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Stream Flow Forecasting By Artificial Neural Network

[1]Onkar Popat Mule, [2]VIvek Vikas Honbute, [2]Sumit Sunil Pawar, [2]Mayur Dilip Chakhale, [2]Prof. A. R. Bansode

[1]Assistant Professor, [2]Research Scholar

[1]Department of Civil Engineering,

[1]Zeal College of Engineering & Research, Pune, India

Abstract:

This Forecasting stream flow in advance is very essential in hydrology such as any water operation and planning. Artificial Neural Network (ANN) recently applied to hydrological related areas. ANN has proven best alternative to convention methods.

This study presents the application of artificial neural network to streamflow prediction of stations namely Budhwad in Pune District in Maharashtra, India. In India monsoon occurs only in June to October therefore only June to October data is used for the study. Due to variation in flow in each month therefore separate models are prepared for each month. ANN models developed with four training algorithms namely Levenberg-Marquardt (LM), Conjugate Gradient Function (CGF), Quasi-Newton's back propagation (BFG) and Gradient Descent (GD). The Results from different algorithms are compared with each other.

Extreme flow prediction is universal problem to ANN. To overcome this problem one technique is implemented and found to be satisfactory in extreme flow prediction.

I. INTRODUCTION

Water is one of the most basic and precious resource of all living things.This source is becoming scarce day by day due to increase in demands in various sectors. Water resource projects are implemented and operated with purpose of making water available for various purposes in sufficient quantities. The availability of water on earth is varying with time and places. Therefore prediction of availability water is one of most important job for hydrologist.

Forecasting a river flow provides a warning of impending stages during floods and assists in regulating reservoir outflows during low river flows for water resources management. An important probe in hydrology is how much stream flow occurs in a river in response to given amount of rainfall. To answer this probe we need to know where water goes when it rains, how long does water exist in a watershed and what pathway does water take to the stream channel. These are the probe addressed in rainfall-runoff processes. A rainfallrunoff model is a mathematical model describing the rainfall-runoff relations of a catchment area, drainage basin or watershed. A rainfall-runoff model can be really helpful in the case of calculating discharge from a basin. The transformation of rainfall into runoff over catchment is known to be very complex hydrological phenomenon as this is highly non-linear, time varying and spatially distributed.

In the present study of stations namely Budhwad in Pune District in India are selected as the case study. The modelling being simulated by Artificial Neural Network (ANN) with different types of training algorithms and results have been compared at the end. Recently Artificial Neural Network (ANN) have been introduced in hydrology related areas such as rainfall-runoff modelling, stream flow forecasting, groundwater modelling, water quality, water management policy, precipitation forecasting (ASCE 2000).

1.2 Rainfall- Runoff processes

One of the most important processes in the hydrological cycle is transformation of rainfall into runoff. The transformation of rainfall into runoff over a catchment is complex hydrologic phenomenon due to under lying subprocesses. Singh (1988) illustrate in simplified manner as shown in Figure No-1. The hydrological cycle has no beginning or end and many processes occur continuously.

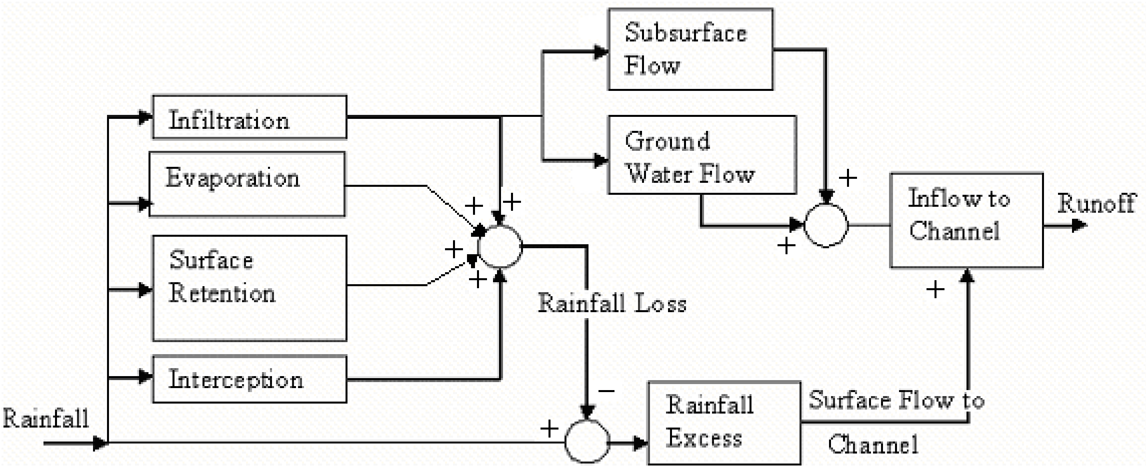

Figure No -1 Rainfall-runoff over a catchment (Singh 1988) The Following processes takes place over catchment when rainfall occurs:

Interception: - A part of rainfall held back on the leaves of plant and building top later gets evaporated and back to the atmosphere.
Surface Retention: - Some portion of rainfall that gets stored in the depression or retained under the vegetal cover is known as surface retention.
Overland flow: - It is the part rainfall, which flows over the ground and meets the stream through gullies and rivulets.
Infiltration: - It is the part of rainfall that immediately enters the soil surface, a portion of which is transpired into the atmosphere through the deep rooted plants and remaining follows the subsurface flow.
Soil moisture: - A portion of the infiltrated water is retained in the upper layer of the soil. Later a part of this is evaporated and remaining part is transpired atmosphere through the plants.
Inter flow: - Another portion of infiltrated water moves towards stream without reaching the ground water table and this called interflow.
Base flow: - Some part of infiltrated water meets the ground water table. A portion this ground water moves towards the stream and seeps into it through the banks and beds and thus it also become runoff water under favourable conditions called as base flow.
Evapo-transpiration: - It is the part of rainfall removed from soil by evaporation and plant transpiration.
Runoff: - The part of the precipitation, snowmelt or irrigation water that is not absorbed by the soil and flows to lower ground eventually draining into a stream, river or the body of water.

1.3 Modelling of rainfall-runoff processes:-

Rainfall-runoff models are assigned to one of the three broad categories (C.W.Dawson and R.L.Wilby).

1) Deterministic (physical) model :-

Deterministic model describe the rainfall-runoff process using physical laws of mass and energy transfer.

2) Conceptual model :-

Conceptual model provides simplified representation of key hydrological process using a perceived system (such as series of interconnected stores and pathways).

3) Parametric model :-

Parametric model use mathematical transfer function (such as multiple linear regression equation) to relate meteorological to runoff.

Hydrological models are further classified as either lumped or distributed. Lumped models treat the catchment as a single unit. They provide no information about the spatial distribution of inputs and outputs, and simulate only the gross, spatially averaged response of the catchment. Conversely, distributed models represent the catchment as a system of interrelated subsystems- both vertically and horizontally.

According to these criteria, artificial neural networks (ANNs) should be classified as parametric models that are generally lumped. This is because neural network engineers regard the rainfall-runoff process as a black box system with inputs and outputs. Consequently, ANN usage does not presuppose a detailed understanding of a catchment's physical characteristics, nor does it require extensive data pre-processing.

II. RESEARCH METHODOLOGY

2.1 Study area and Data

The rainfall and runoff data of stations namely Budhwad are used for study. Station located in Pune district in Maharashtra state in India. Figure No -2 shows the location of stations. The details of case study are given in Table No-1

Table No-1 Case study location

Station Name	District	Taluka	Basin	River	Tributary	Stream
Bushwad	Pune	Maval	Krishna	Krishna	Bhima	Kundalika

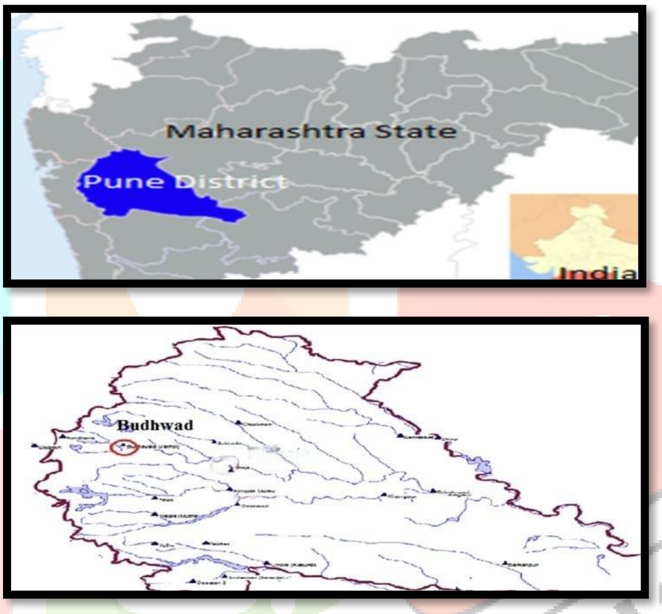

Figure No-2 Map showing case study

In India Monsoon occurs only in five months .i.e. from June to October. Therefore data from June to October is used for the study. For Budhwad data from 1994 to 2007 is used for the present study.

Table No 2- Statistical properties of rainfall (mm) data at Budhwad station.

	BUDHWAD
Mean	20.50
Minimum	0
Maximum	365.6

Table No 3- Statistical properties of runoff (m3/sec) data at Budhwad station.

	BUDHWAD
Mean	14.13
Minimum	0.00579
Maximum	259.0252

The statistical properties such as mean, standard deviation, variance, kurtosis, skewness, minimum, maximum for different months estimated from the 14 year of historical data for rainfall and runoff is presented in Table No- 2 and Table no-3.

Maximum and Minimum Rainfall at Budhwad

Maximum: - 259.0252

Minimum: - 0.00579

Maximum and Minimum Runoff at Budhwad

Maximum: - 259.0252 m3

Minimum: - 0.00579 m3

Table No 4- Statistical properties of runoff (m3/sec) data at Budhwad station.

	BUDHWAD
Mean	14.13
Minimum	0.00579
Maximum	259.0252

The statistical properties such as mean, standard deviation, variance, kurtosis, skewness, minimum, maximum for different months estimated from the 13 year of historical data for rainfall and runoff is presented in Table No- 4 and Table no-5. 7-1996.

2.2.1 Definition:-

Artificial Neural Network (ANN) is a mathematical model or computational model that is inspired by the structure and functional aspects of biological neural networks. An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurones) working in unison to solve specific problems. An ANN is structured to resemble the biological neural network in to two

aspects:

1) Knowledge acquisition through a learning process
2) Storage of knowledge through connections, known as synaptic weight.

2.2.2 Biological Neuron:-

From the neurophysiology, it is know that the human brain contains a massively interconnected net of 1010 to 1011 neurons. Each of the neurons is connected to 103 to 1014 dendrites further down. A very simplified schematic view of a biological neuron is shown in Figure No -3. A typical cell has three major regions – the cell body which also called as the soma, the axon and the dendrites.

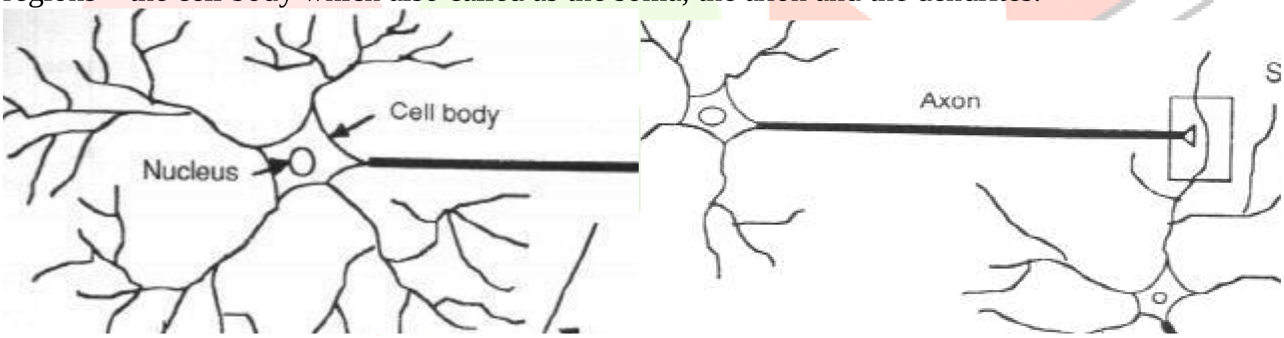

Figure No- 3 Components of Neuron

Much is still unknown about how the brain trains itself to process information, so theories abound. In the human brain, a typical neuron collects signals from others through a host of fine structures called dendrites. The neuron sends out spikes of electrical activity through a long, thin stand known as an axon, which splits into thousands of branches. At the end of each branch, a structure called a synapse converts the activity from the axon into electrical effects that inhibit or excite activity from the axon into electrical effects that inhibit or excite activity in the connected neurones. When a neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapses so that the influence of one neuron on another changes.

2.2.3 Artificial Neural Network:-

Artificial Neural Networks (ANN) consists of a large number of simple processing elements called neuron or node. Each node is then connected to other node by means of connection link. Each link is associated with a weight that represents the strength of outgoing signal. ANN is composed of three layers of function. They consist of an input layer, a hidden layer, and an output layer. The hidden layer may consist of several hidden layers as shown in Figure 4.

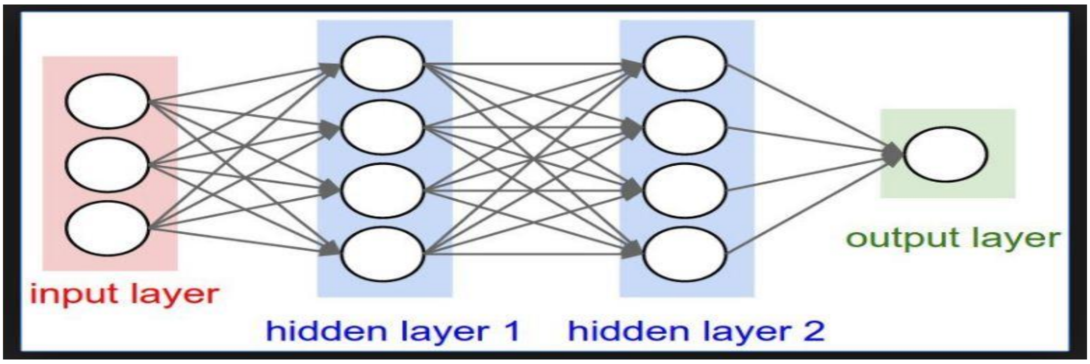

Figure No-4 Artificial Neural structure

In most networks, the input layer receives the input variables for the problem at hand. This consists of all quantities that can influence the output. The input layer is thus transparent and is a means of providing information to the network. The last or output layer consists of values predicted by the network and thus represents model output. The number of hidden layers and number of nodes in each hidden layer are usually determined by a trial and error procedure. (ASCE 2000)

III. RESULTS AND DISCUSSION

3.1 Results for Budhwad:-

3.1.1

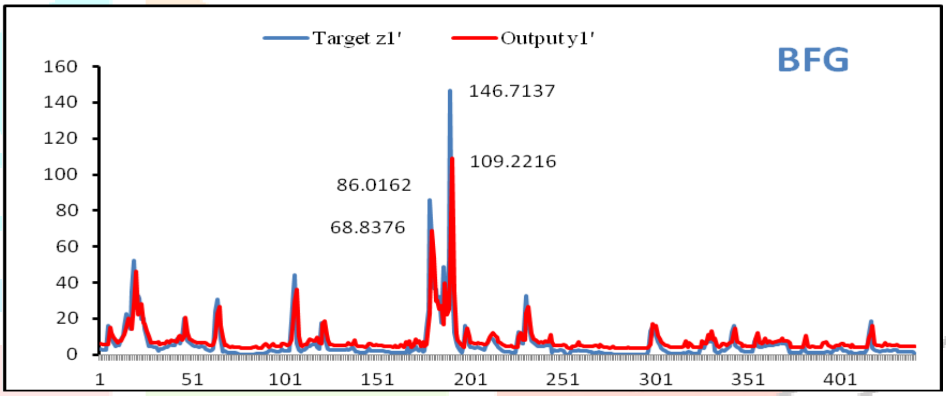

Figure 5-Plotting of 1 day ahead forecasting for the testing period for using ANN-BFG

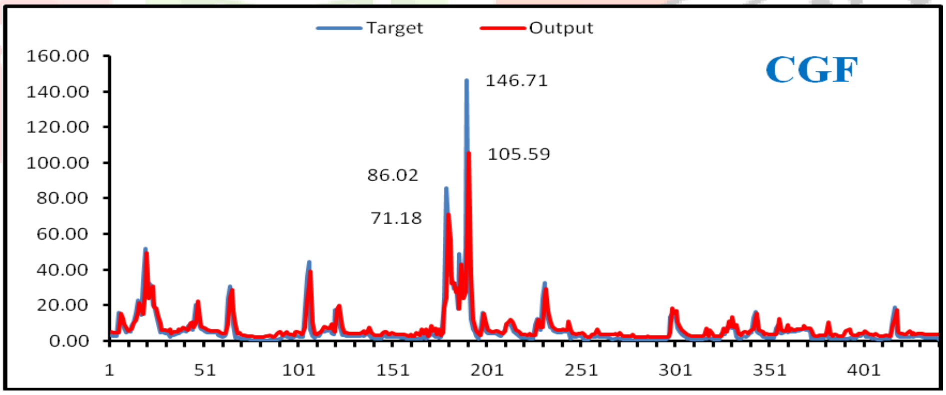

Figure 6 -Plotting of 1 day ahead forecasting for the testing period for using ANN-CGF

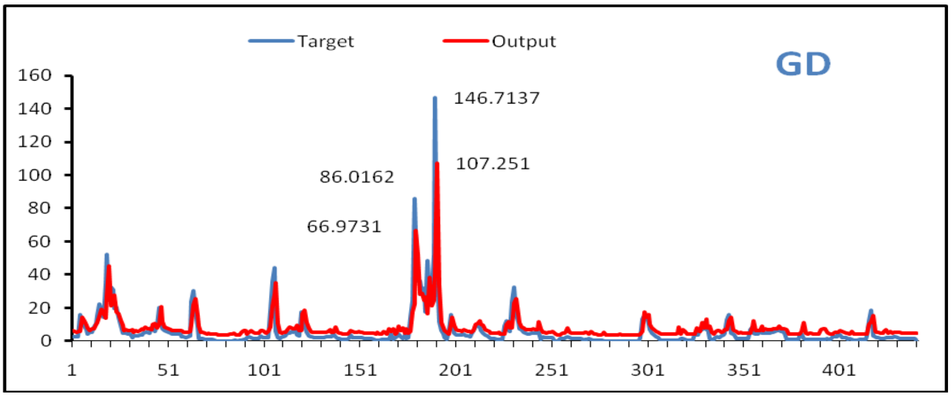

Figure 7 -Plotting of 1 day ahead forecasting for the testing period for using ANN-GD

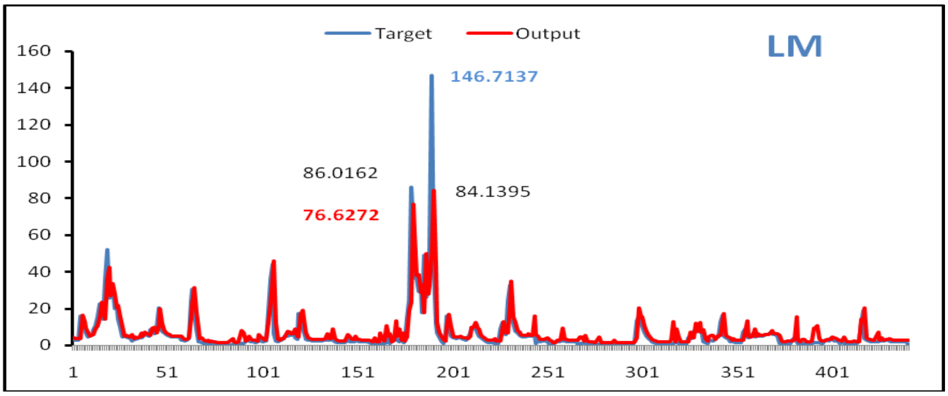

Figure 8 -Plotting of 1 day ahead forecasting for the testing period for using ANN-LM

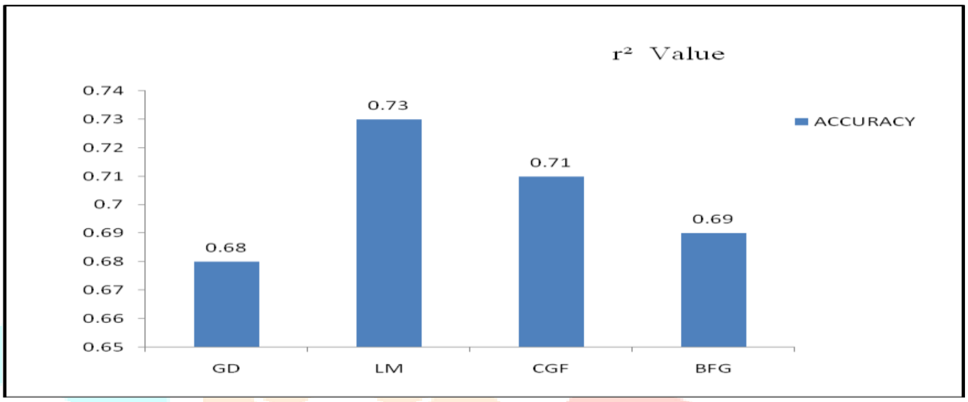

Figure 9 – Correlation Value

One day ahead forecasting for the testing period of all models. The maximum observed flow is 91.17m3/sec. The maximum predicted flow measured by LM model, CGF model, BGF model and GD model are 82.21m3/sec, 86.58 m3/sec, 80.15 m3/sec, and 50.32 m3/sec respectively. It can be seen from figures predicted hydrographs follows trend of observed hydrograph systematically and LM, CGF, BFG perform better in extreme flow prediction as compared to GD model. Figure no. 21 shows the scatter plots of all June models. It can be seen from Figure no. 21 all models perform better, because coefficient of correlation 'r' is above 0.9. only GD is under prediction.

Table No 5- Comparison of statistical parameters

Statistical Parameter	**Training set**	**Testing set**
Mean	8.17	4.548
Minimum	0.2115	0.297
Maximum	146.7137	18.9917

3.1.7 Comparison of Epochs:-

Table No 6 -Comparison of Epochs.

Model	**Epochs**			
	LM	**CGF**	**BFG**	**GD**
budhwad	1000	5000	4000	70000

It can be seen from Table No-24 Gradient descent (GD) required high number of iteration and time. Levenberg and Marquardt (LM), Conjugate gradient function (CGF) and Newton back propagation (BFG) are required less iteration as compared with Gradient descent (GD).

3.1.8 Comparison of Maximum Observed flow with Maximum Predicted flow

It can be seen from Table No-25 the accuracy Conjugate gradient function (CGF) is better in extreme flow prediction. For Levenberg and Marquardt (LM) is perform better in extreme flow prediction.

Table No 7 -Comparison of Maxi. Observed flow with Maxi. Predicted flow.

	Maxi. Observed Flow (m^3/sec)	Maxi. Predicted Flow (m3/sec)			
		LM	CGF	BFG	GD
budhwad	146.7113	84.13	105.59	109.22	107.25

3.1.9 Comparisons of Root mean squared error and Coefficient of efficiency.

Table No-8 Comparisons of Root mean squared error and Coefficient of efficiency.

Model	RMSE				CE			
	LM	CGF	BFG	GD	LM	CGF	BFG	GD
budhwad	3.76	3.56	3.34	5.56	0.9	0.92	0.92	0.77

It is observed from Table No-26 RMSE is minimum and CE is maximum models with Newton back propagation algorithm. For September Levenberg and Marquardt (LM) has minimum RMSE and maximum CE. For October Conjugate gradient descent (CGF) has minimum RMSE and maximum CE.

IV. CONCLUSION

The potential of different ANN algorithms are investigated in daily streamflow forecasting. The data of stations namely Budhwad is used for the case study. The results indicated that the Levenberg - Marquardt (LM) performs better as compared to other algorithms. Conjugate gradient function (CGF) also performs better as compared to Newton back propagation (BFG) and Gradient descent algorithm. Gradient descent algorithm takes high number of iteration and time as compared to other algorithms. Levenberg and Marquardt (LM) and Conjugate gradient descent (CGF) are best in extreme flow prediction.

All models perform better except September model in cases. Because statistical parameter (.i.e. mean, Standard deviation, Variance, Kurtosis, Skewness, Minimum, Maximum) values of testing set are greater than that of training set. This may be reason for the poor performance of September model in both cases.

The extreme flow prediction is universal problem for artificial neural network. If testing set contains maximum value of discharge than that of training set then ANN will not predict that maximum discharge because network only trained for maximum value of discharge in training set. The study also indicated that if maximum discharge value in testing set is used in training set then ANN can predict extreme flow and also perform better.

V. REFERENCES

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