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Generation of Monthly Inflows using Log-Normal Model

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Abstract—*Log Normal Distribution Model was developed to generate monthly inflows of the two reservoirs Maithon and Panchet of Damodar Valley Corporation system. This provides alternative yet equally likely flow sequences to the historical one in terms of some statistical parameters. The 20 years inflow records of reservoirs Maithon and Panchet were used to generate synthetic sequences. Characteristics of the generated series and their resemblance with the parent or historic series are examined through mean, standard deviation, lag-1serial correlation and their absolute error which are well preserved by this data generation technique for the historic series.*

Index Terms*: Streamflow, Panchet, Maithon, Log-Normal Distribution.*

1. INTRODUCTION

Streamflow generation techniques are very important in planning, design and operation of water resources projects. They are used to provide alternate flow sequences to the historical one in terms of statistical parameters. The largest historic sequence available may not span more years than the systems economic time horizon. Therefore the historic sequences can provide, only one response in most cases. Synthetic stream flow generation is required to understand the transformation of precipitation to runoff, in order to forecast streamflow to optimize the system, or, to plan for future expansion or reduction. In this study, monthly stream flows are generated using Two Parameter Log Normal Distribution.

Work on streamflow generation started with that of Hazen in 1914, who obtained an extended sequence by combining the annual flows from fourteen individual streams. The most significant contribution started with the model of Thomas and Fiering in 1962. To generate multivariate synthetic sequences that will resemble multivariate historic sequences in terms of mean, standard deviations, skewness, lag-one serial correlation, and lag-zero cross-correlations, a multi-variate, weakly stationary process was used by N.C Matalas[4]. Techniques of regionalisation and maximum likelihood estimates were used to minimize the biases associated with the estimates of the parameters that characterize historic sequences.T.A. Mcmahan and A.J. Miller [5] applied the Thomas Fiering model to skewed hydrologic data and noted an inconsistency in the transformation to modify random normal variates to random skewed variates used in the model. This procedure appreciably reduces the skewness, thus allowing the transformation to generate within the limits of its consistency. Charles T. Haan in 1972 showed that regardless of the type of probabilistic model used there are two main sources of error, an incorrect model; and incorrect parameter estimates for an otherwise correct model. [3]. Jose M. Mejia and Ignacio Rodriguez Iturbe in 1974 showed that when the lognormal historical process is assumed to follow a Markovian Scheme, its correlation can be well preserved by generation through a normal ARMA (1, I) process. [6]. R. Stedinger, in 1980 demonstrated that use of maximum likelihood parameter estimation dominated other methods for fitting the two-parameter lognormal distribution for samples of 25 or more log normal varieties. [7]. In 1982, Ratnasingham Srikanthan and Thomas A. Mcmahon compared the performances of two streamflow generation models. In one model, seasonalities and periodicities in the monthly flows were removed and the resulting weekly stationary series was modeled [8]. The second approach used the Thomas Fiering monthly model. For highly variable streams, logarithmic transformations of the data were not satisfactory as they resulted in extremely large flows. The TF monthly model preserved the seasonal monthly parameters for all the streams but gave smaller storage estimates than the historical values. The proper model and the method of fragments gave improved storage estimates that preserved the annual parameters. Even though all the models gave similar results for the overall parameters for the less variable streams. In 1988, Richard M. Vogel and Jery R. Stedinger used stochastic streamflow models and synthetic streamflow sequences for the design of storage reservoirs and compared them with design-capacity estimates using historical streamflow records [9]. Their experiments gave the bias and root-mean-square error of estimates of overyear required storage capacity distribution quantiles corresponding to fix or to random levels. The results showed that the use of stochastic streamflow models led to improvements in the precision of reservoir design capacity estimates. According to the authors, the estimates of the design capacity of a storage reservoir based upon relatively simple stochastic streamflow models have smaller root-mean-square errors than corresponding estimates based only on historical record.

The stochastic stream flow models are also useful for generating long sequences multisite streamflow to help refine estimates of the distribution of a whole set of system performance that are required in reservoir system planning or operation studies. These models are particularly valuable in the evaluation of alternative multi-reservoir operating strategies when the number of policy variables exceeds the variety of circumstances and challenges presented by a single historical streamflow record.

2. STUDY AREA

Damodar Valley Corporation (DVC) reservoir system is a multipurpose multi-reservoir system in India which was constructed in two phases to provide 3600 Mm^3 of flood storage and 2800 Mm^3 live storage capacity. In the first phase, four reservoirs: Konar, Tilaiya, Panchet and Maithon and a barrage at Durgapur, were constructed. Konar and Panchet were constructed on river Damodar whereas Tilaiya and Maithon were constructed on the river Barakar, a tributary of the Damodar River as shown in Fig. 1.

Panchet Dam was the last of the four multi-purpose dams included and opened in 1959. Panchet Dam has been constructed a little above its confluence with the Barakar. The Panchet Dam is an earthen dam with concrete spillway. The reservoir taps a catchment area of 10,961 square kilometres. Maithon dam was specially designed for flood control and generates 60,000 kW of electric power. The lake is spread over 65 square kilometers.

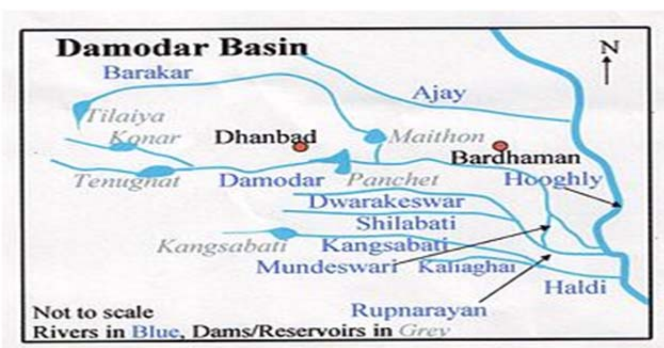


Fig. 1: DVC Reservoir System

3. METHODOLOGY

A stochastic model is one whose outputs are predictable only in a statistical sense. With a stochastic model, repeated use of a given set of model inputs produces outputs that are not the same but follow certain statistical patterns. This type of model might be appropriate for generating a synthetic record of flood peaks. The stochastic model is used as the purpose of streamflow generation is to design the water resources system for operation in future. Here Two Parameter Log Normal Model is used among different other model because of the ease with which observed flows can be transformed to normally distributed random variables and with which generated normal random variables can be converted to synthetic flows. In this study, the inflow records of the two reservoirs of DVC system were used to generate monthly synthetic streamflow sequences.

3.1 Two Parameter Log Normal Distribution

In this procedure, the generation is to be done by transforming the data to the logarithms of the data as $Y=l_n(x_i)$. Thus the generation model is given by as

$$Y_{i+1} = \mu_y + \rho_y^{(1)}\left(Y_i - \mu_y\right) + t_{i+1}\sigma_y\sqrt{1-\rho_y^{(1)^2}} \qquad (1)$$

Where $\boldsymbol{\mu_y}$, $\boldsymbol{\rho_y^{(1)}}$ & $\boldsymbol{\sigma_y}$ are the mean, first order serial correlation, and standard deviation of the logarithms of the original data which are related to the parameter x through the following equation,

$$\mu_x = \exp\left(\sigma_y^2/2 + \mu_y\right) \qquad (2)$$

$$\sigma_x^2 = \exp\left[2\left(\sigma_y^2 + \mu_y\right)\right] - \exp\left(\sigma_y^2 + 2\mu_y\right) \qquad (3)$$

$$\gamma_x = \left[\exp\left(3\sigma_y^2\right) - 3\exp\sigma_y^2 + 2\right] / \left[\exp\left(\sigma_y^2\right) - 1\right]^{3/2} \qquad (4)$$

$$\rho_x^1 = \left[\exp\left(\sigma_y^2\rho_y^1\right) - 1\right] / \left[\exp\left(\sigma_y^2\right) - 1\right] \qquad (5)$$

Where $\mu_x, \sigma_x^2, \gamma_x$, and ρ_x^1 are the mean, standard deviation, co-efficient of skewness and first order serial correlation of the original data.

3.2 Evaluation of Statistical Parameters

The computer programming for Two Parameter Log Normal Distribution consists of separate programs of monthly flows. All the programs have been written in FORTRAN-77 and Subroutines for the calculation of the statistical parameters have been taken from IMSL.

The input consists of the inflow record of 20 years (1961-1980) from the Damodar Valley Corporation for two reservoirs Maithon and Panchet and the output data consists of the statistical parameters of the historic & synthetic sequences generated by the Two Parameter Log Normal Distribution for monthly models for the two reservoirs of the DVC system. But for data generation in Two Parameter Log Normal Model we have taken the following equations after derivation for calculating the parameter μ_x, σ_x, μ_y, σ_y, ρ_y^1 & γ_x for computer programming.

$$\mu_x = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{6}$$

$$\sigma_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \mu_x)^2} \tag{7}$$

$$\mu_y = \ln(\mu_x) - (\sigma_y^2)/2 \tag{8}$$

$$\sigma_y = \sqrt{\log\left[\frac{\sigma_x^2}{\exp\{2\ln(\mu_x)\}} + 1\right]} \tag{9}$$

$$\rho_y^1 = \frac{1}{\sigma_y^2}\log\left[\rho_x^1\left(e^{\varsigma_y^2} - 1\right) + 1\right] \tag{10}$$

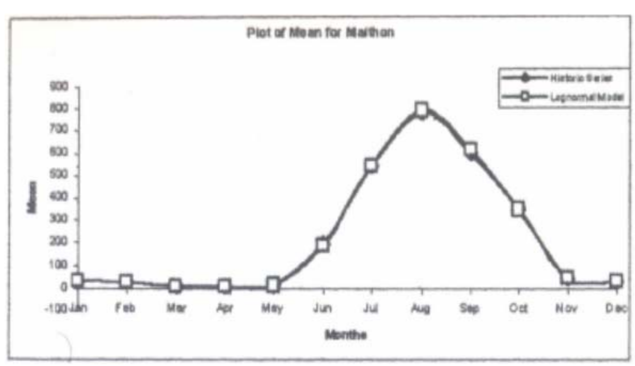
$$\gamma_x = \left(\frac{\sigma_x}{\mu_x}\right)^3 + 3\left(\frac{\sigma_x}{\mu_x}\right) \tag{11}$$

So, we get σ_y from the above Eq.9 and putting this value in eq.8, we get the value of μ_y and putting the known value of σ_y from eq.9 and ρ_x^1 from eq.5, we will calculate ρ_y^1 from above eq.10. The co-efficient of skewness can be obtained from the eq.11.

4. RESULT AND DISCUSSION

Fig. 2 shows that for reservoir Maithon, the distribution pattern of the mean and standard deviation of monthly inflows is well preserved by the Log-Normal model. The maximum mean value is observed for August by the historic series as well as the Log-Normal model. The historic series and the Log-Normal model for Maithon give the highest value of standard deviation for the month of August. The values given by the Log-Normal model is consistently lower than the historic series for most of the time of the year. This is because the length of the synthetic sequence is much greater than the historic series. Fig. 3 shows that the absolute error in mean is negligible except for the monsoon months. The absolute mean error is maximum for the month of September and is minimum for November. Fig. 4 shows the maximum relative standard deviation error in April. The Log-Normal model gave the minimum relative standard deviation error in July.Fig. 2 shows that lag-I serial correlation is well preserved by the Log-Normal model. Low serial correlation for March-April and May-June is observed for both the Log-Normal and the historic series. High serial correlation is observed between months April-May, June-July, July-August and October-November.Fig. 2 shows that the skewness given by the Log-Normal model is higher than that of the historic series for most of' the time of the year. The historic series gives the maximum value of skewness for the month of August and the minimum for November. The Log-Normal model gives the maximum value of skewness for the month of March and the minimum for January.

Fig. 5 shows that for the reservoir Panchet, the pattern of distribution of the mean and standard deviation of the monthly inflows are well preserved by both the Log-Normal model. The maximum mean value is observed for the month of August by the historic series as well as the Log-Normal model. It can be seen from Fig. 6 that the absolute mean error is quite low except for the monsoon months. The absolute mean error given by the Log-Normal model is highest for the month of September. Fig. 7 shows that the relative mean error given by the Log-Normal model is highest for the month of April. The relative mean error given by the model is lowest for the month of October. From Fig. 6 it can be seen that the model gave maximum absolute errors in August and the minimum absolute error for March. The model gave the minimum relative standard deviation error in July. Fig. 5 shows that lag-I serial correlation is well preserved by the model. Very low serial correlation is observed for January-February and negative serial correlation for April-May. High serial correlation is observed for October-November, June-July and July-August; the serial correlation between August and September is lower than that between July and August which may be due to the slight shift in the time of the monsoons from year to year. Fig. 5 shows that the skewness given by the Log-Normal model is higher than that of the historic series for most of the time of the year. The historic series gives the maximum value of skewness for the month of December and the minimum for November. The Log-Normal model gives the highest value of skewness for May and the minimum value of skewness for the month of August. Fig. 7 shows that the Log-Normal model gave the maximum relative standard deviation error in April.



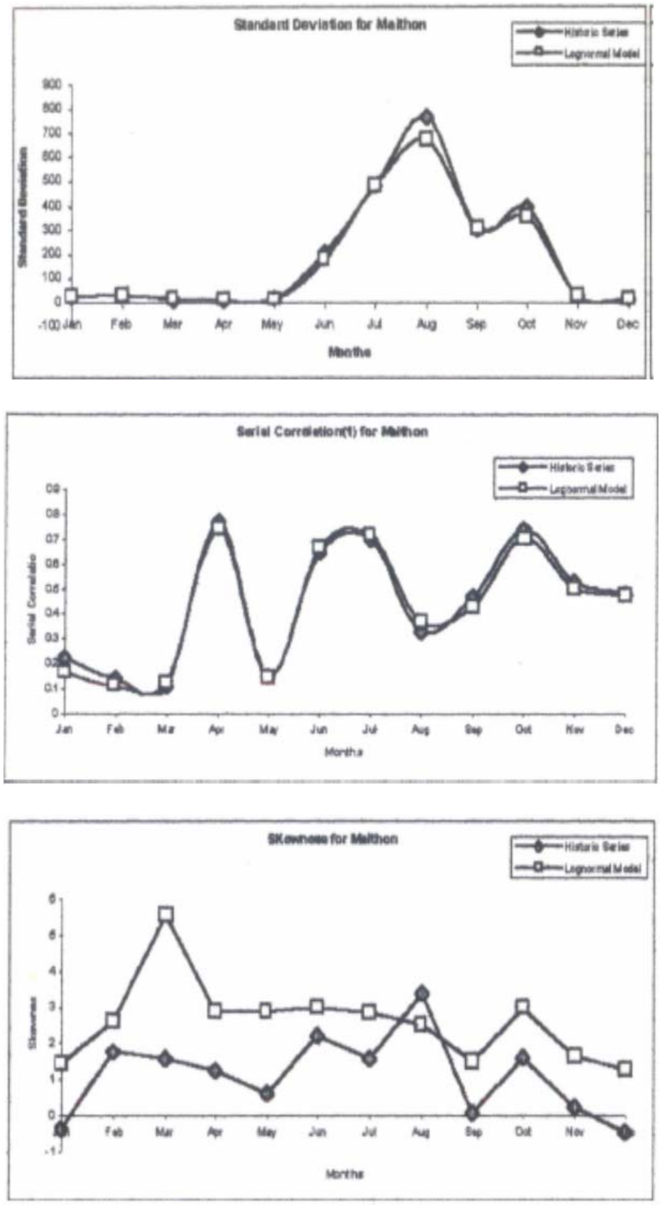


Fig. 2: Statistical Parameters for Reservoir Maithon

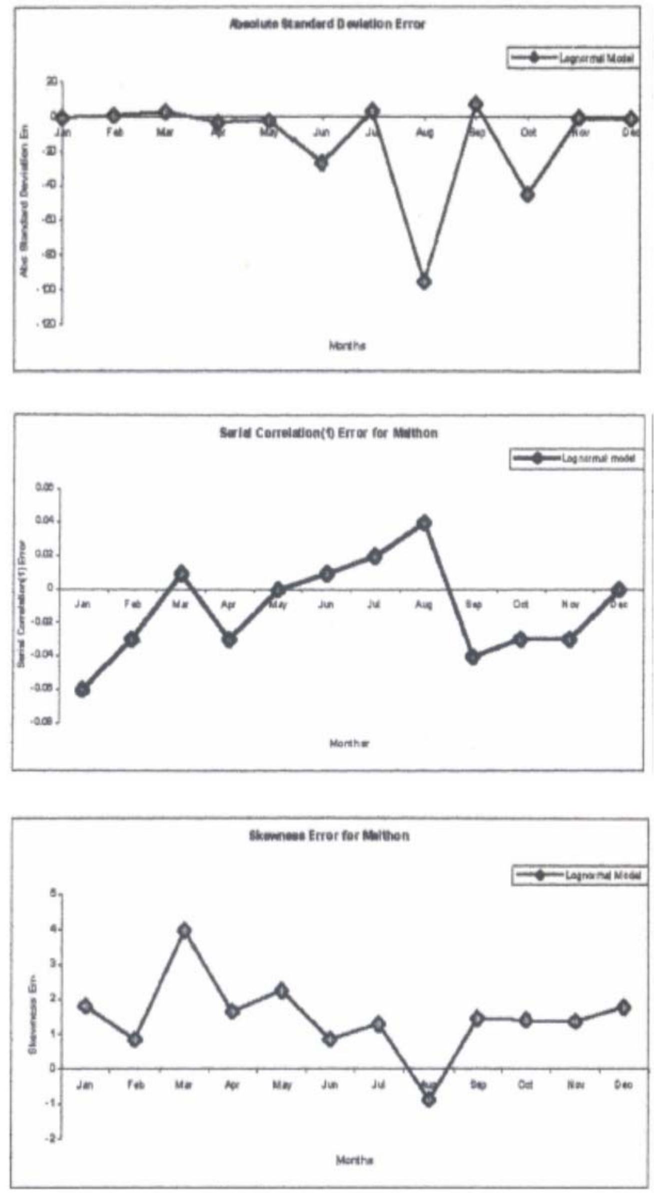
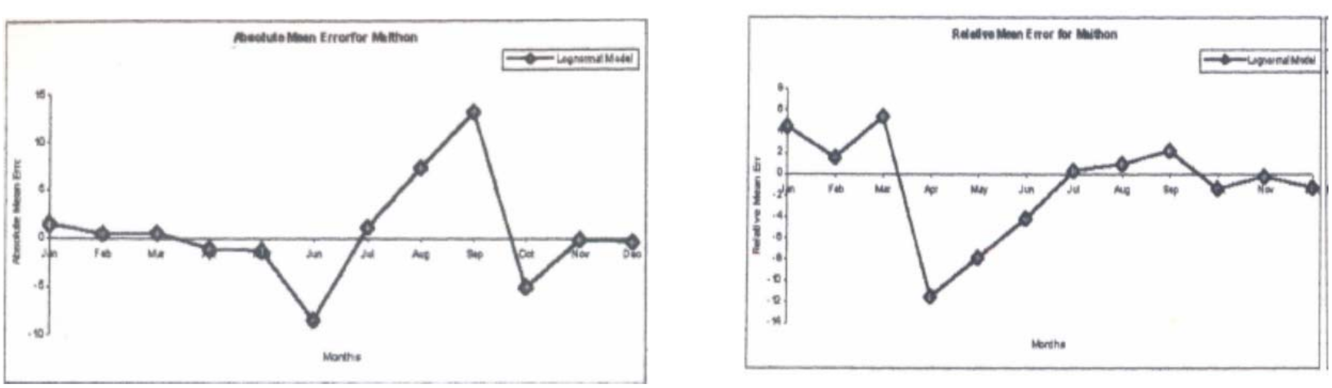


Fig. 3: Absolute Errors for Reservoir Maithon



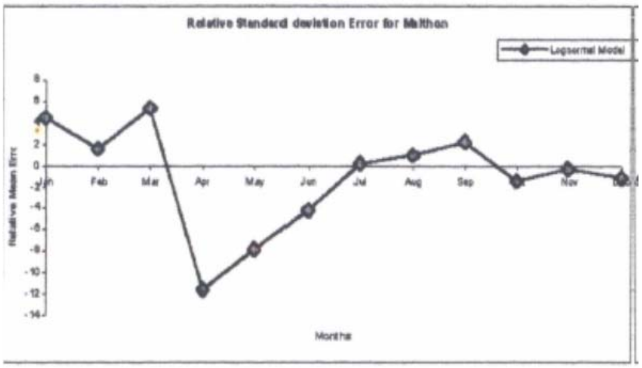


Fig. 4: Relative Errors for Reservoir Maithon

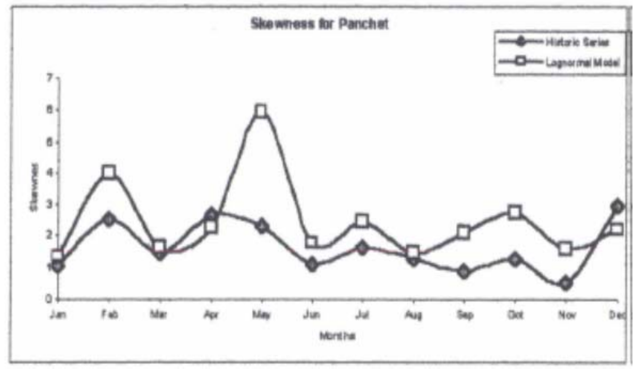
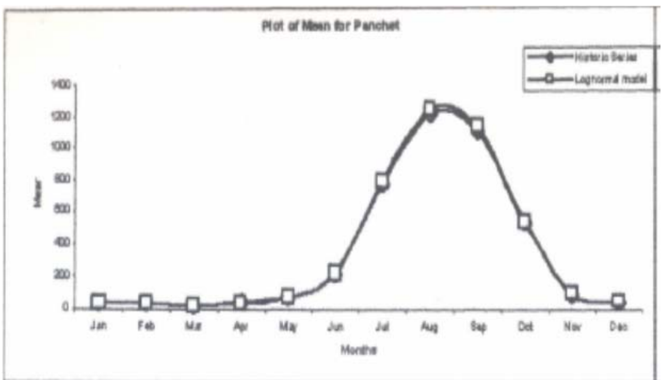
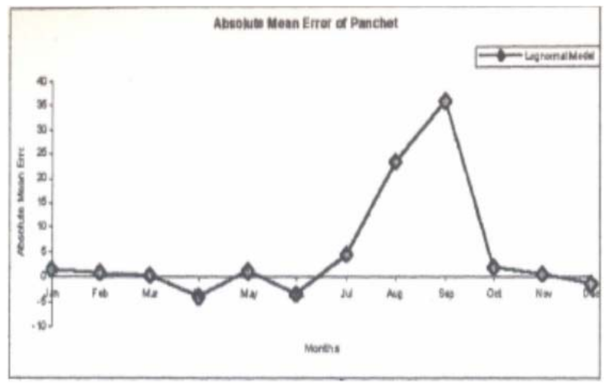
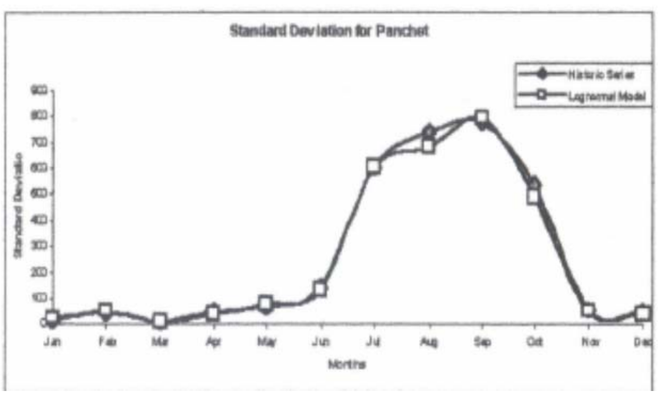
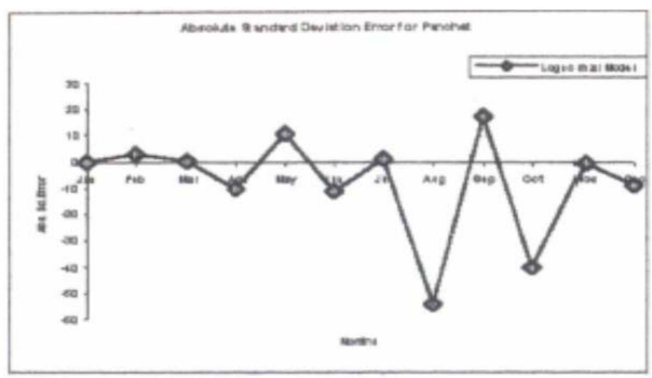


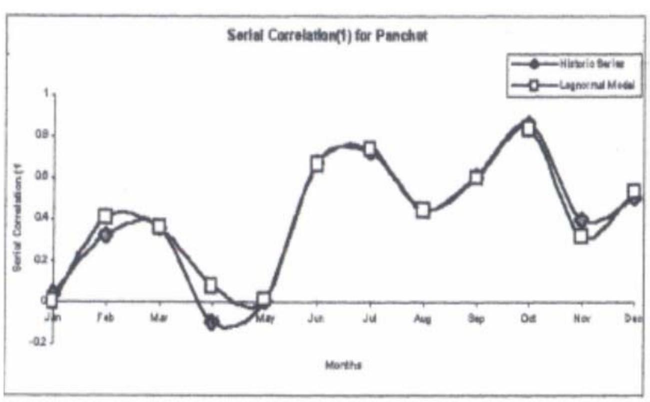
Fig. 5: Statistical Parameters for Reservoir Panchet

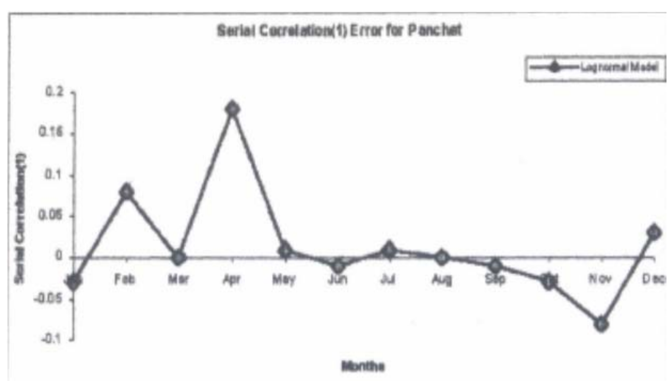












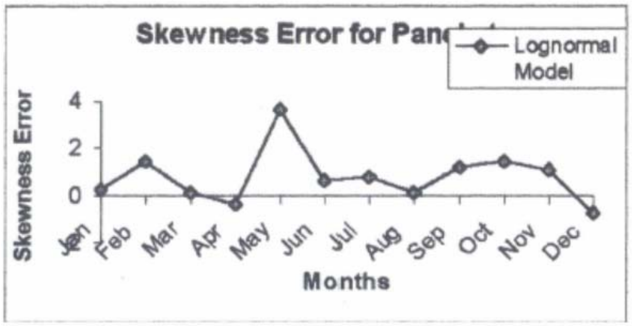


Fig. 6: Absolute Errors for Reservoir Panchet

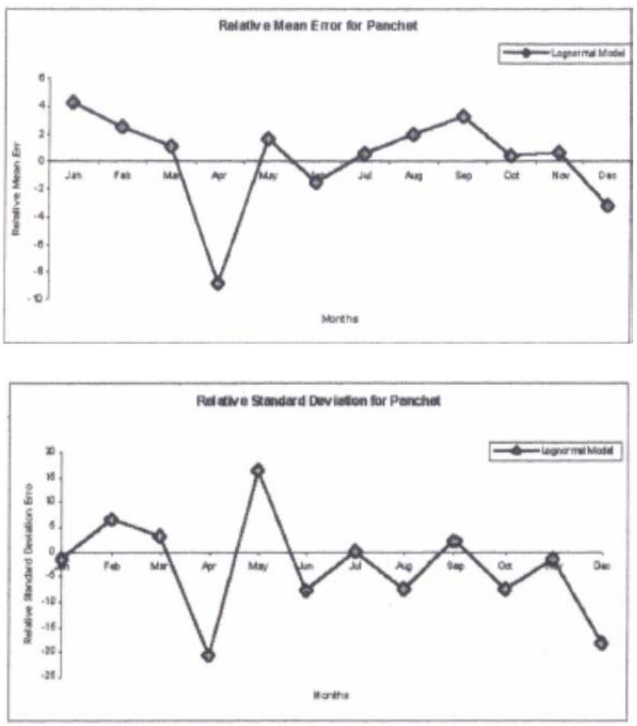


Fig. 7: Relative Errors for Reservoir Panchet

5. CONCLUSION

The statistical parameters of the historic series that is the mean, standard deviation and the lag-I serial correlation are well preserved by two parameter Log-Normal Distribution for both the reservoirs Maithon and Panchet of the DVC system but for all the reservoirs, the skewness is not very well preserved. It is observed from the mean monthly inflows that the Two Parameter Log Normal Distribution gives almost same values as in case of historic series. The standard deviation of the monthly inflows obtained from the model is lower than the historic sequence for all the reservoirs. This is because the length of the historic sequence is only for 20 years whereas the length of the generated sequence is 500 years. In general, Two Parameter Log Normal Distribution give lower values of lag-1 serial correlation compared to the historic sequence for most of the time of the year. The lag-I serial correlation is well preserved by the distribution system for both the reservoirs. Moreover; the inflow to the reservoir Maithon depends on that of Tilaiya and inflow to Panchet on Konar as they are connected. It is therefore very difficult to decide which particular distribution will model the inflows better. This also depends a lot on the purpose for which the synthetic sequence is generated.

REFERENCES

[1] Bobee B. and Robitaille R., (1975). Correction of bias in the estimation of the coefficient of skewness, Water Resources Research, Vol ll, No.6, pages 851-854.

[2] Haan Charles T., A Text Book - Statistical Methods in Hydrology.

[3] Haan Charles T., (1972). Adequating of Hydrologic Records for Parameter Estimation, Journal of Hydrologies Division, Vol. 98, No.HY, Pages 1387-1393.

[4] Matalas N.C., (1967). Mathematical assessment of Synthetic Hydrology, Water Resources Research,Vo1.3, No.4, pages 937-945.

[5] Mcmohan T.A. and Miller A. J., (1971). Application of the Thomas-Fiering Model To Skewed Hydrologic Data, Water Resources Research, Vol.7, No.5, pages 1338-1339.

[6] Mejia Jose M. and Iturbe I. R., (1974). Correlation links between normal and lognormal processes, Water Resources Research, Vo1.10, No.4. pages 689-693.

[7] Srikanthan R. and Mcmohan Thomas A., (1982). Stochastic generation of monthly streamflows, Journal of Hydraulics Division, ASCE, Vo1.108,No.AY3, pages 419-441.

[8] Stedinger J. R., (1980). Fitting log-normal distributions to Hydrologic data, Water Resources Research. VoLl6, No.3, pages 481-490.

[9] Vogel Richard M. and Stedinger Jery R., (1988). The value of stochastic streamflow models in over year reservoir design applications, Water Resources Research, Vol. 24, No.9, pages 1483-1490.