International Conference "Water, Environment, Energy and Society" (WEES–2009)
New Delhi, 12–16 January 2009

Rainfall Prediction for Musi Reservoir Project Raingauge Station

Rajesh Nune and Srinivas Pasupuleti*
Department of Civil Engineering
Koneru Lakshmaiah College of Engineering
Green Fields, Vaddeswaram, Guntur District - 522 502, INDIA
E-mail: *vasu77_p@rediffmail.com

Sunil Raju Kurra[1]
Vishakapatnam Port Trust
Vishakapatnam, INDIA

ABSTRACT: The primary objective of this study is to develop a time series model to predict the rainfall for Musi Reservoir Rain gauge station for the future years. Water is an important resource for the development of any community and especially for a developing country like India it should be used judiciously. Rainfall is the major means by which fresh water is made available. Effective and efficient operation of water resource systems frequently demands the prediction of hydrological sequences like rainfall. Hence forecasting models are necessary to predict the future rainfall based on past and current information. Rainfall prediction will tell us whether the coming years will be a good, bad or average rainfall years. Accordingly contingency measures can be planned well in advance, tide over difficulties in augmenting water for the use of the teeming population. In this study forecasting model namely Box-Jenkins ARMA model is used to predict the rainfall. Rainfall data of rain gauge station located at Musi Reservoir Project for past 37 years, (1968–2004) was obtained. Auto correlogram and partial auto correlogram drawn for the series indicate that model can be ARMA (2, 2). Auto Regressive Moving Average model was fitted to the data and checked its validity by comparing fitted values with actual rainfall values. Forecast was made for next 6 years (2005–2010). Forecast values are well fitted with actual values. Thus prediction of rainfall is necessary for better planning of water resources and for optimum water management and utilization.

INTRODUCTION

Water is a Precious and Important resource for the development of any community. In view of the vital importance of water, the principal constituent for sustenance of all living things in the universe and considering its increasing scarcity for maintaining ecological balance, economic and developmental activities of all kinds, the planning and management of this resource and its optimal, economical and equitable use has become a matter of utmost urgency. Hence, utilization of rainwater which otherwise flows into ocean and not useful, gains significance. Thus forecasting of rainfall is to be made to plan contingency measures well in advance. Makridakis, S. *et al.* (1978) states that effective and efficient operations of water resource systems frequently demand the prediction of hydrological sequences like rainfall. Hence forecasting models are necessary to predict the future rainfall based on past and current information. Before being able to forecast hydrological sequences, models have to be found which describe past data adequately. Ideally these models should preserve the properties of the past rainfall data. There are three basic approaches in forecasting hydrological data, namely conceptual, multi regression and time series models. In conceptual models and multiple regression models the data is expressed as a function of important hydrological variables and parameters, the accurate estimation of these variables is a difficult task. On the other hand, in time series models, the rainfall data is evaluated in the form of an equation and future values are predicted using the equation. Water is an important resource for the development of any community and especially for a developing country like India it should be used judiciously. Rainfall data is of utmost importance to hydrologists as it forms the basis of many hydrological studies. Rainfall prediction will tell us whether the coming years will be a good, bad or average rainfall years. Accordingly contingency measures can be planned well in advance, tide over difficulties in augmenting water for the use of the teeming population.

[1]Conference speaker

Some of the earlier works in forecasting of Hydrological events are listed below:

A real-time river flow forecasting model, SMAR-AR is used for forecasting the Blue Nile river flows at Eldeim station near the Sudenese-Ethiopia border by Asaad Y. Sham seldin *et al.* (1999). Box-Jenkins modeling of time series data can be improved and simplified by adhering to contemporary modeling procedures, proposes by K.W. Hipel *et al.* (1977). P. Srinivas *et al.* (2004) in their article discusses that effective and efficient operation of Water Resource Systems frequently demands the prediction of hydrological sequences like rainfall. Rainfall data of Saidapet rainguage station for past 100 years (1901–2000) is obtained. In this study, forecasting model namely Box-Jenkins Autoregressive Moving Average (ARMA) Model is used to forecast the rainfall. ARMA Model of order (2, 2) is fitted by using 84 years data (1901–1984) and checked its validity by using last 16 years data (1985–2000), by comparing fitted values with actual rainfall data. Then forecast is made for the next 25 years, (2001–2025). Arun Sharma (2002) in his paper, investigated six models of the Auto Regressive Moving Average (ARMA) family for representing the monsoonal river inflow forecast models. The selected models were validated for significance of the residual mean, and for significance of the periodicities in the residuals. Mohan *et al.* (1991) in their paper highlights that forecasting models are necessary to predict inflows into a reservoir that are helpful in making decisions regarding releases from it. J.C. Bertoni *et al.* (1991) in their article, discussed conceptual rainfall runoff model and precipitation forecasting model. Rafel L. Bras (1976) in their paper discusses the on-line hydrologic forecasting application to short-term forecasting of discharges into a river basin and to rainfall over small urban areas. Queen's University Forecasting Method (QUFM) developed by W.E. Watt *et al.* (1982) is a general forecasting method since it incorporates both the deterministic and stochastic components, the relative weights of each varying with application. All the earlier models detailed here have used Box-Jenkins models, for forecasting. Each one has their own adjustments and assumptions to suit their study. The above details are taken as guidance for our study. Box-Jenkins (1976) describe a family of linear stochastic models that are commonly referred as either Box-Jenkins or ARMA models. The objective of the present study is to develop a time series model to predict the rainfall for Musi Reservoir project rainguage station for the future years. The study area is Musi Reservoir Project Rainguage station, which is located near Solipet village in Suryapet mandal of Nalgonda district, Andhra Pradesh, India. The Musi Reservoir Project is located between geographical coordinates of East longitude 79° 33′ and North latitude 17° 14′.

TIME SERIES MODELS

These models use past data as the basis for estimating future results. Past patterns are analyzed and attempts are made to compensate for these patterns in the forecasting process. There are various types of time series models. Some of them are listed below: Single Exponential Smoothing Model, Auto Regressive Moving Average Model (ARMA), Auto Regressive Integrated Moving Average Model (ARIMA), Decomposition Model, Winter's Method, Adaptive Filtering and Census II Method.

METHODOLOGY

Box and Jenkins Method

This is one of the most sophisticated of all time series techniques as it is capable of handling almost any pattern of data. It usually provides the most accurate short-range forecasts of any model and even enables statistical tests to be applied to each forecast along with confidence intervals. The objective of this method is to end up with a specific formula for the forecast values that replicates the pattern in the series as closely as possible and also produce accurate results. The phases involved in this process are:

1. Model Identification Phase
2. Model Estimation and Validation Phase
3. Model Forecasting Phase
4. Model Updating Phase.

Box and Jenkins Model Building Process

1. Plot the original series. Series is said to be stationary if it tends to wander more or less uniformly about mean. Otherwise non-stationary is implied.
2. Non-stationary series can be converted to stationary series by computational process known as regular differencing.
3. Find the Auto correlations and the Partial auto correlations (Partials) of the original series.
4. Examine the Auto correlations, partials for the patterns, which reveal the type of model (AR/MA/ARMA) and its order.
5. Identify the tentative model and parameters needed to construct the model.
6. The best or optimum values for the selected model parameters are determined so that the model

generates fitted values, which are as close as possible to the original series values.

7. Certain diagnostics are provided to check the validity of the model and suggest alternative models.
8. The selected and estimated model is used to generate forecasts of the time series.

The methodology is given in the flowchart Figure 1.

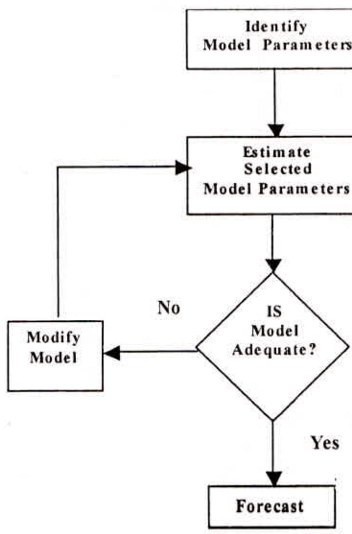

Fig. 1: Time Series Model Building Process

AUTO REGRESSIVE MOVING AVERAGE MODEL (ARMA MODEL)

The ARMA model of order (p, q) is given by the equation as follows,

$$X_t = \Phi_1 X_{t-1} + \Phi_2 X_{t-2} + \ldots + \Phi_p X_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \ldots - \theta_q e_{t-q} \quad \ldots (1)$$

Where

$\Phi_1, \Phi_2, \ldots \Phi_p$ are Auto Regressive parameters

$\theta_1, \theta_2, \ldots \theta_q$ are Moving Average parameters

e_t is random error

The choice of p and q are determined by Auto correlation coefficients calculated for the data.

ANALYSIS OF DATA

The analysis of Musi Reservoir Project rainfall data was done for the past 37 years (1968–2004) are plotted in Figure 2. Auto correlations and Partial Autocorrelations of the original series were found out for corresponding lags. Autocorrelogram is shown in Figure 3. Autocorrelogram and Partial Autocorrelogram clearly indicate that the order of Model can be ARMA (2, 2).

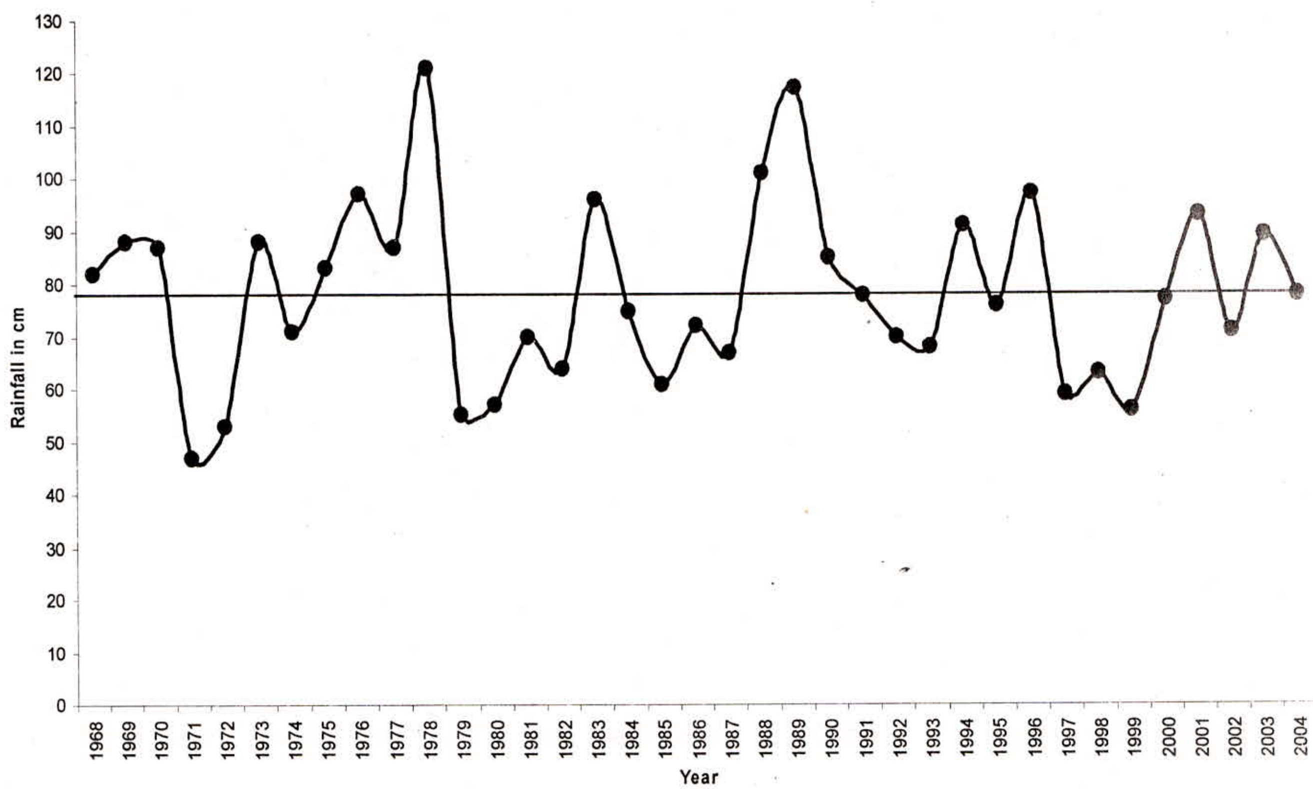

Fig. 2: Musi Reservoir Project Rainfall Data (1968–2004)

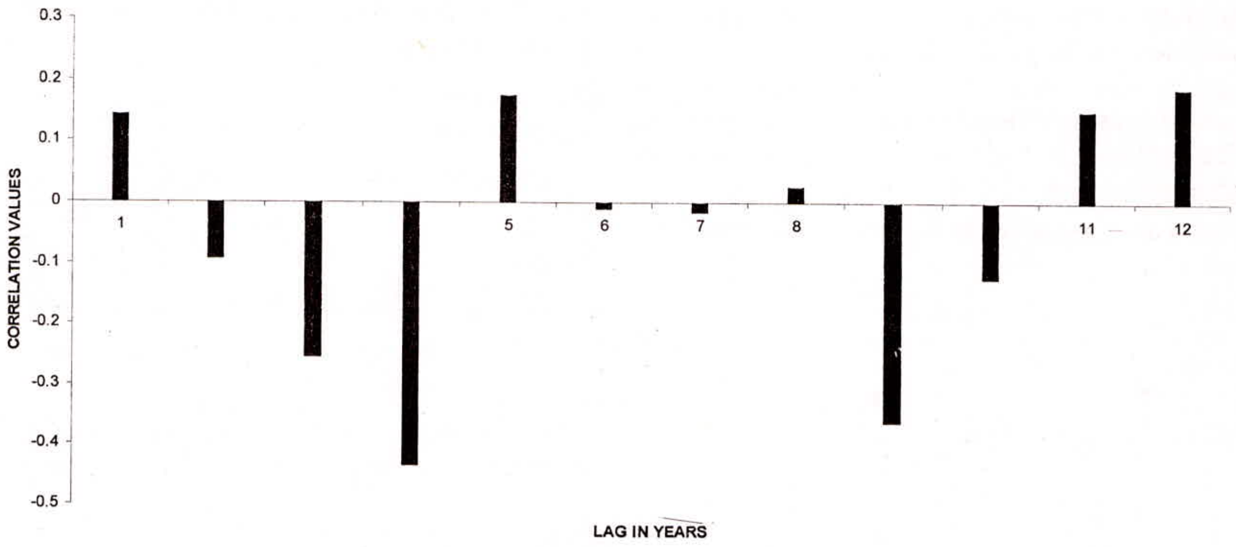

Fig. 3: Autocorrelogram

FORECAST WITH BOX-JENKINS ARMA MODEL

A Box-Jenkins ARMA model of order (2, 2) is fitted to the time series data. Rainfall data for past 37 years (1968–2004) is obtained. 22 years of data is taken to develop the ARMA model. Last 15 years are used to check the validity of model by comparing the fitted values with the actual rainfall values.

The developed ARMA model of order (2, 2) is given by the equation,

$$X_t = 0.52\,X_{t-1} + 0.27\,X_{t-2} + e_t + 0.25e_{t-1} + 0.13e_{t-2} \quad \ldots (2)$$

Rainfall values and fitted values using ARMA (2, 2) for years 1968–2004 are shown in Figure 4.

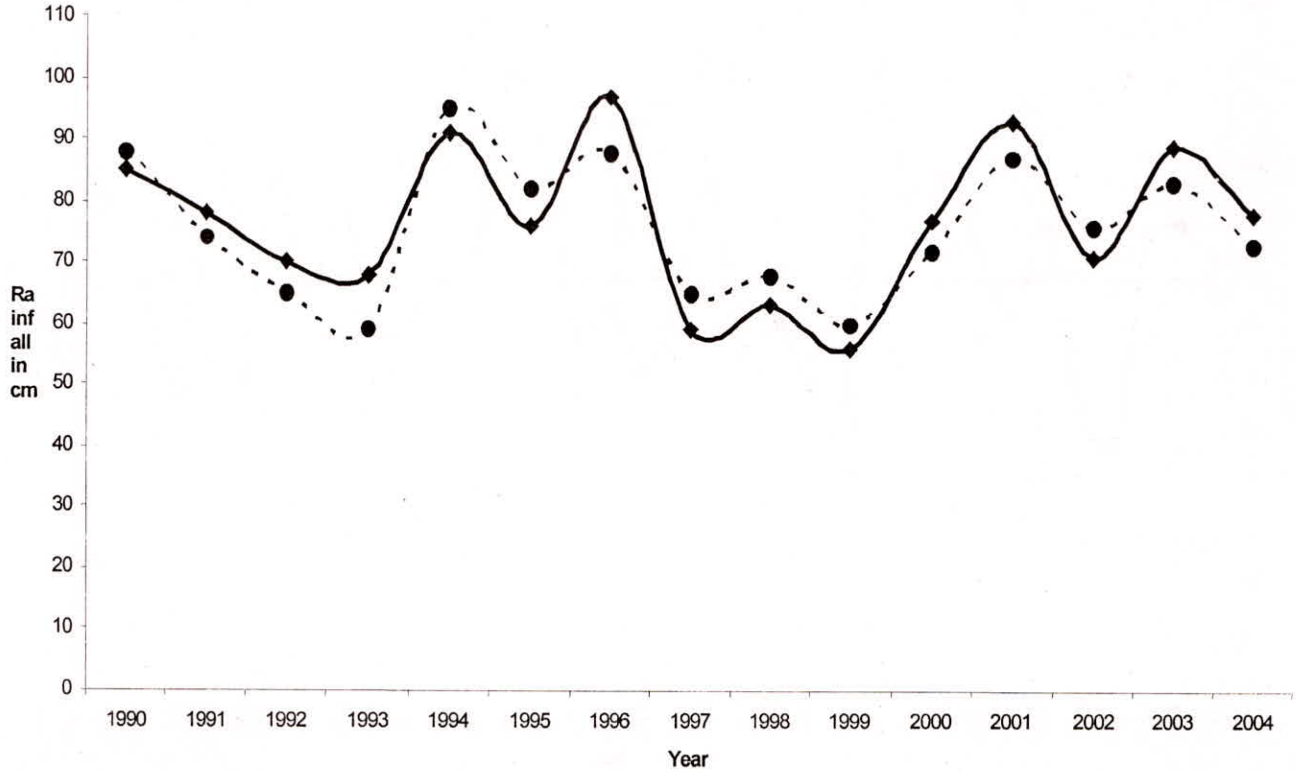

Fig. 4: Comparison of Fitted Values with Rainfall Values

RESULTS AND DISCUSSION

Rainfall data of Musi Reservoir Project rainguage station for the past 37 years, (1968–2004) is obtained for the study. ARMA model of order (2, 2) is fitted by using 22 years data (1968–1989) and checked its validity by using 15 years data (1990–2004), by comparing fitted values with actual rainfall data and tabulated in Table 1. Then prediction of rainfall is done for the next 6 years, (2005–2010). Forecast values for the rainfall using ARMA (2, 2) for the next 6 years, (2005–2010) is tabulated in Table 2. The plot of fitted values and forecast values from 1990 to 2010 were shown in Figure 5. Forecast values plotted were matching fairly with the fitted values. Figure 6, shows the plot of rainfall including fitted and forecast values for 43 years. 3 years moving average and 5 years moving average for 43 years were computed. From the plots and moving average values, a cyclical trend is not clearly visible but it may be inferred that successive droughts recurred once in a decade. There is not much deviation for the Standard Errors calculated for 37 years and 43 years. It reveals that predicted values were well fitted with actual values.

Table 1: Comparison of Fitted Values with Actual Rainfall Values

Year	*Rainfall Value (cm)*	*Fitted Values Using ARMA (2, 2) (cm)*
1990	85	88
1991	78	74
1992	70	65
1993	68	59
1994	91	95
1995	76	82
1996	97	88
1997	59	65
1998	63	68
1999	56	60
2000	77	72
2001	93	87
2002	71	76
2003	89	83
2004	78	73

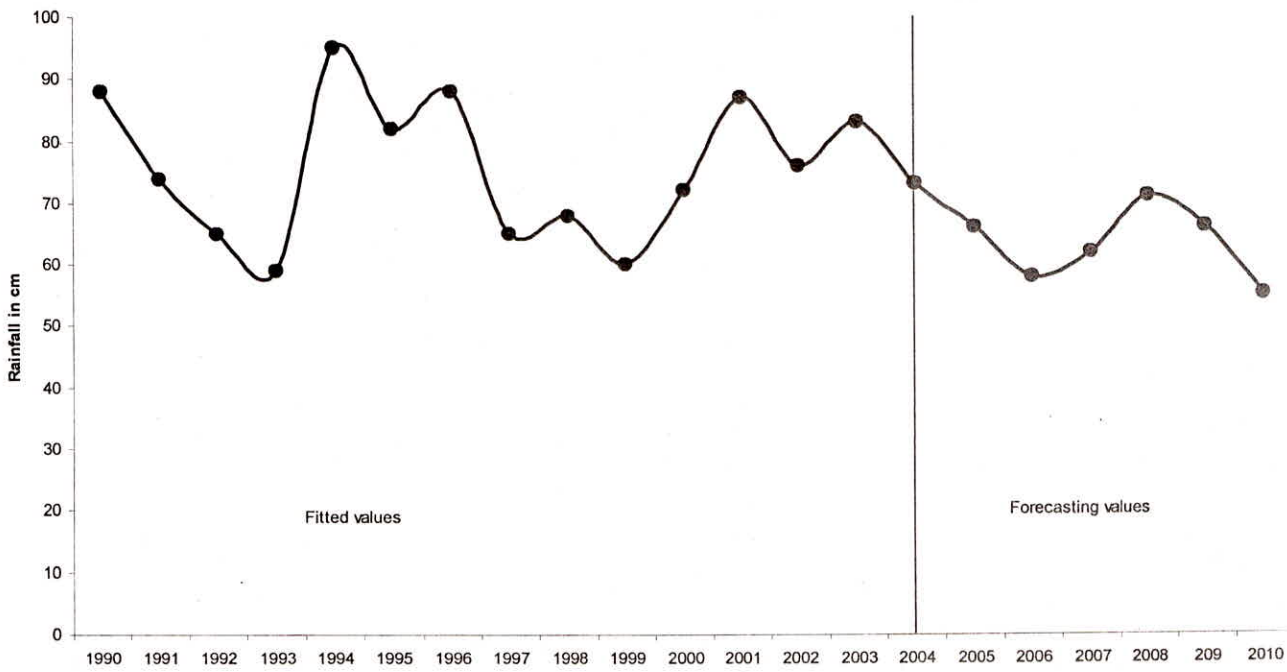

Fig. 5: Rainfall Data of Musi Reservoir Rainguage Station [Both Fitted and Forecast Values] (1990–2010)

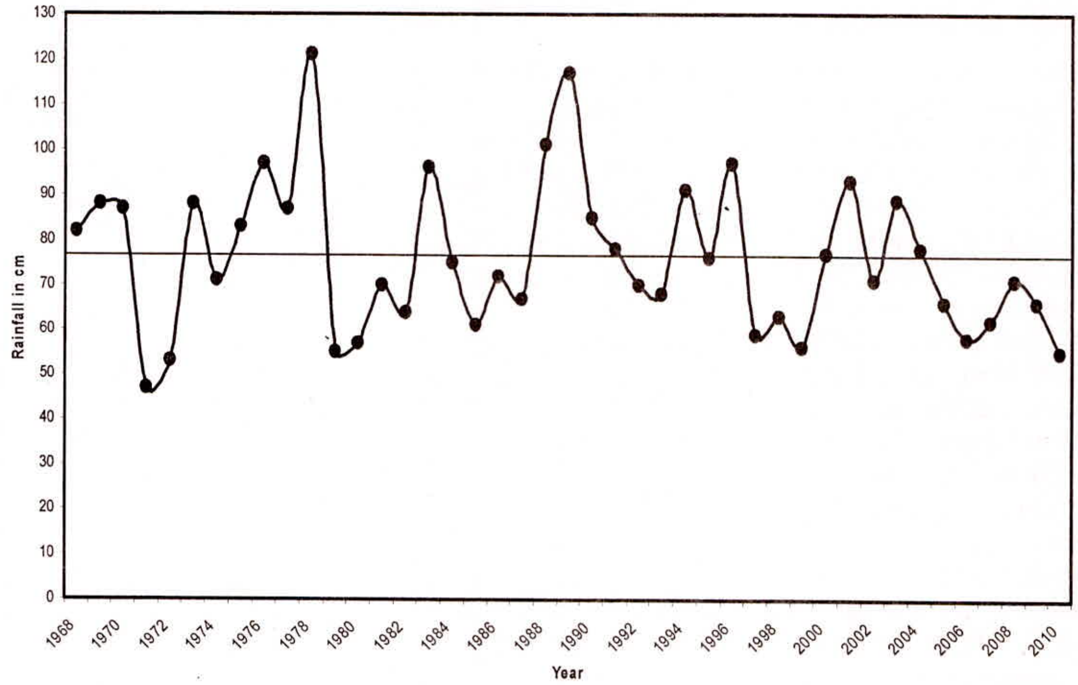

Fig. 6: Rainfall Data of Musi Reservoir [Actual Rainfall Data, Fitted Values, Forecast Values] (1968–2010)

Table 2: Forecast of Rainfall Data for Musi Reservoir Project

Year	*Forecast Values using ARMA (2, 2) (cm)*
2005	66
2006	58
2007	62
2008	71
2009	66
2010	55

CONCLUSIONS

The ARMA (2, 2) model was selected as the best fit from the analysis. Box and Jenkins method is best suited for short-range forecasts. By combining this method with linear regression, forecast was made for next 6 years. Since, droughts may be expected once in a decade there is a need to have better management. Hence necessary steps are to be taken for optimum water management and utilization.

REFERENCES

Sharma, Arun (2002). "Validation of the monsoonal river inflow forecasting model—A case study", *Journal of applied Hydrology*, Vol. XV, pp. 1–12.

Asaad, Y. Shamseldin, Gamal, M. Abdoand and Abderhman, S. Elzein (1999). "Real-time flood forecasting on the Blue Nile River", *Water International*, Vol. 24, pp. 39–45.

Box, G.E.P. and Jenkins, G.M. (1976). "Time Series analysis forecasting and control", Holden Day.

Bertoni, Juan Carlos, Tucci, Carlos Eduardo and Clarke, R. Thomas (1991). "Rainfall-based real-time flood forecasting", *Journal of Hydrology*, Vol. 131, pp. 313–339.

Hipel, Keith W., McLeod, A.I. and Lennox, W.C. (1977). "Advances in Box-Jenkins modeling—Model construction", *Water Resources Research*, Vol. 13, pp. 567–575.

Makridakis, S., Wheelwright, S.C. and Mcgee, V.E. (1978). "Forecasting Methods and Applications", John Wiley and Sons.

Mohan, S., Raman, H. and Premganesh, G. (1991). "A comparative study on models for forecasting Inflows", *Journal of Indian Water Resources Society*, Vol. 11, No. 3, pp. 19–22.

Srinivas, P., Narasiah, M.L. and Thayumanavan, S. (2004). "Rainfall Forecasting of Saidapet Rainguage station by Using Box-Jenkins ARMA Model" *proceedings of the International Conference on "Advanced Modelling Techniques for Sustainable Management of Water Resources-2004*", pp. 56–60.

Bras, Rafel L. (1976). "Short-term forecasting of rainfall and runoff, Real-time forecasting and control of water resources systems", Pergamon Press, pp. 125–137.

Watt, W.E. and Nozdryn, M.J. (1982), "Real-time flood forecasting for flood damage reduction", *Water Resources Publication*, pp. 551–571.