ESTIMATION OF DOKAN RESERVOIR RELIABILITY USING STREAM FLOW DATA GENERATION TECHNIQUES

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Abstract

In the present study, two procedures of capacity-yield are applied to estimate the reliability of Dokan reservoir using data generation techniques. These procedures are the probability matrix (Gould) procedure, and the behavior analysis. Vulnerability, and resilience, are also calculated in the second procedure .The data is generated by using four approaches ,namely ,Thomas-Fiering model with log –transformation (TF-log), Two-Tier model (TTM), modified Two-Tier model (MTTM) and modified Fragment model (MFM).These models are tested and compared with the historical data. It is concluded that among these four procedures the Thomas-Fiering model with log –transformation is the most appropriate for representing the Dokan reservoir inflow .Three factors are examined to determine their influence on the minimum storage estimate .These are the length of stochastically generated sequence, the initial state of storage ,and the starting month. The results reported here show that sequences as long as 10,000 years or more may be needed to minimize the effects of these factors.

المستخلص

في هذه الدراسة طبقت طريقتان من طرق السعة-الإطلاق لتخمين اعتمادية خزان دوكان باستخدام البيانات المولدة. هذه الطرق هي طريقة جولد و طريقة تحليل السلوك.المرونة والضعف حسبتا اعتمادا على الطريقة الأخيرة.تم توليد البيانات باستخدام أربعة طرق هذه الطرق هي طريقة ثوماس-فايرنك مع استخدام التحويلات اللوغاريتمية ، طريقة تو-تاير،طريقة تو-تاير المعدلة ،وطريقة فراكمانت المعدلة . استخدمت البيانات المولدة لمقارنة النتائج مع النتائج المحسوبة باستخدام البيانات التاريخية وفي نفس الوقت لمقارنة نتائج الطرق الأربعة لتوليد البيانات فيما بينها واستنتج إن طريقة ثوماس-فايرنك مع استخدام التحويلات اللوغاريتمية هي الأفضل لتمثيل التصاريف الداخلة لخزان دوكان.

ثلاثة عوامل تم فحصها لإيجاد تأثيرها على تخمين الخزن المطلوب.هذه العوامل هي طول سلسلة التصاريف المولدة، حالة الخزين الأولي للخزان، والبدا بشهر ما. أظهرت النتائج المقدمة في هذه الدراسة بأنه يحتاج إلى سلسلة جريان بحدود 10,000 سنة أو أكثر لتقليل تأثير هذه العوامل.

KEY WORDS: Stream flow data generation, reliability of reservoir, reservoir probability of failure.

Introduction

Reservoirs are built to supplement future river flows, but no-one can forecast what these will be. It is unlikely that history will repeat itself, yet many procedures use only the historical record. To overcome this dilemma, it is often useful to generate synthetic stream flow data .Stochastic data generation provides designers and analysis of resource systems with alterative sequences of stream flow having the same statistical properties as the historical record. It is then possible to determine the storage capacity (or other design parameter) for each sequence, and thus provide the designer with a distribution of the values .This process gives an idea of the confidence which can be placed on the adopted design value. “Synthetic flows or stochastic data” do not improve poor records but merely improve the quality of designs made with whatever records are available.

In the present study, two procedures of capacity-yield are applied to estimate the reliability of Dokan reservoir by using four data generation techniques.

The Dokan Reservoir

The Dokan dam is located at about 60 km from the northen west of Al-Sulaimania town and at about 300 km from Karkok governorate. The main purposes of the Dokan project are to store and regulate the abundant water of the Lesser Zab river, a tributary of the Tigres river, by creating a large scale reservoir, to supply irrigation water required in the area downstream of the dam, and to control discharges downstream by impounding and regulating floods. In addition to the abovementioned purposes, the discharge and head obtained by the dam are to be utilized for power generation for effective use of hydraulic energy, thereby making this a multi-purpose, for irrigation, flood control, and power generation **(Iraqi Ministry of Water Resources,2007**).

Estimation of Reliability Using Data Generation Techniques

A number of generation models are used to evaluate the reliability of a reservoir by behavior analysis and Gould’s procedure. These generation models are designated by the following: TF-log=Thomas-Fiering monthly model with log transformation; TTM=two-tier model using Markovian annual flows; MTTM=modified two-tier model; MFM=modified fragment model;.

Before using the generated data in the estimation of Dokan reservoir reliability, it is necessary to make sure that those generated sequences are extracted from the same population of the historical sample. This can be done by verifying the model used in the generation by the following tests:

1. Comparison of the statistical parameters computed from the generated data with the actual values of those statistics computed from the historical records, for the purpose of simplicity, the relative error (as a percentage) was calculated (**Srikanthan and McMahon,1982**) from the following equation:

   $$\text{Relative Error} = \frac{(Generated - Historical)Value}{(Historic)Value} \times 100\%$$

   Figures (1) to (6) show the relative error of mean, standard deviation, coefficient of variation, coefficient of skewness, correlation coefficient and regression coefficient, respectively. It can be seen that the TF-log,TTM and MTTM models preserved parameters better than the MFM model. However, there was only a small difference between the TF-log and MTTM results, especially for coefficient of variation, coefficient of skewness , correlation coefficient and regression coefficient. There is a worthiness to say here that it is not a condition that the model preserved the statistical parameters to be the best model for reliability, vulnerability and resilience estimation but this will give more trust for this estimation.
2. Comparison of cumulative probability curves for the two series from historical and generated data.Figure (7) shows the cumulative probability curves for Dokan reservoir inflows based on historical and generated data. This figure indicates that all the transformations are not significantly different from that produced from historical data.
3. Comparison of the proportion of negative flows. The model is acceptable so long as the proportion of negative flow is not greater than 5% **(McMahon and Mein, 1986)**.

Table (1) shows a comparison between the statistical properties (mean, standard deviation and correlation coefficient) of all generated series by TF-log, TTM, MTTM, MFM, and that of historical series. This table indicates that the monthly statistical parameters of TF-Log and MFM generated data are very close to those of historical data.

Table (2) shows the comparison between monthly statistical parameters (mean, standard deviation and correlation coefficient) of the generated data by TF-log, TTM, MTTM, MFM and that of historical data. All the monthly means of the generated data pass the t-test and the f-test at 95% significant probability limit. Table (2) shows the results of statistical tests (t-test and f-test) for the monthly means and standard deviations, respectively, for the generated data. It can be seen that the average failure in monthly means and monthly standard deviation is 0% for all generated series.

Analysis of the Results

Figure (8) shows the effect of the number of years used in the analysis on the estimation of reliability by behavior procedure for the four methods of generation used in this research. It could be seen that the (55) year estimation series of reliability diverges away ,this may be to the longer series. Thus, the use of the longest and longest series will converge the results one to another.

Figure (9) shows the same effect of figure (8) but by using the Gould's procedure. This figure indicates that the sensitivity of results by using Gould's procedure will be less than of behavior procedure .Also, it could be seen that Gould's estimation of reliability almost less than the behavior estimation.

Figure (10) shows that the estimated vulnerability tends to move on approximately straight line and converge from one model of generation to another under the effect of time series length with increasing the monthly release from the reservoir.

Figure (11) also shows that there is a high variation in the estimated value of resilience under the effect of number of years used in the analysis and, as in reliability, the longest and longest series will converge the results.

As a result, the use of longest series in the behavior analysis to estimate the reliability, vulnerability and resilience of reservoir will make the results more accurate because of the starting month problem and the assumption of initially full will be overcome by using such series.

Figure (12) shows the reliability-yield reservoir relationship depending on Behavior and Gould's procedure using both historical and generated data .Figure (12-a) indicates that the TF-Log give a smaller reliability estimate than other models where TTM and MTTM results converges to the results based on the historical data which considered to be reasonable one by many researcher in literature. This means that the TTM and MTTM could be considered the best to represent the inflow of Dokan reservoir. Behaviour estimation of reliability is almost more than the case of using Gould's procedure for Dokan reservoir. The 95% reliability, which is considered to be an acceptable limit of reliability(**McMahon et. al ,1972**), could be obtained with a release of (72-80)% and (75-80)% from the mean flow depending on Behaviour analysis and Gould's procedure ,respectively.

Figure (13) shows the vulnerability-yield relationship and indicates that the vulnerability of reservoir increasing and tends to be a straight line with the increasing of the release (decreasing the reliability) by using the historical and generated data. Figure (13) also shows the resilience-yield relationship and indicates that there is a high difference between the historical and generated data estimate. It is also obvious that the reservoir resilience increase with the increasing of the release from the reservoir.

Effect of Starting Month on Storage Estimates

To examine the effect of starting month on storage size are calculated by starting the analysis in different months for two draft cases (55% and 75% of mean flow) at 95% reliability using both Behavior procedure and Gould analysis with historical data. The storage estimates are plotted for comparison in figure (14). It is observed from the results that the storage size estimated through Behavior analysis vary little with starting month.

Figure(15) shows the vulnerability and resilience respectively which were constant with any starting month for both cases .On the other hand Gould's storage estimates differed markedly for different month .

One way to overcome this impact is to use long sequences of synthetic month data in the analysis as shown in figure (16). It can be noted from this figure that the Gould storage estimates varied more than the Behavior estimates which were constant for all cases .However, the Gould estimates based on generated data were considerably less variable than those calculated using historical data.

Effect of Inflow Sequence Length on Storage Estimates

This section investigates the dependence of estimates of reservoir storage capacity derived using Behaviour analysis and Gould's proccedure on the length of inflow sequence used for overyear reservoir simulation.For each method of reliability estimation, 20 different sequence lengths are generated varying from 200 to 10,000 years and the required reservoir storage for each sequence is then predicted.

It follows from the stochstic theory of storage that the reliability of a reservoir operating on a single realization of the inflow process can theoretically attain steady state only as the sequence length approaches infinity**(Moran,1959**, **quoted** in **Abdul-Bari,(2006)**).

The overyear storage estimates as shown in figures (17) and (18) are significantly influenced by the length of inflow sequence analyzed. In order to remove the influence of inflow sequence length on the storage estimates by the above methods, the inflow sequence is generated for 10,000 years because of the storage estimates approached a stationary level by about 6,000 years or more for the methodes examined.

Effect of Initial Conditions on Storage Estimates

The initial reservoir condition (C_0) is typically assumed to be full (**McMahon and mein,1978**), although any initial condition ranging form empty to full could be used.Figure (19,A) showes plots of the behaviour storage estimates againest yield using historical data to explore the influence of the initial full and empty reservoir conditions.To overcom the effectes of the assumed initial conditions, a sequence length of at least 10,000 years would be required because the initially full assumption curve is converged to the initially empty curve for all generated model as shown in figure (19,B-E).

Conclusions

For this study , the following conclusions are deduced:

1. After using four data generation models, it becomes clear that the Thomas-Fiering with log transformation is the best for generating monthly inflows of Dokan reservoir among the other models.

2. Based on the historical data, the Gould storage estimates vary more widely with starting month than the Behaviour estimates which are approximately constant for all cases as well as

the vulnerability and resilience.However, the effect of starting month is relatively substantial in Gould estimates using generated data.

3. The variation in storage estimate becomes neglectable by using sequence length of 6,000 years or more for the methodes examined.

4. The influence of the initial condition (full or empty) in the Behaviour analysis is effectively nullified for inflow sequences longer than about 10,000 years.

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Table 1: Statistical properties of historical and generated data.

Series	Model	Mean (m^3/sec.)	Standard deviation (m^3/sec.)	Cs	R	Negative flows (%)	Max. flow (m^3/sec.)
Hist.		206	290.84	1.9	0.62	0	5470
Gen.	TF-log	203.49	221.57	3.43	0.71	0	2608
	TTM	215.84	261.56	2.66	0.67	0	1811
	MTTM	199.43	230.91	3.11	0.59	0	1910
	MFM	215.89	259.24	2.14	0.99	0	1737

Table 2: Monthly Statistical Parameters of Historical and Generated Monthly Data**.**

	Series	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean (m^3/sec.)	Hist.	192.46	309.11	462.15	570.89	295.71	136.09	76.18	61.27	54.78	58.89	102.06	152.58
	TF-log	196.78	298.47	435.58	579.37	287.65	142.73	81.69	63.60	54.66	58.74	97.36	144.64
	TTM	243.02	354.45	508.30	453.08	302.74	158.77	96.48	64.04	60.29	72.72	110.96	163.86
	MTTM	221.89	327.56	460.51	429.91	289.78	151.91	83.14	57.73	54.79	61.04	103.25	156.40
	MFM	160.92	402.30	742.44	473.02	237.73	98.03	54.86	43.89	43.89	47.55	73.15	212.12
Standard deviation (m^3/sec.)	Hist.	105.63	155.01	312.98	724.42	159.68	67.80	38.50	37.55	24.06	22.78	63.91	110.36
	TF-log	109.74	171.55	220.45	393.00	147.02	71.01	38.96	36.57	25.30	25.63	58.83	86.773
	TTM	185.29	257.74	349.81	479.49	223.12	115.15	83.38	69.20	51.04	68.28	105.46	124.87
	MTTM	138.46	182.83	258.81	479.69	183.60	93.42	46.58	50.86	29.712	32.51	73.56	100.67
	MFM	81.48	203.70	375.91	242.31	120.37	51.12	27.77	22.22	22.22	24.07	37.04	107.40
Correlation coefficient	Hist.	0.667	0.477	0.379	0.284	0.920	0.859	0.778	0.795	0.632	0.541	0.462	0.704
	TF-log	0.767	0.642	0.590	0.504	0.924	0.920	0.851	0.913	0.572	0.721	0.598	0.549
	TTM	0.802	0.646	0.348	0.188	0.922	0.900	0.808	0.830	0.377	0.831	0.721	0.710
	MTTM	0.745	0.600	0.388	0.205	0.815	0.796	0.471	0.865	0.311	0.590	0.642	0.616
	MFM	1.00	1.00	0.999	0.999	0.917	0.917	1.00	1.00	1.00	1.00	0.999	1.00

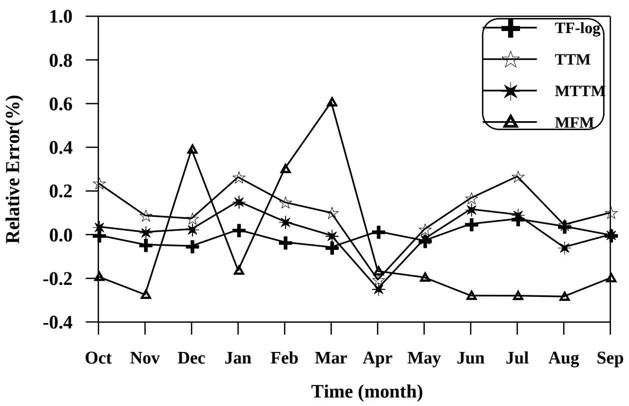


Figure 1: Relative error of the mean.

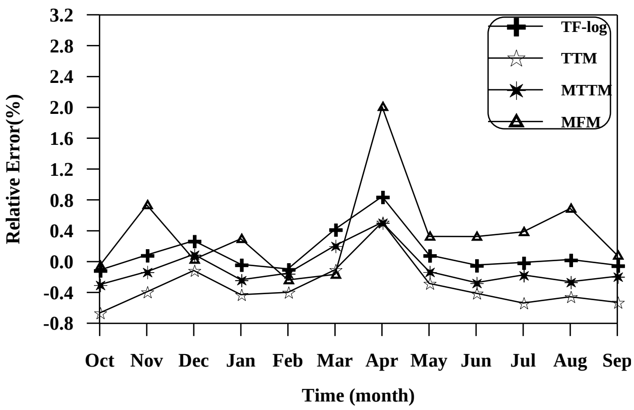


Figure 2: Relative error of the standard deviation.

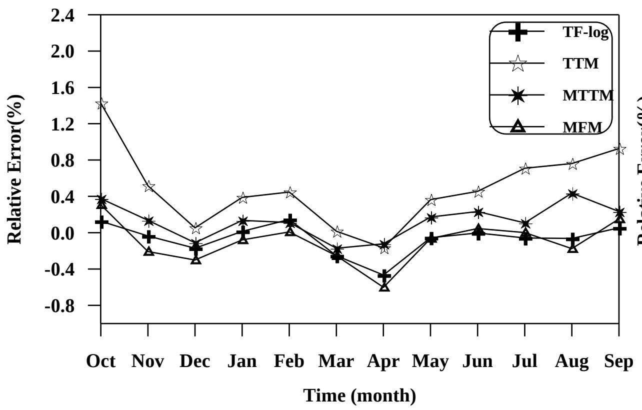


Figure 3: Relative error of the coefficient of variation.

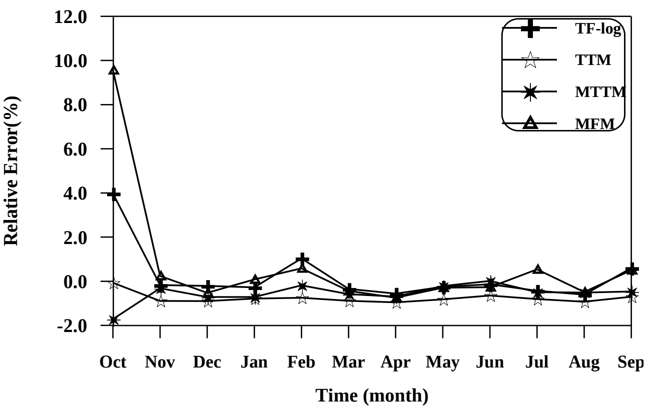


Figure 4: Relative error of the coefficient of skewness.

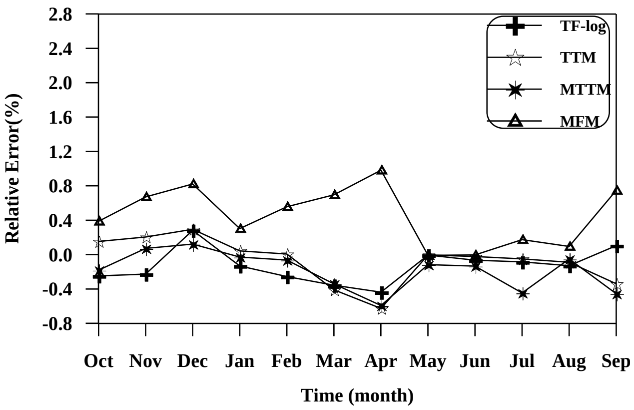


Figure 5: Relative error of the correlation coefficient.

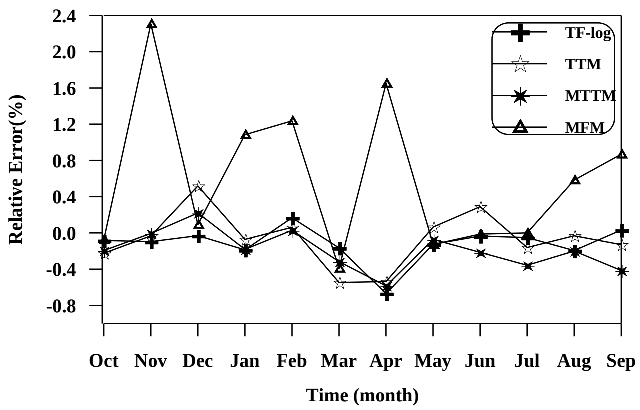


Figure 6: Relative error of the regression coefficient.

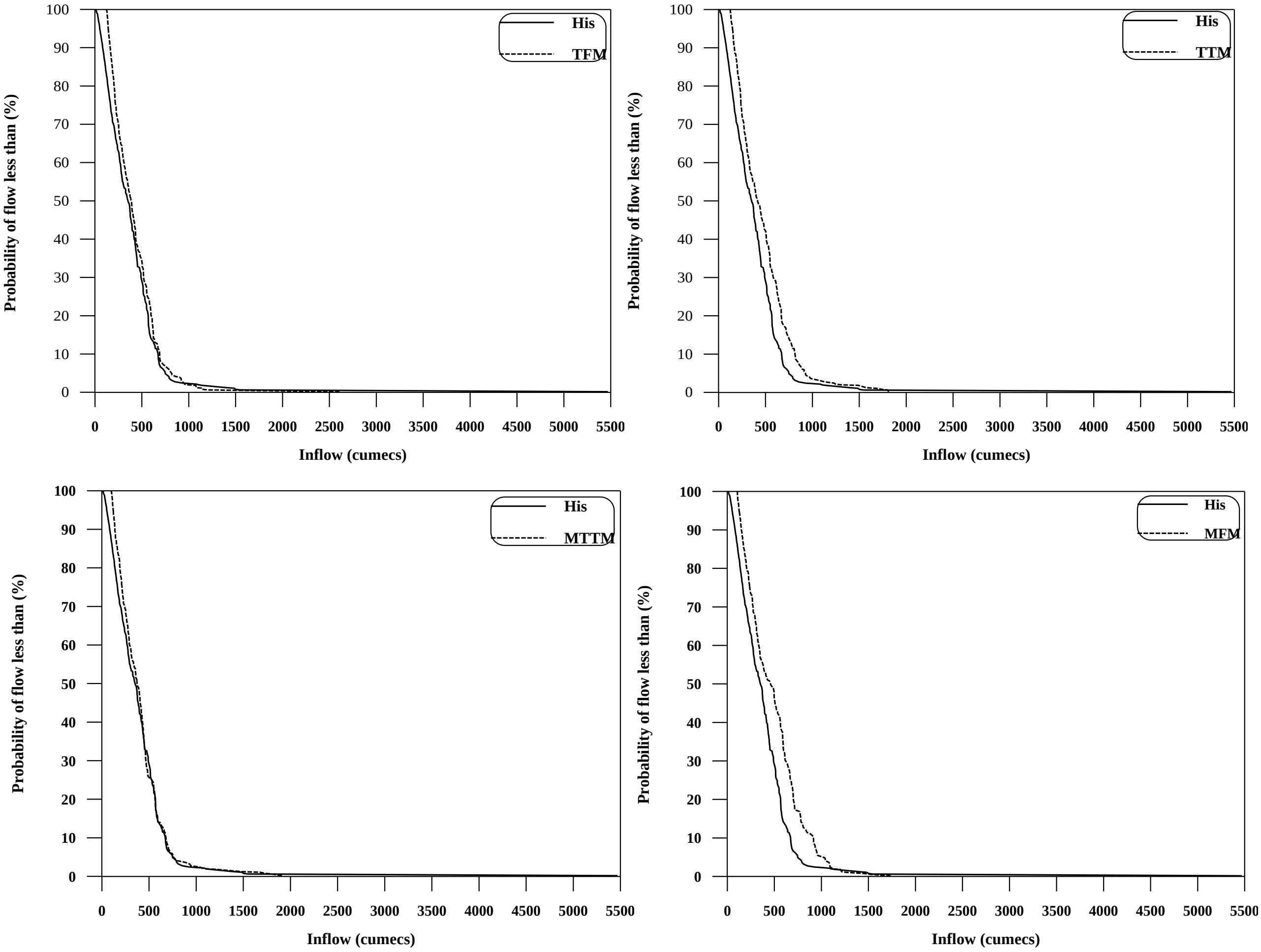
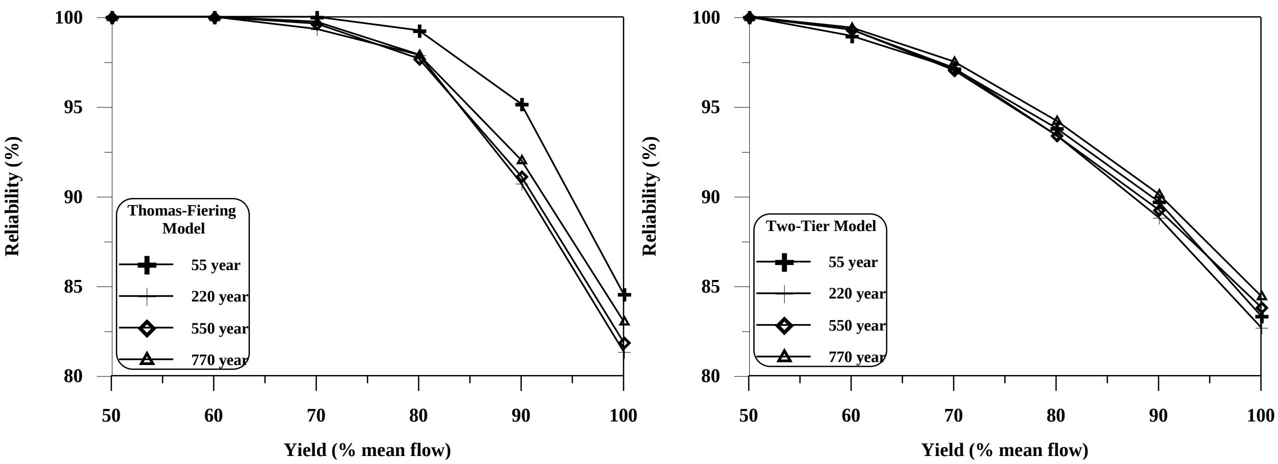


Figure 7: Cumulative probability function for Dokan reservoir inflow using both historical and generated data.



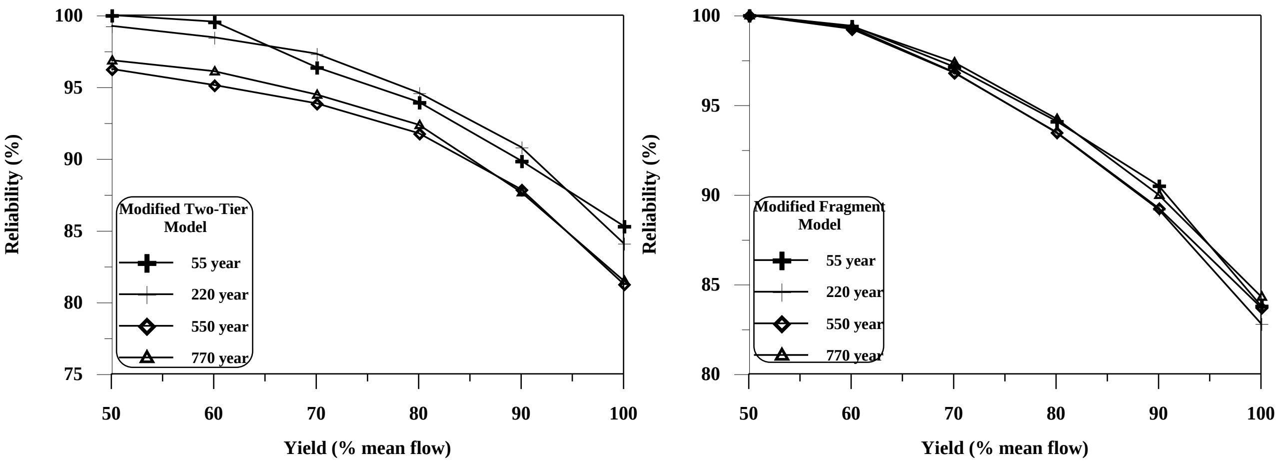


Figure 8: Effect of number of years used in generation on the estimation of reliability by Behavior procedure.

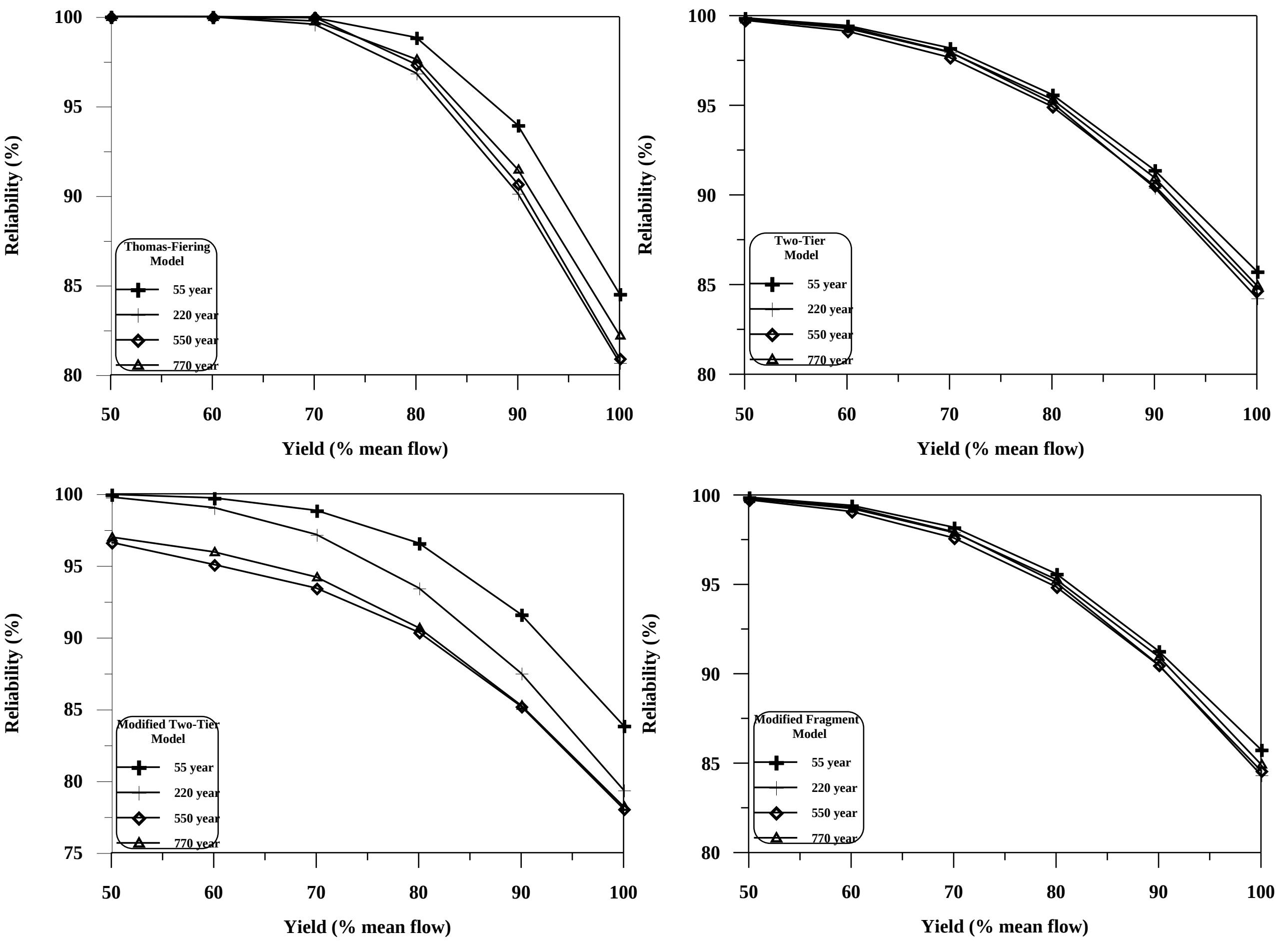


Figure 9:Effect of number of years used in generation on the estimation of reliability by Gould's procedure.

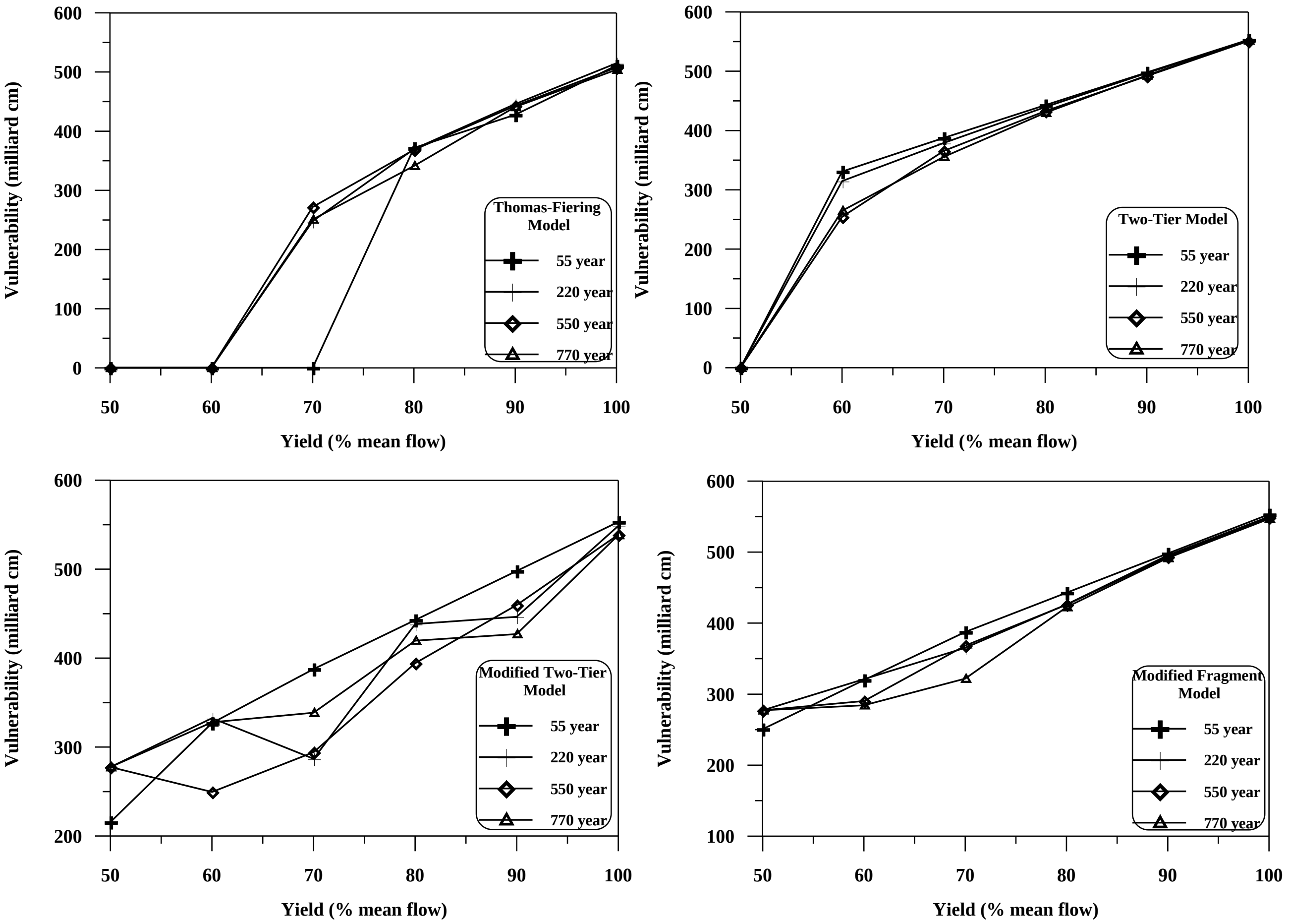
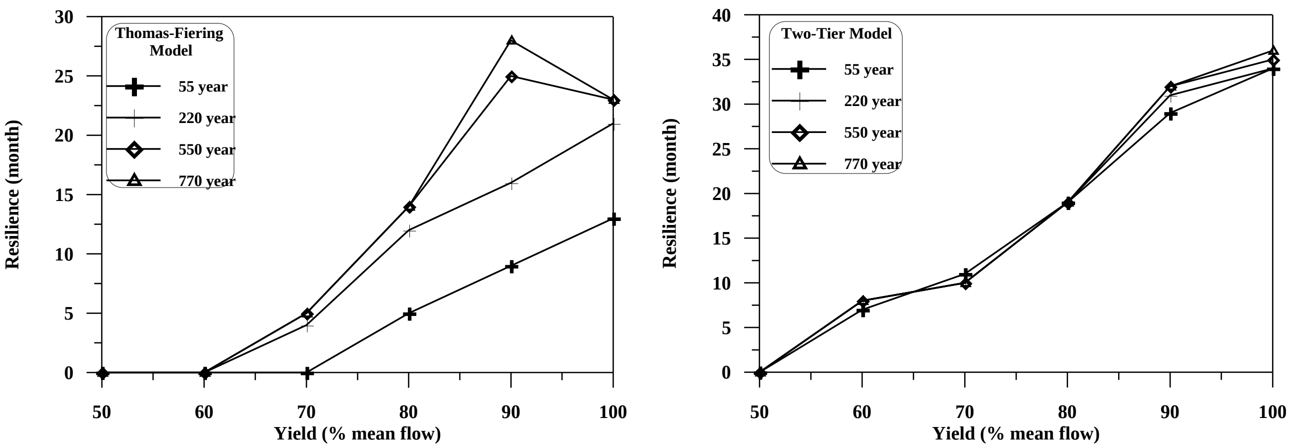


Figure (10): Effect of number of years used in generation on the estimation of vulnerability.



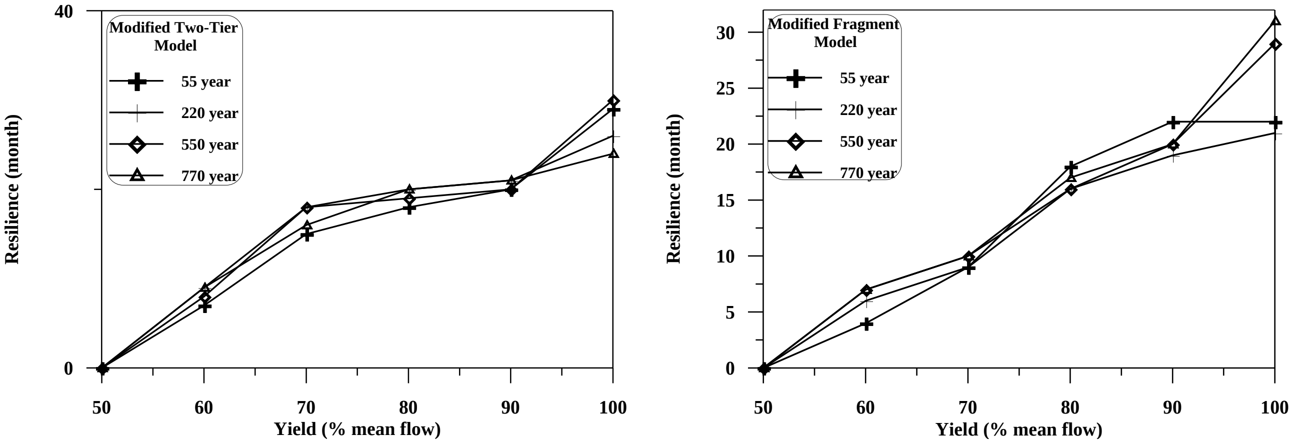


Figure 11: Effect of number of years used in generation on the estimation of resilience.

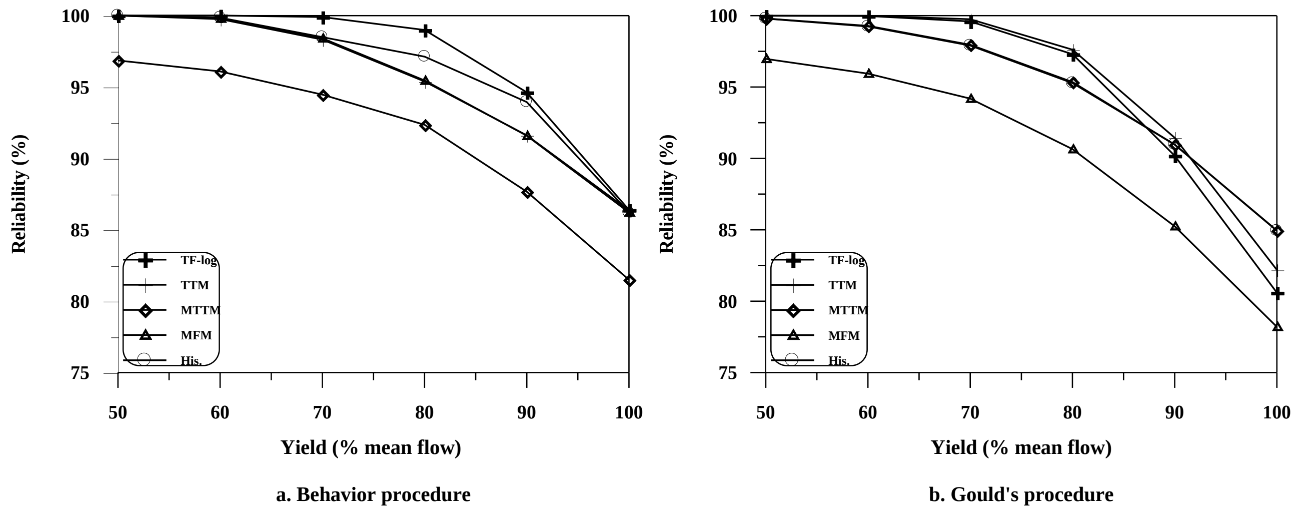


Figure 12: Reliability-yield relationship depending on Behavior and Gould's procedure using both historical and generated data (770 years of generation).

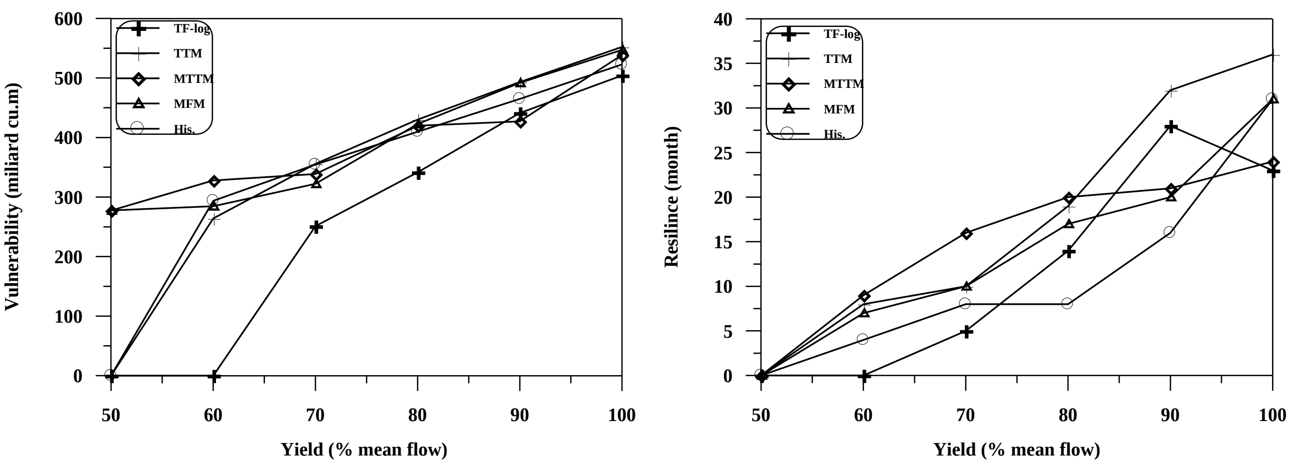


Figure 13: Vulnerability-yield and Resilience-yield relationships depending on both historical and generated data (770 years of generation).

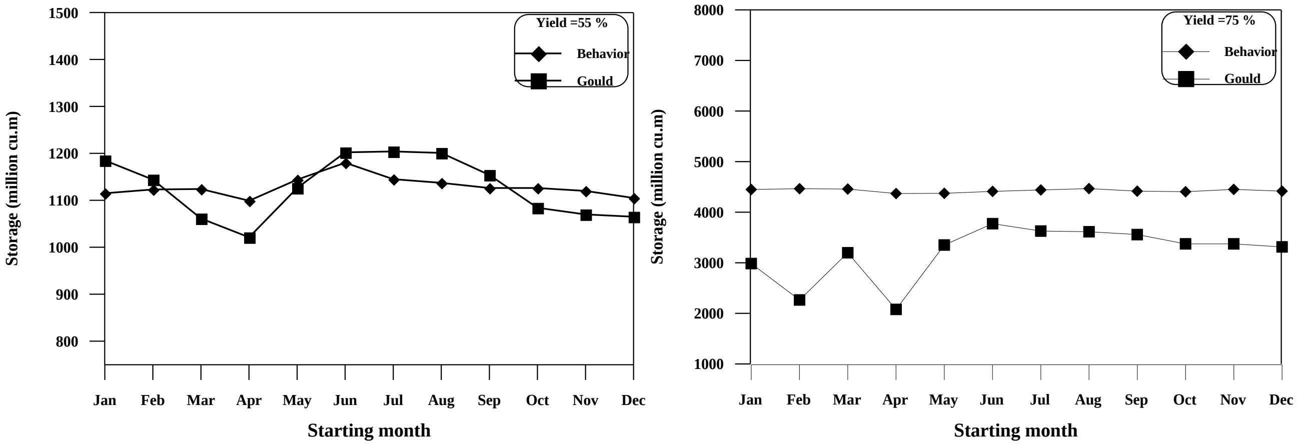


Figure 14:Effect of starting month on Storage estimates using historical data.

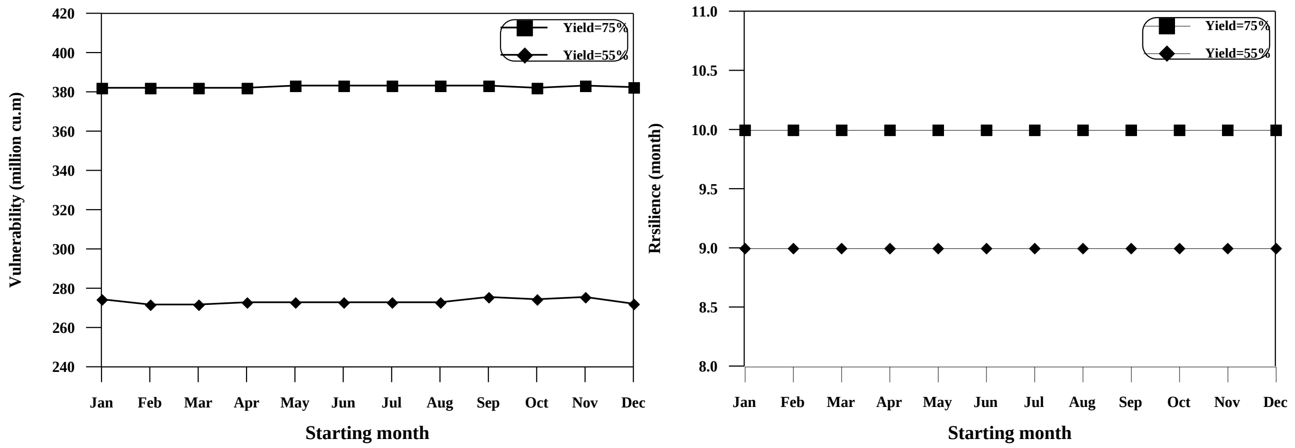


Figure 15:Effect of starting month on Vulnerability and Resilience estimates using historical data.

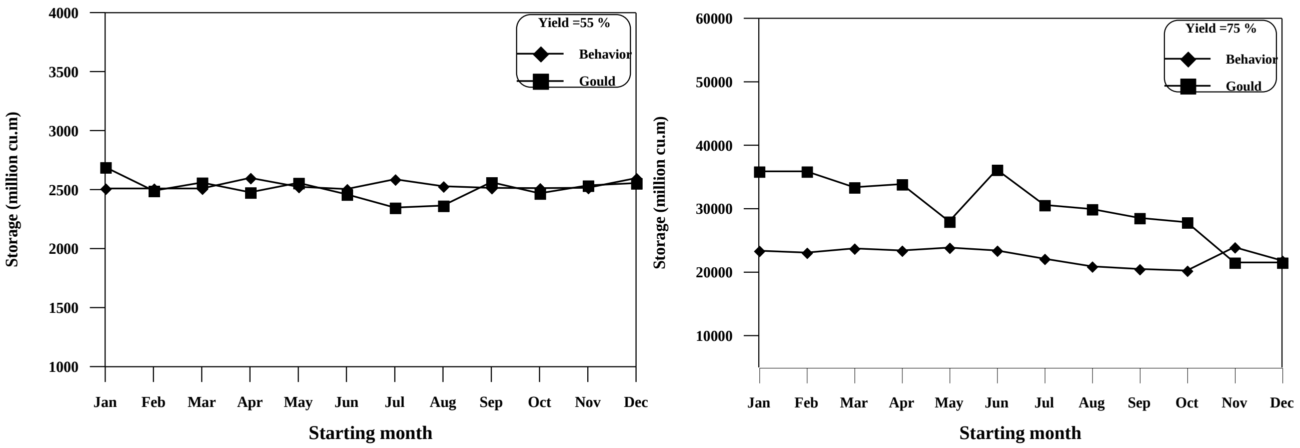


Figure 16:Effect of starting month on Storage estimates using generated data.

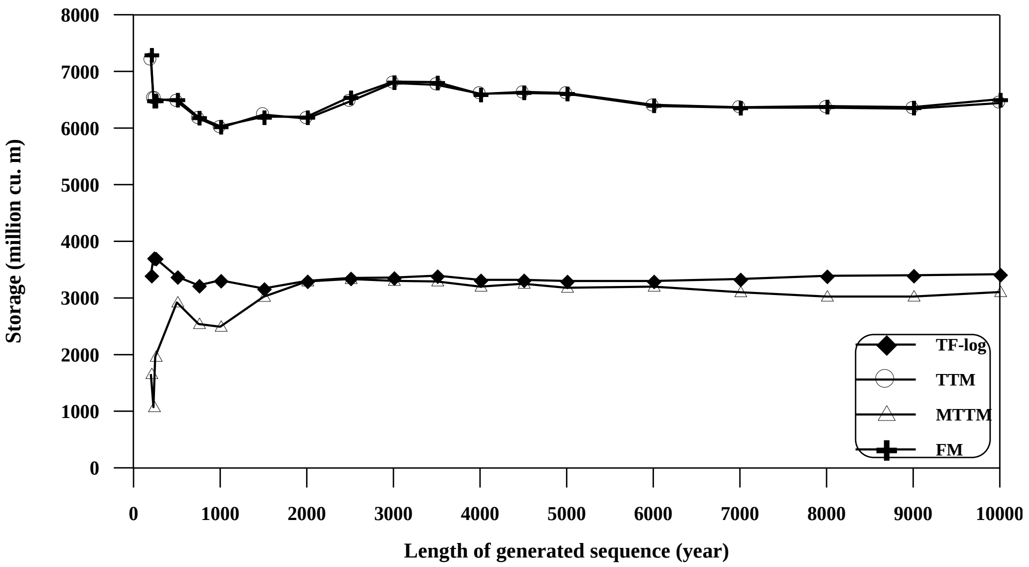


Figure 17:Effect of inflow sequence length on storage estimates by Behavior analysis (yield=75% of mean monthly flow).

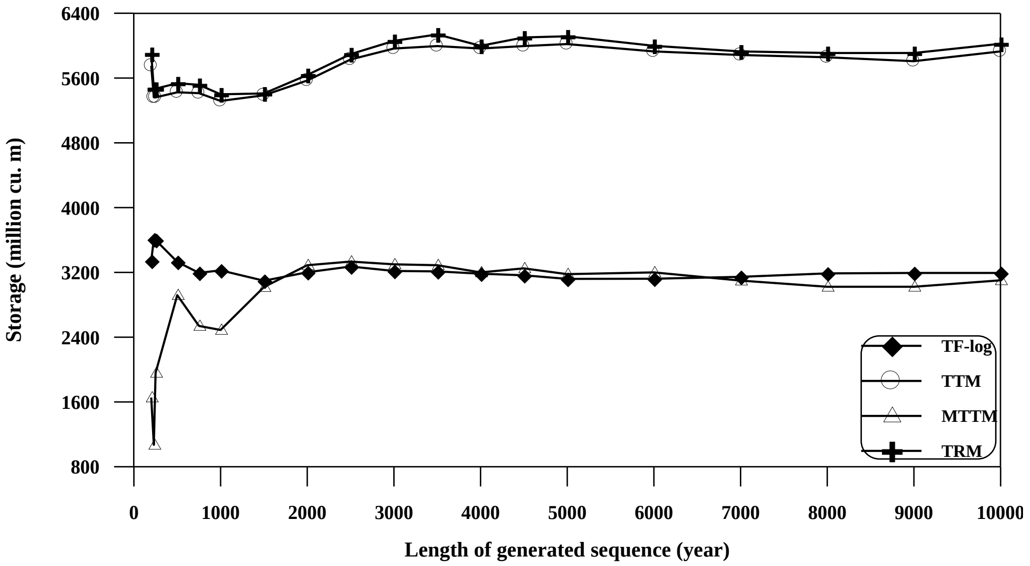


Figure 18:Effect of inflow sequence length on storage estimates by Gould's procedure analysis (yield=75% of mean monthly flow).

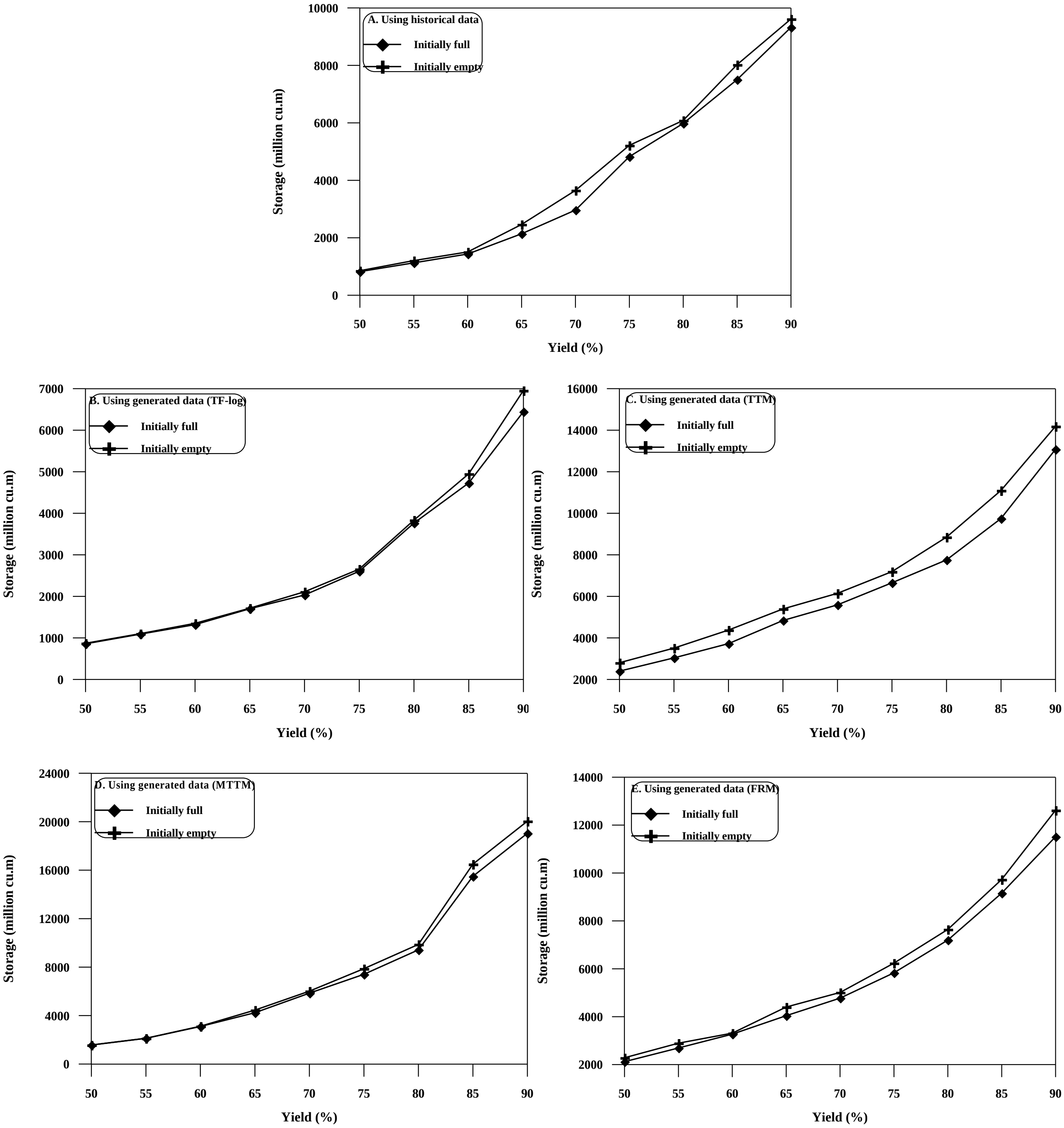


Figure 19:Effect of initial conditions on storage estimates using Behaviour analysis.