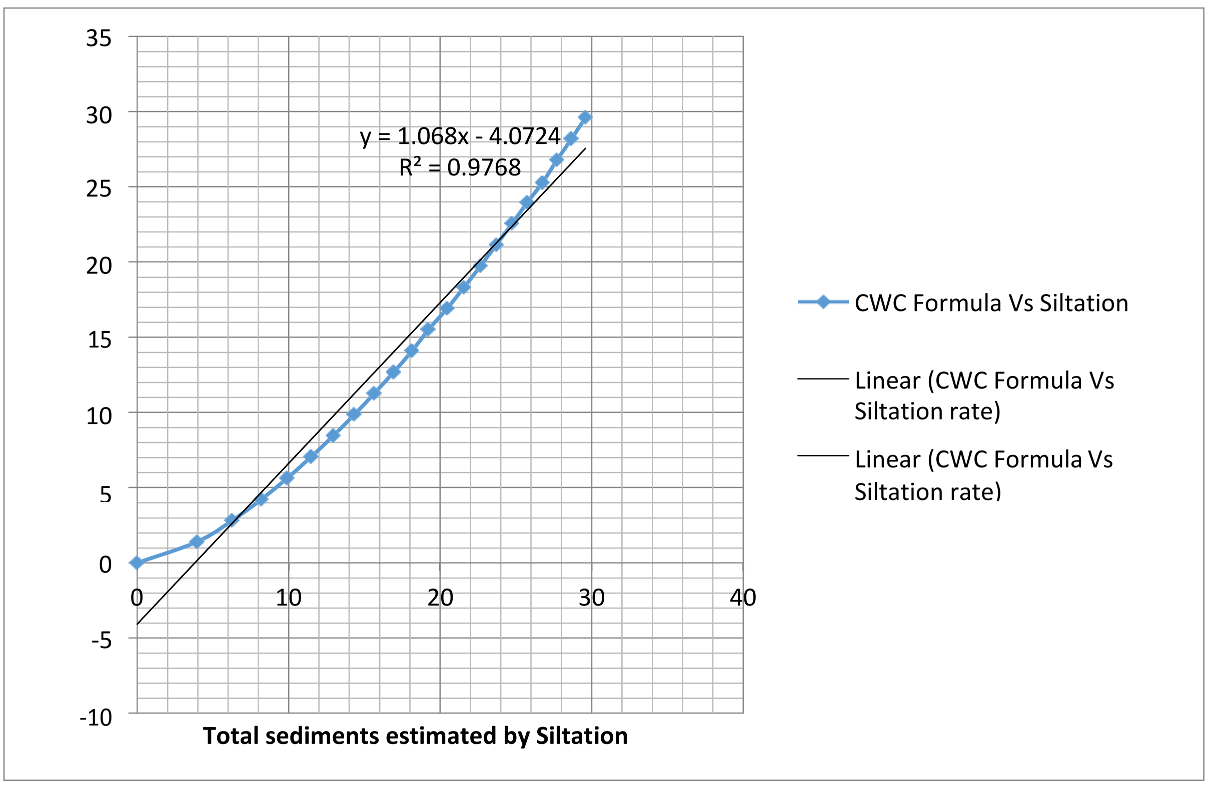

Fig 4.1 Comparison between Total sediments deposited using CWC formulae and Siltation rates

The above fig. 4.1 shows the comparison between the total sediments deposited in the Salaulim Reservoir estimated using formula in the report of Salaulim Reservoir, Goa provided by CWC. The coefficient of R^2 = 0.976 as shown in Fig. 4.1. According to this graph there is a very less deviation in both the results. From the value of R^2 the deviation is 2.4 %.

Again the comparison has been done between the results got from the formula $V_s = KT^{0.66}$ and the results from ANN model. The analysis is shown in Fig. 4.2. The graph of regression coefficient is given below.

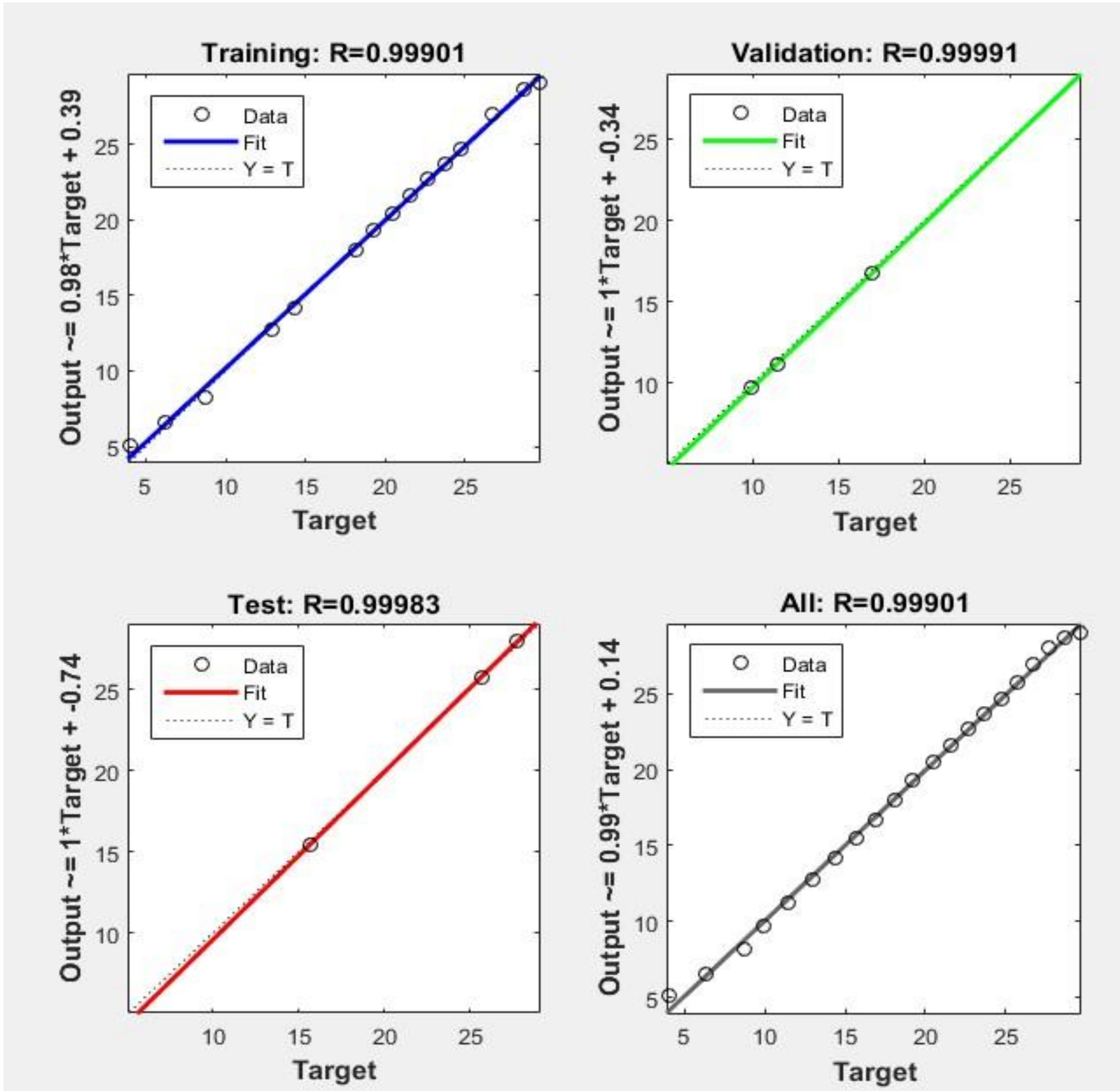

Fig 4.2 Comparison between Estimated Total sediments using ANN model and CWC formula

The above figure 4.2 shows the comparison between the results from ANN model and total amount of sediments deposited in the reservoir estimated using CWC empirical formula. The above figure shows the regression coefficient value for training of data sets, testing of data sets and validating of data sets. The value of R^2 = 0.998 for training of data sets. The value of R^2 = 0.9998 for validating of data sets. The value of R^2 = 0.9996 for testing of data sets. The overall value of R^2 = 0.9998. The deviation in the analysis 0.02 %.

4.3 Estimation of useful life of reservoir

From the formula $V_s = KT^{0.66}$ provided in the report of Salaulim Reservoir, the reduction in the capacity is estimated until the reduction in capacity reached the half of the effective live storage capacity. As we all know that the reservoir will become inefficient when the reduction in capacity will reach up to half the effective live storage capacity.

Live storage capacity as per 2011 survey	= 219.214 M.Cu.m
Capacity at MDDL as per 2011 survey	= 1.822 M.Cu.m.
Effective Live storage as per 2011 survey	= 217.392 M.Cu.m.
Half of the effective live storage as per 2011 survey	= 108.696 M.Cu.m

The fig. 4.3 shows the graph of estimated useful life of reservoir and the reduced capacity according to age of reservoir.

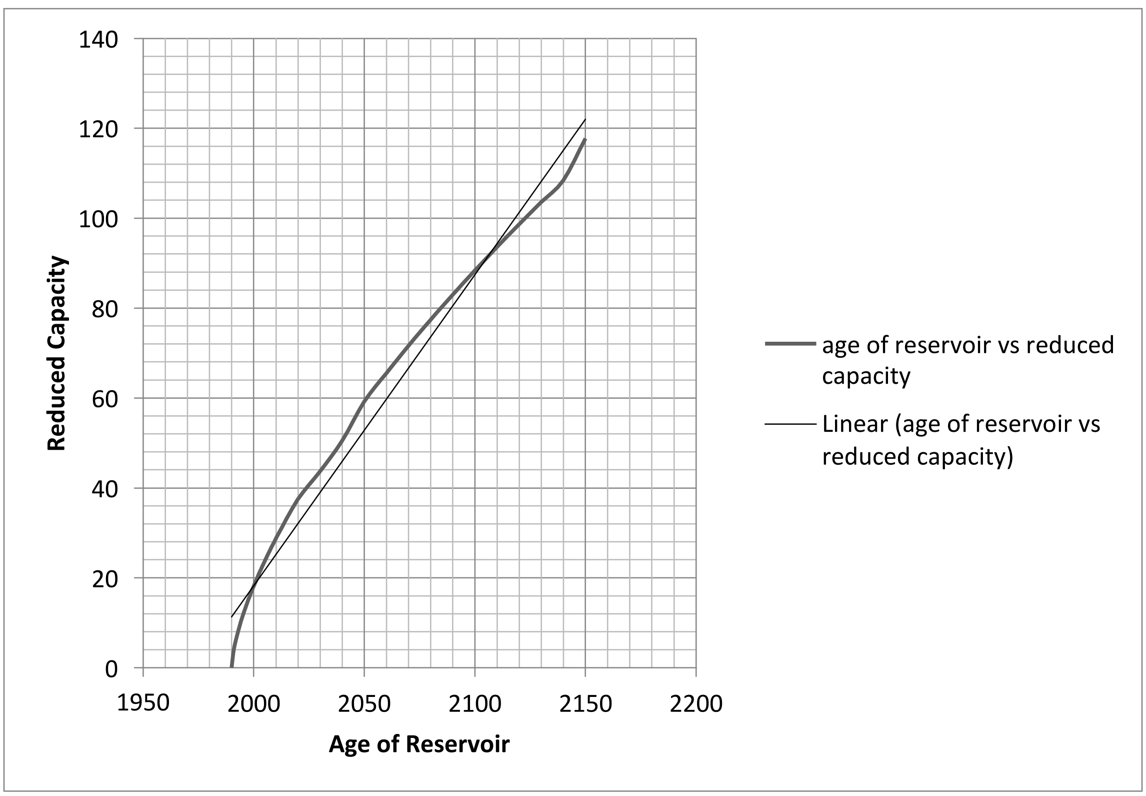

Fig. 4.3 Estimation of useful life of reservoir

The fig. 4.3 given above gives us the estimation of useful life of reservoir. The graph in the above figure 4.3 shows the reduction in capacity of reservoir according to the age of reservoir. The estimated life of Salaulim reservoir is 150 years. After 150 years the reservoir will become inefficient because the volume of estimated sediments deposited in a reservoir is equal to the half of the effective live storage capacity. The reduced capacity in 150 years is equal to 108.39 M.Cu.m. The half of the effective live storage is 108.696 M.Cu.m calculated above.

The results from all methods given above used for the estimation of total sediments deposited in a reservoir gave nearby results with each other. The regression coefficient from ANN model is 0.998 which shows very high co linearity with results got from CWC formula. The regression coefficient from volume of total sediment deposited in a reservoir by siltation rate is 0.976 which shows very less co linearity with formula given in CWC report.

ANN results are closer to the results got from CWC formula. ANN can solve the complexity very easily. CWC formula given in Salaulim Reservoir report $V_s = KT^{0.66}$ depends only on age of reservoir. ANN model has two inputs namely reservoir capacity and age of reservoir. ANN model is faster than other methods.

CHAPTER 5

CONCLUSION

From above all results ANN model can solve complex problems. It is a faster method to estimate volume of total sediments. It yields more accurate results than volume of total sediments estimated by siltation rates. The total volume of sediments deposited in a Salaulim Reservoir, Goa is 29.61 M.Cu.m in 21 years. The annual siltation rate of the Salaulim reservoir is 6.75 mm/ year. The live storage of Salaulim reservoir is 190.858 M.Cu.m. The effective live storage of Salaulim Reservoir is 189.036 M.Cu.m. The loss in the Gross Storage capacity of Salaulim Reservoir at FRL in 21 years is 29.6 M.Cu.m. The percentage loss of gross storage at FRL is 0.63 %.

It was estimated that the useful life of a reservoir estimated is 150 years. The reduction in reservoir capacity decreases with increase in the age of reservoir. There can be a variation in estimated useful life of reservoir because loss in capacity depends upon the sediments deposited as well as evaporation taking place in a reservoir. There can be a variation in a trend of deposition of sediments. The evaporation may variate from the current period. It may increase or decrease.

The ANN model is fast gives more accurate results and can solve the complex problems in short time. Ann model yields better results which are very close to the results got from formula given by CWC. The volume of total sediments calculated from siltation rate gives a uniform amount of sediments deposited each year which may not be possible. Therefore, ANN model is best to estimate the volume of total sediments.

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