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APPLICATION OF RIVER FLOW FORECASTING MODELS ON THE NILWALA RIVER

by

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Abstract

Linear and non linear single as well as multiple input models have been applied to a Sri Lankan basin namely the Nilwala ganga in order to simulate the rainfall runoff transformation of this catchment given its unique hydro geological characteristics. The Nilwala a perennial river, not only becomes peculiar because of its geo-soil structure but also because it possesses a very thick, dense and old tropical forest cover for a good part of its basin.

From a comparative analysis of the model application, it has been found that the linear perturbation model performs better than the simple linear model and that the multiple input series models perform better than the single input models in terms of efficiency and peak forecasting ability of this basin. The soil moisture accounting model does not perform as well as the above for this basin. The results have been analyzed and it has been suggested that for this catchment interception and its ground water flow / storage effects the transformation process most.

1.0 Introduction

Research on rainfall runoff transformation has a long history and has produced many models to simulate this transformation. However the simulation of the uniqueness of each catchment through a few generalized parameters is not easily achieved. Moreover on the continuum of complexities of catchments the simulation of the extremes becomes even more difficult. The Nilwala is one such catchment.

Some of the presently popularly used models which are the linear and nonlinear single input and multiple input series simple linear model and the linear perturbation model, the soil moisture accounting model the Xinan Jiang model, the NAM model etc., have been applied to the Nilwala basin.

Since each of these models has their emphasis on some characteristic of the runoff phenomena by analyzing the resultant model efficiencies and the peak forecasting ability of these models, it is endeavoured to get an insight and thereby a better understanding of the rainfall runoff transformation process of this basin.

Therefore here the known characteristics of the Nilwala river system, the data, the models being used are first presented. Thereafter the results and analysis of same are presented.

2.0 The Nilwala river system

Sri Lanka, an island in the Indian ocean, situated 50^0 north of the equator, possessing tropical climatic conditions receives its precipitation mainly through monsoon rain. Its rainfall distribution is such that one part of the island receives an average annual rainfall of 1700 mm and labelled as the dry zone while the other part receives an average annual rainfall of 3200 mm and called the wet zone. The Nilwala falls into the wet zone of Sri Lanka.

The topography of Sri Lanka is such that the centre is mountainous and stands at an average height of 2500m above mean sea level and this tapers down to the Indian ocean around it. This topography gives rise to over 100 surface water systems within the island's 65,000 km^2 area. Most rivers including the Nilwala originate from the mountainous regions.

The Nilwala has its origins in the Sinharaja area which is about 1500m above mean sea level and traverses a distance of about 162km before it enters the sea in the south of Sri Lanka at a location called Matara. The

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Sinharaja is one of Sri Lanka's well known old, thick dense rainfall forest. This catchment is covered with thick, dense and old vegetal cover for 90% of its area.

The upstream of Nilwala encounters temperatures from 8 - 30^{0}C during the year while the down stream of Nilwala possess temperatures of 20 - 34^{0}C during the year. The total catchment area of the Nilwala is approximately 960 km^2.

3.0 The basin and data

The discharge data has been collected at two points in the river namely Pitabeddera and Bopagoda. Pitabeddera is 25km upstream of Bopagoda and covers a catchment area of 264km^2 . Bopagoda alone encompasses 302 km^2, however in total covers 566 km^2. The rainfall and evaporation data has been obtained for Goluwawatte and Kottawa respectively. The locations of the gauging points are indicated in Fig - 1.

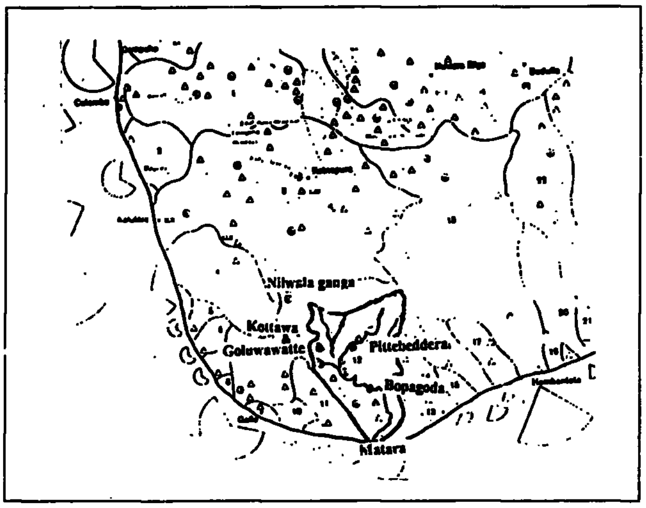

Figure: 1 Location of guaging stations

The discharge, rainfall and evaporation data are all daily data and they are for years 1986 to 1993. The rainfall data had no missing values, the discharge data had very few missing values, while the evaporation had about 5% missing values. These are filled in by linear interpolation.

These catchments are similarly covered with dense, thick and old vegetation for at least 90% of their area. The river in this area is about 20m wide and possesses an average annual temperature of about 28^{0}C with deviations of about 4^{0}C over the year. This area is rich in ground water through-out the year and the main source of water for inhabitants of this area is ground water.

4.0 Flood forecasting models

4.1 Simple linear model

Here it is assumed that the rainfall runoff transformation occurs according to a linear relationship between the total input series and the output series. The input series for this model could be single, which would then be precipitation or multiple series which would then be precipitation as well as upstream discharge.

4.2 Linear perturbation model

This model is based on the principle that if the rainfall follows the seasonal expectations for a given year then the discharge will follow similar seasonal discharge expectations. However when there are departures in seasonal expectations of rainfall then there would be a linearly related departure in discharge from its corresponding seasonal expectation. Therefore this model encompasses a time series analysis as well as a deterministic systems analysis. Here too similar to the simple linear model either single input or multiple input series could be used.

4.3 The soil moisture accounting model

This model is a conceptual model which takes into consideration the rainfall and the evaporation and thereafter attempts to calculate the discharge by means of a water balance. Here the catchment is considered as lumped and the conventional physical process of water flow is followed.

4.4 Other models

Variations of the single and multiple input series, simple linear model and the linear perturbation model are also applied to this catchment, namely, with the inclusion of the antecedent precipitation index (API) for the single input models, and the variable gain factor for the multiple input series models. In addition to this the Xinan Jiang model and the NAM model have also been applied to this catchment.

5.0 Application of the model

The data has been separated to two sets namely one for calibration (1986 - 1990) and the other for verification (1991 - 1993). The Rosenbrock search technique has been used for the optimization of the conceptual models while the ordinary least squares method has been used for the other models. All models have been applied both with and without the Auto Regressive updating for this catchment.

It has been noted that as the memory length increased to take values between 30 to 60, the models performed better. The number of harmonics used in the above application is 6 as it had been found that this amount fits both low flow and high flow satisfactorily.

The model efficiency has been calculated by means of the Nash Sutcliffe criteria which is as follows,

Efficiency $(R^2) = (F_O - F) / F_O$

F_O - Variance associated with mean values of discharge in the calibration period.

$[F_O = (I/n)(Q_{ob} - Q_{mean})^2]$

F - Residual variance calculated by comparing the observed and forecast discharge.

$[F = (1/n)(Q_{ob} - Q_{estim})^2 1]$

The model efficiencies are summarized and presented in Table - 1.

model (Fig- 15) and the NAM model (Fig- 16) is also presented.

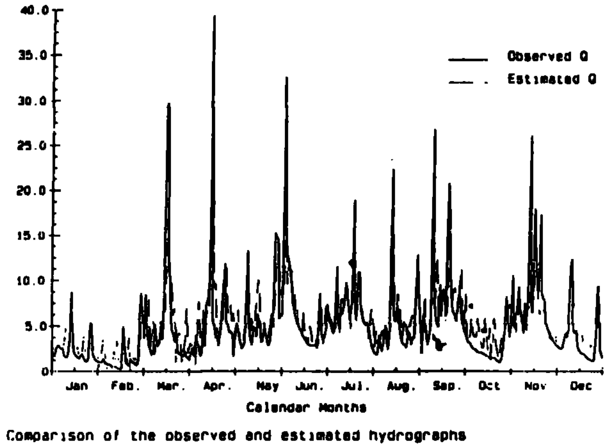

Figure: 2 Single input simple linear model 1998

Table - 1
Summary of model efficiencies

Model type	Without Calibra.	AR upda. Verifica	With Calibr.	AR up. Verifi
Rainfall runoff models (Single input)				
a) linear models- simple linear model	23.9	6.7	43.5	46.9
b)Quasi linear-Linear perturbation model	31.5	15.3	45.1	45.8
C)Non- Linear				
Two threshold multi linear model	12.8	1.8	38.6	40.6
Single input simple linear model-API	23.5	8.6	38.7	40.2
Single input lin. perturbation model-API	29.1	13.8	44.6	46.1
Flow routing models (Multiple input)				
a) Linear model - Simple linear model	76.8	56.7	82.2	75.9
B)Quasi linear-Linear perturbation model	78.2	57.5	82.5	76.1
C)Variable gain factor				
Linear model	74.6	54.6	82.1	76.7
Linear perturbation model	76.2	57.6	82.5	77.3
Conceptual models				
SMAR model	13.1	10.0	14.4	10.1
Xinan Jiang model	1.9	0.2	31.9	39.2
NAM model	1.8	0.1	32.4	29.8

A sample of the figures of the resultant observed and calculated hydrographs with AR updating, one each for calibration (1988) and verification (1991) for the single and multiple input, simple linear model (**Fig-2 - Fig-5**) and the linear purtabation model (**Fig-6 - Fig-9**) is presented. In addition a sample of the hydrographs of the verification for the single input, simple linear model with API (**Fig-10**) and linear purtabation model with API (**Fig-11**) and, multiple input variable gain factor (MIVGF) simple linear model (**Fig-12**) and the MIVGF linear purtabation model (**Fig- 13**), is presented. A sample of the verification of the conceptual models namely the SMAR model (**Fig-14**), Xinan Jiang

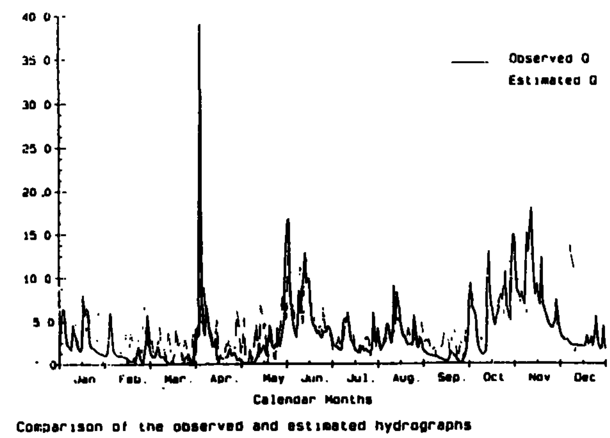

Figure 3: Single input simple linear model 1991

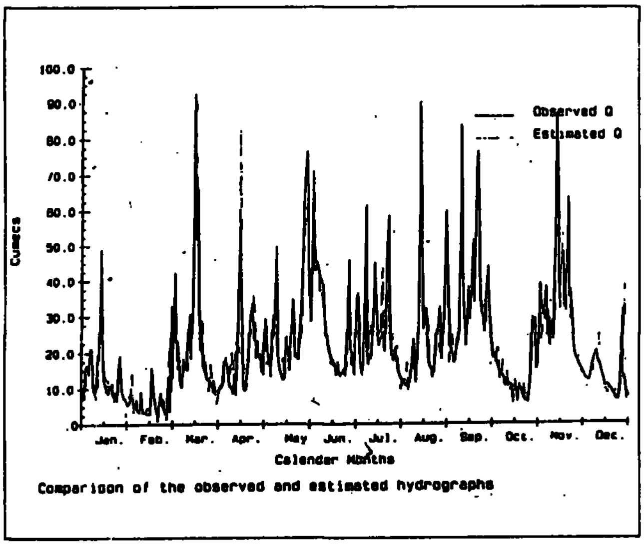

Figure 4: Multiple input simple linear model 1998

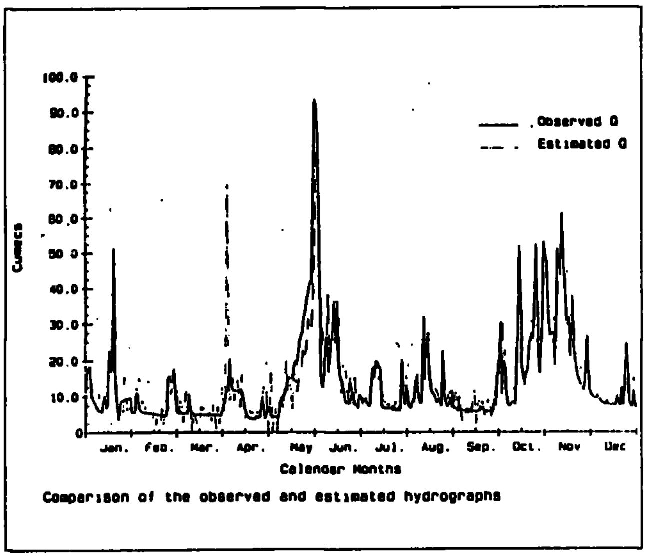

Figure 5: Multiple input simple linear model 1991

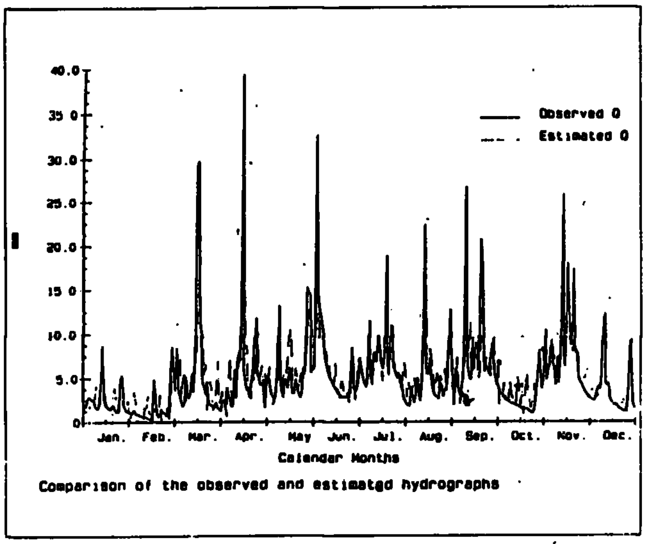

Figure 6: Single input linear purtabation model 1998

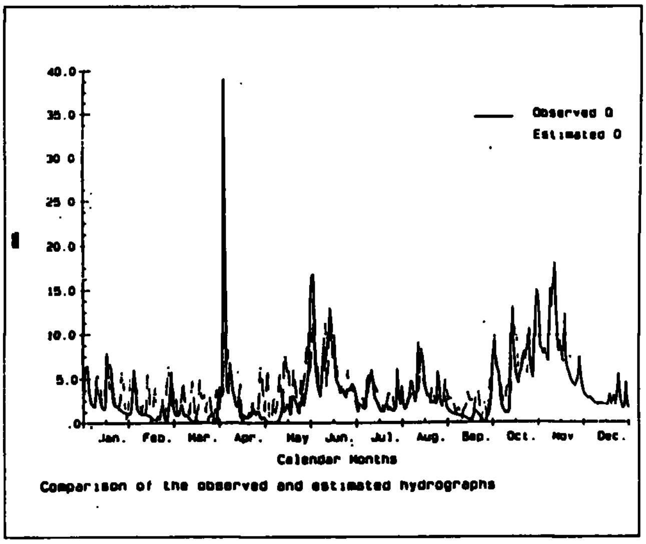

Figure 7: Single input linear purtabation model 1991

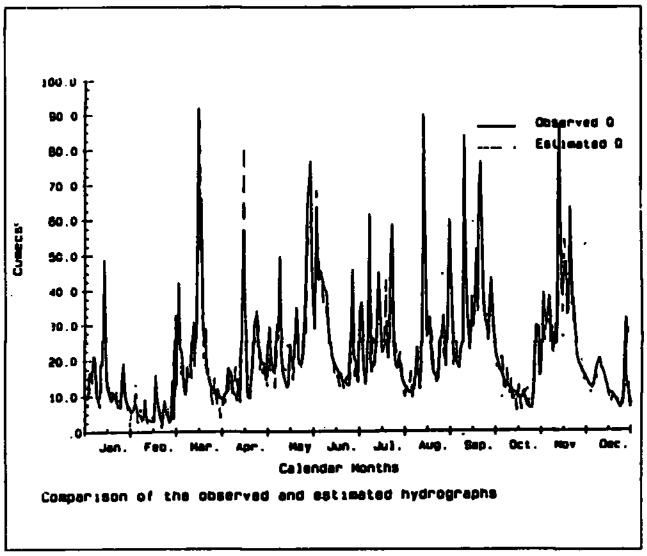

Figure 8: Multiple input linear purtabation model 1998

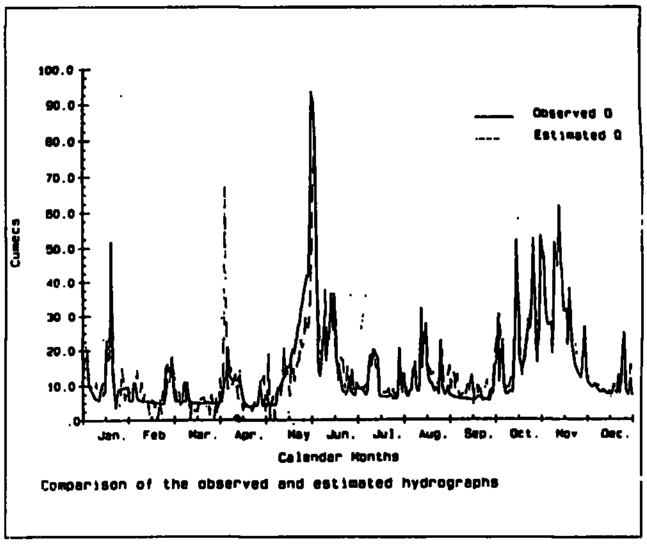

Figure 9: Multiple input linear purtabation model 1991

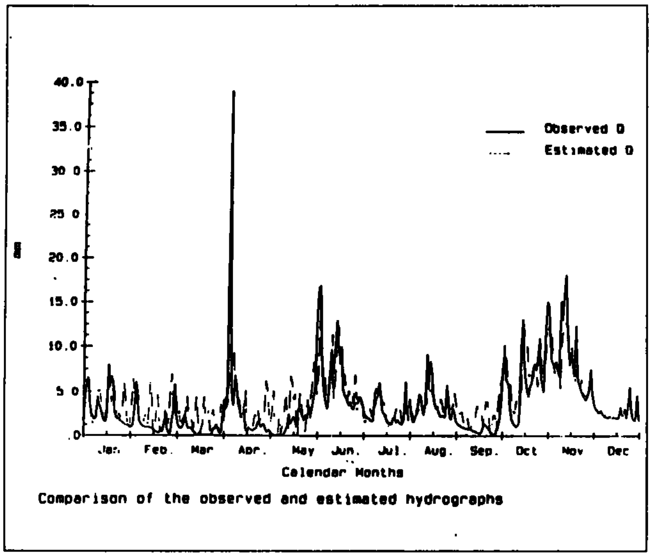

Figure 10: Single input simple linear model with API 1991

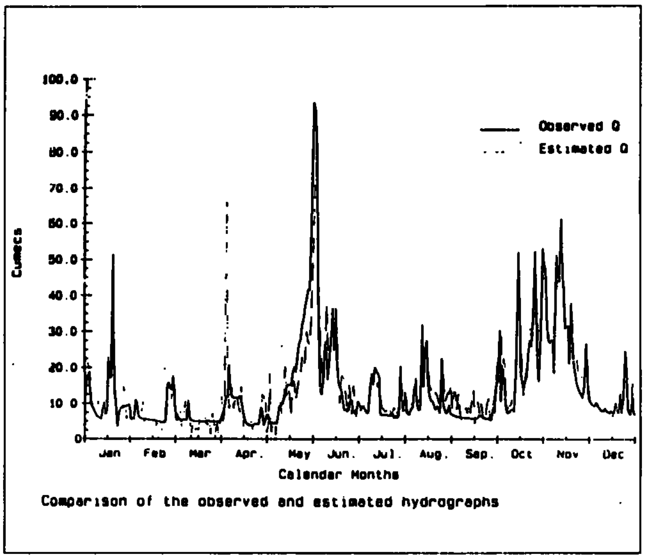

Figure 13: MIVGF linear purtabation model 1991

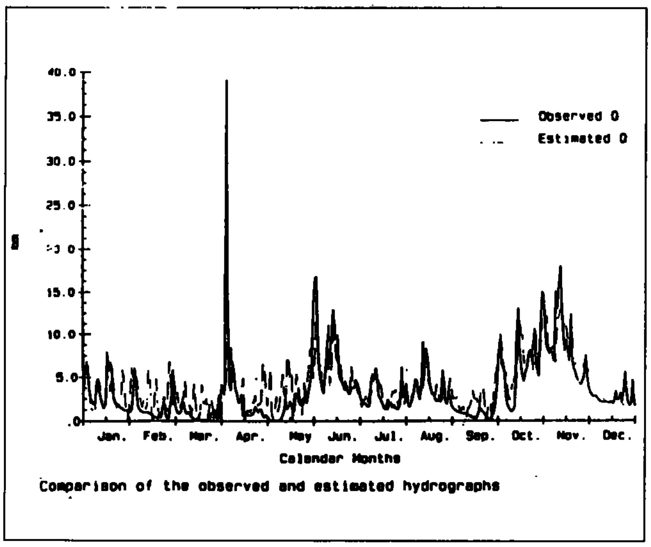

Figure 11: Single input linear purtabation model with API 1991

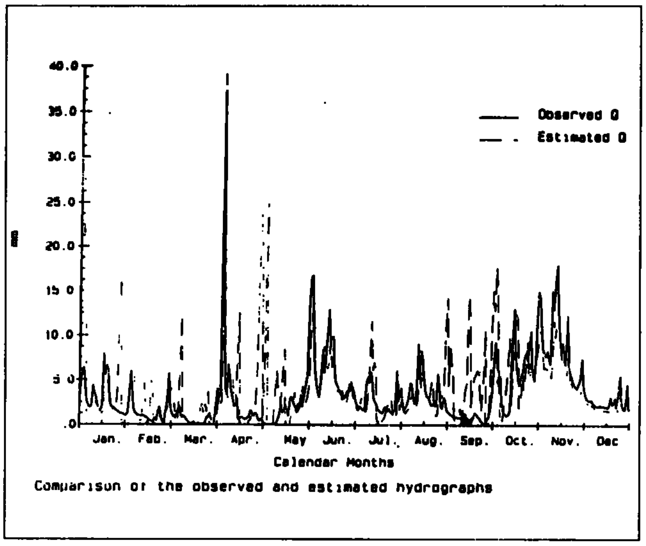

Figure 14: SMAR model 1991

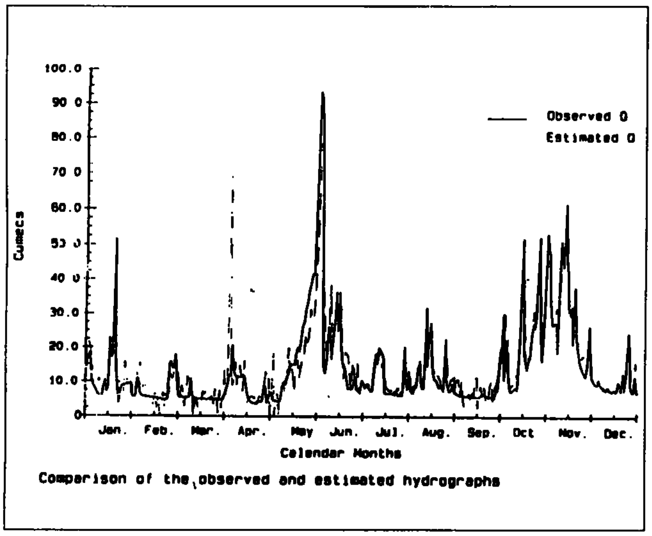

Figure 12: MIVGF simple linear model 1991

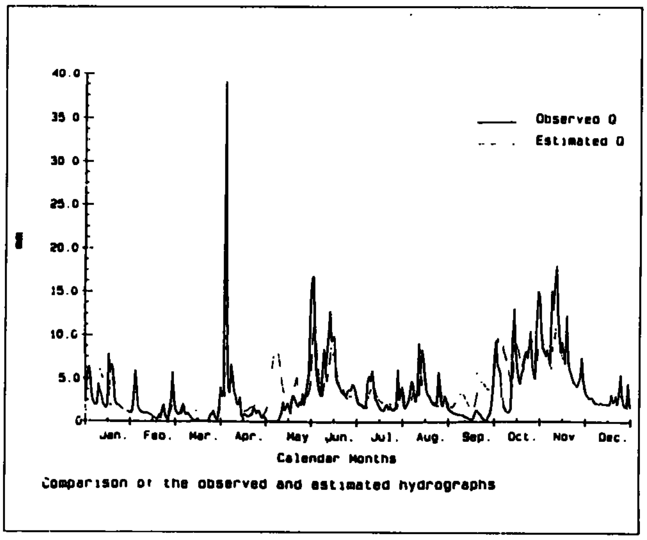

Figure 15: Xinan Jiang model 1991

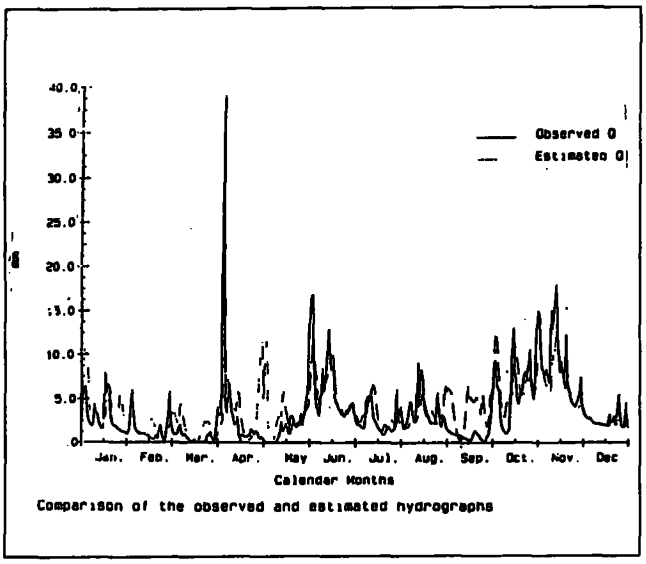

Figure: 16 NAM model 1991

6.0 Analysis of results

It could be seen from **Table - 1**, that the linear perturbation model performed better than the simple linear model in all cases, namely the single input case, the case including the antecedent precipitation index, multiple input series and the case involving the variable gain factor. This superiority is also noticeable in the peak forecasting ability as well. The conceptual models do not perform as well as either of the simple linear model or the linear perturbation models.

The basic difference between the simple linear model and the linear perturbation model is that in one case a direct linear relationship is assumed irrespective of the amplitude of variation in the input while in the other the extent of the departure in the input is related to the output. Therefore it could be said that in this catchment there exists an appreciable decay in the loss of output as the departure of the input increases. It could be either due to its ground water responding fast to departures of a high order or the input finding different paths into the rivers at departures of a higher order.

Another note - worthy comment is that the multiple input series performs better than the single input series. This is probably due to the fact that the upstream discharge values attempt to compensate for the error in the estimation of the inflow from rainfall at the down stream end thereby give better results. This too becomes more in conjunction with the earlier mentioned statement of decay in loss of out - put. The lower performance of the conceptual rainfall runoff models such as the SMAR model, the Xinan Jiang model and the NAM model could also be attributed to this.

7.0 Summary and conclusion

Single and multiple input linear, quasi linear and non linear rainfall runoff simulation models have been applied to the Nilwala catchment and the efficiencies of the resulting estimated hydrographs have been analyzed. Thereby the following findings have been made.

1. The linear perturbation model performs better than the simple linear model in all cases i.e. single and multiple input, with API and the variable gain factor.
2. The multiple input series performs better than the single input case
3. The conceptual models do not perform as well as the above models.

The main reason for this in the Nilwala catchment is probably due to the appreciable decay in the loss of out - put with the increase in departure of the input. This could be due to the ground water responding fast for departures of a high order or the input finding different paths for departures of a high order.

8.0 Acknowledgments

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