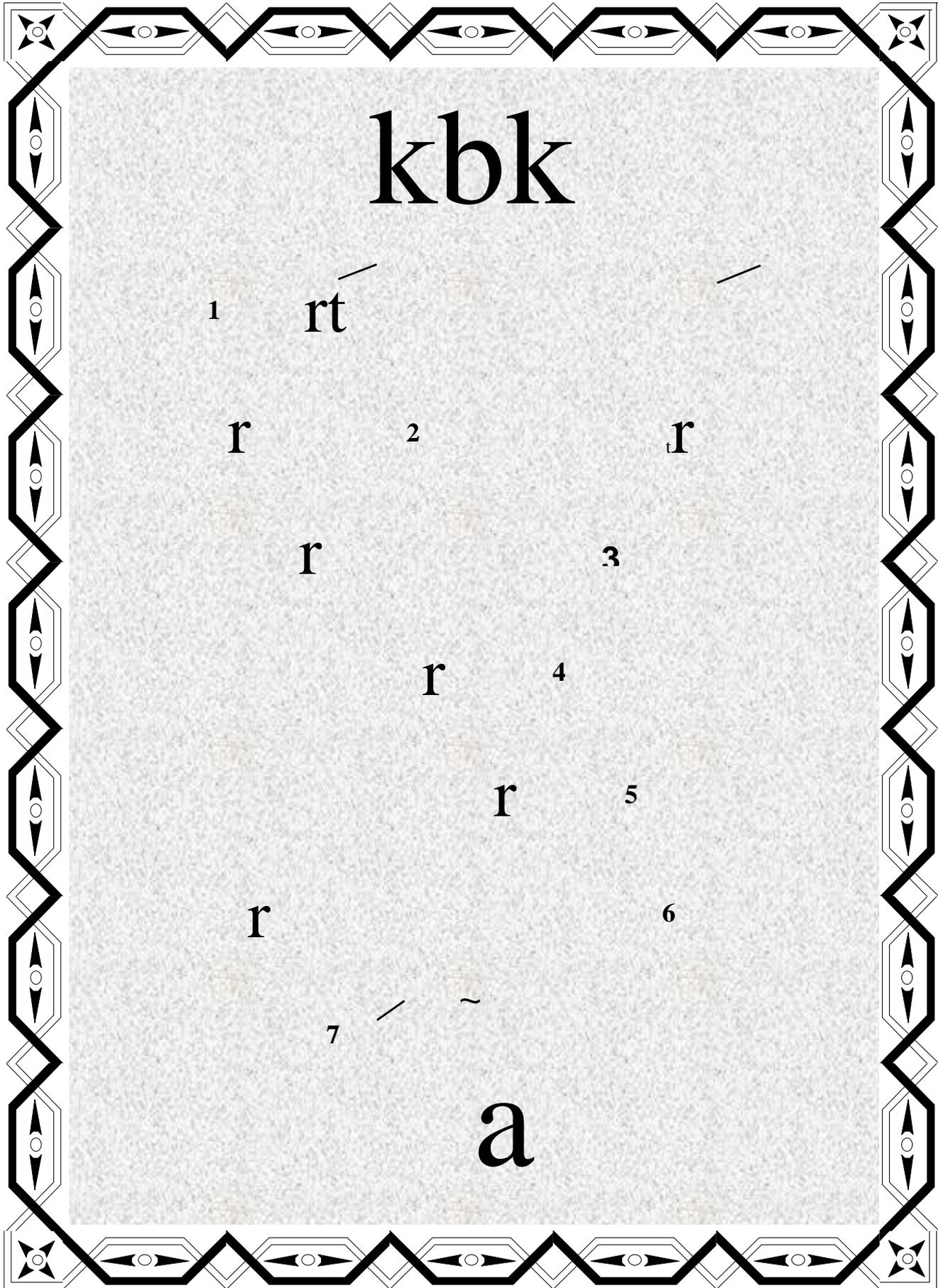


# **OPTIMUM OPERATION OF MAKHOOOL DAM**

**A thesis  
submitted to the Civil Engineering  
Department of the College of Engineering  
University of Babylon  
in partial fulfillment of the requirements for  
the degree of Master of Science  
in Water Resources Engineering**

**By  
Riyadh Hamad Motlib  
(B.Sc. Eng. 1991)**

January - 2004



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To my family, relatives and friends  
especially for

My wife and  
children

Rania , Sara  
&

Ahmed

## **CERTIFICATION**

We certify that this thesis entitled “**The optimum operation of Makhool Dam**”, was prepared by **Riyadh Hamad Motlib**, under our supervision at the Civil Engineering Department, University of Babylon, in partial fulfillment of the requirements for the **Degree of Master of Science in Water Resources Engineering**.

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## ABSTRACT

In this research, the discrete differential dynamic programming approach is used to find the optimal monthly operation of Makhool Dam by adopting an objective function to minimize the release and storage penalty. The historical inflow data of (480) months [from Oct. (1960) to Sep. (1999)] formed the input data to the optimization model.

To preserve the logical state of reserve storage, i.e., save minimum operation storage just before the expected start of the effective flood, and maximum operation storage at the end of the flood season, a new constraint has been introduced. The new constraint also ensured the smoothness of the resulting optimum rule curves (lower, average and upper).

A simulation model is also developed to operate the system depending on the rule curves. Moreover, the recorded data of the water years (1988) and (1999) have been considered to represent a wet year and dry year, respectively. The developed optimization model is applied to two operation scenarios that represent the extreme cases, namely, two consecutive wet years and two consecutive dry years.

The results of the research indicate that:

### ***A- For the simulation model:***

- 1-For the present situation where Bekhma Dam is not existing, the optimum operation policy has shown deficit in satisfying the demands downstream Makhool Dam. The deficiency was noticed during (30) months out of the total operation period considered in the research (which is (480) months).
- 2-Considering Bekhma Dam is operational, the optimum operation policy has shown deficit in satisfying the demands downstream Makhool Dam.

The deficiency was noticed during (21) months out of the total operation period considered in the research.

3-The flood has been completely controlled during the considered operation period whether Bekhma Dam is not existing or when it is operational.

4-As an average, the power station has operated in full capacity in (124) day per year when Bekhma Dam is not existing and in (166) day per year when Bekhma Dam is operational during the total operation period.

***B: For the selected operation scenarios:***

1-The water demands have been fully satisfied during the two consecutive wet years when Bekhma Dam is not existing and when it is operational.

2-The operation has shown deficit in satisfying the demands during the two consecutive dry years. The deficiency was noticed during (6) months in each year of the operation when Bekhma Dam is not existing. A similar trend (out to a less extend) has been noticed when Bekhma Dam is considered in operation.

3-The flood has been completely controlled during the two consecutive wet and dry years when Bekhma Dam is not existing and when it is operational.

# CONTENTS

	<u>Page</u>
<b>Acknowledgment</b>	i
<b>Abstract</b>	ii
<b>List of symbols</b>	vi
<b>List of figures</b>	vii
<b>List of tables</b>	viii
<b>Chapter One: Introduction</b>	viii
1-1 General	
1-2 Objectives of the research	1
1-3 Methodology of the research	4
<b>Chapter Two: Review of literature</b>	4
2-1 General	
2-2 Dynamic programming (DP)	5
2-3 Discrete differential dynamic programming (DDDP)	5
	8
<b>Chapter Three: Principle and theory of dynamic programming and discrete differential dynamic programming</b>	
3-1 Characteristics of dynamic programming	11
3-2 The objective function	16
3-3 The constraints	19
3-4 The discrete differential dynamic programming (DDDP)	21
3-5 Values of the state variables within the corridor	28

## **Chapter Four: The case study**

4-1	Makhool reservoir	31
4-2	Assembly of hydrologic and hydraulic information	32
4-2-1	Reservoir characteristics	32
4-2-2	Maximum and minimum permissible flow	37
4-3	Optimum operation rule curves	38
4-4	Optimum operation by simulation	43
4-4-1	The simulation model	43
4-4-2	Fundamental conditions for simulating monthly operation	45
4-4-3	Monthly operation procedures	45
4-4-4	Results of simulation	48
4-5	Selected operation scenarios	52
4-6	Analysis of the results	55
4- 6-1	Results of the simulation model	55
4- 6- 2	Results of the selected operation scenarios	57

## **Chapter five: Conclusions and recommendations**

5-1	Introduction	59
5-2	Conclusions	59
5-3	Recommendations	62

<b>References</b>	<b>63</b>
-------------------	-----------

**Appendix A**

**Appendix B**

**Appendix C**

**Appendix D**

## LIST OF FIGURES

<b>Fig.No</b>	<b>Title</b>	<b>Page</b>
<b>Chapter Three</b>		
3-1	Mathematical description of DP	15
3-2	Illustration of backward recursion	15
3-3	General scheme of the DDDP procedure	22
3-4	Algorithm in the first and other than first periods	26
3-5	Schematic representation of a trial trajectory, the boundary, the boundary-defining corridor, and optimal trajectory	26
3-6	Algorithm values of state variables	30
<b>Chapter Four</b>		
4-1	Area, Elevation–Storage relationships of Makhool Reservoir	36
4-2	Optimum operation rule curves of Makhool Reservoir when Bekhma Dam is not existing	41
4-3	Optimum operation rule curves of Makhool Reservoir when Bekhma Reservoir is operational	42
4-4	Flowchart showing the simulation model of monthly operation methodology	44
<b>Appendix A</b>		
A-1	Location map of Makhool Dam	A1
A-2	Monthly outflow from Makhool Reservoir resulting from simulated operation when Bekhma Dam is not existing	A2
A-3	Water level at Makhool Reservoir resulting from simulated operation when Bekhma Dam is not existing	A4
<b>Appendix C</b>		
C-1	Monthly outflow from Makhool Reservoir resulting from simulated operation when Bekhma Dam is operational	C1
C-2	Water level at Makhool Reservoir resulting from simulated operation when Bekhma Dam is operational	C3

## LIST OF SYMBOLS

Symbol	Definition	Unit
a,b,c,d,e	Constants.	
DDDP	Discrete differential dynamic programming.	
Delta( $\Delta$ )	Storage increment.	MCM
Dem	Water requirements.	cumecs
$D_i$	Decision variable.	MCM
DOS	Design operation storage	MCM
DP	Dynamic programming.	
ET(j)	The net monthly water (gain or loss).	m
I(i)	Inflow during i-th month.	cumecs
i	Stage.	
MOS	Minimum operation storage.	MCM
minPF	Minimum permissible flow.	cumecs
maxPF	Maximum permissible flow.	cumecs
N	Total number of stages.	
PC	Power capacity.	cumecs
Q (i, j)	Release of water during the i-th month and j-th year.	cumecs
$R_i$	Return variable.	
S max	Maximum storage.	MCM
S min	Minimum storage.	MCM
$S_i$	State variable.	MCM
$T_i$	Stage transformation.	MCM
X	Factor.	
$\alpha, \gamma, \lambda$	Parameters.	

## LIST OF TABLES

Table No.	Title	Page
<b>Chapter One</b>		
1.1	Monthly inflow mean and water requirements at the location of Makhool Dam	3
<b>Chapter Four</b>		
4.1	Basic storage levels in Makhool Reservoir	33
4.2	Estimated mean monthly precipitation and evaporation at Makhool- Reservoir area	34
4.3	Topographic features of Makhool Reservoir	34
4.4	Values of the coefficients of elevation, area and storage relationships of Makhool Reservoir	36
4.5	maximum and minimum permissible flows downstream of Makhool Reservoir	37
4.6	Values of optimum rule curves when Bekhma Dam is not existing.	40
4.7	Values of optimum rule curves when Bekhma Dam is operational.	40
4.8	Results of simulation of the monthly operation of Makhool Reservoir when Bekhma Dam is not existing.	50
4.9	Results of simulation of the monthly operation of Makhool Reservoir when Bekhma Dam is operational.	52
4-10	Inflow data at Makhool Reservoir in wet and dry years	52
4-11	Results of operating Makhool Reservoir when Bekhma Dam is not existing.	53
4-12	Results of operating Makhool Reservoir when Bekhma Dam is operational.	54

	<b>Appendix B</b>	
B-1	Inflow (cumecs) to the Makhool Reservoir when Bekhma Dam is not existing	B1
B-2	Optimum outflow (cumecs) from Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	B2
B-3	Optimum water level (m.a.s.l.) of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	B3
B-4	Optimum outflow (cumecs) from power outlet of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	B4
B-5	Optimum outflow (cumecs) from bottom outlets of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	B5
B-6	Optimum water level (m.a.s.l.) of Tigris River downstream Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	B6
B-7	Optimum rated head (m) of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	B7
B-8	Optimum power output (MW) from Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	B8
B-9	Optimum energy power potential (GWh) of Makhool Dam for the water years (1960 -1999) as obtained by the simulation model.	B9
B-10	Periods when the flow violated the demands for real operation scheme when Bekhma Dam is not existing.	B10
	<b>Appendix D</b>	
D-1	Inflow (cumecs) to Makhool Reservoir when Bekhma Dam is operational	D1
D-2	Optimum outflow (cumecs) from Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	D2
D-3	Optimum water level (m.a.s.l.) of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	D3

D-4	Optimum outflow (cumecs) from power outlet of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	D4
D-5	Optimum outflow (cumecs) from bottom outlets of Makhool Dam for the water years(1960-1999) as obtained by the simulation model.	D5
D-6	Optimum water level (m.a.s.l.) of Tigris River downstream Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	D6
D-7	Optimum rated head (m) at Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	D7
D-8	Optimum power output (MW) from Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	D8
D-9	Optimum energy power potential (GWh) of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.	D9
D-10	Periods when the flow violated the demands for real operation scheme when Bekhma Dam is operational.	D10

# CHAPTER ONE

## INTRODUCTION

### 1-1 General

Iraq has a large area under irrigation. This irrigated area is continuously increased so as to establish ensured irrigated cropping and avoid cropping failure due to famine or untimely water. To secure the benefits of irrigated land, a tremendous amount of capital has been invested in irrigation projects. Since irrigation water is a costly commodity, then, there should be no wastage during its flow from the source to the fields.

Turkey and Syria constructed additional reservoirs like Atatork reservoir in Turkey and Tabaka in Syria. These reservoirs, especially the one in Turkey, reduce the quantity and quality of water which arrives to Iraq. This reduction is reflected in providing sufficient water for irrigation, industrial and domestic uses.

For these reasons, it becomes necessary to control, operate and manage the water resources systems more efficiently and optimally. Consequently, additional reservoirs have been suggested and some are to be constructed like Makhool and Bekhma Reservoirs.

Makhool district is one of the promising areas in Iraq in Province Salah Al- Deen. The Makhool Dam on Tigris River is currently under construction and expected to be put in regular operation during a near time. It is one of the important dams in Iraq that controls the water of Tigris River upstream of Baghdad City to protect it from flood.

The problems in water resources management arise when water is frequently available at a certain time and in excessive quantities (which may destroy the agricultural lands in the neighbourhood) and much less than the normal on another time. Consequently, the various water demands for most economical activities perhaps cannot be satisfied by the normal supply of the stream flow. The inflow to the Makhool Reservoir during October to June and September is usually larger than the water requirements, while it is less in other months when Bekhma Dam is not existing and the inflow usually larger than the water requirements when Bekhma Dam is operational. This discrepancy, especially in wet years, would flood Baghdad City if it coincides with the flood of the downstream distributaries of the Tigris, namely, Al-Adhaim and Diyala rivers. Table (1-1) shows these differences. From the previous explanation, several considerations arise such as, **(Ali (1983))**:

- 1-What structure should be established to satisfy the water requirements, using natural water supply?
- 2- To what extent the water resource should be developed?
- 3- How should the system be operated, provided that it satisfies the water requirements and fulfills the set of objectives included through the constraints?

**Table (1-1): Monthly inflow mean and water requirements at the location of Makhool Dam**  
**[After Al-Furat Center, 2000]**

<b>Month</b>	<b>Inflow mean without Bekhma Dam (cumecs)</b>	<b>Inflow mean with Bekhma Dam ( cumecs)</b>	<b>Water requirements D/S Makhool site (cumecs)</b>
<b>OCT.</b>	829	1209	601.3
<b>NOV.</b>	855	1060	438.8
<b>DEC.</b>	920	759	228.4
<b>JAN.</b>	1025	878	270.1
<b>FEB.</b>	1194	968	473.7
<b>MAR.</b>	1643	1355	615.6
<b>APR.</b>	2461	2017	896.6
<b>MAY</b>	2488	2015	880.7
<b>JUN.</b>	1518	1609	1213.2
<b>JUL.</b>	1098	1476	1122.3
<b>AUG.</b>	969	1375	969.8
<b>SEP.</b>	851	1095	666.5
<b>SUM.</b>	<b>15022</b>	<b>14607</b>	<b>8377.5</b>

Accordingly, the optimum operation of the reservoir to overcome the events of floods and drought along the year, worth the effort.

The normal approach followed in the determination of the optimum operation of a dam usually depends on the historical data of the sequential stream flow measurements. Many techniques of optimization have been used to obtain the optimal operation; the basic ones are linear programming, non-linear programming, and dynamic programming. The

most widely used one is the dynamic programming due to its ability to deal with discrete dynamic models with no limitation on the type of equations governing the system constraints or cost function. In this research, the discrete differential dynamic programming is adopted to find the optimum operation rules for the under - construction dam on the Tigris River, namely, Makhool Dam.

The major objectives of this research are:

Determining the optimum operation policy for Makhool Dam that reflects the benefits aimed at by the construction of the dam, namely:

- a- Satisfaction of water demands.
- b- Flood control.
- c- Hydro-power generation.

### **1- 3 Methodology of the research**

With Makhool Dam as the chosen case study, the methodology of the research can be summarized in the following steps:

- 1-Establishing an optimization model to represent the management and operation of Mokhool Dam. This is achieved in Chapter Three.
- 2-Choosing an appropriate solution procedure to solve the established model. This is presented in Chapter Four.
- 3-Applying the developed model to a set of selected practical operation scenarios. This is presented in Chapter Four.

# CHAPTER TWO

## REVIEW OF LITERATURE

### 2-1 General

Beside the preparation and analysis of the respective hydrologic data, the optimization process involves two distinct steps, namely, the formulation of the optimization model, and the solution of the formulated programming model.

As will be shown in Chapter Three, a dynamic programming (DP), formulation solved by the discrete differential dynamic programming (DDDP) approach is the most appropriate in this regard. Consequently, the review of literature shall concentrate on these two main subjects. Among the so many researches available in this respect, only some representative examples are reviewed.

### 2- 2 Dynamic programming (DP)

Dynamic programming (DP), nowadays, is a well-known technique for formulating an optimization model, particularly in water resources studies. The (DP), unlike most other optimization techniques, is not restricted by any requirements of linearity, convexity, or even continuity. Nevertheless, it is restricted to specific forms of the objective function, namely, the decomposable (**Bellman (1957)**).

**Fult and Hancock (1972)** have presented dynamic programming computer model to accomplish optimum water and power operating strategy for the Shasta –Trinity Division of the Central Valley Project. The model uses state increment dynamic programming and predicted inflows to yield optimum daily releases and storage capacities for (30) day.

**Bhaskar and Whitlach (1980)** applied a backward looking dynamic programming algorithm to single – and multi - purpose reservoir in order to find the optimal rules. The (DP) solves both the one sided and two sided quadratic loss functions. Regression of the optimal set of releases was also used to develop monthly policies and again linear policies were as good as or better than non- linear policies for two sides quadratic loss function.

**Yeh and Becker (1982)** used two sets of monthly historical stream flows. One set is corresponding to a drought year and the second set to an excessive water year to develop a practical procedure for the analysis of multiple purpose, multiple reservoir system in California Central Valley Project. They showed that the modified linear and dynamic programming algorithm is good technique to develop and guide real time decisions concerning the optimal operation for the California Central Valley Project.

**Turgeon (1982)** stated that increment dynamic programming may not converge to the optimum solution if the same objective function is used for every stage.

**Yakowitz (1982)** used a four- reservoirs problem to illustrate the efficiency of constrained differential dynamic programming algorithm. He also enlarged the problem to (10) reservoir case and computed the optimal policy.

**Marino and Mohammadi (1983)** determined optimum monthly release for a multi – purposes reservoir developing a reliability – programming model. The model is based on chance constrained linear programming and dynamic programming. The flood and drought reliabilities were represented in the chance constrained linear programming in the form of chance constraint. They applied their model to the Faisom Reservoir of the California Central Valley Project.

**Mohammadi and Marino (1984)** applied (DP) for the maximization of monthly water and energy output of a system of two reservoirs. Then, they presented a daily operation model from the monthly model. The model used optimum monthly water and energy contrast levels obtained from the monthly release policy.

**Gulton (1985)** applied a dynamic programming technique model that was developed by **(Harboe (1979))** to determine an optimal policy in the long term for a multi purpose single reservoir located on the Fuerte River in the north western part of Mexico.

**Paudyal and Gupta (1990)** have used techniques of linear programming (LP), dynamic programming (DP), simulation, and a combination of any two of these to optimize the integrated use of surface and ground water resources for irrigation. A solution strategy has been developed to solve a large system in a computationally satisfactory manner, more attractively, on microcomputers.

## 2-3 Discrete differential dynamic programming (DDDP)

Discrete differential dynamic programming is a solution technique of a model formulated as a dynamic program. It permits to solve a high – dimensional dynamic programming problem within the range of computers now available.

**Heidari et al. (1971)** presented the solution of the problem of four reservoirs by a method which is named (DDDP) and gave a detailed numerical solution for a hypothetical four- reservoirs system, which became a benchmark test problem for the researchers after that.

**Jamshidi and Mohseni (1976)** used the four- reservoirs problem with statistical observation on the incoming water flows, depending on the same technique of **(Heidari et al. (1971))** to obtain the optimum trajectories.

**Ali (1978)** presented the analysis of a complex water resource system for multiple use of water. The system includes six reservoirs and two major streams located on the Teedule River in the United Kingdom. The problem was to minimize objective functions, which depended on release of water and storage states. This was accomplished by combining deterministic (DDDP) algorithm and regression analysis. The operation rules were constructed to define the optimal policy estimated as a function of inflow, storage, past inflow and time of the year.

**Murray and Yakowitz (1979)** used the four – reservoirs problem to illustrate the efficiency of their constrained differential dynamic programming algorithm. Then, they enlarged the problem to solve (10) reservoirs case and computed the optimal policy.

**Houck and Toebes (1983)** have represented a study of the optimal operation of an existing multi- purpose, multi- reservoir system by using forecasts. An optimization model was constructed for a system of four flood control reservoirs in the Green River Basin.

**Ali (1984)** compared the differences between the (DP) solution method and the (DDDP) method. He showed that the (DDDP) is faster than the conventional (DP) procedure of solution in providing the results, and does not need a high memory and computer time when they are applied to solve the problem of a large water resources system involving multi- purpose reservoirs.

**Hameed (1985)** studied the reservoirs of Diyala River in Iraq (Derbndi Khan and Hamrin Reservoirs), with (20) year record of historical monthly flow data by using the (DDDP) as a solution technique with regression analysis to define a set of release rules. He found out that the system was safe against flood but was not adequate during drought periods.

**Saleh (1989)** applied (DDDP) to develop optimal monthly release policies for the Euphrates River system in Iraq. He showed that a quantity of water should be diverted from upstream Ramadi Barrage to Habbaniya Lake in order to control flood downstream the barrage and refresh Habbaniya Lake by almost continuous mixing.

**Fadhil (1990)** used the (DDDP) to obtain the optimum monthly releases from each of Mosul, Bekhma and Dokan reservoirs system in Iraq. These reservoirs were operated individually and independently.

**Mark (1992)** applied the (DDDP) technique to find the daily optimum operation rule curves of Bekhma Reservoir by using (10) years of historical hydrological daily data. The aim of the study was to reduce

the losses in the objective function caused by drought, flood and exceeding the reservoir storage limits. He found that the operation of the reservoir provides a full protection against floods.

**Al- Delewy (1995)** developed a (DDDP) model to solve the problem of monthly operation of a multi- purpose, multi- reservoir system. The objective function was to control floods, pollution, while providing irrigation requirements and generation of electrical power. He applied his model to the system of Diyala- River reservoirs with a (30) year record of monthly inflow historical data.

**Nandalal and Bogardi (1995)** used (DDDP) technique to present two optimization models in order to derive operation policies for a reservoir when the quality considered are important in addition to satisfying the quantity requirements.

**Ishaq (1998)** used the (DDDP) approach to find the monthly optimal operation for the Iraqi reservoirs system. A historical inflow data of (420) month from October (1962) were used in this study.

**Lateef (1999)** used (DDDP) technique to present the optimization of Al- Adheem Dam operative policy. A historical inflow data of (60) year from (1936) to (1996) and daily data for seven years were used in this study.

**Muhsun (2002)** used the (DDDP) method to find the optimum operation policy of the Tigris reservoirs system with the effect of the under- construction reservoirs (Bekhma and Makhool) on the behavior of the system. The optimum operation rule curve driven from the result of the optimization solution was used to develop a monthly simulation model in order to determine the real- time monthly operation plan for the system with and without the under- construction reservoirs.

# CHAPTER THREE

## PRINCIPLES AND THEORY OF DYNAMIC PROGRAMMING AND DISCRETE DIFFERENTIAL DYNAMIC PROGRAMMING

An optimization process constitutes formulating the respective mathematical optimization model, then solving the formulated model by an appropriate solution procedure.

### 3-1 Characteristics of dynamic programming

A water-resources system may supply water for consumptive, hydroelectric and sanitary purposes. It may provide storage reservations for flood protection and may maintain minimum levels for recreation or drought periods. In view of the diversity of needs, it becomes necessary to seek optimal decisions in the planning, design and operation of the system. The decisions, based on economic, environmental, legal, and other requirements, if implemented, would cause the greatest benefit to the community. For such purposes, application of optimization techniques seems to be a suitable approach for planning, design and management of complex water resources system.

Linear programming, (LP) was the first optimization technique used in the formulating optimization problems; it remained as the most popular formulation technique for some time. However, some of the drawbacks in linear programming led to methods of non-linear programming and of recursive optimization called dynamic program (DP). Dynamic programming is one of the most important and advanced methods in

optimization, particularly in the design and operation of complex water-resources systems. The solution of a formulated (DP) model was commonly achieved by the conventional (DP) procedure which considers all possible combinations of alternatives. However, this method of solution generally encounters two great difficulties in application. They are the high-computer time and large memory requirements. These two obstacles limit the conventional DP solution in water resources system analysis, which often involves many variables. Therefore (DDDP) technique was developed and used as an iterative technique for solving (DP) problems in such a way that the problems arising from high dimensionality of the (DP) technique are overcome.

Dynamic programming treats sequential decision processes; a decision produces a result which has an effect on the next decision and produces an impact on the objective which is independent of the magnitude of all other decisions in the sequence. According to **(Bellman (1957))**, the sequence of decisions that constitute an optimal policy has a property that, whatever the initial state and initial decision are, remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision.

DP is not restricted to linear objective and constraint functions and may have linear and non-linear equations in all the objective function and the constraints. Although the concept seems not to be easy, the application will not be difficult if the basic principles are clearly understood. So, in order to understand and formulate a (DP) model, the following basic concepts should be defined, **(Ali (1978))**:

**A- State variables ( $S_i$ ):**

The state variables of a process are those variables whose values completely specify the instantaneous situation of the process. The values of these variables show all required information of the system for the purpose of making decisions about it. In the problem of reservoir operation, state variables may represent the amount of water stored in the reservoir.

**B- Decision variables ( $D_i$ ):**

Decision variables are those variables of input to the system which are controlled or partially controlled by the decision - maker. In reservoir operation studies, the decision variables may be the amount of water to be released from the reservoir at the current time. This decision will transform the amount of water stored in the reservoir from the current amount to a new amount for the next stage.

**C- Stage ( $i$ ):**

The stage is a certain point, usually of time, in which the decision about the system can be taken.

**D- Return variables ( $R_i$ ):**

The return variables are scalar variables that measure the total reward achieved in every stage ( $i$ ). They are functions of decision ( $D_i$ ) and states ( $S_i$ ) variables, that is:

$$R_i = R_i (S_i, D_i) \quad \text{--- (3-1)}$$

where:

$$i = 1, 2, \dots, N;$$

$N$  = total number of stages.

**E- Stage transformation ( $T_i$ ):**

The stage transformation is a transformation expressing each component of stage output ( $S_{i-1}$ ) and ( $S_i$ ) and decision ( $D_i$ ) corresponding to the stage (i); that is:

$$S_{i-1} = T_i (S_i, D_i) \quad \text{--- (3-2)}$$

In general, all the five parameters mentioned above could be explained together as follows:

The point at which a decision is made may be denoted as (stage), and the input parameters as (state). The decision is governed by some sort of equations or rules called a (transformation). At each stage, a decision that has a relative benefit equation should be made. This equation represents a return function (i.e., return variables). Every set of decisions will result in a return. This return will, in general, depend on both the state variables ( $S_i$ ) and the decision ( $D_i$ ) made at stage (i). An optimal decision at stage (i) would be that decision which yields a maximum (or minimum) return (or cost) for a given value of the state variable ( $S_i$ ). The foregoing discussion is schematically illustrated in Fig. (3-1).

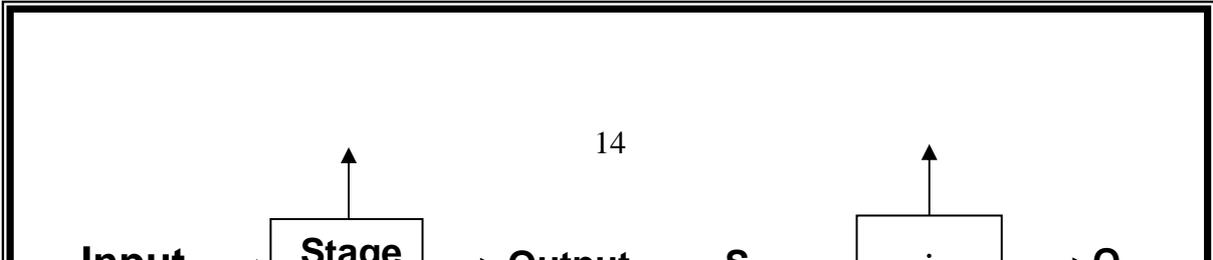
The accumulated optimal outcome calculated over (i) stages may be denoted by  $F^*(S_i)$ . Therefore, the recursive relationship, for example, in the case of a minimization problem, could be expressed by:

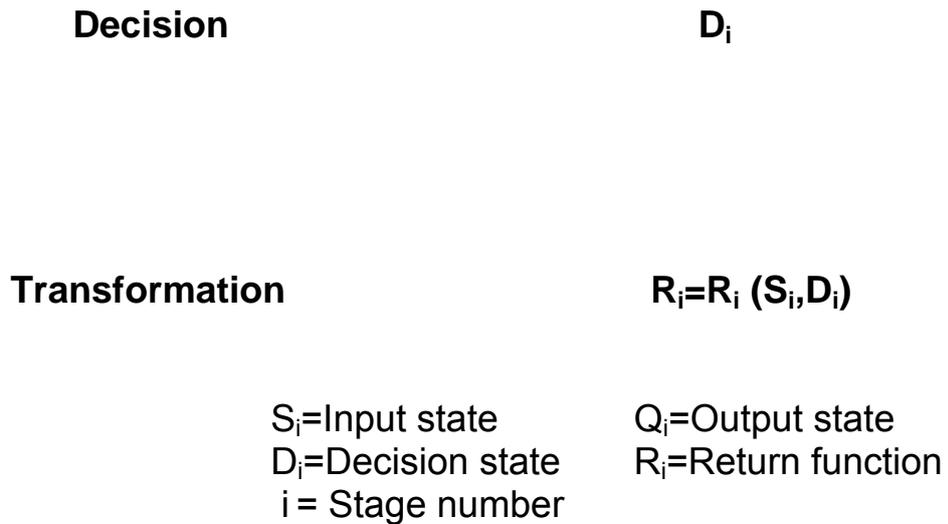
$$F^*(S_i) = \text{Min}_{D_i} (R_i (S_i, D_i) + F^*(S_{i-1})) \quad \text{-- (3-3)}$$

where:

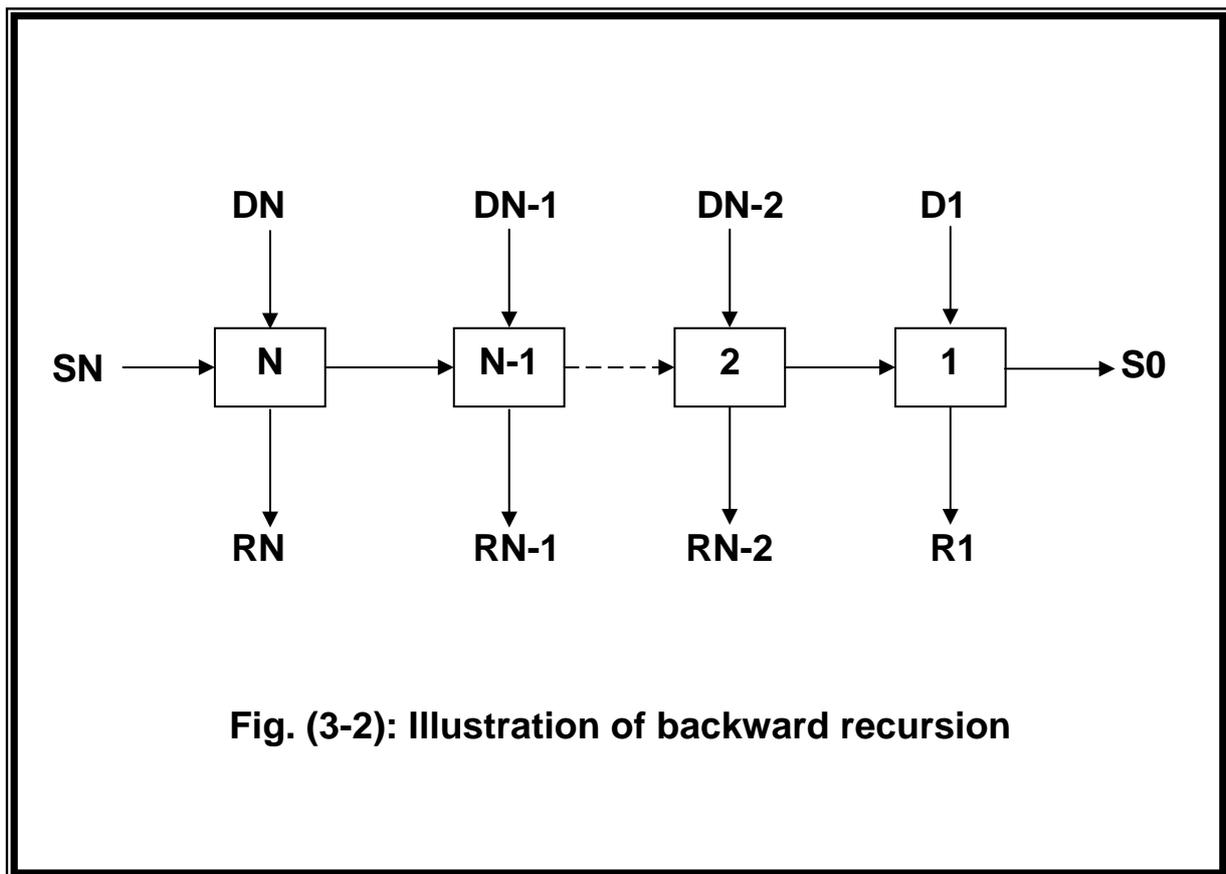
- $S_i$  and  $D_i$ : input and output states, respectively;
- $R_i (S_i, D_i)$ : return function as defined earlier.

The dynamic programming recursive relationship, Eq. (3-3), for N-stages system is started from stage (1), and proceeds to stage (N) with  $[F^*(S_i)=0]$  at (i=1). This is called backward recursion, as shown in Fig. (3-2). However, the solution procedure can be developed from stage (N) to stage (1) and this is called forward recursion.





**Fig. (3-1): Mathematical Description of DP (Pictorially and Functionally), (Phillips et al,1976).**



**Chow and Meredith, (1969)** identified four concepts, which characterize any problem solved via (DP):

1. The problem is divided into stages where decisions are required at each stage .To determine the optimal releases from a reservoir, the stage represents different points in time.
2. Each stage of the problem must have a finite number of state variables associated with it.
3. The effect of decisions at past stage is transformed to the next stage.
4. For given current stage and state of the problem, the optimal decision is independent of the decision made in the previous stage.

### **3-2 The objective function**

The operation of any system, e.g., a system of reservoirs, could be considered an optimum operation (ideal operation) if any reservoir is operated so that all of the targets are satisfied. There are two targets that should be realized in order to operate any water resources system. The first one is the storage level, which should be within two limits, design and minimum operation levels. The second target is the release, which should be within two limits, the minimum and maximum flow of the reach.

When the operation of the system deviates from any target, it would be called a non-ideal operation. Thus, the total penalty represents the losses associated with deviation from the ideal operation, and whose losses should be minimized. So, the objective function for release and storage will be written as follows:

#### ***A: Objective function of release***

The objective function of the release goals to minimize the losses associated with deviating from the demands or the capacity of the river during flood or drought periods, respectively. Therefore, the optimal release should be equal to or greater than the demands and less than the capacity of the river. This may be formulated as follows:

$$\text{Min.P (Q)} = \sum_{i=1}^N \sum_{j=1}^{12} (\text{loss (Q (i, j))}) \quad \text{---(3-4)}$$

where:

i : serial number denoting year, i=1,2, --- , N;

j : serial number denoting month, j=1, 2, --- , 12;

Min. P (Q): the total minimum penalty due to release;

Loss Q (i, j): the loss function of the release in i-th year and j-th month, which could be expressed as follows:

If  $Q (i, j) < \text{Dem} (j)$  then

$$\text{Loss Q (i, j)} = a * [Q (i, j) - \text{Dem} (j)]^2 \quad \text{--- (3-5)}$$

If  $Q (i, j) > \text{MPF}$  then

$$\text{Loss Q (i, j)} = b * [Q (i, j) - \text{MPF}]^2 \quad \text{--- (3-6)}$$

and, If  $\text{Dem} (j) \leq Q (i, j) \leq \text{MPF}$  then

$$\text{Loss Q (i, j)} = 0 \quad \text{--- (3-7)}$$

where:

Q (i, j): the release of water during the i-th year and j-th month;

Dem(j): the total water requirements during the j-th month (Irrigation + Industrial + Environmental);

MPF : the maximum permissible flow, which represents the capacity of the river for flood;

a, b : constants, which represent weighting factors which reflect the effect of violating the constraints of irrigation deficiency and flood control in the river, respectively. Their values depend on the consideration of the decision maker. Values of (a) and (b) in this research have been both taken equal to (one).

**B: Objective function of storage**

In the optimum operation of any reservoir, the storage should be less than the maximum design level during the flood periods and not less than the minimum operation level during the drought periods. This could be represented as follow:

$$\text{Min. P(S)} = \sum_{i=1}^N \sum_{j=1}^{12} \text{Loss (S (i +1, j))} \quad \text{--- (3-8)}$$

where:

Min. P (S): the total minimum penalty due to storage;

Loss S (i, j): the loss function of the storage at the end of the i-th year and j-th month, which could be expressed as follows:

If S (i+1, j) < MOS then

$$\text{Loss S (i+1, j)} = c * [S (i+1, j) - \text{MOS}]^2 \quad \text{--- (3-9)}$$

If S (i +1, j) > DOS then

$$\text{Loss S (i+1, j)} = d * [S (i+1, j) - \text{DOS}]^2 \quad \text{--- (3-10)}$$

If MOS ≤ S (i+1, j) ≤ DOS then

$$\text{Loss S (i +1, j)} = 0 \quad \text{--- (3-11)}$$

where:

S (i+1, j): the storage at the end of the i-th year and j-th month;

MOS: the minimum operation storage;

DOS: the maximum operation storage;

c, d: constants, which represent weighting factors which reflect the effect of violating the constraints of DOS and MOS. Their values depend on the consideration of the decision maker. Values of (c) and (d) in this research have been both taken equal to (one).

Last but not least, the objective of the optimization of the whole system will be:

$$\text{Optimum Total Penalty (O.T.P)} = F = \text{Total} [\text{Min.P (Q)} + \text{Min.P(S)}]$$

$$\text{Or, O. T. P} = F = \text{Minimize } \sum (\text{Loss (Q (i, j))}) + \text{Minimize } \sum (\text{Loss S(i+1, j)}) \quad \text{--- (3-12)}$$

However, the objective function O.T.P, Eq. (3-12), is subjected to important constraints related to storage in reservoir and reach, which will be discussed in the following item.

### 3- 3 The Constraints

The constraints in the dynamic program (DP) are divided into storage constraints, release (outflow) constraints and continuity constraints as follows:

#### **A: Storage constraints:**

In each reservoir of a system, the storage at the beginning of the period (i = 1), should be a known quantity, while the storage in the other periods should be within the set of admissible limits which are already defined, that is:

$$\text{MOS} \leq S (i) \leq \text{DOS} \quad \text{--- (3-13)}$$

where:

MOS and DOS: the minimum and maximum operating limits of storage, respectively.

The MOS and DOS may be the minimum and maximum capacity storage in the reservoir or they may be the minimum and maximum design operation storage in the reservoir, respectively. However, this decision depends on the designer and the risk.

**B: Release (outflow) constraints:**

in the river during any i-th year and j-th month should be within the range of feasible release, that is:

$$\text{Dem}(j) \leq Q(i, j) \leq \text{MPF} \quad \text{--- (3-14)}$$

where all variables are as defined before.

**C: Continuity constraints:**

Continuity constraints should include contents of the reservoir from the beginning of one period to the next. This presents the inflow-outflow activity of the reservoir and can be represented as:

$$Q(i, j) = I(i, j) + S(i, j) - S(i+1, j) + ET(j) \quad \text{--- (3-15)}$$

where:

$I(i, j)$  : inflow during i-th year and j-th month;

$S(i, j)$  : storage during i-th year and j-th month;

$ET(j)$  : net monthly water (gain or loss) from the reservoir during the j-th month, which may be expressed as follows:

$ET(j) = (\text{precipitation} - \text{Evaporation}) \cdot \text{surface area of the reservoir.}$

However, the relationships concerning precipitation, evaporation surface area and other parameters will be discussed in the next chapter.

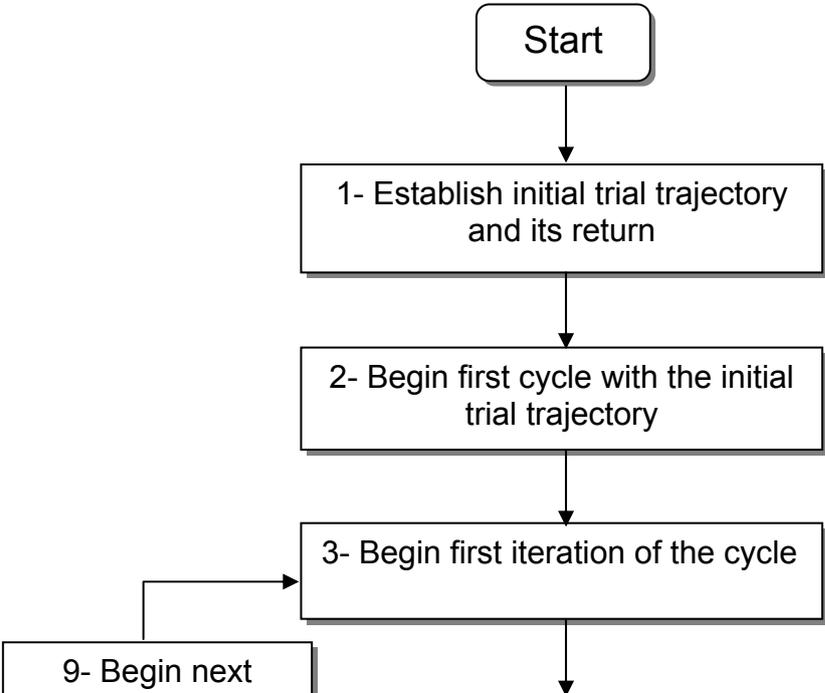
**3-4 The Discrete differential dynamic programming(DDDP)**

To overcome the “curse of dimensionality” which necessarily arises in solving even a relatively high-dimensional optimization problem formulated as a (DP) problem, (Heidari et al.(1971)) developed the solution procedure named the “discrete differential dynamic

programming”, (DDDP),. The (DDDP) is an iterative technique to solve high dimensional (DP) problems within the range of computer time and memory capacities of the digital computers now available, **(Chow and Rivera (1974))**.

The (DDDP) procedure uses the same reservoir equation of (DP), (Eq.3.3), to search for an improved trajectory in a (corridor) in the state –stage domain in the neighbourhood of a specified trial trajectory, the mentioned terms are defined hereafter. At the end of each iteration, a locally improved trajectory is obtained and then used as the trial trajectory in the next iteration. This procedure is repeated until a sufficiently near optimal trajectory is found. This is a substitute to searching for optimal trajectory over the entire state-stage domain.

The (DDDP) procedure is shown in Fig. (3-3) in a form that explains a flowchart of a computer program to carry out the computations for the (DDDP).





**Fig.(3-3): General scheme of the DDDP procedure  
(Chow and Cortes – Rivera,1974 )**

In order to use the (DDDP) solution to optimize any water resources problem which has been formulated as a (DP) model, it is necessary to discuss the following important terms.

***A : Trajectory:***

A trajectory is the path of the iteration through a corridor .The trajectory is either initial trial or optimal, **(Ali (1978))**.

The initial trial trajectory is a path within a corridor that should be feasible and so close to optimal trajectory as possible, since it is considered the first approximation of the optimal trajectory. The choice of the initial trajectory should be done carefully to satisfy all the imposed

constraints and to reduce the time required to reach the optimal trajectory.

**Ali(1978)** stated that an initial trial trajectory,  $S(1)$ , could be assumed as :

$$S(1) = \frac{S_{\max} + S_{\min}}{2} \quad \text{--- (3-16)}$$

where:

DOS: maximum allowable storage;

$S_{\min}$ : minimum allowable storage.

The optimal trajectory is a modified path within the corridor from stage (i) to stage (N) resulting from the initial trajectory.

### ***B: Construction of corridors:***

A corridor is a boundary above and below the initial trial trajectory in order to specify the limiting values of the state variables used in the optimization of the system. After the assumption of an initial trial trajectory, a corridor should be constructed around it, which is the next important step in the (DDDP) procedure. In order to construct any corridor, the following considerations should be taken in account.

1. The initial trial trajectory precedes the construction of the corridor.
2. Select the suitable corridor width.

The storage increment is selected for the first iteration as:

$$\Delta = \frac{(S_{\max} - S_{\min})}{X} \quad \text{--- (3-17)}$$

where:

$\Delta$ : Storage increment in Eq. (3-16); thus, the corridor width will equal  $(2 \Delta)$  when it is uniform;

$X$  : is a factor that specifies the initial increment  $\Delta$ .

**Ali (1978)** found that when the value of  $(x)$  is equal to  $(8)$ , the computer time required to reach an optimal trajectory will be reduced to minimum.

The state sub domain becomes:

$$S(i) = \begin{bmatrix} S(i) + \Delta \\ S(i) \\ S(i) - \Delta \end{bmatrix} \quad \text{--- (3-18)}$$

where:

$S(i) + \Delta$  =Upper storage

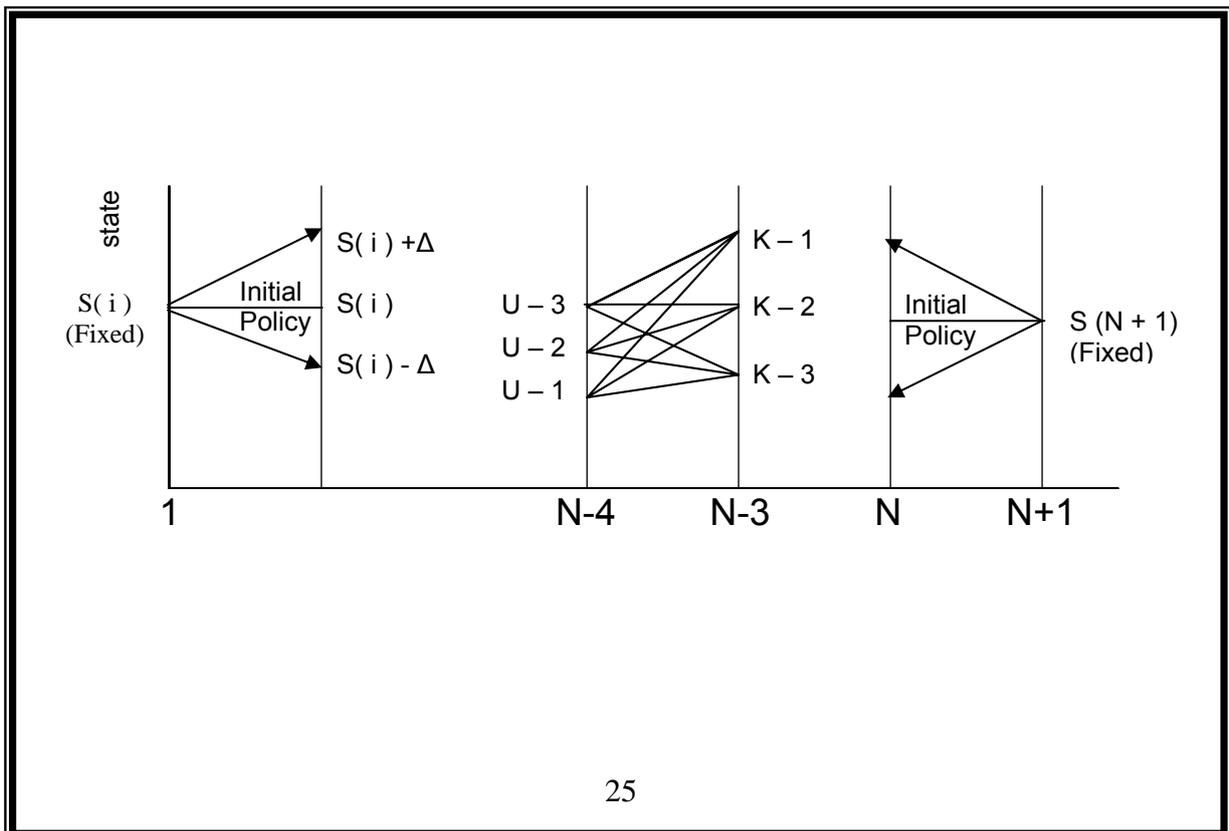
$S(i)$  =Initial storage

$S(i) - \Delta$  =Lower storage

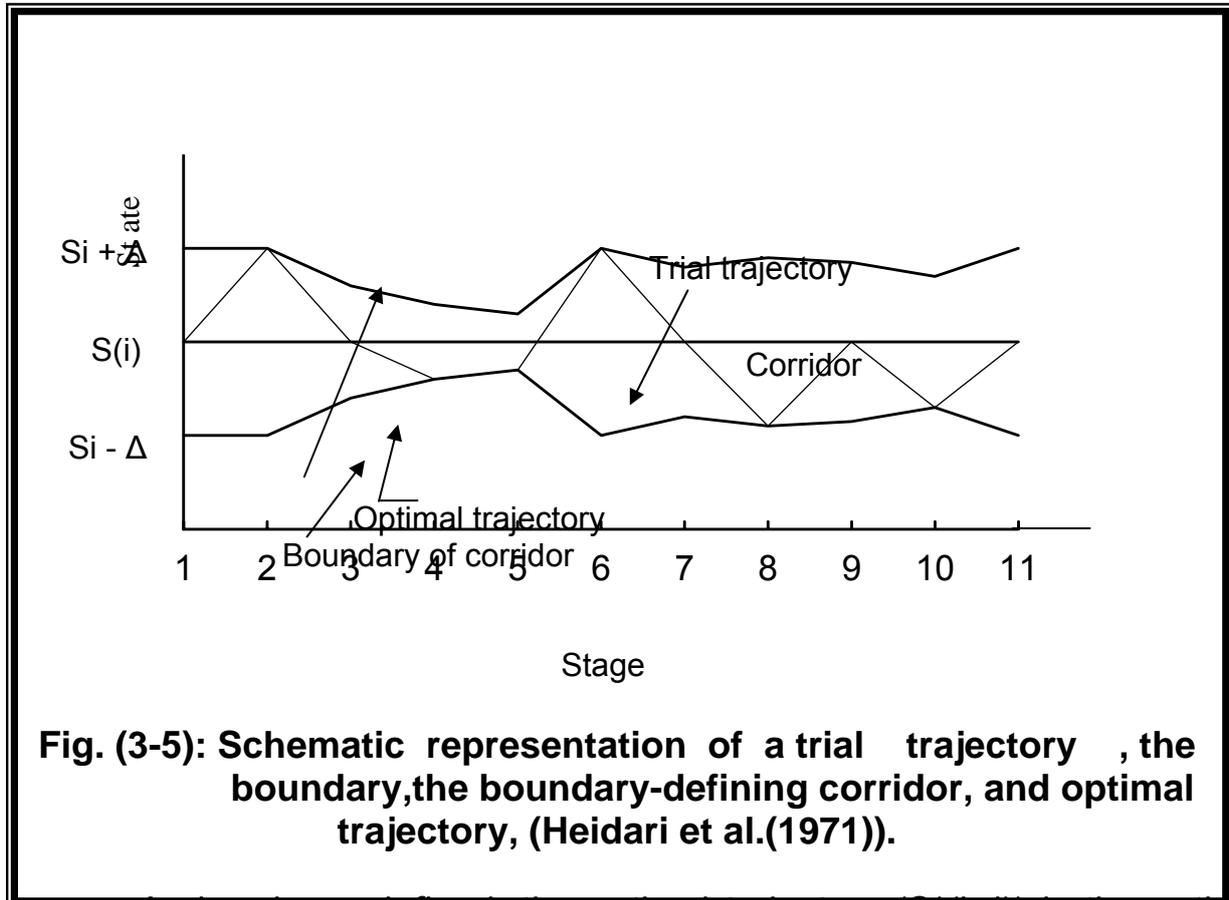
In this way, a symmetric corridor would result .If any of the boundaries of the corridor exceeds the limits of the respective state variable, a non-symmetric corridor may result .A two - values corridor is produced if the trial trajectory passes through one of the two limits of the state variable.

Figure (3-4) illustrates the algorithm in the first, second, - - -, N-th periods, while Figure (3-5) represents the first trajectory, corridor, and optimal trajectory.

The solution of the (DP) reservoir equation, Eq. (3.3), gives the optimal value of the objective function. This should be done inside the corridor and subjected to the transformation equation and all the constraints imposed on the system. Then, the optimal trajectory is retrieved by computation, which follows the opposite direction to the one used in the solution of the (DP) recursive equation. This step must be performed for every iteration of a computation cycle, as it is shown in step (5) of Fig. (3-3).



**Fig. (3-4) : Algorithm in the first and other than first periods, (Heidari et al. (1971)).**



As has been defined, the optimal trajectory ( $S^*(i, j)$ ) is the path that has a minimum total penalty ( $F^*$ ) in the corridor which has been calculated by applying (DP) recursive equation on the state variables  $S(i, j)$ . In any cycle, when the total penalty of present optimal trajectory is found, the following steps should be done in order to test whether the solution has converged or not.

1. Calculate  $F_0^*$

$F_0^*$  is the total penalty which is due to introducing the trial trajectory  $S(i, j)$  and trial policy into the (DP) recursive equation.

2. Calculate  $F^*$  that corresponds to the current calculation cycle (the current corridor).
3. If  $|F^* - F_o^*| > \lambda$  , then go to step (7).
4. If  $|F^* - F_o^*| \leq \lambda$ , and if  $\frac{\Delta}{S_{max}} > \gamma$  , then go to step (5),  
Else go to step (6).
5.  $\Delta = \frac{\Delta}{2}$  ; go to step (7).
6. If  $|F^* - F_o^*| \leq \lambda$  , and if  $\frac{\Delta}{S_{max}} \leq \gamma$ ,  
or If  $F^* \leq \alpha$  , then stop the iteration.
7. Let  $F_o^* = F^*$  and  $S(i, j) = S^*(i, j)$ , then go to step (2).

In this formulation,  $\lambda, \gamma$  and  $\alpha$  are parameters for convergence test. As suggested by **(Heidari et al. (1971))**, their values could be assumed as follows:

$$\lambda = \text{Max.} (\Delta, \Delta^2)$$

$$\gamma = 0.001$$

$$\alpha = 0.01$$

When the convergence criterion of the final cycle is satisfied, the (DDDP) procedure stops.

In general and briefly, the procedure of the (DDDP) as can be seen from Fig. (3.3), is composed of cycles, which in turn are made of iterations. Each computation cycle corresponds to the process. Starting from a trial trajectory (See, Item 3-4/ A), to search for the optimal trajectory within all the corridors of a given width (See, Item 3-4/ B). The computation cycle will be carried out for the recursive equation (Eq. (3.3), sec. (3-1)) subject to all constraints (sec. (3-3)) until the process has

converged to the optimal trajectory according to the convergence criterion which is illustrated in (3-4/ B).

**3- 5 Values of the state variables within the corridor**

Figure (3-4) shows that there are only (3) possible states (values = k), in the 1<sup>st</sup> stage. These are:

$S_i (1, 1), S_i (1,2), S_i (1,3)$ , which are calculated as follows:

$$S_i (1, 1) = S_i (1, 1) + \Delta \quad \text{with } i = 2 \quad \text{--- (3-19)}$$

$$S_i (1, 2) = S_i (1, 2) \quad \text{with } i = 2 \quad \text{--- (3-20)}$$

$$S_i (1, 3) = S_i (1, 3) - \Delta \quad \text{with } i = 2 \quad \text{--- (3-21)}$$

where:

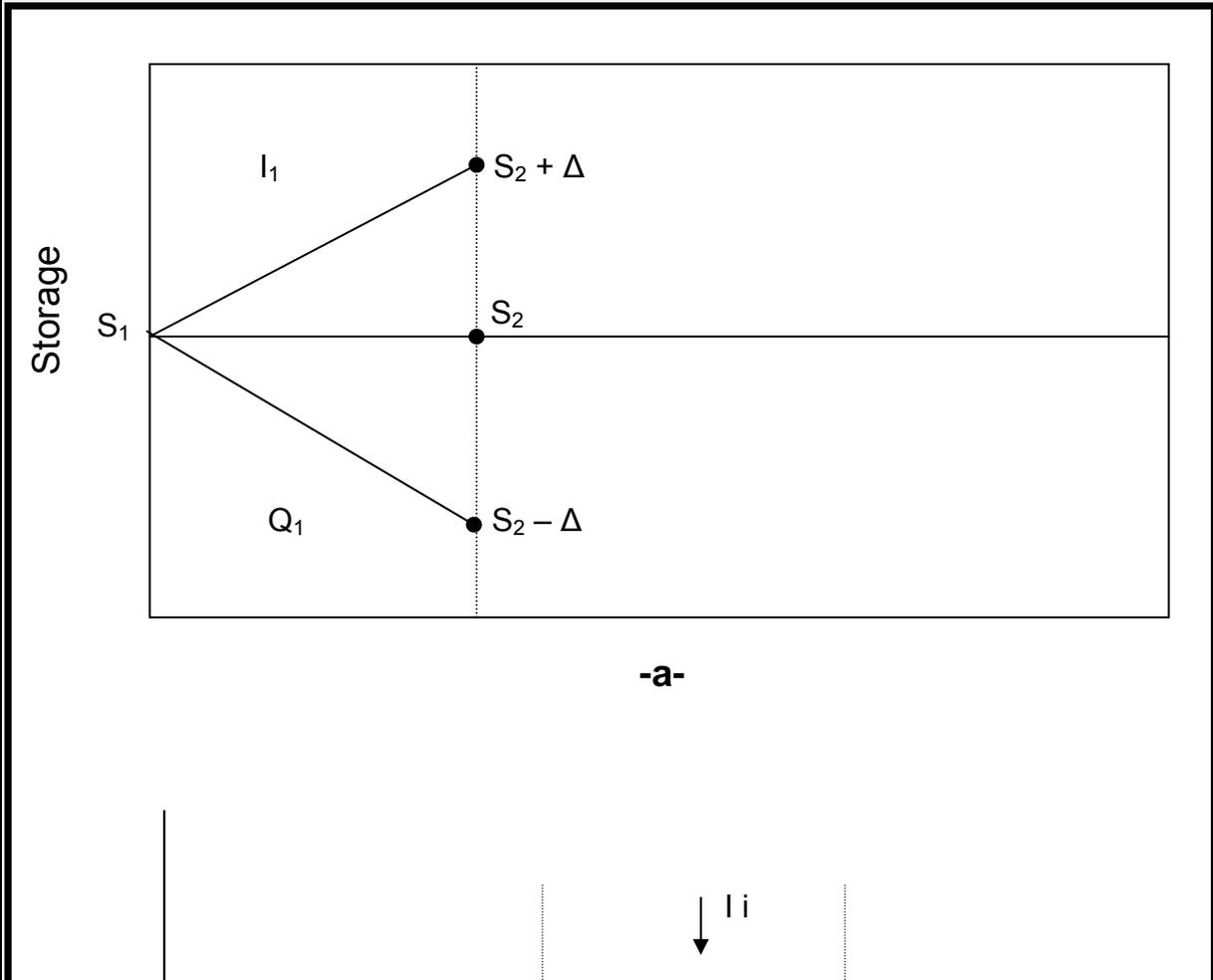
$S_i$  :storage in the reservoir at the end of the first stage or at the beginning of the second stage (i=2).

By using the continuity equation, (Eq. (3-15)), the decision variable (outflow Q (i)) during any month can be obtained.

After calculating the decision variable (Q (i)), the program proceeds to the objective function for checking whether this policy in this month satisfies the system constraints or not (sec., 3-3). If not, it should compute a penalty due to the policy violation in this period, (sec. 3-2). Then, the above process will be repeated with another possible policy and so on until the three possible policies are investigated. For the second month, (i=2), the values of states become nine states at each stage.

From Fig. (3-4), these values could be expressed as  $S(1,1), S(1,2), S(1,3), S(2,1), S(2,2), S(2,3), S(3,1), S(3,2), S(3,3)$ . As shown in Fig. (3-6), the computation procedure that was used in the first stage

must be performed here nine times to determine a better state of the system which produces a minimum penalty during this period, and so on for the other stages (i.e.,  $i = 3, 4, \dots, N$ ).



**Fig. (3- 6): Algorithm values of the state variables**  
**A: For the reservoir in the first period, (i=1)**  
**B: For the reservoir in the other periods (i=2,3,- - -,N)**

# CHAPTER FOUR

## THE CASE STUDY

### 4-1 Makhool reservoir

As outlined in item (1-1), Makhool Dam has been taken as the case study. The main purpose behind the intention of constructing Makhool Dam is to store excess water running in Tigris River and its tributaries, the Greater Zab and the Lesser Zab. The storage water may be used for power generation. In addition, the dam will control the flood wave and assure the fulfillment of downstream water requirements for permissible maximum and minimum limits that depend on the downstream conditions.

Makhool Reservoir is a relatively small reservoir when compared with the others. It is located on Tigris River downstream of the junction where the Lesser Zab tributary ends, as shown in Fig. (A-1)(in Appendix (A)). The site is about (260 km) from Mosul Dam. The Tigris River in this reach crosses the Hemrin - Makhool Mountains just after the site. It lies between latitude ( $34^{\circ}$ ) and ( $36^{\circ}$ ) North, and between longitudes ( $38^{\circ} 90'$ ) and ( $39^{\circ} 40'$ ). The inflow to the reservoir is the water beyond the demand downstream Mosul and Dokan Reservoirs, as well as the end discharge of the Greater Zab tributary. The dam is under construction, and it is expected to be finished in the near future (**Al-Furat Center (2000)**).

### 4- 2 Assembly of hydrologic and hydraulic information

The basic hydrologic data are the amounts of water available in the basin. This implicitly involves the inflow to the reservoir, evaporation, precipitation, and water demand. Hydraulic data include the information that represents the characteristics of the reservoir such as the maximum and minimum capacity of the reservoir and maximum capacity of the reach. The hydrologic and hydraulic data represent the input to the (DDDP) model.

#### **4-2-1 Reservoir characteristics**

Reservoir characteristics represent the physical properties of the reservoir such as the minimum and maximum capacity, which describe the criteria under which the reservoir is operated. They could be classified as follows:

##### ***A: Maximum and minimum storage:***

There are several levels of storage in any reservoir, which could be represented as follows:

- 1- Maximum capacity level (or storage).
- 2- Maximum design operation level (or storage).
- 3- Normal operation level (or storage).
- 4- Minimum design operation level (or storage).
- 5- Minimum capacity level (or storage, i.e. dead storage).

The aforementioned levels for Makhool Reservoir are shown in Table (4-1).

**Table (4-1): Basic storage levels in Makhool Reservoir  
(Muhsun, (2002))**

Item	Symbol	Unit	Value
Maximum storage	Smax	MCM	2665
Minimum storage	Smin	MCM	200
Design operation storage	DOS	MCM	2222
Normal operation storage	NOS	MCM	1478
Minimum operation storage	MOS	MCM	744
Maximum water level	Lmax	m.a.s.l	152.15
Minimum water level	Lmin	m.a.s.l	132.5
Design operation water level	DOL	m.a.s.l	150.0
Normal operation water level	NOL	m.a.s.l	145.7
Minimum operation water level	MOL	m.a.s.l	140.0

***B: Precipitation and evaporation:***

By all means, direct precipitation over the reservoir and evaporation from the reservoir are basic elements in any water budget of the reservoir.

The importance of precipitation varies successively with the areal extent of the reservoir water-surface and the wetness of the district (which is the result of frequent precipitation with high intensity and long duration).

The importance of evaporation for operation of any dam in arid and semi-arid districts (like that of Makhool Reservoir) is self-evident since evaporation losses represent a major factor of the total amount of water lost from the reservoir. The evaporation rates in the project area are generally high. Table (4-2) shows the estimated mean monthly precipitation and evaporation at the area of Makhool Reservoir.

**Table (4- 2): Estimated mean monthly precipitation and evaporation at Makhool- Reservoir area (mm per month)**

**(Al-Furat Center (2000))**

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Precipitation	7.9	27.8	31.0	37.3	32.4	34.6
Evaporation	128.7	58.0	32.7	31.4	48.4	85.8

Month	Apr.	May	Jun.	Jul.	Aug.	Sep.
Precipitation	16.9	8.7	0.6	0.0	0.0	0.5
Evaporation	135.7	209.7	274.3	305.7	279.7	199.8

***C: Elevation-area-storage relationships:***

Table (4-3) gives an indication of the natural topography of Makhool Reservoir. The data have been used to find the relationship between the storage, surface area and the elevation of water of Makhool Reservoir, which are required to estimate the quantity of water that is added to or subtracted from the storage due to precipitation or evaporation, respectively.

**Table (4- 3): Topographic features of Makhool Reservoir  
(Al-Furat Center (2000))**

<b>Elevation(m.a.s.l)</b>	135	140	145	150	155
<b>Area (sq.km)</b>	63.12	103.08	147.51	195.5	246.78
<b>Storage(MCM)</b>	332	744	1367	2222	3325

Many relationships were derived between the elevation, area and storage of Iraqi reservoirs system by several past or present researchers, in order to estimate the volume of the precipitation and evaporation. Such formulas took different forms that have different values of correlation, which vary from good to excellent. However, **(Muhsun, (2002))** found that the following model could be used to

represent the relationship between the elevation (or the area) and the storage of all the reservoirs in Iraq, with excellent value of correlation coefficient, which is:

$$Y=[a* (b + S)^c]+d \quad \text{--- (4-1)}$$

where :

Y :is either the surface area of the reservoir in (sq. km) or the

water level in (m.a.s.l);

S :the reservoir storage in MCM;

a,b,c,d :coefficients , their values could be estimated through a non-linear optimization method. In this work, **(Statistica**

**Package)** was used to estimate the respective values.

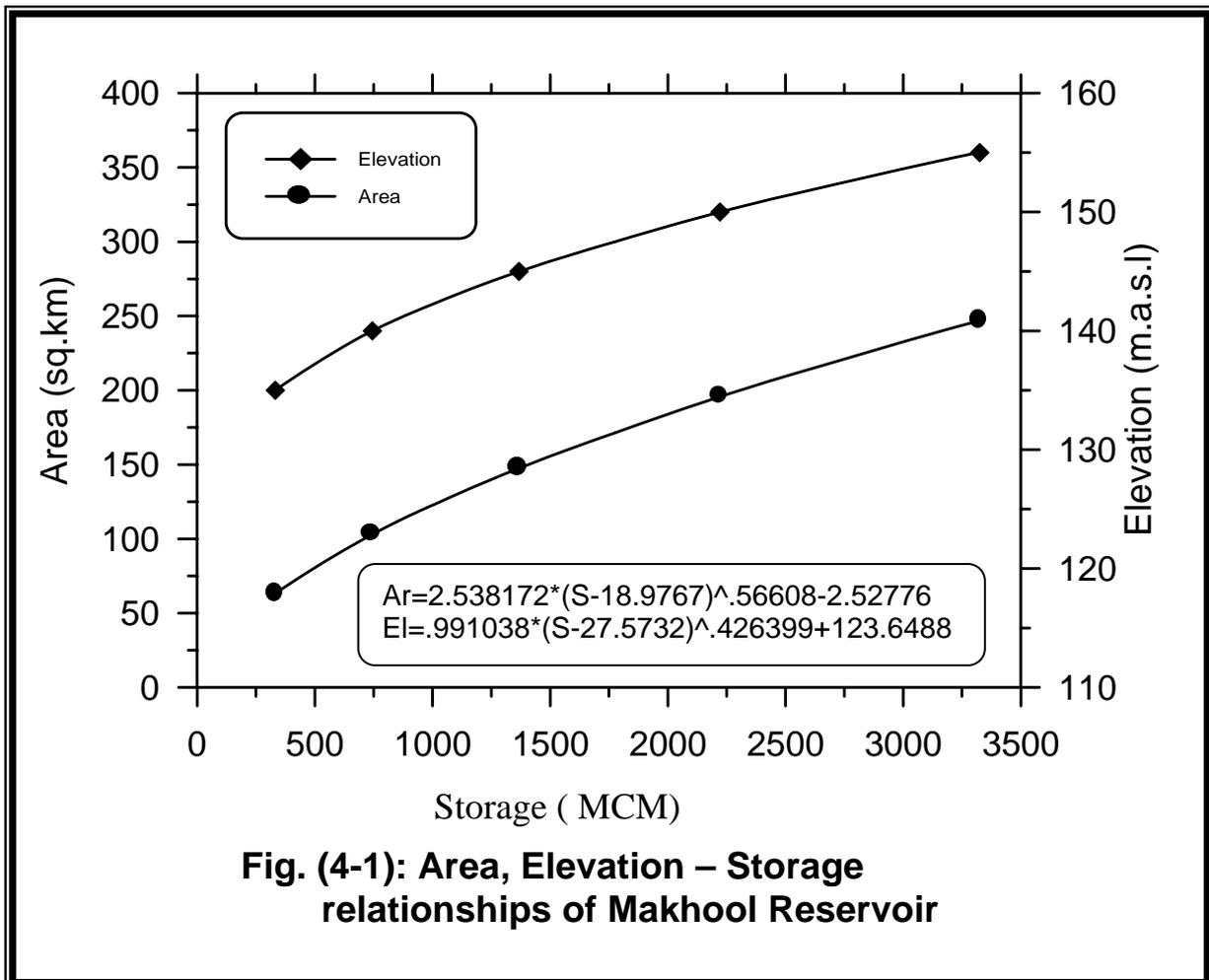
Table (4-4) shows the values of (a, b, c, d) for Makhool Reservoir with their respective values of correlation coefficients. Figure (4-1) shows the relationships of the elevation, area and storage of Makhool Reservoir.

**Table (4- 4): Values of the coefficients of elevation, area and storage relationships of**

## Makhool Reservoir

<b>AREA – STORAGE RELATIONSHIP</b>				
$Y=Area=a*(b+S)^c +d$				
<b>a</b>	<b>b</b>	<b>c</b>	<b>d</b>	<b>R</b>
2.538172	-18.9767	0.566080	-2.52776	0.999999

<b>ELEVATION – STORAGE RELATIONSHIP</b>				
$Y=Elevation=a*(b+S)^c +d$				
<b>a</b>	<b>b</b>	<b>c</b>	<b>d</b>	<b>R</b>
0.991038	-27.5732	0.426399	123.6488	0.999999



Accordingly, the net monthly effect (gain or loss) of precipitation-evaporation at the reservoir area could be given by:

$$ET_{(j)} = AVR * [P_{(j)} - EV_{(j)}] \quad \text{--- (4-2)}$$

where :

$ET_{(j)}$  :the net monthly water(gain or loss) from precipitation-evaporation at Makhool Reservoir during the j - th month, (MCM);

AVR : the average surface area of Makhool Reservoir during the j-th month, (sq. km);

$P_{(j)}$  and  $EV_{(j)}$  :the average precipitation and evaporation over the surface area of Makhool Reservoir during the j- th month, respectively, (m).

#### 4-2-2 Maximum and minimum permissible flow

The maximum permissible flow (maxPF) is that value which will cause flood and / or subsequent damage if it is exceeded. The minimum permissible flow (minPF) represents the minimum flow in the reach. Therefore, when the flow drops below this limit, an environmental problem will appear in the reach. Table (4-5) shows the maximum and minimum permissible flows in the reach downstream of Makhool Reservoir.

**Table (4- 5): maximum and minimum permissible flow downstream of Makhool Reservoir, (Al-Furat Center (2000))**

Reach	Maximum flow (cumeecs)	Minimum flow (cumeecs)
D/S Makhool Reservoir	3000	38

#### 4- 3 Optimum operation rule curves

The continuity equation, (Eq., (3-15)), is one of the several physical constraints of dynamic programming. It represents the relationship between the inflow, outflow, evaporation, precipitation and the storage at each stage.

The formulated (DP) model has been solved by the (DDDP) approach, (sec., (3-4)), to determine an optimal operation of the Makhool Reservoir using historical stream flow records for (480) month [from Oct. (1960) to Sep. (1999)]. In this research, an additional new constraint to obtain the optimal operation for each month has been used. This has been achieved by introduce the parameter (e) which takes a variable values such that it ensures the smoothness of the respective rule curves. This smoothness, with the compulsory constraints stated in Eqs.(3-13) and (3-14) of keeping the current storage between the upper and lower allowed limits and make the storage in the reservoir with the minimum operation storage just before the expected start of the effective flood and almost with the design operation storage at the end of flood season; have resulted in decreasing the period of deficient supply which has been noticed in the initial runs of the model.

Mathematically, the aforementioned procedure has been performed as follows:

If  $j=m$  then

$$P(S_i)=e*(S_{max} - S(i)) \quad \text{--- (4-3)}$$

where:

m: the month under consideration;

e: constant; values of (e) used in the research where in the range (0.01-1000) depending on the respective inflow available, storage and demands during the considered month.

other variables are as defined before.

Taking into consideration that the rule curves (upper, average and lower) should fall between the minimum and design operation storage, a computer program written in (Q. Basic) language is used to determine these rule curves.

The average rule curve has been obtained by averaging the values of the storage obtained by the model over the considered period [(40) years], upper and lower rule curves have been derived depending on the non-exceeding probability values of (90%,10%) of the probability distribution of the optimal storage to represent the upper and lower rule curves. The normal probability distribution approach is used to determine these rule curves.

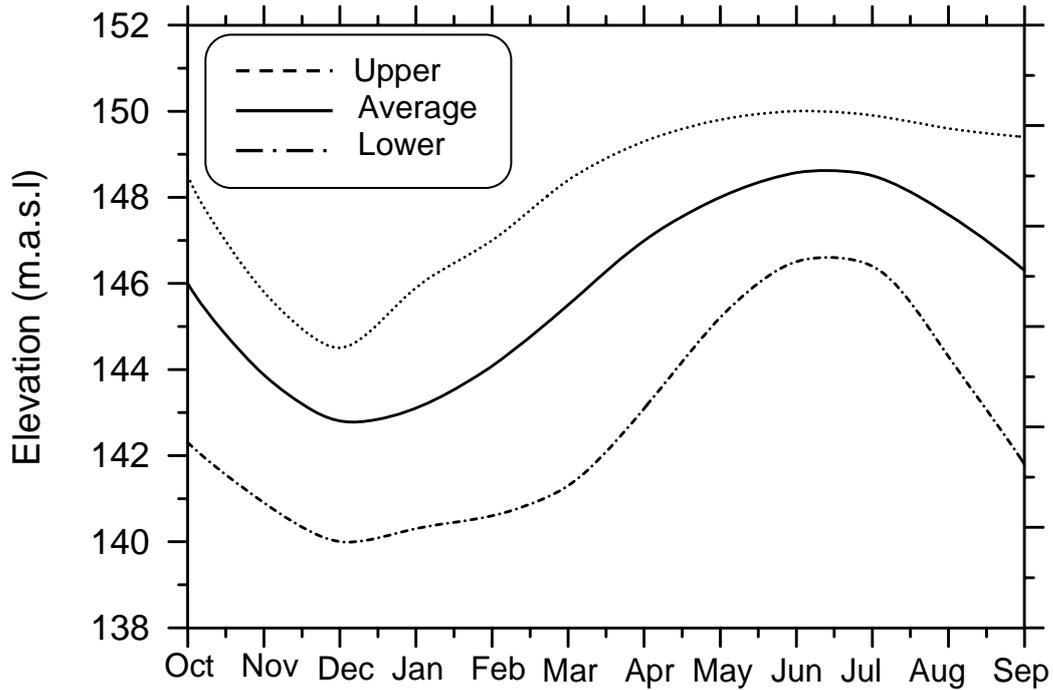
Bekhma Dam is a proposed huge dam on the Greater Zab. Its construction was started in (1987) and its foundation has been almost completed. However, the construction was postponed due to unavoidable circumstance. When considering Bekhma Dam is operational in this research, its optimal –operation policy according to **(Al-Furat Center (2000))** is considered. The results of optimal operation rule curves, when Bekhma Dam is not existing and when it is operational are tabulated in Tables (4-6) and (4-7) and shown schematically in Figs. (4-2) and (4-3), respectively.

**Table (4- 6): Values of optimum rule curves when Bekhma Dam is not existing.**

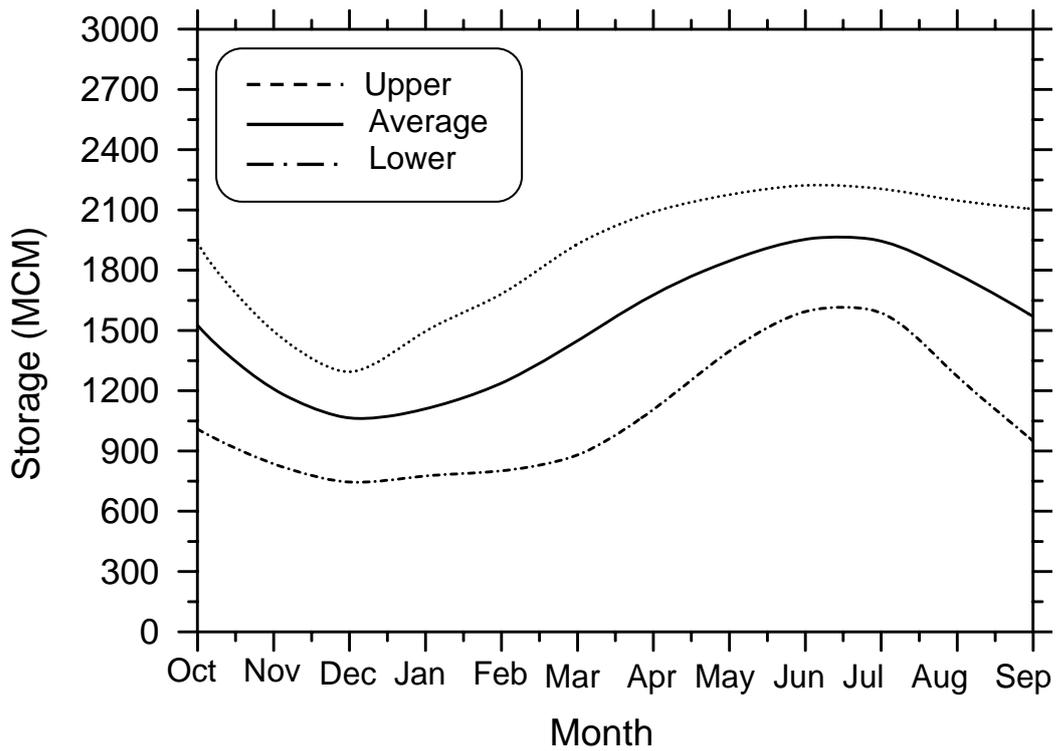
Month	Rule curves based on the storage (MCM)			Rule curves based on the elevation (m.a.s.l)		
	Upper	Average	Lower	Upper	Average	Lower
<b>Oct.</b>	1934.2	1525.1	1008.2	148.5	146.0	142.3
<b>Nov.</b>	1495.5	1207.3	835.5	145.8	143.8	140.9
<b>Dec.</b>	1294.5	1063.1	744.0	144.5	142.8	140.0
<b>Jan.</b>	1496.3	1109.6	775.9	145.9	143.1	140.3
<b>Feb.</b>	1682.1	1237.2	801.4	147.0	144.1	140.5
<b>Mar.</b>	1929.5	1448.0	880.0	148.4	145.5	141.3
<b>Apr.</b>	2089.4	1677.3	1105.3	149.3	147.0	143.1
<b>May</b>	2174.3	1845.8	1398.7	149.8	148.0	145.2
<b>Jul.</b>	2222.0	1953.1	1592.3	150.0	148.6	146.5
<b>Jun.</b>	2208.2	1945.8	1568.6	149.9	148.5	146.4
<b>Aug.</b>	2146.2	1781.4	1271.8	149.6	147.6	144.3
<b>Sep.</b>	2104.9	1569.7	948.4	149.4	146.3	141.8

**Table (4- 7): Values of optimum rule curves when Bekhma Dam is operational.**

Month	Rule curves based on the storage (MCM)			Rule curves based on the elevation (m.a.s.l)		
	Upper	Average	Lower	Upper	Average	Lower
<b>Oct.</b>	1975.5	1504.3	990.6	148.7	145.9	142.2
<b>Nov.</b>	1693.4	1262.4	789.1	147.1	144.3	140.4
<b>Dec.</b>	1374.8	1075.8	744.0	145.0	142.8	140.0
<b>Jan.</b>	1564.1	1084.3	744.0	146.3	142.9	140.0
<b>Feb.</b>	1788.3	1252.5	744.0	147.3	144.2	140.0
<b>Mar.</b>	1894.2	1445.4	919.5	148.2	145.5	141.6
<b>Apr.</b>	2014.7	1641.6	1183.2	148.9	146.7	143.7
<b>May</b>	2124.6	1833.5	1500.6	149.5	147.9	145.9
<b>Jul.</b>	2222.0	1946.4	1626.3	150.0	148.5	146.7
<b>Jun.</b>	2184.0	1921.7	1576.8	149.9	148.4	146.5
<b>Aug.</b>	2092.5	1756.1	1384.2	149.3	147.5	145.1
<b>Sep.</b>	1941.3	1539.5	1099.7	148.5	146.1	143.1



-a-

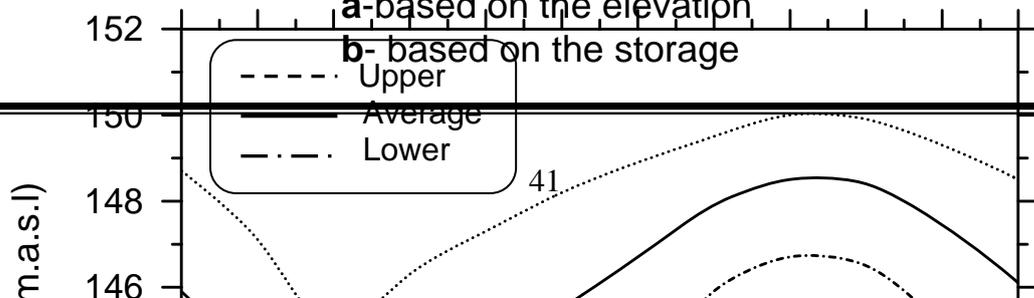


-b-

**Fig. (4-2): Optimum operation rule curves of Makhool Reservoir when Bekhma Dam is not existing:**

**a-** based on the elevation

**b-** based on the storage



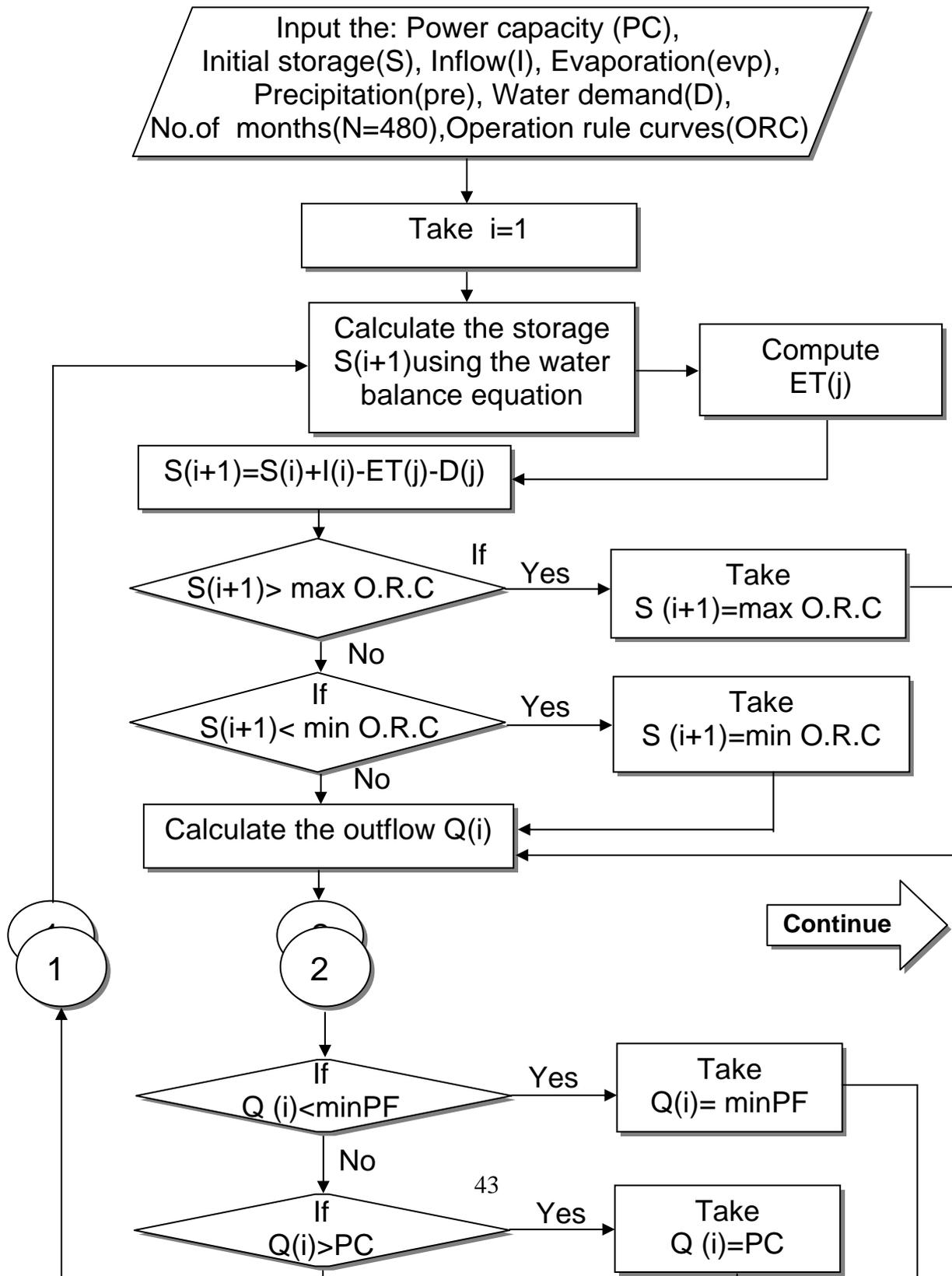
Storage (MCM)

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

#### **4- 4 : Optimum operation by simulation**

##### **4-4-1 : The simulation model**

Simulation (in operations research) is a methodology of representing the problem in a mathematical form applied to the reservoir and is manageable by computer. The simulation process is a trial and error technique rather than an analytical process that converges to a global optimum solution, **(Al-Delewy, (1995))**. Figure (4-4) shows the simulation methodology in a flow – chart representation.



**Fig. (4- 4): Flowchart showing the simulation model of monthly operation methodology**

**4-4-2 Fundamental conditions for simulating of monthly operation**

Reservoir operation is necessarily to be made in such a manner that it functions according to the respective purpose of design.

The Makhool Dam is a multi-purpose dam. It serves flood control, regulation of the flow of Tigris River upstream Samarra Barrage, and for power generation.

The storage capacity of Makhool Reservoir [(1478) MCM, between design operation water level of (150 m.a.s.l.) and lower operation water level of (140 m.a.s.l.)], is to be utilized for irrigation and power generation. The operation rules for Makhool Reservoir are to be fixed on the bases of the following factors:

- 1-Irrigation and power generation are carried out within the range of the storage capacity of (1478) MCM.
- 2-Maximum discharge from power outlets is fixed, which is equal to (1240) cumecs.
- 3-Operation is done in a manner that spillage from the reservoir is minimum.
- 4-Operation for power generation is performed in such a manner that the necessary irrigation water is secured even in fairly dry years.

#### **4-4-3 Monthly operation procedures**

Using the rule curves, Tables (4-6) and (4-7) represent a real time monthly operation of Makhool Reservoir. The outputs of the Makhool Reservoir simulation model are reservoir storage, reservoir water level, outflow from power outlet and spillway and the output of power generation.

The real-time monthly operation of the Makhool Reservoir has been obtained by using historical monthly inflow data for the period from October (1960) to September (1999). These forty-years inflow data represent the input to the model.

The following procedures have been used for planning the monthly operating schedule:

- 1- Prepare the input data, which should include the inflow, evaporation, precipitation, demands, and rule curves of the Makhool Reservoir. The initial storage of the reservoir at the first month was assumed equal to the average of the upper rule curve and the lower rule curve for the first month.
- 2- An amount of water equal to or more than the water requirement is released from the reservoir and should neither be more than the maximum permissible flow nor less than the minimum permissible flow of the river.
- 3- Calculate the water losses due to evaporation from the reservoir at that month.
- 4- The storage should be within the operation rule curves range and neither be more than design operation storage nor less than minimum operation storage of the reservoir.
- 5- Determine reservoir water level (WL), which, as previously mentioned, is a function of the amount of reservoir storage.
- 6- Compare the reservoir water level with the rule curves. If it exceeds the rule curves, then the computed storage and water level are readjusted.
- 7- Calculate the outflow from the power generating outlets, which should not exceed the capacity of the power outlets, and store the remaining release in the reservoir. The minimum operation level represents the minimum level for operation the power generators.

8-Calculate the water level of Tigris River downstream Makhool Dam site. Based on an available hydraulic data **(Al-Furat Center, (2000))** the following relationship has been derived:

$$W_{Lr} = 0.092715 Q^{0.482024} + 116.2275 \quad \text{--- (4-4)}$$

where:

W<sub>Lr</sub>: Water level in the river in m.a.s.l;

Q: Outflow from the reservoir.

9-Calculate the rated head (H) on the power – generation units, which depend on the water level in the reservoir, the amount of release (which produces the river water level) and the total head loss [equals (3 m)], **(Al-Furat Center, (2000))** so that:

$$H = W_L - W_{Lr} - 3 \quad \text{--- (4-5)}$$

where all variables are as defined before.

10-Compute the output power production from the reservoir power station which depends on the flow passing through the power outlets and the rated head. The output power production is calculated by the following equation:

$$P = 9.8 * Q * H * \text{Eff} / 1000 \quad \text{--- (4-6)}$$

where:

P : Power production, (MW);

Q : Outflow, (cumecs);

Eff: Efficiency of the power – generation units, taken in the research

as (93%) **(Al-Furat Center (2000))**.

11-Compute the energy power potential, which is calculated by the following equation:

$$PP=9.8*Q*H*Eff*24*30/1000000 \quad \text{--- (4-7)}$$

where:

PP: The energy power potential, (GWh).

12-Repeat the previous steps for each of following months.

#### **4-4-4 Results of simulation**

Two cases for monthly simulation models that depend on whether the Behkma Dam is not existing or operational are considered.

##### ***A : Bakhma Dam is not existing:***

Tables ((B-1) through (B-9)), [in Appendix (B)] show the results of the monthly simulation model, which are:

- Table (B -1) shows the inflow to Makhool Reservoir.
- Table (B -2) shows the outflow from Makhool Reservoir.
- Table (B -3) shows the water level of Makhool Reservoir.
- Table (B -4) shows the outflow from power outlets.
- Table (B -5) shows the outflow from bottom outlets.
- Table (B -6) shows the Tigris River water level downstream Makhool Reservoir.
- Table (B -7) shows the rated head of Makhool Reservoir.
- Table (B -8) shows the output power production of Makhool power station.

- Table (B -9) shows the energy power potential of Makhool power station.

The results of running the monthly simulation model are summarized in Table (4-8), which indicates the following distinguished points:

- 1-The monthly inflow to Makhool Reservoir varied from (267 cumecs) to (6990 cumecs), with an annual mean of (1323 cumecs).
- 2-The maximum outflow from the reservoir is (6981 cumecs) in April (1988) with (1240 cumecs) from power outlets and (5741 cumecs) from bottom outlets.
- 3-The outflow from the reservoir is less than the water requirements downstream Makhool Dam in (30) months out of the (480) months, total operation period considered in the research.
- 4-During the performed operation, the minimum water level in the reservoir was (141.8 m.a.s.l.) and the maximum was (150 m.a.s.l.).
- 5-The Tigris River water level downstream Makhool Dam ranged from (117.5 m.a.s.l.) to (122.8 m.a.s.l.).
- 6-The Makhool monthly power output production ranged between (50.1 MW) and (315.5 MW). The annual power output production ranged between (119.5 MW) and (276.6 MW) with an average of (235.2 MW).
- 7- The Makhool monthly energy power production ranged between (37.3 GWh) and (233.6 GWh). The annual energy power production ranged between (1048 GWh) and (2453GWh) with an average of (2060 GWh).

**Table (4- 8): Results of simulation of the monthly operation of Makhool Reservoir when Bekhma Dam is not existing.**

Description	Unit	Monthly		Annual		
		Min.	Max.	Min.	Max.	Mean
<b>Inflow to Makhool Reservoir.</b>	cumecs	267	6990	529	2988	1323
<b>Outflow from Makhool Reservoir.</b>	cumecs	229	6981	533	2951	1314
<b>Water level of Makhool Reservoir.</b>	m.a.s.l.	141.8	150	145.6	148.2	147.5
<b>Outflow from power outlets.</b>	cumecs	229	1240	533	1192	1008
<b>Outflow from bottom outlets.</b>	cumecs	0.0	5741	0.0	1766	309
<b>Tigris river water level downstream Makhool Dam.</b>	m.a.s.l.	117.5	122.8	118.1	120.4	119.0
<b>Makhool rated head.</b>	m	23.5	31.1	27.5	29.1	28.4
<b>Makhool power output production.</b>	MW	50.1	315.5	119.5	276.6	235.2
<b>Makhool energy power potential.</b>	GWh	37.3	233.6	1048	2453	2060

***B : Bekhma Dam is operational:***

Tables ((D-1) through (D -9)), [in Appendix (D)] show the results of the monthly simulation model, which are:

- Table (D -1) shows the inflow to Makhool Reservoir.
  - Table (D -2) shows the outflow from Makhool Reservoir.
  - Table (D -3) shows the water level of Makhool Reservoir.
  - Table (D -4) shows the outflow from power outlets.
  - Table (D -5) shows the outflow from bottom outlets.
  - Table (D -6) shows the Tigris River water level downstream Makhool Reservoir.

- Table (D -7) shows the rated head of Makhool Reservoir.
- Table (D -8) shows the output power production of Makhool power station.
- Table (D -9) shows the energy power potential of Makhool power station.

The results of running the monthly simulation model are summarized in Table (4-9), which indicates the following distinguished points:

- 1-The monthly inflow to Makhool Reservoir varied from (184 cumecs) to (6665 cumecs), with an annual mean of (1318 cumecs).
- 2-The maximum outflow from the reservoir is (6656 cumecs) in April (1988) with (1240 cumecs) from power outlets and (5416 cumecs) from bottom outlets.
- 3-The outflow from the reservoir is less than the water requirements downstream Makhool Dam in (21) months out of the (480) months, total operation period considered in the research.
- 4-During the performed operation, the minimum water level in the reservoir was (143.1 m.a.s.l.) and the maximum was (150.0 m.a.s.l.).
- 5-The Tigris River water level downstream Makhool Dam ranged from (117.5 m.a.s.l.) to (122.7 m.a.s.l.).
- 6-The Makhool monthly power output production ranged between (51.3 MW) and (315.6 MW). The annual power output production ranged between (156.4 MW) and (287.1 MW) with an average of (244.6 MW).
- 7- The Makhool monthly energy power production ranged between (38.1 GWh) and (233.9 GWh). The annual energy power production ranged between (1370 GWh) and (2514 GWh) with an average of (2145GWh).

**Table (4- 9): Results of simulation of the monthly operation of Makhool Reservoir when Bekhma Dam is operational.**

Description	Unit	Monthly		Annual		
		Min.	Max.	Min.	Max.	Mean
<b>Inflow to Makhool Reservoir.</b>	cumecs	184	6665	662	2982	1318
<b>Outflow from Makhool Reservoir.</b>	cumecs	229	6656	685	2964	1309
<b>Water level of Makhool Reservoir.</b>	m.a.s.l.	143.1	150.0	146.3	148.2	147.9
<b>Outflow from power Outlets.</b>	cumecs	229	1240	685	1240	1031
<b>Outflow from bottom outlets.</b>	cumecs	0.0	5416	0.0	1732	277
<b>Tigris river water level downstream Makhool Dam.</b>	m.a.s.l.	117.5	122.7	118.0	120.5	119.0
<b>Makhool rated head.</b>	m	24.8	31.0	28.0	29.5	28.8
<b>Makhool power output production.</b>	MW	51.3	315.6	156.4	287.1	244.6
<b>Makhool energy power potential.</b>	GWh	38.1	233.9	1370	2514	2145

#### 4- 5 Selected operation scenarios

According to available inflow record (Oct. (1960) to Sep. (1999) inclusive), the water years (1988), and (1999) may be considered to represent a wet year and a dry year, respectively. The inflows during these considered extremists, with and without Bekhma Dam are given in Table (4-10).

**Table (4- 10): Inflow data at Makhool Reservoir in wet and dry years  
a- When Bekhma Dam is not existing**

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
<b>1988</b>	831	1075	2204	3115	2204	5518	6990	5530	2876	2080	1798	1638
<b>1999</b>	695	683	615	578	615	490	648	545	455	319	327	380

### B-When Bekhma Dam is operational

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
<b>1988</b>	1222	1270	1990	2936	1970	4630	6665	5527	2948	2423	2253	1944
<b>1999</b>	1086	912	574	535	481	529	547	409	749	813	706	601

Two operation scenarios are considered in this respect, namely:

- Case (1): Two consecutive wet years.
- Case (2): Two consecutive dry years.

The results of running the monthly operation model for the two assumed operation scenarios are summarized in Tables (4- 11) and (4- 12), respectively.

**Table (4- 11): Results of operating Makhool Reservoir when Bekhma Dam is not existing.**

#### Case (1): Two consecutive wet years.

Description	Unit	Monthly		Anu.
		Min.	Max.	
<b>Inflow to Makhool Reservoir.</b>	cumecs	831	6690	2988
<b>Outflow from Makhool Reservoir.</b>	cumecs	817	6949	2971
<b>Water level of Makhool Reservoir.</b>	m.a.s.l.	144.5	150.0	149.4
<b>Outflow from power outlets.</b>	cumecs	817	1240	1204
<b>Outflow from bottom outlets</b>	cumecs	0.0	5709	1766
<b>Tigris River water level downstream Makhool Dam.</b>	m.a.s.l.	118.6	122.8	120.4
<b>Makhool rated head.</b>	m	24.5	30.0	27.7
<b>Makhool power output production.</b>	MW	179.9	305.6	270.9
<b>Makhool energy power potential.</b>	GWh	133	227	2372

**Case (2): Two consecutive dry years.**

Description	Unit	Monthly		Anu.
		Min.	Max.	
<b>Inflow to Makhool Reservoir.</b>	cumecs	319	695	529
<b>Outflow from Makhool Reservoir.</b>	cumecs	347	616	527
<b>Water level of Makhool Reservoir.</b>	m.a.s.l.	141.8	148.4	145.5
<b>Outflow from power outlets.</b>	cumecs	347.7	712.1	527.2
<b>Outflow from bottom outlets.</b>	cumecs	0	0	0
<b>Tigris River water level downstream Makhool Dam.</b>	m.a.s.l.	117.8	118.4	118.1
<b>Makhool rated head.</b>	m	24.1	30.2	27.3
<b>Makhool power output production.</b>	MW	92.3	162.3	117.8
<b>Makhool energy power potential.</b>	GWh	48	117	1032

**Table (4-12): Results of operating Makhool Reservoir when  
Bekhma Dam is operational.**

**Case (1): Two consecutive wet years.**

Description	Unit	Monthly		Anu.
		Min.	Max.	
<b>Inflow to Makhool Reservoir.</b>	cumecs	1222	6665	2982
<b>Outflow from Makhool Reservoir.</b>	cumecs	1136	6614	2964
<b>Water level of Makhool Reservoir.</b>	m.a.s.l.	145.8	150.0	148.1
<b>Outflow from power outlets.</b>	cumecs	1136	1240	1236
<b>Outflow from bottom outlets.</b>	cumecs	0.0	5374	1728
<b>Tigris River water level downstream Makhool Dam.</b>	m.a.s.l.	119.0	122.7	120.5
<b>Makhool rated head.</b>	m	25.3	29.7	27.7
<b>Makhool power output production.</b>	MW	246.6	301.9	278.1
<b>Makhool energy power potential.</b>	GWh	184	225	2435

### Case (2): Two consecutive dry years.

Description	Unit	Monthly		Anu.
		Min.	Max.	
<b>Inflow to Makhool Reservoir.</b>	cumecs	409	1086	662
<b>Outflow from Makhool Reservoir.</b>	cumecs	472	1033	663
<b>Water level of Makhool Reservoir.</b>	m.a.s.l.	142.2	147.4	146.2
<b>Outflow from power outlets.</b>	cumecs	472	1033	663
<b>Outflow from bottom outlets.</b>	cumecs	0.0	0.0	0.0
<b>Tigris River water level downstream Makhool Dam.</b>	m.a.s.l.	117.8	118.7	118.3
<b>Makhool rated head.</b>	m	24.8	29.3	27.6
<b>Makhool power output production.</b>	MW	80.2	237.7	147.6
<b>Makhool energy power potential.</b>	GWh	60	171	1294

## 4- 6 Analysis of the results

### 4- 6-1 Results of the simulation model

***A : Bekhma Dam is not existing***

1-The operation plan outlined in (sec, (4-4-2) includes the general standard steps which should be followed by the operator. The operation of the simulation model shows that this plan causes deficit in satisfying the demands; the quantitative monthly deficiency was in the range [from (20.8) cumecs to (772.9) cumecs], with maximum deficit in September, (1999). Quantitatively, the total deficit represents (0.021%) of the total demand. The deficiency was noticed during (30) months from the total operation period (which is (480) months) as shown in

Table (B-10)(in Appendix (B)). This problem is overcome by transferring the excess water to Al-Tharthar Lake via Tigris -Tharthar Canal and transfers the water from Al-Tharthar Lake to Tigris River via Tharthar-Tigris Canal in the months when the flow downstream Makhool Reservoir is less than water requirements. This operation is illustrated in Fig. (A-2)(in Appendix (A)).

2-The operation of the reservoir has been contained within the upper and lower rule curves as shown in Fig. (A-3) (in Appendix (A)).

3-The maximum discharge of (1240 cumecs) from the power outlets makes the bottom outlets to be used in (33.9%) of the total operation period, with an average period of (124) day per year; the power station would be operating in full capacity for the same period.

***B : Bekhma Dam is operational***

1-The operation plan outlined in (sec, (4-4-2) includes the general standard steps which should be followed by the operator. The operation of the simulation model shows that this plan causes deficit in satisfying the demands. The quantitative monthly deficiency was in the range [from (16.8) cumecs to (592) cumecs], with maximum deficit in September, (1989). Quantitatively, the total deficit represents (0.016%) of the total demand. The deficiency was noticed during (21) months from the total operation period (which is (480) months) as shown in Table (B-10)(in Appendix (B)). This problem is overcome by transferring the excess water to Al-Tharthar Lake via Tigris - Tharthar Canal and transfers the water from Al-Tharthar Lake to Tigris River via Tharthar - Tigris Canal in the months when the flow downstream Makhool Reservoir is less than water requirements. This operation is illustrated in Fig. (C-1) (in Appendix (C)).

- 2-The operation of the reservoir has been contained within the upper and lower rule curves as shown in Fig. (C-2) (in Appendix (C)).
- 3-The maximum discharge of (1240 cumecs) from the power outlets make the bottom outlets to be used in (45.4%) of total operation period, with an average period of (166) day per year; the power station would be operating in full capacity for the same period.

#### **4- 6- 2 Results of the selected operation scenarios**

##### ***A: Bekhma Dam is not existing***

##### **A1: For two consecutive wet years.**

- 1-The water demands has been fully satisfied during the two years.
- 2-The operation of the reservoir has been contained within the upper and lower rule curves.
- 3-The maximum discharge of (1240 cumecs) from the power outlets make the bottom outlets to be used in (83.3%) of the total operation period, with an average period of (304) day per year; the power station would be operating in full capacity for the same period.

##### **A2: For two consecutive dry years**

- 1- The operation has shown deficit in satisfying the demands during the two years. The quantitative monthly deficiency was in the range [from (184.5) cumecs to (704.1) cumecs], with maximum deficit in November. Quantitatively, the total deficit represents (35%) of the demand. The deficiency was noticed during six-months in each year of the operation.
- 2-The operation of the reservoir has been contained within the upper and lower rule curves.

3-The maximum discharge of (1240 cumecs) from the power outlets results in no water passing through bottom outlets, and power station does not operate in full capacity during the two years.

***B: Bekhma Dam is operational***

**B1: For two consecutive wet years.**

1-The water demands has been fully satisfied during the two years.

2-The operation of the reservoir has been contained within the upper and lower rule curves.

3-The maximum discharge of (1240 cumecs) from the power outlets make the bottom outlets to be used in (95.8%) of the total operation period, with an average period of (350) day per year; the power station would be operating in full capacity for the same period.

**B2: For two consecutive dry years**

1-The operation has shown deficit in satisfying the demands during the two years. The quantitative monthly deficiency was in the range [from (33.4) cumecs to (530.4) cumecs], with maximum deficit in August. Quantitatively, the total deficit represents (21.6%) of the demand. The deficiency was noticed during six-months in each year of the operation.

2-The operation of the reservoir has been contained within the upper and lower rule curves.

3-The maximum discharge of (1240 cumecs) from the power outlets results in no water passing through bottom outlets, and power station does not operate in full capacity during the two years.

# CHAPTER FIVE

## Conclusions and recommendations

### 5-1 Introduction

This research is set out to investigate the optimal multiple purpose operation of Makhool Dam. The available monthly data for (40) years from [Oct. (1960) to Sep. (1999)], in addition to the hydrologic and meteorological data, have been analyzed in both the DDDP technique and simulation of monthly models.

A simulation model is developed to estimate the release from Makhool Reservoir, based on the optimum rule curves which are developed by an optimization model. A simulation model is adopted carefully to achieve an operation as close to the optimum operation as possible, and to keep the storage and release within their targets.

The model has been operated for two critical cases, namely:

- 1-Two consecutive wet years.
- 2-Two consecutive dry years.

### 5-2 Conclusions

Based on the obtained results, the following conclusions are abstracted:

#### **A: Results of the simulation**

- 1-Bekhma Dam significantly affects the optimum operation of Makhool Reservoir. It increases the probable safety of Makhool Dam besides decreasing the period of deficit supply of the demands downstream.
- 2-The operation shows deficit in satisfying the demands; the deficiency is in the range [from (20.8) cumecs to (772.9) cumecs], with maximum deficit in September, (1999). Quantitatively, the total deficit represents (0.021%) of the total demand. The deficiency is during (30) months from the total operation period (which is (480) months) when Bekhma Dam is not existing.
- 3-The operation shows deficit in satisfying the demands; the deficiency is in the range [from (16.8) cumecs to (592) cumecs], with maximum deficit in September, (1989). Quantitatively, the total deficit represents (0.016%) of the total demand. The deficiency is during (21) months from the total operation period (which is (480) months) when Bekhma Dam is operational.
- 4-The flood has been completely controlled during the considered operation period whether Bekhma Dam is not existing or when it is operational.
- 5-As an average, the power station operates in full capacity in (124) day per year when Bekhma Dam is not existing and in (166) day per year when Bekhma Dam is operational during the total operation period without being completely idle for any time.

## **B: Results of the selected operation scenarios**

- 1-The water demands have been fully satisfied during the two consecutive wet years when Bekhma Dam is not existing and when it is operational.
- 2-The operation shows deficit in satisfying the demands during the two consecutive dry years. The deficiency is in the range [from (184.5) cumecs to (704.1) cumecs], with maximum deficit in November. Quantitatively, the total deficit represents (35%) of the demand. The deficiency is during (6) months in each year of the operation period when Bekhma Dam is not existing.
- 3-The operation shows deficit in satisfying the demands during the two consecutive dry years. The deficiency is in the range [from (33.4) cumecs to (530.4) cumecs], with maximum deficit in August. Quantitatively, the total deficit represents (21.6%) of the demand. The deficiency is during (6) months in each year of the operation period when Bekhma Dam is operational.
- 4-The flood has been completely controlled during the two consecutive wet and dry years when Bekhma Dam is not existing and when it is operational.

### **-3 Recommendations**

The following are recommended for further studies:

- 1-Applying the developed simulation model to a grouped system of Iraqi Reservoirs, e. g., those of the Tigris River, collectively.
- 2-Using the monthly optimum rule curves, which are derived in this research to develop a daily simulation model in order to determine the daily storage, release and energy power potential for Makhool Reservoir.
- 3-Optimization of the operation of Makhool Dam on the basis of optimal power generation.

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**Table (D-1): Inflow (cumecs) to Makhool Reservoir when Bekhma Dam is operational [Al-Furat Center(2000)]**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	908	905	745	715	691	926	1069	1222	1363	1310	1192	874	<b>993</b>
<b>1961</b>	1094	981	184	445	451	509	799	710	861	1216	1098	771	<b>760</b>
<b>1962</b>	1062	894	752	929	861	981	1093	1117	1307	1258	1096	773	<b>1010</b>
<b>1963</b>	986	726	477	943	1036	1179	4133	5597	2983	1514	1596	1487	<b>1888</b>
<b>1964</b>	1232	1127	819	863	938	2419	2931	2131	1897	1605	1294	1214	<b>1539</b>
<b>1965</b>	1084	797	724	870	950	1086	1297	1394	1866	1453	1278	1086	<b>1157</b>
<b>1966</b>	1286	1011	664	642	1143	1243	2148	1709	1366	1275	1256	1015	<b>1230</b>
<b>1967</b>	984	858	522	569	724	898	1780	3500	1801	1393	1326	1113	<b>1289</b>
<b>1968</b>	1177	993	905	1158	952	2442	3551	3004	1743	1425	1506	1210	<b>1672</b>
<b>1969</b>	1166	1072	1605	2448	1972	4868	6250	5717	2585	2116	1852	1416	<b>2756</b>
<b>1970</b>	1383	1196	884	981	884	1162	1294	1336	1346	1401	1194	853	<b>1160</b>
<b>1971</b>	973	854	477	318	353	827	1319	1292	1161	1343	1189	836	<b>912</b>
<b>1972</b>	1083	960	646	517	614	1275	1438	3277	1973	1515	1494	1376	<b>1347</b>
<b>1973</b>	1348	1239	839	908	858	817	945	643	1281	1430	1217	1007	<b>1044</b>
<b>1974</b>	1221	976	518	537	514	1619	2004	1569	2125	1498	1353	1163	<b>1258</b>
<b>1975</b>	1262	948	497	544	798	1082	1157	1182	1243	1315	1132	816	<b>998</b>
<b>1976</b>	1114	936	573	755	873	1061	2819	3347	2160	1440	1515	1323	<b>1493</b>
<b>1977</b>	1349	1259	830	859	874	1077	1288	1390	1612	1369	1233	1176	<b>1193</b>
<b>1978</b>	1236	1025	742	992	1139	1355	2368	1882	1643	1814	1789	1370	<b>1446</b>
<b>1979</b>	1483	1212	918	1130	1211	1098	1341	771	1314	1460	1273	1011	<b>1185</b>
<b>1980</b>	1241	1077	722	802	921	1222	3289	2321	1759	1680	1538	1315	<b>1491</b>
<b>1981</b>	1440	1221	768	774	908	1431	1332	1617	1614	1634	1811	1555	<b>1342</b>
<b>1982</b>	1529	1212	786	874	991	971	1360	2869	1643	1712	1724	1597	<b>1439</b>
<b>1983</b>	1498	1314	977	922	542	812	1073	1167	1324	1767	1483	1281	<b>1180</b>
<b>1984</b>	1323	874	490	645	620	903	973	612	850	1308	1179	902	<b>890</b>
<b>1985</b>	1144	1325	353	398	1466	1836	2176	2077	1826	1697	1494	1299	<b>1424</b>
<b>1986</b>	919	768	369	275	352	603	855	735	982	1044	999	805	<b>726</b>
<b>1987</b>	925	1010	580	648	1357	2289	2928	3012	2041	1315	1143	1099	<b>1529</b>
<b>1988</b>	1222	1270	1990	2936	1970	4630	6665	5527	2948	2423	2253	1944	<b>2982</b>
<b>1989</b>	1769	1399	838	827	682	772	790	563	627	973	894	750	<b>907</b>
<b>1990</b>	1052	903	862	678	967	1084	932	1263	1100	1240	2201	851	<b>1094</b>
<b>1991</b>	852	815	444	554	983	1014	809	413	741	1247	1170	1002	<b>837</b>
<b>1992</b>	893	928	493	711	1756	1608	2522	3408	1985	1835	1469	1167	<b>1565</b>
<b>1993</b>	1086	1084	1476	1415	1365	1453	3367	4138	2896	2043	1807	1272	<b>1950</b>
<b>1994</b>	1532	1424	869	1109	1156	1408	2392	1519	1463	1397	1317	1098	<b>1390</b>
<b>1995</b>	1232	1481	1591	1506	1910	1457	2706	2444	1939	1627	1201	723	<b>1651</b>
<b>1996</b>	1603	1229	529	755	786	689	1602	1162	1316	1222	1117	623	<b>1053</b>
<b>1997</b>	1388	1009	533	724	627	759	1497	1779	1624	1550	1322	1071	<b>1157</b>
<b>1998</b>	1196	1185	776	891	1056	809	1849	793	1287	1372	1299	945	<b>1122</b>
<b>1999</b>	1086	912	574	535	481	529	547	409	749	813	706	601	<b>662</b>
<b>Min.</b>	<b>852</b>	<b>726</b>	<b>184</b>	<b>275</b>	<b>352</b>	<b>509</b>	<b>547</b>	<b>409</b>	<b>627</b>	<b>813</b>	<b>706</b>	<b>601</b>	
<b>Max.</b>	<b>1769</b>	<b>1481</b>	<b>1591</b>	<b>1506</b>	<b>1910</b>	<b>4868</b>	<b>6665</b>	<b>5527</b>	<b>2983</b>	<b>2423</b>	<b>2253</b>	<b>1944</b>	<b>1318</b>

**Table (B-1): Inflow (cumecs) to the Makhool Reservoir when Bekhma Dam is not existing [Al-Furat Center(2000)]**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	614	664	798	849	923	1107	1490	1870	1277	876	828	679	<b>998</b>
<b>1961</b>	777	819	267	540	618	587	1294	1387	850	810	720	572	<b>770</b>
<b>1962</b>	738	732	998	1181	1267	1330	1500	1640	1335	916	751	576	<b>1080</b>
<b>1963</b>	662	489	724	1130	1270	1470	5075	5600	3001	1375	1173	919	<b>1907</b>
<b>1964</b>	774	932	976	977	1279	2912	3189	2620	1788	1134	979	932	<b>1541</b>
<b>1965</b>	693	596	819	983	1180	1360	1770	2050	1654	1074	938	853	<b>1164</b>
<b>1966</b>	895	811	757	780	1382	1501	2489	2120	1267	862	912	851	<b>1219</b>
<b>1967</b>	729	648	616	714	893	1120	2225	4360	1731	990	929	807	<b>1314</b>
<b>1968</b>	786	798	1119	1337	1166	2751	4139	3350	1761	1053	994	904	<b>1680</b>
<b>1969</b>	775	877	1819	2627	2206	5771	6559	5720	2511	1721	1451	1110	<b>2762</b>
<b>1970</b>	992	1001	1058	1196	1072	1270	1550	1611	1179	986	865	698	<b>1123</b>
<b>1971</b>	714	658	601	372	382	914	2210	1935	1188	979	843	671	<b>956</b>
<b>1972</b>	762	761	771	606	803	1579	2020	3840	1991	1216	1037	938	<b>1360</b>
<b>1973</b>	957	1044	958	1005	1130	974	1461	1337	1054	1051	926	723	<b>1052</b>
<b>1974</b>	830	779	634	640	624	2090	2480	2088	1944	1119	1058	883	<b>1264</b>
<b>1975</b>	871	742	586	619	1054	1189	1380	1510	1157	987	866	690	<b>971</b>
<b>1976</b>	823	693	681	907	1272	1230	3650	3916	2103	1171	1025	962	<b>1536</b>
<b>1977</b>	958	1064	997	1032	1167	1368	1647	1918	1429	1016	934	870	<b>1200</b>
<b>1978</b>	845	830	956	1171	1373	1646	2731	2429	1560	1512	1320	1064	<b>1453</b>
<b>1979</b>	1092	1014	1134	1309	1445	1352	1743	1249	1175	1081	957	753	<b>1192</b>
<b>1980</b>	850	882	936	981	1155	1513	3673	2864	1666	1312	1128	1009	<b>1497</b>
<b>1981</b>	1049	1026	909	1026	1142	1722	1695	2180	1567	1336	1293	1243	<b>1349</b>
<b>1982</b>	1138	1017	973	1080	1225	1223	1765	3432	1553	1332	1323	1291	<b>1446</b>
<b>1983</b>	1107	1119	1111	1070	752	1155	1521	1730	1164	1323	1176	1014	<b>1187</b>
<b>1984</b>	932	679	667	733	798	1178	1305	1065	947	952	830	678	<b>897</b>
<b>1985</b>	753	1130	519	625	1700	2127	2656	2527	1600	1317	1163	1056	<b>1431</b>
<b>1986</b>	528	548	510	503	640	788	1217	1122	934	676	621	606	<b>724</b>
<b>1987</b>	637	815	794	827	1591	2580	3371	3498	1939	925	764	793	<b>1545</b>
<b>1988</b>	831	1075	2204	3115	2204	5518	6990	5530	2876	2080	1798	1638	<b>2988</b>
<b>1989</b>	1378	1129	878	829	632	744	764	750	600	530	515	529	<b>773</b>
<b>1990</b>	696	787	1070	743	1125	1328	1292	1760	1155	797	1822	630	<b>1100</b>
<b>1991</b>	558	635	520	586	1180	1452	1210	902	698	804	791	801	<b>845</b>
<b>1992</b>	610	746	854	1002	2360	1985	3459	4234	1955	1440	1026	861	<b>1711</b>
<b>1993</b>	695	889	1690	1594	1599	1744	3730	4701	2914	1677	1289	1063	<b>1965</b>
<b>1994</b>	1047	1229	1083	1288	1390	1699	2755	2043	1277	998	943	903	<b>1388</b>
<b>1995</b>	858	1219	1869	1685	2144	1748	3069	3007	1776	1186	874	842	<b>1690</b>
<b>1996</b>	975	913	610	805	875	1045	2287	1745	1089	843	781	722	<b>1058</b>
<b>1997</b>	746	737	747	903	842	1067	2004	2203	1550	1152	924	765	<b>1137</b>
<b>1998</b>	805	990	990	1070	1290	1100	2430	1145	1060	985	930	750	<b>1129</b>
<b>1999</b>	695	683	615	578	615	490	648	545	455	319	327	380	<b>529</b>
<b>Min.</b>	<b>528</b>	<b>489</b>	<b>267</b>	<b>372</b>	<b>382</b>	<b>490</b>	<b>648</b>	<b>545</b>	<b>455</b>	<b>319</b>	<b>327</b>	<b>380</b>	
<b>Max.</b>	<b>1378</b>	<b>1229</b>	<b>2204</b>	<b>1685</b>	<b>2360</b>	<b>2912</b>	<b>6990</b>	<b>5720</b>	<b>3001</b>	<b>2080</b>	<b>1822</b>	<b>1638</b>	<b>1323</b>

**Table(D-10): Periods when the flow violated the demands for real operation scheme when Bekhma Dam is operational**

<b>Year</b>	<b>Month</b>	<b>Outflow</b>	<b>Demand</b>
1961	7	742.5	896.6
1961	8	651.3	880.7
1961	9	854.6	1213.2
1973	8	812.2	880.7
1984	8	783.6	880.7
1984	9	843.6	1213.2
1986	7	748.3	896.6
1986	8	676.3	880.7
1986	9	975.6	1213.2
1986	10	1105.5	1122.3
1989	8	583.9	880.7
1989	9	620.6	1213.2
1989	10	1034.5	1122.3
1991	8	452	880.7
1991	9	734.6	1213.2
1999	7	543	896.6
1999	8	350.3	880.7
1999	9	742.6	1213.2
1999	10	874.5	1122.3
1999	11	796.9	969.8
1999	12	633.1	666.5

**Table (B-10): Periods when the flow violated the demands for real operation scheme when Bekhma Dam is not existing**

<b>Year</b>	<b>Month</b>	<b>Outflow</b>	<b>Demands</b>
1961	9	1074.7	1213.2
1961	10	909.2	1122.3
1961	11	825.8	969.8
1961	12	539.7	666.5
1962	12	550	666.5
1984	9	1171.7	1213.2
1984	10	1051.2	1122.3
1984	11	935.8	969.8
1984	12	645.7	666.5
1986	9	1158.7	1213.2
1986	10	775.2	1122.3
1986	11	726.8	969.8
1986	12	573.7	666.5
1989	8	786.2	880.7
1989	9	585.3	1213.2
1989	10	629.2	1122.3
1989	11	620.8	969.8
1989	12	496.7	666.5
1990	10	1054.6	1122.3
1991	9	911.4	1213.2
1991	10	903.2	1122.3
1991	11	896.8	969.8
1996	10	1037.8	1122.3
1996	11	886.8	969.8
1999	7	712.1	896.6
1999	8	461.4	880.7
1999	9	440.3	1213.2
1999	10	418.2	1122.3
1999	11	432.8	969.8
1999	12	347.7	666.5

**Table(D-8) :Optimum power output (MW) from Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	181.4	236.2	145.6	148.4	148.1	212.9	251.4	293.5	314.3	313.3	305.3	207.8	<b>230.1</b>
<b>1961</b>	289.6	252.7	51.3	58.2	113.3	144.0	159.6	145.8	195.2	251.2	242.3	183.5	<b>174.5</b>
<b>1962</b>	282.2	233.8	147	194.7	186.7	225.6	257	268.4	315	314	282.6	184	<b>241.2</b>
<b>1963</b>	264.6	196.8	89.4	197.7	225.8	271	278	275.5	298.6	310.9	303.4	296.1	<b>251.8</b>
<b>1964</b>	299.7	282.5	160.8	180.5	203.9	283.8	287	300.7	308.4	309.9	306.9	286.6	<b>268.0</b>
<b>1965</b>	287.3	212.5	141.2	182	206.6	249.8	303.2	308.6	308.7	311.6	307.1	257.2	<b>256.1</b>
<b>1966</b>	299.1	259.3	128.8	132.4	249.4	285.5	293.9	305	314.2	313.8	307.3	240.7	<b>261.4</b>
<b>1967</b>	264.1	225.9	99	116.3	155.7	206.4	297.6	289.2	309.4	312.3	306.5	263.4	<b>237.1</b>
<b>1968</b>	300.4	255.4	178.4	243.3	207.1	283.6	282.2	293	310	312	304.4	285.7	<b>271.0</b>
<b>1969</b>	300.6	272.5	256.1	261.6	277.9	265.7	265.2	274.8	301.9	304.7	300.7	296.9	<b>282.3</b>
<b>1970</b>	298	281.6	174.1	205.8	191.8	267.1	303.2	309.3	314.5	312.2	305.8	202.8	<b>264.8</b>
<b>1971</b>	261.5	225	89.4	63.3	112.6	134.4	299.7	309.9	309.2	303.7	304.6	198.8	<b>218.7</b>
<b>1972</b>	287	248.2	125	104.7	130.5	292.8	301.4	290.9	307.6	310.9	304.5	297.4	<b>250.6</b>
<b>1973</b>	298.4	281.1	164.9	190.2	186	187.5	222.7	206.7	272.3	286.3	307.8	238.8	<b>237.0</b>
<b>1974</b>	299.9	251.7	98.1	109.2	113.6	287.9	295.3	306.6	306.1	311.1	306.2	274.9	<b>247.2</b>
<b>1975</b>	299.4	245.6	93.7	110.7	172.5	248.9	272.1	284	313.3	313.3	291.1	194.1	<b>237.8</b>
<b>1976</b>	294.2	242.9	109.7	157.1	189.4	244	287.9	290.3	305.8	311.8	304.3	298	<b>253.5</b>
<b>1977</b>	298.3	280.8	163.1	179.6	189.6	247.7	302.6	308.7	311.4	312.6	307.6	277.9	<b>265.1</b>
<b>1978</b>	299.7	262.3	145	208.1	248.5	294.9	291.8	303.2	311.1	307.7	301.3	297.5	<b>273.4</b>
<b>1979</b>	296.8	281.4	181	237.4	264.3	252.5	302.6	223.6	283.2	300.7	307.1	239.8	<b>264.9</b>
<b>1980</b>	299.6	273.5	140.8	167.3	200.1	280.8	284.1	298.9	309.8	309.1	304	298.1	<b>264.1</b>
<b>1981</b>	297.3	281.3	150.3	161.2	197.2	294	302.7	306	311.4	309.6	301.1	295.3	<b>267.6</b>
<b>1982</b>	296.3	281.4	154	182.9	215.8	223.3	302.4	294.1	311.1	308.8	302	294.8	<b>264.0</b>
<b>1983</b>	296.7	280.2	193	193.2	113.8	186.3	252.3	280.4	314.8	308.2	304.6	298.6	<b>252.4</b>
<b>1984</b>	298.7	229.4	92.2	133.1	131.9	207.6	228.7	199.9	192.8	251.2	295.6	214.3	<b>206.3</b>
<b>1985</b>	300.8	280.1	62.8	78	283.4	289.5	293.6	301.2	309.1	308.9	304.5	298.3	<b>259.6</b>
<b>1986</b>	249	206.1	66.3	63.3	109.5	129.9	154.5	151.2	221.5	247.6	206.5	146	<b>163.0</b>
<b>1987</b>	219.8	259	111.2	133.7	284.7	285	287	293	306.9	313.3	293.7	260.2	<b>254.1</b>
<b>1988</b>	299.9	280.7	252	257.4	277.9	267.2	262.9	275.9	298.9	301.9	296.8	291.1	<b>280.8</b>
<b>1989</b>	293.8	279.2	164.7	172.7	146.1	177	222.7	138.4	143.7	232.5	206.5	133.9	<b>193.5</b>
<b>1990</b>	191.2	235.7	169.6	140.3	210.4	249.3	222.7	297.4	309.2	271.7	297.3	202.4	<b>233.1</b>
<b>1991</b>	233.3	216.4	82.4	112.9	214	233.2	222.7	109.3	169	251.2	270.1	237.7	<b>196.7</b>
<b>1992</b>	242.9	241.2	92.8	147.5	280.1	292	290.4	289.9	307.5	307.5	304.8	275.8	<b>256.5</b>
<b>1993</b>	287.7	275.1	257.6	272.2	284.6	293.7	283.5	284.6	299.3	305.4	301.1	298.7	<b>287.1</b>
<b>1994</b>	296.3	278.9	171.1	232.9	252.3	294.3	291.6	307.1	313.1	312.3	306.6	259.9	<b>276.9</b>
<b>1995</b>	299.7	278.3	256.2	271.1	278.5	293.7	288.8	297.8	308	309.7	307.4	172.1	<b>280.0</b>
<b>1996</b>	295.5	281.2	100.5	157.1	169.7	157.4	299.6	279.2	314.9	314.4	287.6	165.1	<b>235.4</b>
<b>1997</b>	287	258.8	101.3	150.4	133.5	173.9	300.8	304.3	311.3	310.5	306.5	253.7	<b>241.5</b>
<b>1998</b>	300.2	281.7	152	186.5	230.2	185.6	296.9	223.6	287	301.1	306.8	224.4	<b>248.4</b>
<b>1999</b>	287.7	237.7	109.9	108.7	113.6	146.8	122.7	80.2	170.7	198.2	171.3	125.7	<b>156.4</b>
<b>Min.</b>	<b>181.4</b>	<b>196.8</b>	<b>51.3</b>	<b>58.2</b>	<b>109.5</b>	<b>129.9</b>	<b>122.7</b>	<b>80.2</b>	<b>143.7</b>	<b>198.2</b>	<b>171.3</b>	<b>125.7</b>	
<b>Max.</b>	<b>300.8</b>	<b>282.5</b>	<b>257.6</b>	<b>272.2</b>	<b>284.7</b>	<b>294.9</b>	<b>303.2</b>	<b>309.9</b>	<b>315.6</b>	<b>314.4</b>	<b>307.8</b>	<b>298.7</b>	<b>244.6</b>

**Table(B-8) :Optimum power output (MW) from Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	134.2	164	152	173.1	190.2	253	305.3	306.1	315.4	286.3	212.6	130.4	<b>218.0</b>
<b>1961</b>	120.8	197.3	50.1	95.8	121.7	152.6	274.2	311.4	275.5	205.1	171.4	101.9	<b>173.6</b>
<b>1962</b>	115.7	161.7	191.7	242.4	265.4	297.6	305.2	308.5	314.7	286.3	218.6	104.4	<b>234.5</b>
<b>1963</b>	115.7	90.2	135.6	231.9	266.1	295.9	276.5	278.3	298.5	313.2	294.2	243.5	<b>236.8</b>
<b>1964</b>	228	220.8	187.4	200.1	268	281.9	289.4	299	309.5	289.4	247.4	246.6	<b>255.9</b>
<b>1965</b>	209.1	150	156.2	201.3	246.6	297.3	302.2	304.3	311	286.3	240.3	198	<b>241.2</b>
<b>1966</b>	256.1	195.6	143.7	158.4	281.3	295.6	295.2	303.6	315.5	286.3	210.4	139	<b>240.3</b>
<b>1967</b>	186.7	161.1	115.1	144.3	183.5	256	297.6	286	310.1	286.3	229.1	156.5	<b>217.0</b>
<b>1968</b>	230.8	192.8	215.4	268.4	243.5	283.3	282.5	293.1	309.8	286.3	237.5	222.5	<b>255.6</b>
<b>1969</b>	228.3	209.4	247.6	255.1	272.4	262.6	268	277.6	302.6	309.3	308.7	289.2	<b>269.2</b>
<b>1970</b>	278.5	235.1	203.5	245.5	223	290.4	304.6	308.8	309.2	279.5	221.9	142.2	<b>253.4</b>
<b>1971</b>	144.2	163.3	112	69.6	112.3	149.3	297.8	305.4	309.2	280.7	222.1	139.9	<b>192.8</b>
<b>1972</b>	139.4	185.1	146.5	121	163.5	294.7	299.6	289.5	307.5	309.3	261.5	248.1	<b>230.1</b>
<b>1973</b>	270.4	244	183.8	205.9	235.7	222.2	305.6	312	309.2	260.9	213.9	143.1	<b>242.4</b>
<b>1974</b>	178.9	188.9	118.8	128.4	123	289.3	295.3	303.9	307.9	286.3	265.6	234.8	<b>226.3</b>
<b>1975</b>	250.6	181.1	109	123.8	219.1	271.9	306.6	310	309.2	276.3	219	140.1	<b>226.0</b>
<b>1976</b>	158.1	170.7	128.3	185.4	266.5	281.3	285.9	289	306.4	298.4	258.5	253.8	<b>240.6</b>
<b>1977</b>	270.7	248.1	191.5	211.6	243.8	297.2	303.5	305.6	313.5	286.3	232.6	180.8	<b>257.1</b>
<b>1978</b>	244.5	199.6	183.4	240.4	281.4	293.9	293.1	300.7	312	311.6	310.3	278.2	<b>270.5</b>
<b>1979</b>	298.7	237.8	218.3	268.7	280.6	297.4	302.5	307.2	309.2	278.9	234.5	166.5	<b>266.7</b>
<b>1980</b>	245.7	210.4	179.5	200.9	241.1	295.4	285.8	297	310.8	313.9	283.4	265.1	<b>260.0</b>
<b>1981</b>	291.6	240.3	174.1	210.3	238.3	293.1	303	303	311.9	313.6	310.6	308.1	<b>274.4</b>
<b>1982</b>	298.1	238.4	186.8	221.6	256.3	279.7	302.2	292.5	312.1	313.7	310.2	307.5	<b>276.6</b>
<b>1983</b>	298.5	259.4	213.8	219.5	152	264.1	304.9	307.5	309.2	304.6	294.9	266.3	<b>266.5</b>
<b>1984</b>	264.7	167.7	125.5	148.4	162.3	269.4	307.5	262.8	299.1	235.4	192.9	120.9	<b>213.3</b>
<b>1985</b>	115.7	247.4	95.2	125.1	277.6	288.9	293.7	299.8	311.6	313.9	291.8	276.3	<b>244.0</b>
<b>1986</b>	170.1	139.7	93.3	98.5	126.7	178.5	292.6	276.6	295.9	176.2	151.8	108	<b>175.1</b>
<b>1987</b>	115.7	144.2	151.2	168.4	278.8	284.8	288	292	308	286.3	219.9	128.3	<b>222.2</b>
<b>1988</b>	161.3	250.4	243.7	251.1	272.4	264.1	265.7	278.7	299.5	305.6	304.9	303.5	<b>266.8</b>
<b>1989</b>	295.3	261.4	167.9	168.9	124.9	168.1	226	184.5	134.7	144.2	130.5	94.1	<b>175.4</b>
<b>1990</b>	115.7	158.5	205.8	150.5	234.6	297.7	307.7	307.2	309.2	260.2	248.4	173.2	<b>230.3</b>
<b>1991</b>	177.2	158.4	95.4	116.7	246.6	296.2	290.9	225.7	234	203.8	185.3	124.6	<b>196.0</b>
<b>1992</b>	126.7	154.5	163.2	205.3	270.9	290.3	287.3	286.8	307.8	312.4	258.8	229.5	<b>241.7</b>
<b>1993</b>	209.5	211.9	248.9	265.3	278.7	292.8	285.3	283.8	299.2	309.7	310.6	278	<b>272.6</b>
<b>1994</b>	291.1	267.8	208.4	264.4	281.2	293.3	292.9	304.3	315.4	286.3	230.2	185.2	<b>268.9</b>
<b>1995</b>	247.6	268	247	264.3	273	292.8	290.3	295.8	309.7	302	246.2	189.4	<b>268.5</b>
<b>1996</b>	274.6	216.9	113.9	163.8	179.5	238.7	297	307.4	309.2	247.2	183.3	124.6	<b>221.1</b>
<b>1997</b>	118.3	173	141.7	184.5	172.2	243.8	299.8	302.8	312.1	293.8	246.2	188.7	<b>223.2</b>
<b>1998</b>	235.2	232.9	190.1	219.5	270.4	251.4	295.7	282.2	309.2	261.9	204.5	136.8	<b>240.3</b>
<b>1999</b>	141.4	168.6	114.9	114.9	121	152.6	162.3	101.8	102.4	97.3	92.3	66.8	<b>119.5</b>
<b>Min.</b>	<b>115.7</b>	<b>90.2</b>	<b>50.1</b>	<b>69.6</b>	<b>112.3</b>	<b>149.3</b>	<b>162.3</b>	<b>101.8</b>	<b>102.4</b>	<b>97.3</b>	<b>92.3</b>	<b>66.8</b>	
<b>Max.</b>	<b>298.7</b>	<b>268.0</b>	<b>248.9</b>	<b>268.7</b>	<b>281.4</b>	<b>297.7</b>	<b>307.7</b>	<b>312.0</b>	<b>315.5</b>	<b>313.9</b>	<b>310.6</b>	<b>308.1</b>	<b>235.2</b>

**Table(D-9) :Optimum energy power potential (GWh) of Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	135	170	108.3	110.4	99.5	158.4	181	218.4	226.3	233.1	227.1	149.6	<b>2017</b>
<b>1961</b>	215.4	182	38.1	43.3	76.2	107.1	114.9	108.5	140.6	186.9	180.3	132.1	<b>1525</b>
<b>1962</b>	209.9	168.3	109.4	144.8	125.4	167.9	185.1	199.7	226.8	233.6	210.2	132.5	<b>2114</b>
<b>1963</b>	196.8	141.7	66.5	147.1	151.7	201.6	200.2	205	215	231.3	225.7	213.2	<b>2196</b>
<b>1964</b>	223	203.4	119.7	134.3	137	211.2	206.6	223.7	222	230.6	228.3	206.4	<b>2346</b>
<b>1965</b>	213.7	153	105.1	135.4	138.8	185.8	218.3	229.6	222.3	231.9	228.4	185.1	<b>2247</b>
<b>1966</b>	222.5	186.7	95.8	98.5	167.6	212.4	211.6	226.9	226.3	233.4	228.7	173.3	<b>2284</b>
<b>1967</b>	196.5	162.6	73.6	86.5	104.6	153.6	214.3	215.2	222.7	232.4	228	189.6	<b>2080</b>
<b>1968</b>	223.5	183.9	132.7	181	139.1	211	203.2	218	223.2	232.1	226.5	205.7	<b>2380</b>
<b>1969</b>	223.6	196.2	190.5	194.6	186.7	197.7	190.9	204.5	217.4	226.7	223.7	213.8	<b>2466</b>
<b>1970</b>	221.7	202.8	129.5	153.1	128.9	198.7	218.3	230.1	226.4	232.3	227.5	146	<b>2315</b>
<b>1971</b>	194.6	162	66.5	47.1	75.6	100	215.8	230.6	222.6	225.9	226.6	143.2	<b>1910</b>
<b>1972</b>	213.6	178.7	93	77.9	87.7	217.8	217	216.4	221.5	231.3	226.6	214.1	<b>2196</b>
<b>1973</b>	222	202.4	122.7	141.5	125	139.5	160.3	153.8	196.1	213	229	172	<b>2077</b>
<b>1974</b>	223.1	181.2	73	81.2	76.3	214.2	212.6	228.1	220.4	231.5	227.8	197.9	<b>2167</b>
<b>1975</b>	222.7	176.8	69.7	82.4	115.9	185.1	195.9	211.3	225.6	233.1	216.6	139.8	<b>2075</b>
<b>1976</b>	218.9	174.9	81.6	116.9	127.3	181.6	207.3	216	220.2	232	226.4	214.6	<b>2218</b>
<b>1977</b>	222	202.2	121.3	133.6	127.4	184.3	217.9	229.7	224.2	232.6	228.9	200.1	<b>2324</b>
<b>1978</b>	223	188.9	107.9	154.8	167	219.4	210.1	225.6	224	228.9	224.2	214.2	<b>2388</b>
<b>1979</b>	220.8	202.6	134.7	176.6	177.6	187.9	217.9	166.4	203.9	223.7	228.5	172.6	<b>2313</b>
<b>1980</b>	222.9	196.9	104.8	124.5	134.5	208.9	204.6	222.4	223.1	230	226.2	214.7	<b>2313</b>
<b>1981</b>	221.2	202.5	111.9	120	132.5	218.7	218	227.7	224.2	230.3	224	212.6	<b>2344</b>
<b>1982</b>	220.5	202.6	114.6	136	145	166.1	217.7	218.8	224	229.7	224.7	212.3	<b>2312</b>
<b>1983</b>	220.7	201.7	143.6	143.7	76.5	138.6	181.7	208.6	226.6	229.3	226.7	215	<b>2213</b>
<b>1984</b>	222.2	165.2	68.6	99	88.6	154.4	164.7	148.7	138.8	186.9	219.9	154.3	<b>1811</b>
<b>1985</b>	223.8	201.6	46.7	58	190.4	215.4	211.4	224.1	222.6	229.8	226.6	214.8	<b>2265</b>
<b>1986</b>	185.2	148.4	49.3	47.1	73.6	96.6	111.3	112.5	159.5	184.2	153.6	105.1	<b>1426</b>
<b>1987</b>	163.5	186.5	82.7	99.5	191.3	212.1	206.6	218	221	233.1	218.5	187.3	<b>2220</b>
<b>1988</b>	223.1	202.1	187.5	191.5	186.7	198.8	189.3	205.3	215.2	224.6	220.8	209.6	<b>2455</b>
<b>1989</b>	218.6	201	122.6	128.5	98.2	131.7	160.3	103	103.5	173	153.6	96.4	<b>1690</b>
<b>1990</b>	142.3	169.7	126.2	104.4	141.4	185.5	160.3	221.3	222.6	202.1	221.2	145.7	<b>2043</b>
<b>1991</b>	173.5	155.8	61.3	84	143.8	173.5	160.3	81.3	121.7	186.9	200.9	171.1	<b>1714</b>
<b>1992</b>	180.7	173.7	69.1	109.8	188.2	217.2	209.1	215.7	221.4	228.8	226.8	198.6	<b>2239</b>
<b>1993</b>	214.1	198	191.6	202.5	191.3	218.5	204.1	211.8	215.5	227.2	224	215	<b>2514</b>
<b>1994</b>	220.4	200.8	127.3	173.3	169.5	218.9	210	228.5	225.4	232.3	228.1	187.1	<b>2422</b>
<b>1995</b>	223	200.4	190.6	201.7	187.1	218.5	208	221.5	221.7	230.4	228.7	123.9	<b>2456</b>
<b>1996</b>	219.9	202.5	74.7	116.9	114.1	117.1	215.7	207.7	226.7	233.9	214	118.9	<b>2062</b>
<b>1997</b>	213.5	186.4	75.4	111.9	89.7	129.4	216.5	226.4	224.1	231	228.1	182.7	<b>2115</b>
<b>1998</b>	223.3	202.9	113.1	138.8	154.7	138.1	213.8	166.4	206.6	224	228.3	161.6	<b>2171</b>
<b>1999</b>	214.1	171.1	81.8	80.9	76.3	109.2	88.4	59.7	122.9	147.5	127.5	90.5	<b>1370</b>
<b>Min.</b>	<b>135.0</b>	<b>141.7</b>	<b>38.1</b>	<b>43.3</b>	<b>73.6</b>	<b>96.9</b>	<b>88.4</b>	<b>59.7</b>	<b>103.5</b>	<b>147.5</b>	<b>127.5</b>	<b>90.5</b>	
<b>Max.</b>	<b>223.8</b>	<b>203.4</b>	<b>191.6</b>	<b>202.5</b>	<b>191.3</b>	<b>219.4</b>	<b>218.3</b>	<b>230.6</b>	<b>226.8</b>	<b>233.9</b>	<b>229.0</b>	<b>215.0</b>	<b>2145</b>

**Table(B-9) :Optimum energy power potential (GWh) of Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	99.9	118.1	113.1	128.8	127.8	188.2	219.8	227.7	227.1	213	158.2	93.9	<b>1916</b>
<b>1961</b>	89.9	142	37.3	71.3	81.8	113.5	197.4	231.7	198.3	152.6	127.5	73.4	<b>1517</b>
<b>1962</b>	86.1	116.4	142.6	180.4	178.4	221.4	219.7	229.5	226.6	213	162.6	75.2	<b>2052</b>
<b>1963</b>	86.1	64.9	100.9	172.5	178.8	220.2	199	207.1	214.9	233	218.9	175.3	<b>2072</b>
<b>1964</b>	169.6	159	139.4	148.8	180.1	209.8	208.4	222.5	222.9	215.3	184.1	177.6	<b>2237</b>
<b>1965</b>	155.5	108	116.2	149.8	165.7	221.2	217.6	226.4	223.9	213	178.8	142.6	<b>2119</b>
<b>1966</b>	190.6	140.8	106.9	117.9	189.1	219.9	212.5	225.9	227.2	213	156.6	100.1	<b>2100</b>
<b>1967</b>	138.9	116	85.6	107.4	123.3	190.5	214.3	212.8	223.3	213	170.5	112.6	<b>1908</b>
<b>1968</b>	171.7	138.8	160.2	199.7	163.7	210.8	203.4	218.1	223.1	213	176.7	160.2	<b>2239</b>
<b>1969</b>	169.8	150.8	184.2	189.8	183.1	195.4	193	206.6	217.9	230.1	229.7	208.2	<b>2358</b>
<b>1970</b>	207.2	169.3	151.4	182.7	149.9	216.1	219.3	229.8	222.6	207.9	165.1	102.4	<b>2224</b>
<b>1971</b>	107.3	117.5	83.4	51.7	75.4	111.1	214.4	227.2	222.6	208.9	165.3	100.7	<b>1686</b>
<b>1972</b>	103.7	133.2	109	90	109.8	219.2	215.7	215.4	221.4	230.1	194.5	178.6	<b>2021</b>
<b>1973</b>	201.2	175.7	136.8	153.2	158.4	165.3	220	232.2	222.6	194.1	159.2	103	<b>2122</b>
<b>1974</b>	133.1	136	88.4	95.5	82.7	215.2	212.6	226.1	221.7	213	197.6	169.1	<b>1991</b>
<b>1975</b>	186.4	130.4	81.1	92.1	147.2	202.3	220.7	230.6	222.6	205.6	163	100.9	<b>1983</b>
<b>1976</b>	117.6	122.9	95.5	137.9	179.1	209.3	205.9	215	220.6	222	192.4	182.8	<b>2101</b>
<b>1977</b>	201.4	178.6	142.5	157.4	163.8	221.1	218.5	227.3	225.7	213	173.1	130.1	<b>2253</b>
<b>1978</b>	181.9	143.7	136.5	178.8	189.1	218.7	211	223.7	224.7	231.8	230.8	200.3	<b>2371</b>
<b>1979</b>	222.2	171.2	162.4	199.9	188.5	221.2	217.8	228.6	222.6	207.5	174.5	119.9	<b>2336</b>
<b>1980</b>	182.8	151.5	133.5	149.5	162.1	219.8	205.7	220.9	223.8	233.6	210.8	190.9	<b>2285</b>
<b>1981</b>	216.9	173	129.5	156.5	160.1	218.1	218.1	225.4	224.6	233.3	231.1	221.8	<b>2409</b>
<b>1982</b>	221.8	171.7	139	164.8	172.3	208.1	217.6	217.6	224.7	233.4	230.8	221.4	<b>2423</b>
<b>1983</b>	222.1	186.8	159.1	163.3	102.2	196.5	219.5	228.8	222.6	226.6	219.4	191.7	<b>2339</b>
<b>1984</b>	196.9	120.8	93.4	110.4	109.1	200.4	221.4	195.5	215.3	175.1	143.5	87	<b>1869</b>
<b>1985</b>	86.1	178.1	70.8	93.1	186.6	215	211.5	223.1	224.3	233.5	217.1	198.9	<b>2138</b>
<b>1986</b>	126.5	100.6	69.4	73.3	85.1	132.8	210.7	205.8	213.1	131.1	112.9	77.8	<b>1539</b>
<b>1987</b>	86.1	103.8	112.5	125.3	187.4	211.9	207.4	217.3	221.8	213	163.6	92.4	<b>1942</b>
<b>1988</b>	120	180.3	181.3	186.8	183.1	196.5	191.3	207.4	215.7	227.4	226.8	218.5	<b>2335</b>
<b>1989</b>	219.7	188.2	124.9	125.6	83.9	125.1	162.7	137.3	97	107.3	97.1	67.8	<b>1537</b>
<b>1990</b>	86.1	114.2	153.1	112	157.7	221.5	221.5	228.6	222.6	193.6	184.8	124.7	<b>2020</b>
<b>1991</b>	131.8	114	70.9	86.8	165.7	220.3	209.5	167.9	168.5	151.6	137.9	89.7	<b>1715</b>
<b>1992</b>	94.3	111.2	121.4	152.7	182.1	216	206.9	213.4	221.6	232.4	192.5	165.2	<b>2110</b>
<b>1993</b>	155.9	152.6	185.2	197.4	187.3	217.9	205.4	211.1	215.4	230.4	231.1	200.1	<b>2390</b>
<b>1994</b>	216.6	192.8	155	196.7	189	218.2	210.9	226.4	227.1	213	171.3	133.3	<b>2350</b>
<b>1995</b>	184.2	192.9	183.8	196.6	183.5	217.8	209	220.1	223	224.7	183.2	136.4	<b>2355</b>
<b>1996</b>	204.3	156.2	84.7	121.8	120.7	177.6	213.9	228.7	222.6	183.9	136.4	89.7	<b>1940</b>
<b>1997</b>	88	124.5	105.4	137.3	115.7	181.4	215.8	225.3	224.7	218.6	183.2	135.8	<b>1956</b>
<b>1998</b>	175	167.7	141.4	163.3	181.7	187	212.9	209.9	222.6	194.8	152.1	98.5	<b>2107</b>
<b>1999</b>	105.2	121.4	85.5	85.5	81.3	113.5	116.9	75.8	73.7	72.4	68.7	48.1	<b>1048</b>
<b>Min.</b>	<b>86.1</b>	<b>64.9</b>	<b>37.3</b>	<b>51.7</b>	<b>75.4</b>	<b>111.1</b>	<b>116.9</b>	<b>75.8</b>	<b>73.7</b>	<b>72.4</b>	<b>68.7</b>	<b>48.1</b>	
<b>Max.</b>	<b>222.2</b>	<b>192.9</b>	<b>185.2</b>	<b>199.9</b>	<b>189.1</b>	<b>221.5</b>	<b>222.5</b>	<b>232.2</b>	<b>227.2</b>	<b>233.6</b>	<b>231.1</b>	<b>221.8</b>	<b>2060</b>

**Table(D-4) :Optimum outflow(cumecs)from power outlet of Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	822	1026	674	652	624	878	1018	1171	1240	1240	1229	847	<b>952</b>
<b>1961</b>	1191	1102	229	270	474	616	743	651	855	1122	1027	744	<b>752</b>
<b>1962</b>	1159	1015	681	866	794	933	1042	1066	1240	1240	1133	746	<b>993</b>
<b>1963</b>	1083	847	406	880	969	1131	1240	1240	1240	1240	1240	1240	<b>1063</b>
<b>1964</b>	1240	1240	748	800	871	1240	1240	1240	1240	1240	1240	1187	<b>1127</b>
<b>1965</b>	1181	918	653	807	883	1038	1240	1240	1240	1240	1240	1059	<b>1062</b>
<b>1966</b>	1240	1132	593	579	1076	1195	1240	1240	1240	1240	1240	988	<b>1084</b>
<b>1967</b>	1081	979	451	506	657	850	1240	1240	1240	1240	1240	1086	<b>984</b>
<b>1968</b>	1240	1114	834	1095	885	1240	1240	1240	1240	1240	1240	1183	<b>1149</b>
<b>1969</b>	1240	1193	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	<b>1236</b>
<b>1970</b>	1240	1240	813	918	817	1114	1240	1240	1240	1240	1231	826	<b>1097</b>
<b>1971</b>	1070	975	406	270	474	616	1240	1240	1213	1240	1226	809	<b>898</b>
<b>1972</b>	1180	1081	575	454	547	1227	1240	1240	1240	1240	1240	1240	<b>1042</b>
<b>1973</b>	1240	1240	768	845	791	769	897	812	1213	1240	1240	980	<b>1003</b>
<b>1974</b>	1240	1097	447	474	474	1240	1240	1240	1240	1240	1240	1136	<b>1026</b>
<b>1975</b>	1240	1069	426	481	731	1034	1106	1131	1230	1240	1169	789	<b>970</b>
<b>1976</b>	1211	1057	502	692	806	1013	1240	1240	1240	1240	1240	1240	<b>1060</b>
<b>1977</b>	1240	1240	759	796	807	1029	1237	1240	1240	1240	1240	1149	<b>1101</b>
<b>1978</b>	1240	1146	671	929	1072	1240	1240	1240	1240	1240	1240	1240	<b>1145</b>
<b>1979</b>	1240	1240	847	1067	1144	1050	1240	881	1213	1240	1240	984	<b>1115</b>
<b>1980</b>	1240	1198	651	739	854	1174	1240	1240	1240	1240	1240	1240	<b>1108</b>
<b>1981</b>	1240	1240	697	711	841	1240	1240	1240	1240	1240	1240	1240	<b>1117</b>
<b>1982</b>	1240	1240	715	811	924	923	1240	1240	1240	1240	1240	1240	<b>1108</b>
<b>1983</b>	1240	1240	906	859	475	764	1022	1116	1240	1240	1240	1240	<b>1048</b>
<b>1984</b>	1240	995	419	582	553	855	922	784	844	1122	1199	875	<b>866</b>
<b>1985</b>	1240	1240	282	335	1240	1240	1240	1240	1240	1240	1240	1240	<b>1085</b>
<b>1986</b>	1016	889	298	270	474	616	748	676	976	1105	970	667	<b>725</b>
<b>1987</b>	938	1131	509	585	1240	1240	1240	1240	1240	1240	1180	1072	<b>1071</b>
<b>1988</b>	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	<b>1240</b>
<b>1989</b>	1240	1240	767	764	615	724	897	584	621	1034	970	667	<b>843</b>
<b>1990</b>	910	1024	791	615	900	1036	897	1197	1213	1139	1240	824	<b>982</b>
<b>1991</b>	949	936	373	491	916	966	897	452	735	1122	1130	975	<b>828</b>
<b>1992</b>	990	1049	422	648	1240	1240	1240	1240	1240	1240	1240	1140	<b>1077</b>
<b>1993</b>	1183	1205	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	<b>1232</b>
<b>1994</b>	1240	1240	798	1046	1089	1240	1240	1240	1240	1240	1240	1071	<b>1160</b>
<b>1995</b>	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1238	696	<b>1194</b>
<b>1996</b>	1240	1240	458	692	719	641	1240	1111	1240	1240	1154	667	<b>970</b>
<b>1997</b>	1240	1130	462	661	560	711	1240	1240	1240	1240	1240	1044	<b>1001</b>
<b>1998</b>	1240	1240	705	828	989	761	1240	881	1213	1240	1240	918	<b>1041</b>
<b>1999</b>	1183	1033	503	472	474	616	543	350	743	874	797	633	<b>685</b>
<b>Min.</b>	<b>882</b>	<b>847</b>	<b>228</b>	<b>270</b>	<b>273</b>	<b>615</b>	<b>543</b>	<b>350</b>	<b>620</b>	<b>874</b>	<b>796</b>	<b>633</b>	
<b>Max.</b>	<b>1240</b>	<b>1031</b>											

**Table(B-4) :Optimum outflow(cumecs)from power outlet of Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	601	738	722	780	820	1044	1240	1240	1240	1122	970	667	<b>932</b>
<b>1961</b>	614	895	229	433	515	616	1158	1240	1075	909	826	540	<b>754</b>
<b>1962</b>	601	755	922	1112	1164	1240	1240	1240	1240	1122	970	550	<b>1013</b>
<b>1963</b>	601	439	644	1061	1167	1240	1240	1240	1240	1240	1169	967	<b>1020</b>
<b>1964</b>	933	1008	900	908	1176	1240	1240	1240	1240	1135	975	980	<b>1081</b>
<b>1965</b>	852	672	743	914	1077	1240	1240	1240	1240	1122	970	816	<b>1010</b>
<b>1966</b>	1054	887	681	711	1240	1240	1240	1240	1240	1122	970	667	<b>1024</b>
<b>1967</b>	799	724	540	645	790	1057	1240	1240	1240	1122	970	676	<b>920</b>
<b>1968</b>	945	874	1043	1240	1063	1240	1240	1240	1240	1122	970	903	<b>1093</b>
<b>1969</b>	934	953	1240	1240	1240	1240	1240	1240	1240	1240	1240	1158	<b>1183</b>
<b>1970</b>	1151	1077	982	1127	969	1207	1240	1240	1213	1122	970	667	<b>1080</b>
<b>1971</b>	666	734	525	303	474	675	1240	1240	1213	1122	970	667	<b>819</b>
<b>1972</b>	668	837	695	537	700	1240	1240	1240	1240	1217	1033	986	<b>969</b>
<b>1973</b>	1116	1120	882	936	1027	911	1240	1240	1213	1122	970	667	<b>1037</b>
<b>1974</b>	813	855	558	571	521	1240	1240	1240	1240	1122	1051	931	<b>948</b>
<b>1975</b>	1030	818	510	550	951	1126	1240	1240	1213	1122	970	667	<b>953</b>
<b>1976</b>	749	769	605	838	1169	1167	1240	1240	1240	1172	1021	1010	<b>1018</b>
<b>1977</b>	1117	1140	921	963	1064	1240	1240	1240	1240	1122	970	770	<b>1085</b>
<b>1978</b>	1004	906	880	1102	1240	1240	1240	1240	1240	1240	1240	1112	<b>1140</b>
<b>1979</b>	1240	1090	1058	1240	1240	1240	1240	1217	1213	1122	970	691	<b>1130</b>
<b>1980</b>	1009	958	860	912	1052	1240	1240	1240	1240	1240	1124	1057	<b>1097</b>
<b>1981</b>	1208	1102	833	957	1039	1240	1240	1240	1240	1240	1240	1240	<b>1151</b>
<b>1982</b>	1240	1093	897	1011	1122	1160	1240	1240	1240	1240	1240	1240	<b>1163</b>
<b>1983</b>	1240	1195	1035	1001	649	1092	1240	1240	1213	1240	1172	1062	<b>1114</b>
<b>1984</b>	1091	755	591	664	695	1115	1240	1033	1172	1051	936	646	<b>915</b>
<b>1985</b>	601	1169	443	556	1240	1240	1240	1240	1240	1240	1159	1104	<b>1039</b>
<b>1986</b>	687	624	434	434	537	725	1176	1090	1159	775	727	574	<b>745</b>
<b>1987</b>	601	734	718	758	1240	1240	1240	1240	1240	1122	970	667	<b>980</b>
<b>1988</b>	761	1151	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	<b>1192</b>
<b>1989</b>	1240	1205	802	760	529	681	897	786	585	629	621	497	<b>769</b>
<b>1990</b>	601	767	994	674	1022	1240	1240	1240	1213	1055	1240	678	<b>997</b>
<b>1991</b>	717	711	444	517	1077	1240	1169	881	911	903	897	667	<b>844</b>
<b>1992</b>	601	739	778	933	1240	1240	1240	1240	1240	1240	1022	909	<b>1035</b>
<b>1993</b>	854	965	1240	1240	1240	1240	1240	1240	1240	1240	1240	1111	<b>1174</b>
<b>1994</b>	1206	1240	1007	1219	1240	1240	1240	1240	1240	1122	970	794	<b>1146</b>
<b>1995</b>	1017	1240	1240	1240	1240	1240	1240	1240	1240	1187	970	787	<b>1156</b>
<b>1996</b>	1134	989	534	736	772	982	1240	1240	1213	1038	887	667	<b>952</b>
<b>1997</b>	601	792	671	834	739	1004	1240	1240	1240	1153	970	761	<b>937</b>
<b>1998</b>	964	1066	914	1001	1187	1037	1240	1113	1213	1122	970	667	<b>1041</b>
<b>1999</b>	650	759	539	509	512	616	712	461	440	418	433	348	<b>533</b>
<b>Min.</b>	<b>601</b>	<b>438</b>	<b>228</b>	<b>302</b>	<b>473</b>	<b>615</b>	<b>712</b>	<b>461</b>	<b>440</b>	<b>418</b>	<b>432</b>	<b>347</b>	
<b>Max.</b>	<b>1240</b>	<b>1005</b>											

**Table (D-5): Optimum outflow (cumecs) from bottom outlets of Makhool Dam for the water years(1960-1999) as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.	88	0.0	0.0	17
1961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1962	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54	36	0.0	0.0	8
1963	0.0	0.0	0.0	0.0	0.0	0.0	2842	430.	1730	292	393	220.	815
1964	89	8	0.0	0.0	0.0	1131	1640	840.	644	383	91	0.0	40.0
1965	0.0	0.0	0.0	0.0	0.0	0.0	6	10.0	613	231	75	0.0	86
1966	143	0.0	0.0	0.0	0.0	0.0	857	418	113	53	53	0.0	136
1967	0.0	0.0	0.0	0.0	0.0	0.0	489	220.	548	171	123	0.0	295
1968	34	0.0	0.0	0.0	0.0	1154	2260	1713	490.	20.0	30.0	0.0	513
1969	23	0.0	294	1145	665	3580	4959	4426	1332	894	649	149	1510
1970	240.	77	0.0	0.0	0.0	0.0	3	45	93	179	0.0	0.0	53
1971	0.0	0.0	0.0	0.0	0.0	0.0	6	1	0.0	60.0	0.0	0.0	6
1972	0.0	0.0	0.0	0.0	0.0	0.0	147	1986	720	293	291	10.0	296
1973	20.0	120.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45	14	0.0	32
1974	78	0.0	0.0	0.0	0.0	30.0	713	278	872	276	150	0.0	223
1975	119	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	93	0.0	0.0	18
1976	0.0	0.0	0.0	0.0	0.0	0.0	1528	20.0	90.0	218	312	56	423
1977	20.0	140	0.0	0.0	0.0	0.0	0.0	99	359	147	30.0	0.0	82
1978	93	0.0	0.0	0.0	0.0	67	10.0	591	390	592	586	10.0	292
1979	340.	93	0.0	0.0	0.0	0.0	50.0	0.0	0.0	167	70.0	0.0	60.0
1980	98	0.0	0.0	0.0	0.0	0.0	1998	10.0	50.0	458	335	48	373
1981	297	10.0	0.0	0.0	0.0	143	41	326	361	412	60.0	288	215
1982	386	93	0.0	0.0	0.0	0.0	69	1578	390.	490	521	330.	321
1983	355	195	0.0	0.0	0.0	0.0	0.0	0.0	71	545	280	14	122
1984	180.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15
1985	1	20.0	0.0	0.0	159	548	885	786	573	475	291	32	330.
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	50.0	10.0	1637	1721	788	93	0.0	0.0	441
1988	79	151	679	1633	663	3342	5416	4236	1695	1201	10.0	677	1732
1989	626	280	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	998	0.0	83
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.0	0.0	0.0	0.0	449	320.	1231	2117	732	613	266	0.0	477
1993	0.0	0.0	165	112	58	165	20.0	2847	1643	821	60.0	5	70.0
1994	389	30.0	0.0	0.0	0.0	120.	110.	228	210	175	114	0.0	220.
1995	89	362	280.	20.0	60.0	169	1415	1153	686	40.0	0.0	0.0	447
1996	460	110	0.0	0.0	0.0	0.0	311	0.0	63	0.0	0.0	0.0	79
1997	177	0.0	0.0	0.0	0.0	0.0	20.0	488	371	328	119	0.0	141
1998	53	66	0.0	0.0	0.0	0.0	558	0.0	0.0	74	96	0.0	71
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<b>Min.</b>	<b>0.0</b>												
<b>Max.</b>	<b>626</b>	<b>362</b>	<b>679</b>	<b>1633</b>	<b>664</b>	<b>3580</b>	<b>5416</b>	<b>4236</b>	<b>1695</b>	<b>1201</b>	<b>998</b>	<b>677</b>	<b>277</b>

**Table (B-5): Optimum outflow (cumecs) from bottom outlets of Makhool Dam for the water years(1960-1999) as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	0.0	0.0	0.0	0.0	0.0	0.0	20.0	598	22	0.0	0.0	0.0	<b>69</b>
<b>1961</b>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115	0.0	0.0	0.0	0.0	<b>9</b>
<b>1962</b>	0.0	0.0	0.0	0.0	0.0	27	219	368	80.0	0.0	0.0	0.0	<b>57</b>
<b>1963</b>	0.0	0.0	0.0	0.0	0.0	167	3794	4328	1746	136	0.0	0.0	<b>847</b>
<b>1964</b>	0.0	0.0	0.0	0.0	0.0	160.	190.	1348	533	0.0	0.0	0.0	<b>449</b>
<b>1965</b>	0.0	0.0	0.0	0.0	0.0	57	489	778	399	0.0	0.0	0.0	<b>143</b>
<b>1966</b>	0.0	0.0	0.0	0.0	39	198	120.	848	12	0.0	0.0	0.0	<b>192</b>
<b>1967</b>	0.0	0.0	0.0	0.0	0.0	0.0	944	30.0	476	0.0	0.0	0.0	<b>375</b>
<b>1968</b>	0.0	0.0	0.0	28	0.0	1448	2858	20.0	50.0	0.0	0.0	0.0	<b>576</b>
<b>1969</b>	0.0	0.0	50.0	1318	863	4468	5278	4448	1256	482	20.0	0.0	<b>1568</b>
<b>1970</b>	0.0	0.0	0.0	0.0	0.0	0.0	269	339	0.0	0.0	0.0	0.0	<b>50.0</b>
<b>1971</b>	0.0	0.0	0.0	0.0	0.0	0.0	929	663	0.0	0.0	0.0	0.0	<b>132</b>
<b>1972</b>	0.0	0.0	0.0	0.0	0.0	276	739	2568	736	0.0	0.0	0.0	<b>359</b>
<b>1973</b>	0.0	0.0	0.0	0.0	0.0	0.0	180.	65	0.0	0.0	0.0	0.0	<b>20.0</b>
<b>1974</b>	0.0	0.0	0.0	0.0	0.0	787	1199	816	689	0.0	0.0	0.0	<b>290.</b>
<b>1975</b>	0.0	0.0	0.0	0.0	0.0	0.0	99	238	0.0	0.0	0.0	0.0	<b>28</b>
<b>1976</b>	0.0	0.0	0.0	0.0	0.0	0.0	2369	2644	848	0.0	0.0	0.0	<b>488</b>
<b>1977</b>	0.0	0.0	0.0	0.0	0.0	65	366	646	174	0.0	0.0	0.0	<b>10.0</b>
<b>1978</b>	0.0	0.0	0.0	0.0	30.0	343	1450	1157	30.0	273	76	0.0	<b>30.0</b>
<b>1979</b>	11	0.0	0.0	0.0	10.0	49	462	0.0	0.0	0.0	0.0	0.0	<b>51</b>
<b>1980</b>	0.0	0.0	0.0	0.0	0.0	210.	2392	1592	411	73	0.0	0.0	<b>389</b>
<b>1981</b>	0.0	0.0	0.0	0.0	0.0	419	414	90.0	312	97	49	51	<b>187</b>
<b>1982</b>	57	0.0	0.0	0.0	0.0	0.0	484	2160	298	93	79	99	<b>272</b>
<b>1983</b>	26	0.0	0.0	0.0	0.0	0.0	240.	458	0.0	23	0.0	0.0	<b>62</b>
<b>1984</b>	0.0	0.0	0.0	0.0	0.0	0.0	24	0.0	0.0	0.0	0.0	0.0	<b>2</b>
<b>1985</b>	0.0	0.0	0.0	0.0	357	824	1375	1255	345	78	0.0	0.0	<b>352</b>
<b>1986</b>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<b>0.0</b>
<b>1987</b>	0.0	0.0	0.0	0.0	248	1277	20.0	2226	684	0.0	0.0	0.0	<b>543</b>
<b>1988</b>	0.0	0.0	888	1800	861	4215	5741	4258	1621	841	554	446	<b>1766</b>
<b>1989</b>	297	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<b>24</b>
<b>1990</b>	0.0	0.0	0.0	0.0	0.0	25	11	488	0.0	0.0	256	0.0	<b>64</b>
<b>1991</b>	0.0	0.0	0.0	0.0	0.0	149	0.0	0.0	0.0	0.0	0.0	0.0	<b>12</b>
<b>1992</b>	0.0	0.0	0.0	0.0	10.0	682	2178	2962	70.0	20.0	0.0	0.0	<b>644</b>
<b>1993</b>	0.0	0.0	374	285	256	4300	2449	3429	1659	438	45	0.0	<b>781</b>
<b>1994</b>	0.0	65	0.0	0.0	47	396	1474	771	22	0.0	0.0	0.0	<b>231</b>
<b>1995</b>	0.0	55	553	376	80.0	445	1788	1735	521	0.0	0.0	0.0	<b>522</b>
<b>1996</b>	0.0	0.0	0.0	0.0	0.0	0.0	10.0	473	0.0	0.0	0.0	0.0	<b>123</b>
<b>1997</b>	0.0	0.0	0.0	0.0	0.0	0.0	723	931	295	0.0	0.0	0.0	<b>162</b>
<b>1998</b>	0.0	0.0	0.0	0.0	0.0	0.0	1149	0.0	0.0	0.0	0.0	0.0	<b>95</b>
<b>1999</b>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<b>0.0</b>
<b>Min.</b>	<b>0.0</b>												
<b>Max.</b>	<b>297</b>	<b>65</b>	<b>888</b>	<b>1800</b>	<b>863</b>	<b>4468</b>	<b>5741</b>	<b>4448</b>	<b>1746</b>	<b>841</b>	<b>554</b>	<b>445</b>	<b>309</b>

**Table(D-2) :Optimum outflow(cumecs)from Makhool Dam for the warer years (1960-1999) as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov</b>	<b>Dec</b>	<b>Jan.</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr.</b>	<b>May</b>	<b>Jun</b>	<b>Jul.</b>	<b>Aug</b>	<b>Sep</b>	<b>Anu</b>
<b>1960</b>	822	1026	674	632	646	878	1018	1185	1328	1288	1240	884	<b>968</b>
<b>1961</b>	1191	1102	229	270	474	616	743	670	825	1122	1037	744	<b>752</b>
<b>1962</b>	1159	1015	681	846	816	933	1042	1080	1272	1240	1176	746	<b>1001</b>
<b>1963</b>	1083	847	406	860	991	1131	4044	5582	2962	1492	1576	1472	<b>1870</b>
<b>1964</b>	1240	1240	936	780	893	2293	2922	2116	1876	1583	1274	1240	<b>1533</b>
<b>1965</b>	1233	918	653	787	905	1038	1240	1349	1845	1431	1258	1166	<b>1152</b>
<b>1966</b>	1240	1240	631	559	1098	1195	2059	1694	1345	1253	1240	1091	<b>1220</b>
<b>1967</b>	1081	979	451	486	679	850	1691	3485	1780	1371	1306	1193	<b>1279</b>
<b>1968</b>	1240	1149	834	1075	907	2316	3542	2989	1722	1403	1486	1240	<b>1659</b>
<b>1969</b>	1240	1240	1314	2448	1971	4864	6241	5702	2564	2094	1832	1401	<b>2743</b>
<b>1970</b>	1374	1240	1085	898	839	1114	1240	1288	1325	1379	1240	865	<b>1157</b>
<b>1971</b>	1070	975	406	270	474	616	1240	1247	1213	1251	1240	843	<b>904</b>
<b>1972</b>	1180	1081	575	434	569	1227	1349	3262	1952	1493	1474	1361	<b>1330</b>
<b>1973</b>	1339	1240	1081	825	813	769	897	831	1213	1240	1240	1022	<b>1042</b>
<b>1974</b>	1240	1178	447	454	474	1489	1995	1554	2104	1476	1333	1240	<b>1249</b>
<b>1975</b>	1240	1195	426	461	753	1034	1106	1145	1213	1288	1216	789	<b>989</b>
<b>1976</b>	1211	1057	502	672	828	1013	2730	3332	2139	1418	1495	1308	<b>1475</b>
<b>1977</b>	1340	1257	1076	776	829	1029	1237	1339	1591	1347	1240	1228	<b>1191</b>
<b>1978</b>	1240	1240	673	909	1094	1240	2348	1867	1622	1792	1769	1355	<b>1429</b>
<b>1979</b>	1474	1240	1134	1047	1166	1050	1252	881	1213	1393	1253	1091	<b>1183</b>
<b>1980</b>	1240	1240	708	719	876	1174	3200	2306	1738	1658	1518	1300	<b>1473</b>
<b>1981</b>	1431	1240	993	691	863	1305	1323	1602	1593	1612	1791	1540	<b>1332</b>
<b>1982</b>	1520	1240	1002	791	946	923	1271	2854	1622	1690	1704	1582	<b>1429</b>
<b>1983</b>	1489	1312	1223	839	497	764	1022	1130	1289	1745	1463	1266	<b>1170</b>
<b>1984</b>	1314	1199	419	562	575	855	922	802	814	1122	1209	875	<b>889</b>
<b>1985</b>	1240	1240	482	315	1285	1832	2167	2062	1805	1675	1474	1284	<b>1405</b>
<b>1986</b>	1108	889	298	270	474	616	748	695	946	1116	970	667	<b>733</b>
<b>1987</b>	938	1131	509	565	1240	2228	2919	2997	2020	1293	1227	1072	<b>1512</b>
<b>1988</b>	1240	1240	1898	2936	1969	4626	6656	5512	2927	2401	2233	1929	<b>2964</b>
<b>1989</b>	1760	1397	1084	744	637	724	897	603	591	1045	970	667	<b>926</b>
<b>1990</b>	910	1024	791	595	922	1036	897	1211	1213	1125	2133	931	<b>1066</b>
<b>1991</b>	949	936	373	471	938	966	897	471	705	1122	1140	975	<b>828</b>
<b>1992</b>	990	1049	422	628	1575	1604	2513	3393	1964	1813	1449	1240	<b>1553</b>
<b>1993</b>	1190	1205	1240	1335	1364	1449	3358	4123	2875	2021	1787	1257	<b>1934</b>
<b>1994</b>	1523	1422	1115	1026	1111	1282	2383	1504	1442	1375	1297	1178	<b>1388</b>
<b>1995</b>	1240	1367	1591	1506	1909	1453	2697	2429	1918	1605	1240	742	<b>1641</b>
<b>1996</b>	1503	1240	762	672	741	641	1513	1162	1281	1240	1162	667	<b>1048</b>
<b>1997</b>	1240	1240	533	641	582	711	1408	1764	1603	1528	1302	1151	<b>1142</b>
<b>1998</b>	1240	1240	822	808	1011	761	1760	881	1213	1301	1279	1025	<b>1112</b>
<b>1999</b>	1183	1033	503	452	474	616	564	369	713	885	797	633	<b>685</b>
<b>Min.</b>	<b>822</b>	<b>847</b>	<b>229</b>	<b>270</b>	<b>474</b>	<b>616</b>	<b>564</b>	<b>369</b>	<b>591</b>	<b>885</b>	<b>797</b>	<b>633</b>	
<b>Max.</b>	<b>1866</b>	<b>1602</b>	<b>1919</b>	<b>2852</b>	<b>1927</b>	<b>4820</b>	<b>6656</b>	<b>5680</b>	<b>2948</b>	<b>2449</b>	<b>2290</b>	<b>1917</b>	<b>1309</b>

**Table (B-2): Optimum outflow (cumecs) from Makhool Dam for the water years (1960-1999) as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	601	738	722	780	820	1044	1430	1855	1256	1122	970	667	<b>1000</b>
<b>1961</b>	618	895	229	433	515	616	1158	1355	1072	911	826	540	<b>764</b>
<b>1962</b>	601	755	922	1112	1164	1240	1468	1625	1314	1122	970	555	<b>1071</b>
<b>1963</b>	601	439	644	1061	1167	1357	5066	5585	2980	1353	1197	967	<b>1868</b>
<b>1964</b>	933	1008	900	908	1176	2799	3180	2605	1767	1140	975	980	<b>1531</b>
<b>1965</b>	852	672	743	914	1077	1247	1761	2035	1633	1122	970	821	<b>1154</b>
<b>1966</b>	1054	887	681	711	1240	1423	2480	2105	1246	1122	970	667	<b>1216</b>
<b>1967</b>	804	724	540	645	790	1057	2165	4345	1710	1122	970	681	<b>1296</b>
<b>1968</b>	945	874	1043	1240	1094	2638	4130	3335	1740	1122	970	908	<b>1670</b>
<b>1969</b>	934	953	1472	2627	2205	5767	6550	5705	2490	1699	1431	1203	<b>2753</b>
<b>1970</b>	1151	1077	982	1127	969	1207	1490	1596	1213	1122	970	667	<b>1131</b>
<b>1971</b>	666	734	525	303	474	675	2150	1920	1213	1122	970	667	<b>952</b>
<b>1972</b>	668	837	695	537	700	1466	2011	3825	1970	1222	1033	986	<b>1329</b>
<b>1973</b>	1116	1120	882	936	1027	911	1401	1322	1213	1122	970	667	<b>1057</b>
<b>1974</b>	813	855	558	571	521	1977	2471	2073	1923	1125	1054	931	<b>1239</b>
<b>1975</b>	1030	818	510	550	951	1126	1320	1495	1213	1122	970	667	<b>981</b>
<b>1976</b>	749	769	605	838	1169	1167	3590	3901	2082	1177	1021	1010	<b>1506</b>
<b>1977</b>	1117	1140	921	963	1064	1255	1638	1903	1408	1122	970	776	<b>1190</b>
<b>1978</b>	1004	906	880	1102	1240	1560	2722	2414	1539	1490	1300	1157	<b>1443</b>
<b>1979</b>	1240	1101	1058	1240	1240	1331	1734	1240	1213	1122	970	686	<b>1181</b>
<b>1980</b>	1009	958	860	912	1052	1400	3664	2849	1645	1290	1152	1057	<b>1487</b>
<b>1981</b>	1208	1102	833	957	1039	1609	1686	2165	1546	1314	1273	1240	<b>1331</b>
<b>1982</b>	1240	1240	904	1011	1122	1160	1705	3417	1532	1310	1303	1276	<b>1435</b>
<b>1983</b>	1240	1240	1121	1001	649	1092	1461	1715	1213	1240	1194	1062	<b>1186</b>
<b>1984</b>	1091	755	591	664	695	1115	1245	1056	1164	1053	936	646	<b>918</b>
<b>1985</b>	601	1169	443	556	1476	2123	2647	2512	1579	1295	1187	1104	<b>1391</b>
<b>1986</b>	687	624	434	434	537	725	1176	1095	1151	777	727	574	<b>745</b>
<b>1987</b>	601	734	718	758	1367	2576	3362	3483	1918	1122	970	667	<b>1523</b>
<b>1988</b>	766	1151	1857	3115	2203	5514	6981	5515	2855	2058	1778	1623	<b>2951</b>
<b>1989</b>	1369	1240	1039	760	529	681	897	795	574	631	621	497	<b>803</b>
<b>1990</b>	601	767	994	674	1022	1240	1258	1745	1213	1055	1452	723	<b>1062</b>
<b>1991</b>	717	711	444	517	1077	1339	1220	881	909	905	897	667	<b>857</b>
<b>1992</b>	601	739	778	933	2136	1981	3450	4219	1934	1418	1050	909	<b>1679</b>
<b>1993</b>	854	965	1343	1594	1598	1740	3721	4686	2893	1655	1269	1156	<b>1956</b>
<b>1994</b>	1206	1240	1070	1219	1240	1628	2746	2028	1256	1122	970	800	<b>1377</b>
<b>1995</b>	1017	1240	1575	1685	2143	1744	3060	2992	1755	1192	970	787	<b>1680</b>
<b>1996</b>	1134	989	534	736	772	982	2227	1730	1213	1038	887	667	<b>1076</b>
<b>1997</b>	601	792	671	834	739	1004	1944	2188	1529	1158	970	761	<b>1099</b>
<b>1998</b>	964	1066	914	1001	1187	1037	2370	1136	1213	1122	970	667	<b>1137</b>
<b>1999</b>	645	759	539	509	512	616	712	470	429	420	433	348	<b>533</b>
<b>Min.</b>	<b>601</b>	<b>439</b>	<b>229</b>	<b>303</b>	<b>734</b>	<b>616</b>	<b>712</b>	<b>470</b>	<b>429</b>	<b>420</b>	<b>433</b>	<b>347</b>	
<b>Max.</b>	<b>1537</b>	<b>1305</b>	<b>2129</b>	<b>3046</b>	<b>2257</b>	<b>5708</b>	<b>6981</b>	<b>5693</b>	<b>2975</b>	<b>2086</b>	<b>1794</b>	<b>1686</b>	<b>1314</b>

**Table(D-7) :Optimum rated head (m) of Makhool Dam for the water years (1960-1999) as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	27.2	28.2	26.7	28.0	29.0	29.6	30.1	30.5	30.8	30.7	30.2	29.9	<b>29.2</b>
<b>1961</b>	29.6	28.1	27.5	26.6	29.2	28.6	26.6	27.5	28.0	27.5	28.9	30.0	<b>28.2</b>
<b>1962</b>	29.7	28.2	26.7	27.6	28.8	29.5	30.0	30.6	30.8	30.8	30.3	30.0	<b>29.4</b>
<b>1963</b>	29.8	28.5	27.1	27.6	28.5	29.3	27.6	27.4	29.4	30.5	29.8	29.2	<b>28.7</b>
<b>1964</b>	29.5	28	26.6	27.7	28.7	28.1	28.4	29.6	30.3	30.4	30.1	29.5	<b>28.9</b>
<b>1965</b>	29.7	28.4	26.7	27.7	28.7	29.4	29.8	30.3	30.3	30.5	30.1	29.6	<b>29.3</b>
<b>1966</b>	29.4	28.1	26.8	28.1	28.4	29.2	29	30.0	30.8	30.7	30.2	29.7	<b>29.2</b>
<b>1967</b>	29.8	28.3	27.1	28.2	29	29.6	29.3	28.6	30.3	30.6	30.1	29.6	<b>29.2</b>
<b>1968</b>	29.6	28.1	26.4	27.4	28.7	28.1	27.9	28.9	30.4	30.6	29.9	29.5	<b>28.8</b>
<b>1969</b>	29.6	28	25.6	26.1	27.6	26.5	26.4	27.3	29.7	29.9	29.6	29.2	<b>28.0</b>
<b>1970</b>	29.3	27.9	26.5	27.6	28.7	29.3	29.8	30.3	30.8	30.6	30.2	29.9	<b>29.3</b>
<b>1971</b>	29.8	28.3	27.1	28.7	29	26.9	29.5	30.4	30.9	29.8	30.2	29.9	<b>29.2</b>
<b>1972</b>	29.7	28.2	26.8	28.3	29.2	29.2	29.6	28.7	30.2	30.5	29.9	29.3	<b>29.1</b>
<b>1973</b>	29.4	27.8	26.5	27.7	28.8	29.7	30.2	30.9	27.6	28.3	30.2	29.7	<b>28.9</b>
<b>1974</b>	29.5	28.1	27.1	28.3	29.3	28.5	29.1	30.1	30.1	30.5	30.1	29.5	<b>29.2</b>
<b>1975</b>	29.5	28.2	27.1	28.2	28.9	29.4	30.0	30.5	30.9	30.7	30.3	30	<b>29.5</b>
<b>1976</b>	29.6	28.2	27.0	27.9	28.8	29.4	28.4	28.7	30.0	30.6	29.9	29.3	<b>29.0</b>
<b>1977</b>	29.4	27.8	26.6	27.7	28.8	29.4	29.8	30.3	30.5	30.6	30.2	29.5	<b>29.2</b>
<b>1978</b>	29.5	28.1	26.7	27.6	28.4	29.1	28.8	29.8	30.5	30.2	29.6	29.3	<b>29.0</b>
<b>1979</b>	29.2	27.9	26.4	27.4	28.3	29.4	29.8	30.8	28.6	29.6	30.1	29.7	<b>28.9</b>
<b>1980</b>	29.5	28	26.7	27.8	28.7	29.2	28.1	29.4	30.4	30.3	29.9	29.4	<b>29.0</b>
<b>1981</b>	29.3	27.9	26.6	27.9	28.7	29	29.8	30.1	30.5	30.4	29.6	29.1	<b>29.1</b>
<b>1982</b>	29.2	27.9	26.6	27.7	28.6	29.5	29.7	29.0	30.5	30.3	29.7	29.1	<b>29.0</b>
<b>1983</b>	29.2	27.8	26.4	27.7	29.3	29.7	30.1	30.5	30.8	30.2	29.9	29.4	<b>29.3</b>
<b>1984</b>	29.4	28.3	27.1	28.1	29.1	29.6	30.2	31.0	28.1	27.5	30.0	29.9	<b>29.0</b>
<b>1985</b>	29.6	27.8	27.4	28.5	28	28.6	29.0	29.6	30.3	30.3	29.9	29.4	<b>29.0</b>
<b>1986</b>	29.9	28.4	27.4	28.7	28.3	26.1	25.6	27.5	27.9	27.6	26.3	27.0	<b>27.6</b>
<b>1987</b>	28.7	28.1	26.9	28.1	28.2	28.2	28.4	28.9	30.1	30.7	30.3	29.6	<b>28.8</b>
<b>1988</b>	29.5	27.8	25.3	25.8	27.6	26.6	26.2	27.4	29.4	29.7	29.2	28.7	<b>27.8</b>
<b>1989</b>	29.0	27.7	26.5	27.8	29.0	29.8	30.2	29	28.4	27.6	26.3	25.0	<b>28.0</b>
<b>1990</b>	26.0	28.2	26.5	28	28.6	29.4	30.2	30.2	30.9	29.2	29.3	29.9	<b>28.9</b>
<b>1991</b>	29.9	28.3	27.2	28.2	28.6	29.5	30.2	29.5	28.2	27.5	29.2	29.7	<b>28.8</b>
<b>1992</b>	29.9	28.2	27.1	28.0	27.8	28.8	28.7	28.6	30.2	30.2	29.9	29.5	<b>28.9</b>
<b>1993</b>	29.7	28	25.8	27.1	28.2	29.0	28.1	28.2	29.5	30.0	29.6	29.4	<b>28.5</b>
<b>1994</b>	29.2	27.7	26.5	27.4	28.4	29.0	28.8	30.1	30.7	30.6	30.1	29.6	<b>29.0</b>
<b>1995</b>	29.5	27.6	25.7	27	27.6	29.0	28.5	29.3	30.2	30.4	30.2	30.1	<b>28.8</b>
<b>1996</b>	29.1	27.9	27.0	27.9	28.9	29.9	29.5	30.5	30.8	30.8	30.3	30.1	<b>29.4</b>
<b>1997</b>	28.4	28.1	27.0	27.9	29.1	29.8	29.6	29.9	30.5	30.4	30.1	29.6	<b>29.2</b>
<b>1998</b>	29.5	27.9	26.6	27.7	28.5	29.7	29.2	30.8	28.9	29.6	30.1	29.8	<b>29.0</b>
<b>1999</b>	29.7	28.2	27.0	28.3	29.3	29.1	27.8	28.1	28.2	27.8	26.6	24.8	<b>27.9</b>
<b>Min.</b>	<b>26.0</b>	<b>27.6</b>	<b>25.3</b>	<b>25.8</b>	<b>27.6</b>	<b>26.1</b>	<b>25.6</b>	<b>27.3</b>	<b>27.6</b>	<b>27.5</b>	<b>26.3</b>	<b>24.8</b>	
<b>Max.</b>	<b>29.9</b>	<b>28.5</b>	<b>27.5</b>	<b>28.7</b>	<b>29.3</b>	<b>29.9</b>	<b>30.2</b>	<b>31.0</b>	<b>30.9</b>	<b>30.8</b>	<b>30.3</b>	<b>30.3</b>	<b>28.8</b>

**Table(B-7) :Optimum rated head(m)of Makhool Dam for the water years (1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
1960	27.5	27.4	26.1	27.3	28.0	29.6	30.0	30.1	30.9	31.0	27.0	24.4	28.0
1961	24.6	27.2	27.0	27.2	28.0	30.2	28.0	30.5	31.0	27.7	25.7	23.7	27.7
1962	24.1	26.5	25.8	26.9	28.0	29.3	30.0	30.3	30.8	31.0	27.7	23.8	27.8
1963	24.1	25.5	26.1	27.0	28.0	29.2	27.4	27.6	29.4	30.7	30.6	30.6	28.0
1964	29.8	27.0	25.8	27.2	28.0	27.9	28.0	29.4	30.4	30.9	30.8	30.6	28.0
1965	29.9	27.5	26.0	27.1	28.0	29.3	29.7	29.9	30.5	31.0	30.2	29.6	29.1
1966	29.6	27.2	26.1	27.4	27.9	29.1	29.1	29.8	30.9	31.0	26.8	25.9	28.0
1967	28.0	27.4	26.3	27.5	28.0	29.6	29.3	28.0	30.4	31.0	28.0	28.0	28.0
1968	29.8	27.2	25.6	26.7	28.0	28	28.0	28.0	30.4	31.0	29.8	30.0	28.0
1969	29.8	27.1	24.9	25.6	27.1	26.2	26.7	27.5	29.7	30.3	30.3	30.4	28.0
1970	29.5	26.9	25.7	26.9	28.0	29.4	29.9	30.3	30.9	30.3	28.0	26.4	28.0
1971	26.8	27.4	26.4	28.0	29.0	27.2	29.3	30.0	30.9	30.4	28.0	26.0	28.0
1972	25.9	27.2	26.1	27.7	28.0	29	29.5	28.0	30.2	30.9	30.8	30.6	28.0
1973	29.6	26.9	25.8	27.1	28.0	29.7	30.0	30.6	30.9	28.0	27.2	26.5	28.0
1974	27.1	27.2	26.3	27.6	28.0	28.0	29.1	29.9	30.2	31.0	30.7	30.7	28.0
1975	29.7	27.3	26.4	27.7	28.0	29.5	30.1	30.4	30.9	30.0	27.8	26.0	28.0
1976	26.1	27.3	26.2	27.2	28.0	29.4	28.0	28.0	30.1	30.9	30.8	30.6	28.0
1977	29.6	26.9	25.8	27.1	28.0	29.3	29.8	30.0	30.7	31.0	29.3	28.0	28.0
1978	29.7	27.2	25.8	26.9	27.9	29.0	28.0	29.6	30.6	30.5	30.4	30.4	28.0
1979	29.4	26.9	25.6	26.8	27.8	29.3	29.7	30.7	30.9	30.2	29.5	29.4	28.0
1980	29.7	27.1	25.9	27.1	28.0	29.1	28.0	29.3	30.5	30.7	30.6	30.5	28.0
1981	29.5	26.9	25.9	27.1	28.0	28.0	29.8	29.8	30.6	30.7	30.5	30.2	29.0
1982	29.4	26.9	25.8	27.0	28.0	29.4	29.7	28.0	30.6	30.7	30.4	30.2	28.0
1983	29.4	26.8	25.6	27.0	28.0	29.5	30.0	30.2	30.9	29.9	30.6	30.5	29.1
1984	29.6	27.4	26.3	27.5	28.0	29.5	30.2	30.9	31.0	27.5	25.6	23.5	28.0
1985	24.1	26.2	26.5	27.7	27.5	28.0	29.0	29.5	30.5	30.7	30.6	30.4	28.0
1986	30.1	27.6	26.5	27.9	28.0	30.0	30.3	30.8	31.0	27.9	25.9	23.6	28.0
1987	24.1	24.5	26.1	27.4	27.6	28.0	28.0	28.0	30.2	31.0	27.9	24.1	27.4
1988	26.2	26.8	24.5	25.2	27.1	26.3	26.5	27.6	29.5	30.0	29.9	29.8	27.5
1989	29.1	26.8	25.9	27.4	28.0	30.1	30.6	28.0	28.0	28.0	26.0	23.8	27.8
1990	24.1	25.7	25.7	27.5	28.0	29.3	30.2	30.2	30.9	30.0	25.0	31.0	28.0
1991	30.1	27.4	26.5	27.7	28.0	29.2	30.3	31.0	31.0	27.7	25.6	23.5	28.0
1992	26.1	25.9	26.0	27.1	27.0	28.0	28.0	28.0	30.2	30.6	30.8	30.7	28.0
1993	29.9	27.1	25.0	26.5	27.6	28.0	28.0	28.0	29.4	30.4	30.5	30.4	28.0
1994	29.5	26.7	25.7	26.8	27.9	28.0	28.0	29.9	30.9	31.0	29.0	28.0	28.0
1995	29.7	26.7	24.8	26.4	27.1	28.0	28.0	29.1	30.4	30.9	30.8	29.4	28.0
1996	29.5	27.0	26.4	27.4	28.0	29.6	29.3	30.2	30.9	29.1	25.7	23.5	28.0
1997	24.6	26.9	26.1	27.3	28.0	29.6	29.5	29.8	30.6	30.9	30.8	30.2	28.0
1998	29.7	26.9	25.8	27.0	28.0	29.6	29.1	30.8	30.9	28.0	26.1	25.5	28.0
1999	26.8	27.4	26.3	27.8	28.0	30.2	28.0	27.2	28.0	28.0	26.4	24.1	27.5
<b>Min.</b>	<b>24.1</b>	<b>24.5</b>	<b>24.5</b>	<b>25.2</b>	<b>27.0</b>	<b>26.2</b>	<b>26.5</b>	<b>27.2</b>	<b>28.2</b>	<b>27.5</b>	<b>25.0</b>	<b>23.5</b>	
<b>Max.</b>	<b>30.1</b>	<b>27.6</b>	<b>27.0</b>	<b>28.2</b>	<b>29.0</b>	<b>30.2</b>	<b>30.6</b>	<b>31.1</b>	<b>31.1</b>	<b>31.0</b>	<b>30.8</b>	<b>31.0</b>	<b>28.4</b>

**Table(D-3) :Optimum water level(m.a.s.l.)of Makhool Dam for the water years (1960-1999)as obtained by the simulation model.**

<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	145.8	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.0</b>
<b>1961</b>	148.7	147.1	145.0	144.2	147.3	146.9	145.0	145.9	146.7	146.5	147.7	148.5	<b>146.6</b>
<b>1962</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1963</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1964</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1965</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1966</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1967</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1968</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1969</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1970</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1971</b>	148.7	147.1	145.0	146.3	147.1	145.2	148.6	149.5	150.0	149	149.3	148.5	<b>147.9</b>
<b>1972</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1973</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	146.7	147.5	149.3	148.5	<b>147.7</b>
<b>1974</b>	148.7	147.1	145.0	146.3	147.3	147.9	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1975</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1976</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1977</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1978</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1979</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	147.7	148.9	149.3	148.5	<b>148.0</b>
<b>1980</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1981</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1982</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1983</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1984</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	146.7	146.5	149.1	148.5	<b>147.7</b>
<b>1985</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1986</b>	148.7	147.1	145.0	146.3	146.4	144.4	144.1	145.9	146.7	146.5	145.1	145.4	<b>146.0</b>
<b>1987</b>	147.4	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.1</b>
<b>1988</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1989</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	147.2	146.7	146.5	145.1	143.4	<b>146.7</b>
<b>1990</b>	144.7	147.1	145.0	146.3	147.3	148.2	148.9	149.3	150.0	148.1	149.3	148.5	<b>147.7</b>
<b>1991</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	147.5	146.7	146.5	148.2	148.5	<b>147.4</b>
<b>1992</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1993</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1994</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1995</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1996</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.2</b>
<b>1997</b>	147.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	150.0	149.9	149.3	148.5	<b>148.1</b>
<b>1998</b>	148.7	147.1	145.0	146.3	147.3	148.2	148.9	149.5	148	148.8	149.3	148.5	<b>148.0</b>
<b>1999</b>	148.7	147.1	145.0	146.3	147.3	147.4	145.9	145.9	146.7	146.5	145.1	143.1	<b>146.2</b>
<b>Min.</b>	<b>144.7</b>	<b>147.1</b>	<b>145.0</b>	<b>144.2</b>	<b>146.4</b>	<b>144.4</b>	<b>144.1</b>	<b>145.9</b>	<b>146.7</b>	<b>146.5</b>	<b>145.1</b>	<b>143.1</b>	
<b>Max.</b>	<b>148.7</b>	<b>147.1</b>	<b>145.0</b>	<b>146.3</b>	<b>147.3</b>	<b>148.2</b>	<b>148.9</b>	<b>149.5</b>	<b>150.0</b>	<b>149.9</b>	<b>149.4</b>	<b>148.5</b>	<b>147.9</b>

**Table(B-3) :Optimum water level(m.a.s.l.)of Makhool Dam for the water years (1960-1999)as obtained by the simulation model.**

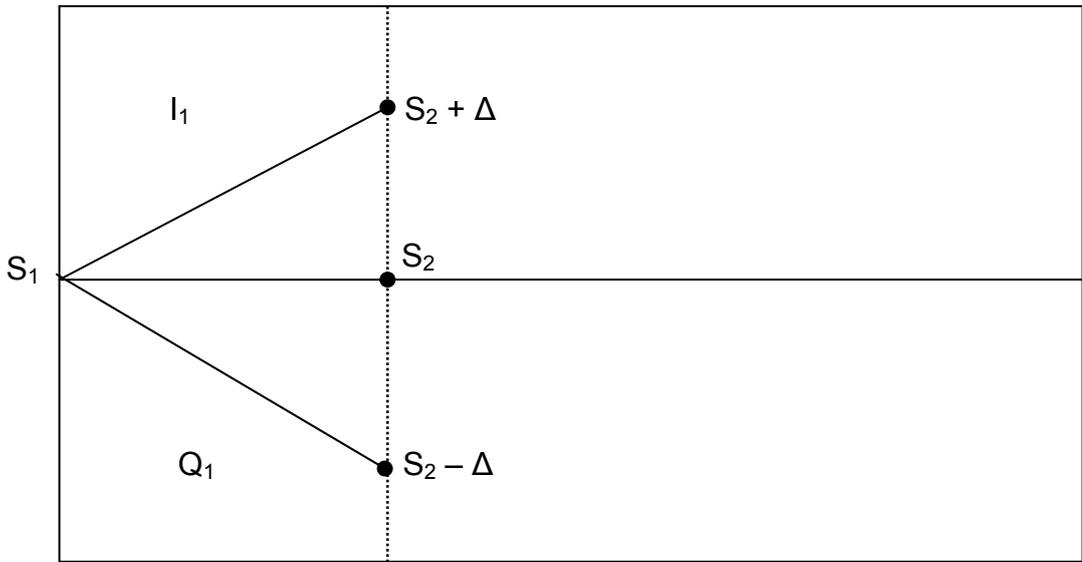
<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	145.7	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	145.8	142.8	<b>147.1</b>
<b>1961</b>	142.9	145.8	144.5	145.2	147.0	148.4	148.0	149.8	150.0	146.4	144.3	141.8	<b>146.2</b>
<b>1962</b>	142.3	144.9	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	146.5	142.0	<b>146.7</b>
<b>1963</b>	142.3	143.5	144.4	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>147.5</b>
<b>1964</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>148.2</b>
<b>1965</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	148.9	148.2	<b>148.0</b>
<b>1966</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	145.6	144.2	<b>147.4</b>
<b>1967</b>	147.1	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	147.7	146.7	<b>147.7</b>
<b>1968</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	148.6	148.7	<b>148.0</b>
<b>1969</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>148.2</b>
<b>1970</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.3	146.9	144.7	<b>147.5</b>
<b>1971</b>	145.1	145.8	144.5	145.9	147.0	145.6	149.3	149.8	150.0	149.4	146.9	144.4	<b>147.0</b>
<b>1972</b>	144.2	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>147.8</b>
<b>1973</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	147.5	146.0	144.9	<b>147.3</b>
<b>1974</b>	145.7	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>147.9</b>
<b>1975</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.0	146.5	144.4	<b>147.4</b>
<b>1976</b>	144.6	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>147.9</b>
<b>1977</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	148.1	147.2	<b>147.9</b>
<b>1978</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>148.2</b>
<b>1979</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.2	148.3	147.8	<b>147.9</b>
<b>1980</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>148.2</b>
<b>1981</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>148.2</b>
<b>1982</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>148.2</b>
<b>1983</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.1	149.6	149.4	<b>148.1</b>
<b>1984</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	146.4	144.3	141.8	<b>146.8</b>
<b>1985</b>	142.3	145.2	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>147.6</b>
<b>1986</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	146.4	144.3	141.8	<b>146.8</b>
<b>1987</b>	142.3	143	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	146.6	142.5	<b>146.6</b>
<b>1988</b>	144.7	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>147.9</b>
<b>1989</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	147.3	146.5	146.4	144.3	141.8	<b>146.3</b>
<b>1990</b>	142.3	144.2	144.5	145.9	147.0	148.4	149.3	149.8	150.0	148.9	144.3	149.4	<b>147.0</b>
<b>1991</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	149.8	146.4	144.3	141.8	<b>146.8</b>
<b>1992</b>	144.3	144.4	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>147.7</b>
<b>1993</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	149.4	<b>148.2</b>
<b>1994</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	147.8	147.1	<b>147.8</b>
<b>1995</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	147.9	<b>148.1</b>
<b>1996</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	148	144.3	141.8	<b>146.9</b>
<b>1997</b>	142.8	145.5	144.5	145.9	147.0	148.4	149.3	149.8	150.0	149.9	149.6	148.7	<b>147.6</b>
<b>1998</b>	148.5	145.8	144.5	145.9	147.0	148.4	149.3	149.8	150.0	147.5	144.9	143.8	<b>147.1</b>
<b>1999</b>	145.2	145.8	144.5	145.9	147.0	148.4	146.4	145.2	146.5	146.4	144.3	141.8	<b>145.6</b>
<b>Min.</b>	<b>142.3</b>	<b>143.0</b>	<b>144.4</b>	<b>145.2</b>	<b>147.0</b>	<b>145.6</b>	<b>146.4</b>	<b>145.2</b>	<b>146.5</b>	<b>146.4</b>	<b>144.3</b>	<b>141.8</b>	
<b>Max.</b>	<b>148.5</b>	<b>145.8</b>	<b>144.5</b>	<b>145.9</b>	<b>147.0</b>	<b>148.4</b>	<b>149.4</b>	<b>149.8</b>	<b>150.0</b>	<b>149.9</b>	<b>149.6</b>	<b>149.4</b>	<b>147.5</b>

**Table(D-6) :Optimum water level (m.a.s.l.) of Tigris River downstream Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

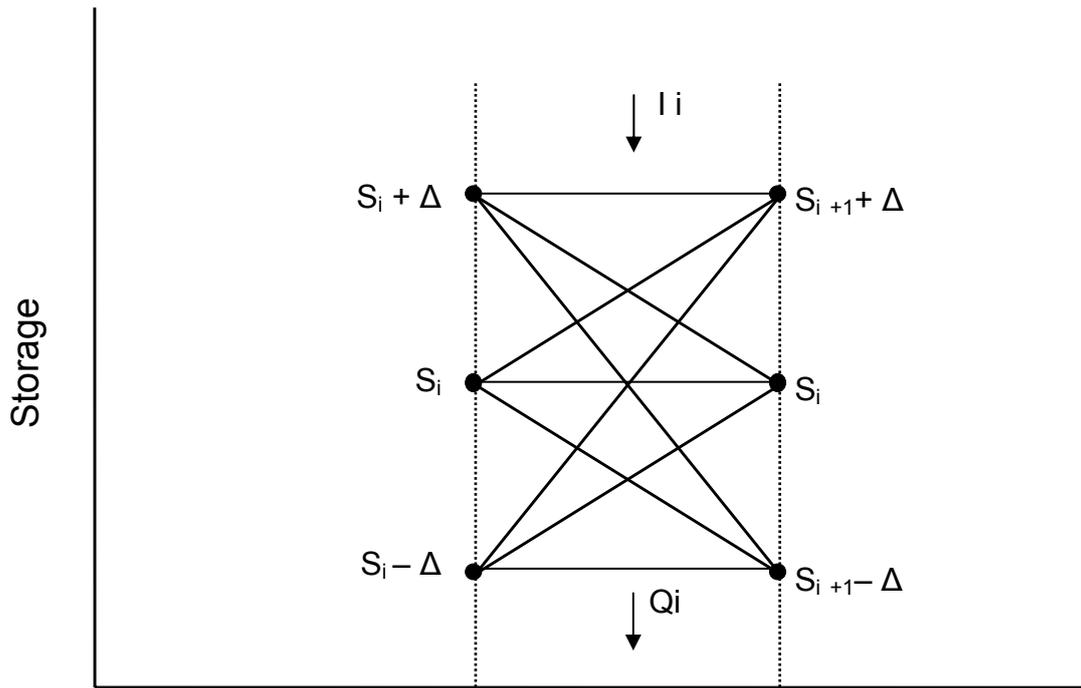
<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
<b>1960</b>	118.0	118.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1961</b>	119.0	118.0	117.5	117.6	118.0	118.0	118.0	118.0	118.0	119.0	118.0	118.0	<b>118.0</b>
<b>1962</b>	119.0	118.0	118.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1963</b>	118.0	118.0	117.9	118.0	118.0	119.0	121.3	122.1	120.6	119.0	119.0	119.0	<b>119.0</b>
<b>1964</b>	119.0	119.0	118.0	118.0	118.0	120.2	120.5	119.0	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1965</b>	119.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1966</b>	119.0	119.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1967</b>	118.0	118.0	118.0	118.0	118.0	118.0	119.0	120.9	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1968</b>	119.0	119.0	118.0	118.0	118.0	120.2	121.0	120.6	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1969</b>	119.0	119.0	119.0	120.2	119.0	121.8	122.5	122.2	120.3	120	119.0	119.0	<b>120.3</b>
<b>1970</b>	119.0	119.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1971</b>	118.0	118.0	117.9	117.6	118.0	118.0	119.0	119.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1972</b>	119.0	118.0	118.0	118.0	118.0	119.0	119.0	120.8	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1973</b>	119.0	119.0	118.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1974</b>	119.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1975</b>	119.0	118.0	117.9	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1976</b>	119.0	118.0	118.0	118.0	118.0	118.0	120.5	120.8	120	119.0	119.0	119.0	<b>119.0</b>
<b>1977</b>	119.0	119.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1978</b>	119.0	119.0	118.0	118.0	118.0	119.0	120.1	119.0	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1979</b>	119.0	119.0	118.0	118.0	119.0	118.0	119.0	118.0	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1980</b>	119.0	119.0	118.0	118.0	118.0	119.0	120.8	120.1	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1981</b>	119.0	119.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1982</b>	119.0	119.0	118.0	118.0	118.0	118.0	119.0	120.5	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1983</b>	119.0	119.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1984</b>	119.0	118.0	117.9	118.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	118.0	<b>118.0</b>
<b>1985</b>	119.0	119.0	117.6	117.8	119.0	119.0	120	119.0	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1986</b>	118.0	118.0	117.7	117.6	118.0	118.0	118.0	118.0	118.0	118.0	118.0	118.0	<b>118.0</b>
<b>1987</b>	118.0	119.0	118.0	118.0	119.0	120.0	120.5	120.6	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1988</b>	119.0	119.0	119.0	120.5	119.0	121.6	122.7	122.1	120.6	120.2	120.1	119.0	<b>120.5</b>
<b>1989</b>	119.0	119.0	118.0	118.0	118.0	118.0	118.0	118.0	118.0	118.0	118.0	118.0	<b>118.0</b>
<b>1990</b>	118.0	118.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	120.0	118.0	<b>118.0</b>
<b>1991</b>	118.0	118.0	117.8	118.0	118.0	118.0	118.0	118.0	118.0	119.0	119.0	118.0	<b>118.0</b>
<b>1992</b>	118.0	118.0	117.9	118.0	119.0	119.0	120.2	120.9	119.0	119.0	119.0	119.0	<b>119.0</b>
<b>1993</b>	119.0	119.0	119.0	119.0	119.0	119.0	120.8	121.3	120.5	119.0	119.0	119.0	<b>119.0</b>
<b>1994</b>	119.0	119.0	118.0	118.0	118.0	119.0	120.1	119.0	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1995</b>	119.0	119.0	119.0	119.0	119.0	119.0	120.4	120.2	119.0	119.0	119.0	118.0	<b>119.0</b>
<b>1996</b>	119.0	119.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1997</b>	119.0	119.0	118.0	118.0	118.0	118.0	119.0	119.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1998</b>	119.0	119.0	118.0	118.0	118.0	118.0	119.0	118.0	119.0	119.0	119.0	118.0	<b>118.0</b>
<b>1999</b>	119.0	118.0	118.0	118.0	118.0	118.0	118.0	117.8	118.0	118.0	118.0	118.0	<b>118.0</b>
<b>Min.</b>	<b>118.6</b>	<b>118.6</b>	<b>117.5</b>	<b>117.6</b>	<b>118.0</b>	<b>118.3</b>	<b>118.2</b>	<b>117.8</b>	<b>118.3</b>	<b>118.7</b>	<b>118.5</b>	<b>118.3</b>	
<b>Max.</b>	<b>119.7</b>	<b>119.5</b>	<b>119.8</b>	<b>120.5</b>	<b>119.8</b>	<b>121.8</b>	<b>122.7</b>	<b>122.2</b>	<b>120.6</b>	<b>120.2</b>	<b>120.1</b>	<b>119.8</b>	<b>119.0</b>

**Table(B-6) :Optimum water level (m.a.s.l.) of Tigris River downstream Makhool Dam for the water years(1960-1999)as obtained by the simulation model.**

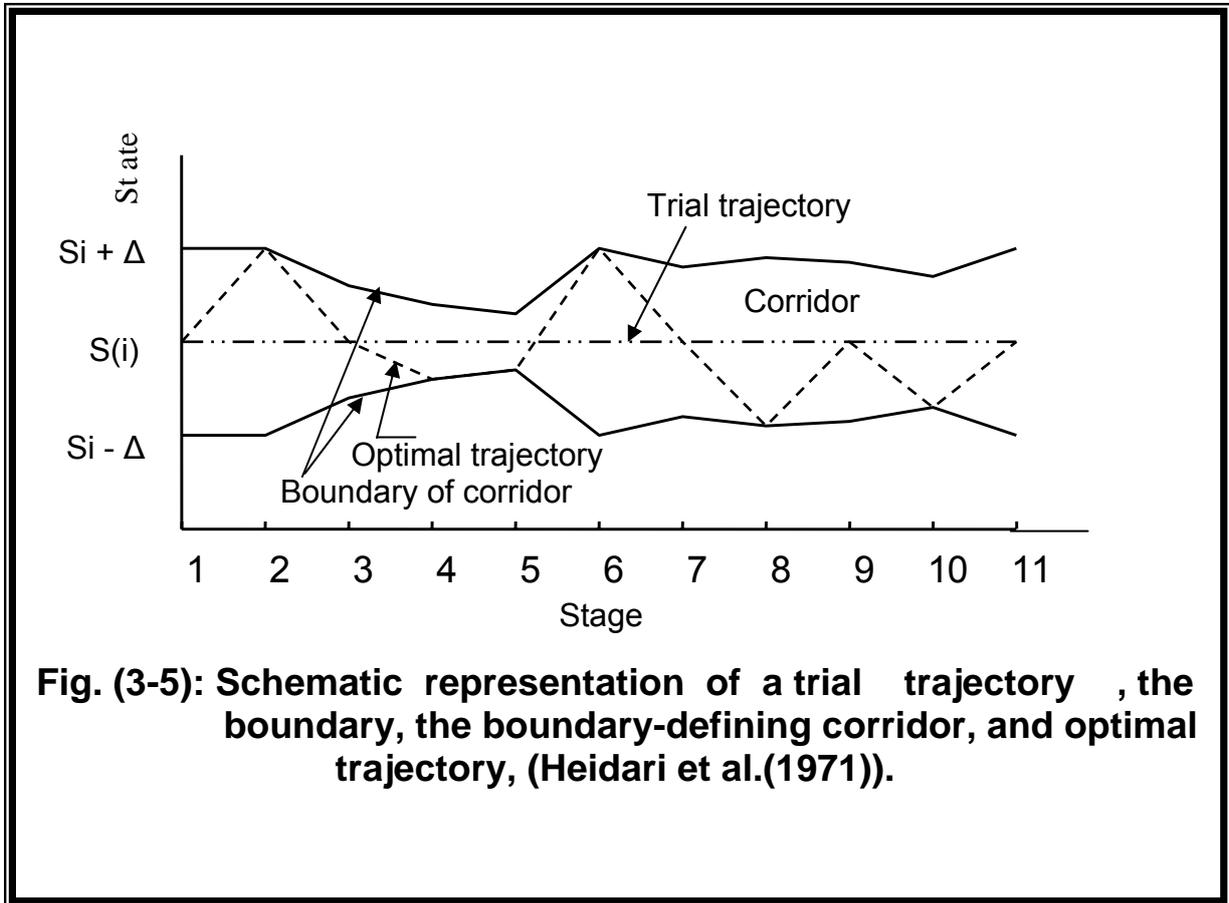
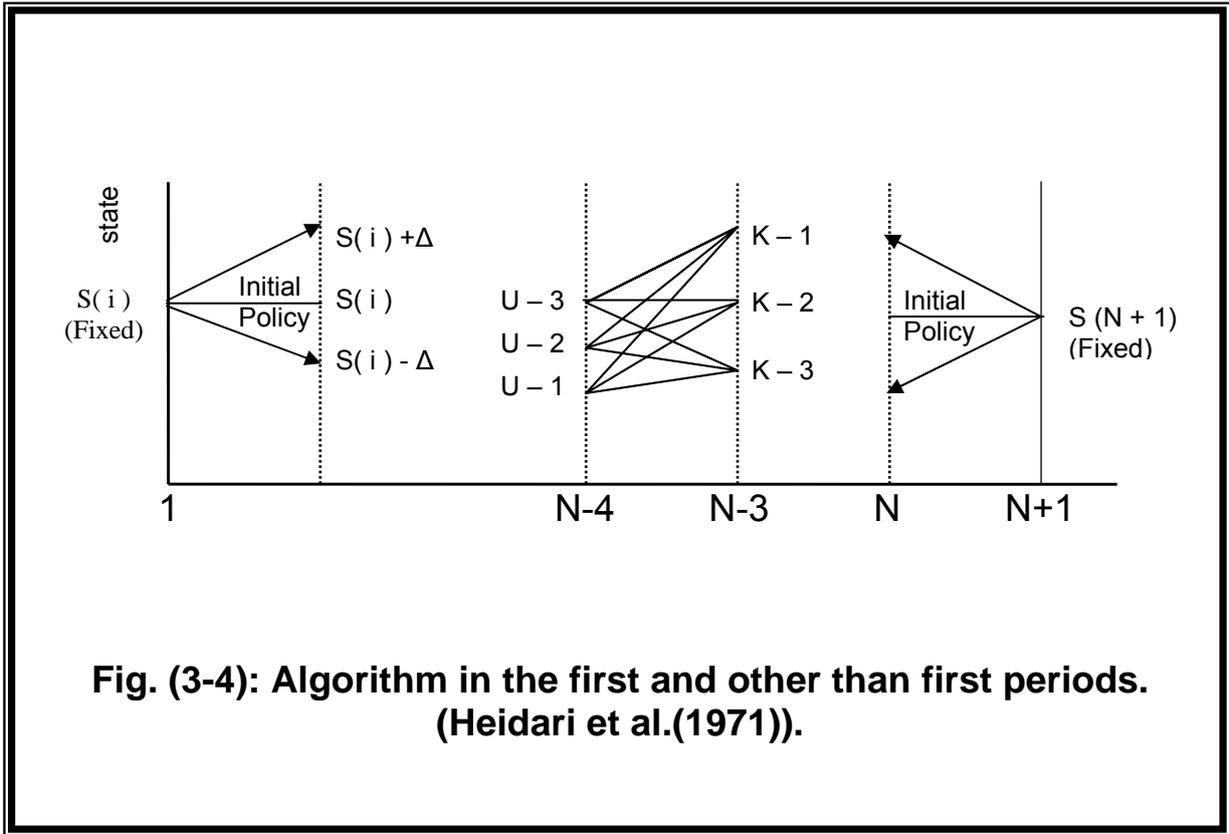
<b>Year</b>	<b>Oct.</b>	<b>Nov.</b>	<b>Dec.</b>	<b>Jan.</b>	<b>Feb.</b>	<b>Mar.</b>	<b>Apr.</b>	<b>May</b>	<b>Jun.</b>	<b>Jul.</b>	<b>Aug.</b>	<b>Sep.</b>	<b>Anu.</b>
1960	118.3	118.5	118.4	118.5	118.6	118.9	119.0	119.0	119.0	119.0	118.8	118.4	118.8
1961	118.3	118.7	117.5	118.0	118.1	118.3	119.0	119.0	118.9	118.7	118.6	118.2	118.4
1962	118.3	118.5	118.7	119.0	119.0	119.0	119.0	119.0	119.0	119.0	118.8	118.2	118.9
1963	118.3	118	118.3	118.9	119.0	119.0	121.9	122.2	120.6	119.0	119.0	118.8	119.0
1964	118.7	118.8	118.7	118.7	119.0	120.5	120.7	120.3	119.0	119.0	118.8	118.8	119.0
1965	118.6	118.4	118.5	118.7	118.9	119.0	119.0	119.0	119.0	119.0	118.8	118.6	119.0
1966	118.9	118.7	118.4	118.4	119.0	119.0	120.2	119.0	119.0	119.0	118.8	118.4	119.0
1967	118.6	118.4	118.2	118.3	118.5	118.9	120	121.5	119.0	119.0	118.8	118.4	119.0
1968	118.7	118.7	118.9	119.0	118.9	120.4	121.3	120.8	119.0	119.0	118.8	118.7	119.0
1969	118.7	118.8	119.0	120.3	119.0	122.2	122.6	122.2	120.3	119.0	119.0	119.0	120.2
1970	119.0	118.9	118.8	119.0	118.8	119.0	119.0	119.0	119.0	119.0	118.8	118.4	119.0
1971	118.4	118.5	118.1	117.7	118	118.4	120.0	119.0	119.0	119.0	118.8	118.4	118.7
1972	118.4	118.6	118.4	118.1	118.4	119.0	119.0	121.2	119.0	119.0	118.9	118.8	119.0
1973	119.0	119.0	118.7	118.7	118.9	118.7	119.0	119.0	119.0	119.0	118.8	118.4	118.9
1974	118.6	118.6	118.2	118.2	118.1	119.0	120.2	119.0	119.0	119.0	118.9	118.7	119.0
1975	118.9	118.6	118.1	118.2	118.8	119.0	119.0	119.0	119.0	119.0	118.8	118.4	118.8
1976	118.5	118.5	118.3	118.6	119.0	119.0	121.0	121.2	119.0	119.0	118.8	118.8	119.0
1977	119.0	119.0	118.7	118.8	118.9	119.0	119.0	119.0	119.0	119.0	118.8	118.5	119.0
1978	118.8	118.7	118.7	118.9	119.0	119.0	120.4	120.2	119.0	119.0	119.0	119.0	119.0
1979	119.0	118.9	118.9	119.0	119.0	119.0	119.0	119.0	119.0	119.0	118.8	118.4	119.0
1980	118.8	118.8	118.6	118.7	118.9	119.0	121.0	120.5	119.0	119.0	119.0	118.9	119.0
1981	119.0	118.9	118.6	118.8	118.9	119.0	119.0	120.0	119.0	119.0	119.0	119.0	119.0
1982	119.0	118.9	118.7	118.8	119.0	119.0	119.0	120.9	119.0	119.0	119.0	119.0	119.0
1983	119.0	119.0	118.9	118.8	118.3	118.9	119.0	119.0	119.0	119.0	119.0	118.9	119.0
1984	118.9	118.5	118.2	118.4	118.4	119.0	119.0	118.9	119.0	118.9	118.7	118.3	118.7
1985	118.3	119.0	118.0	118.2	119.0	119.0	120.3	120.3	119.0	119.0	119.0	118.9	119.0
1986	118.4	118.3	118.0	118	118.1	118.4	119.0	118.9	119.0	118.5	118.4	118.2	118.4
1987	118.3	118.5	118.4	118.5	119.0	120.3	120.9	120.9	119.0	119.0	118.8	118.4	119.0
1988	118.5	119.0	120.0	120.7	119.0	122.1	122.8	122.1	120.5	119.0	119.0	119.0	120.4
1989	119.0	119.0	118.6	118.5	118.1	118.4	118.7	118.5	118.2	118.3	118.3	118.1	118.5
1990	118.3	118.5	118.8	118.4	118.8	119.0	119.0	119.0	119.0	118.9	119.0	118.4	118.9
1991	118.4	118.4	118.0	118.1	118.9	119.0	119.0	118.7	118.7	118.7	118.7	118.4	118.6
1992	118.3	118.5	118.5	118.7	120.1	119.0	120.9	121.4	119.0	119.0	118.8	118.7	119.0
1993	118.6	118.8	119.0	119.0	119.0	119.0	121.1	121.7	120.6	119.0	119.0	119.0	119.0
1994	119.0	119.0	118.8	119.0	119.0	119.0	120.4	119.0	119.0	119.0	118.8	118.5	119.0
1995	118.8	119.0	119.0	119.0	119.0	119.0	120.6	120.6	119.0	119.0	118.8	118.5	119.0
1996	119.0	118.8	118.1	118.5	118.5	118.8	120.1	119.0	119.0	118.9	118.7	118.4	118.9
1997	118.3	118.5	118.4	118.6	118.5	118.8	119.0	120.0	119.0	119.0	118.8	118.5	118.9
1998	118.8	118.9	118.7	118.8	119.0	118.9	120.2	119.0	119.0	119.0	118.8	118.4	118.9
1999	118.3	118.5	118.2	118.1	118.1	118.3	118.4	118.0	118.0	117.9	118.0	117.8	118.1
<b>Min.</b>	<b>118.3</b>	<b>118.0</b>	<b>117.5</b>	<b>117.7</b>	<b>118.0</b>	<b>118.3</b>	<b>118.4</b>	<b>118.0</b>	<b>118.0</b>	<b>117.9</b>	<b>118.0</b>	<b>117.8</b>	
<b>Max.</b>	<b>119.4</b>	<b>119.2</b>	<b>120.0</b>	<b>120.7</b>	<b>120.1</b>	<b>122.2</b>	<b>122.8</b>	<b>122.2</b>	<b>120.6</b>	<b>119.9</b>	<b>119.7</b>	<b>119.6</b>	<b>119.0</b>

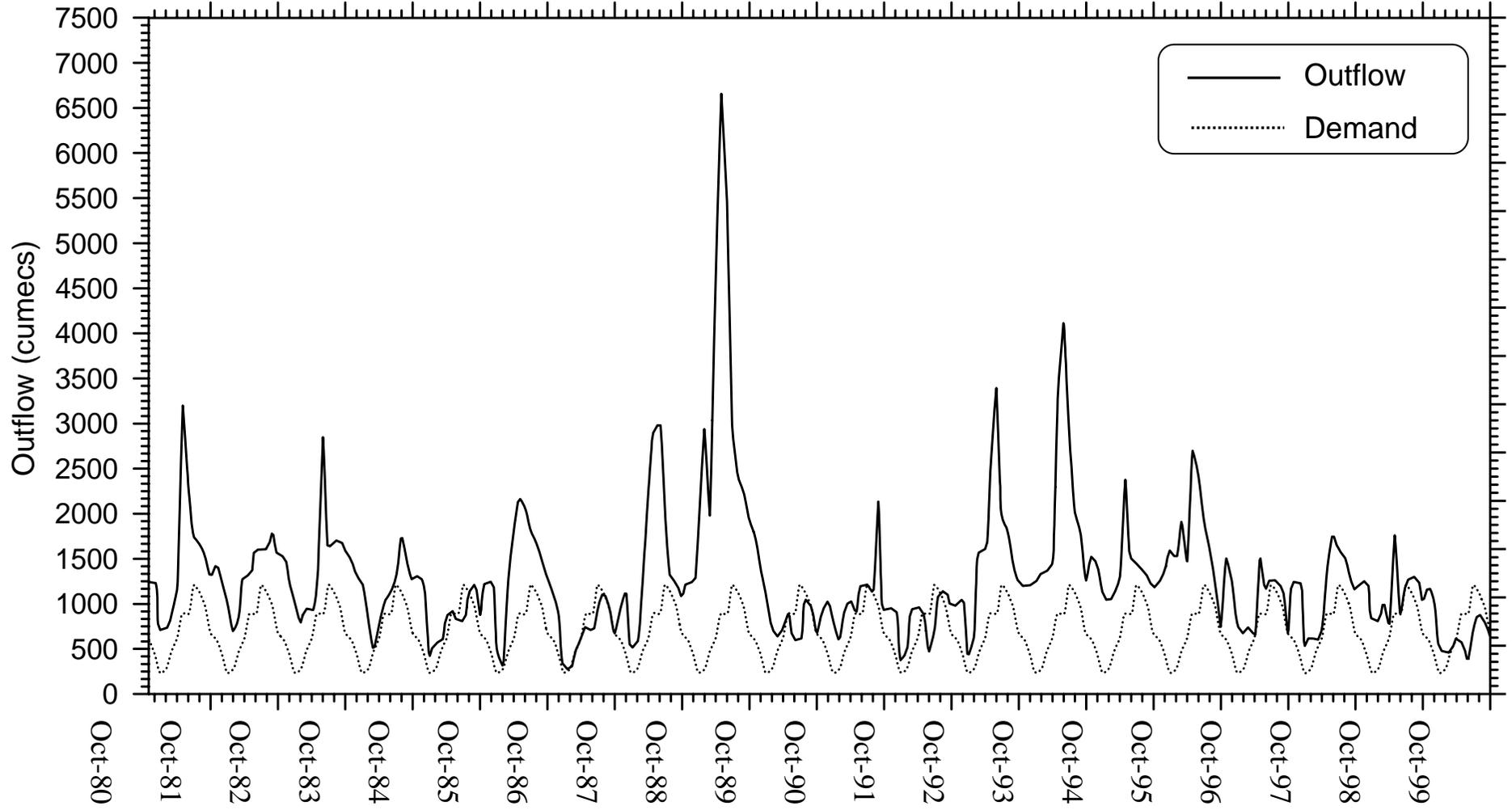


-a-



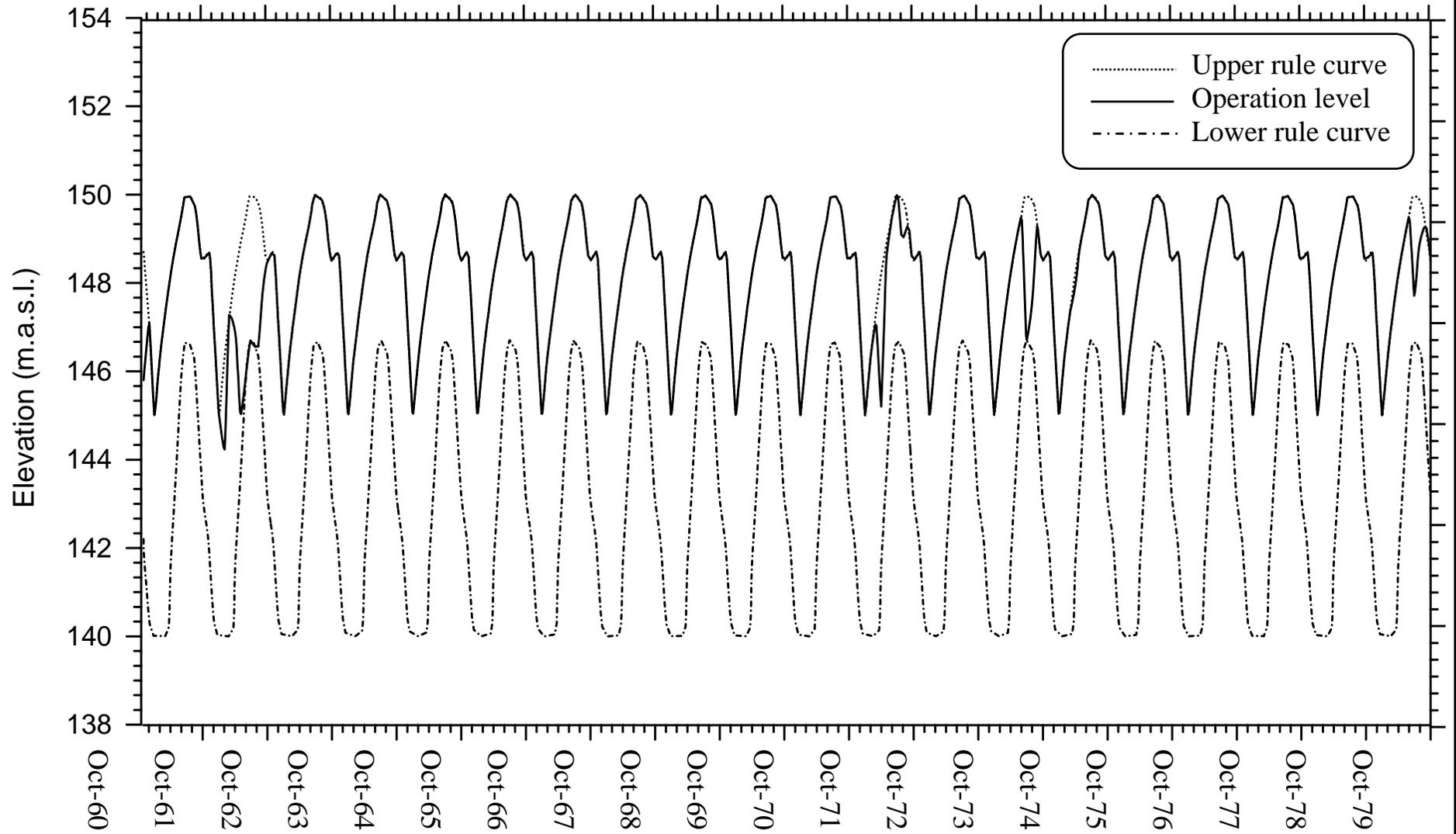
-b-





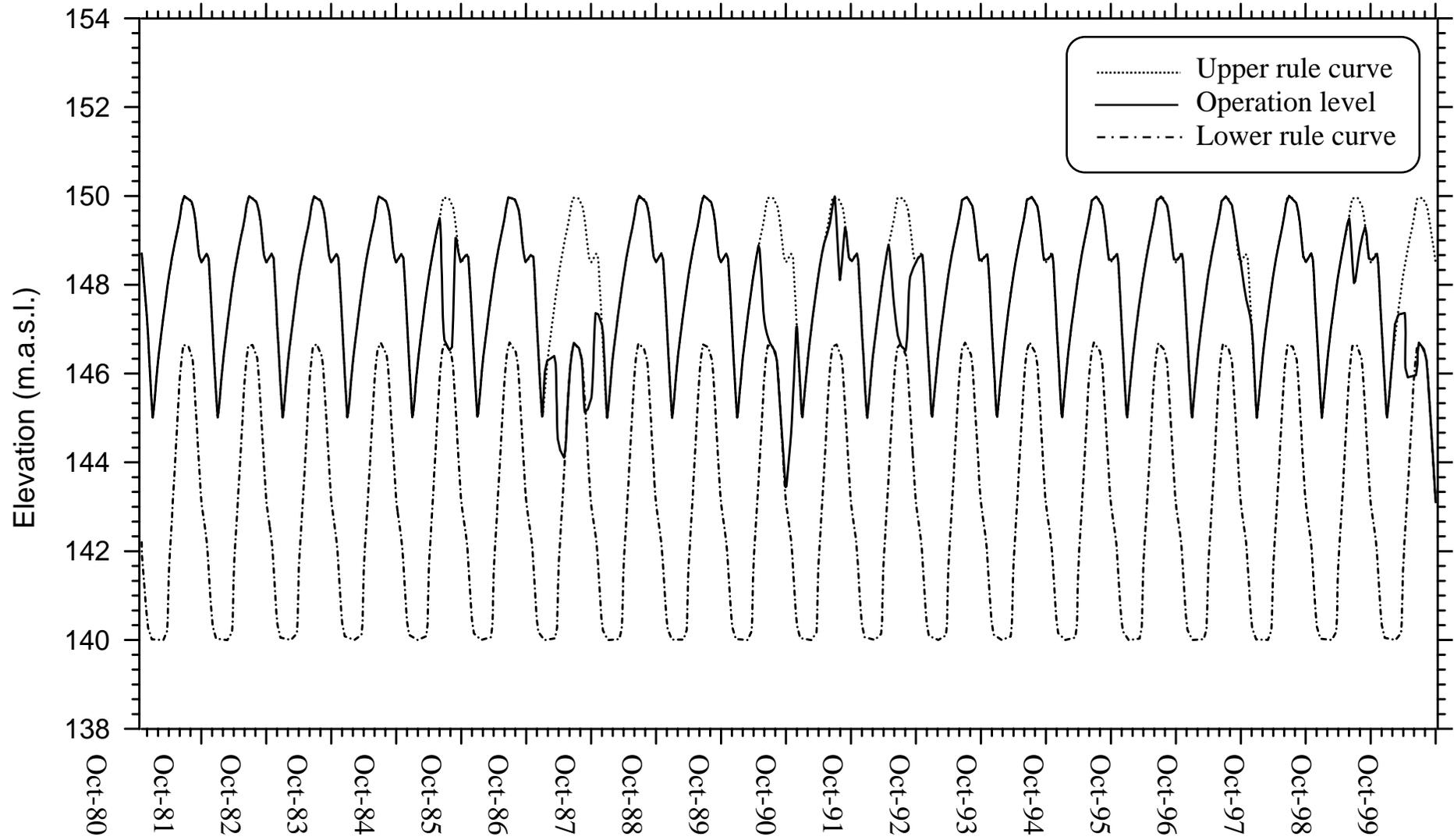
(Cont.) →

Fig. (C-1)



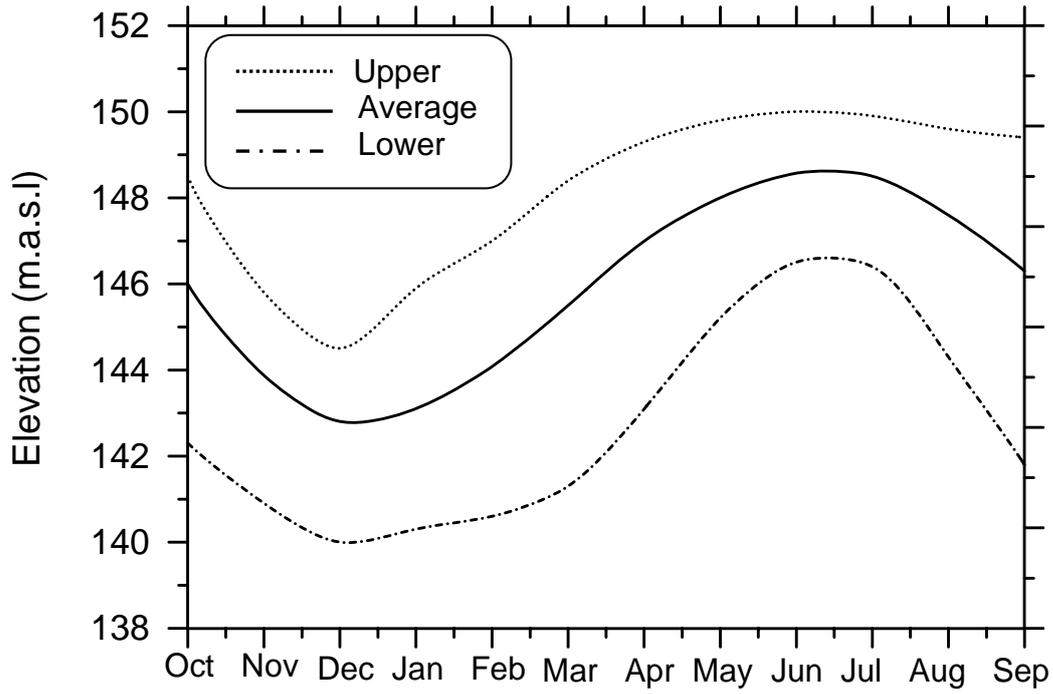
**Fig. (C-2): Water level at Makhool Reservoir resulting from simulated operation when Bekhma Dam is operational (Cont.)**



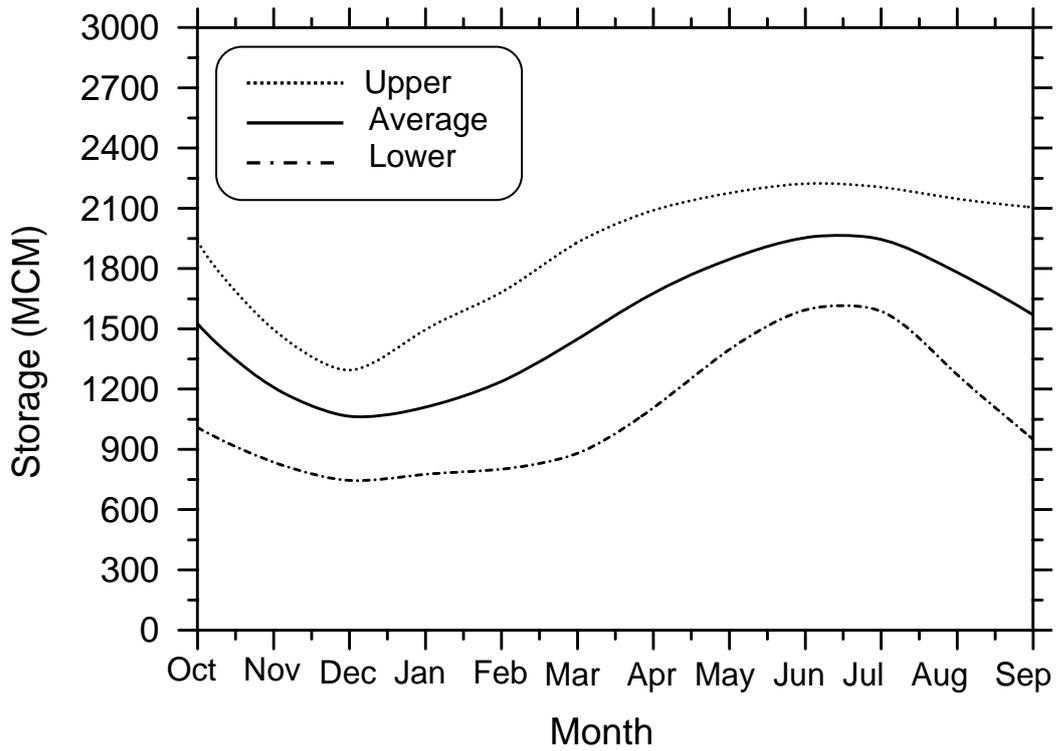


(Cont.)

Fig. (C- 2)



-a-

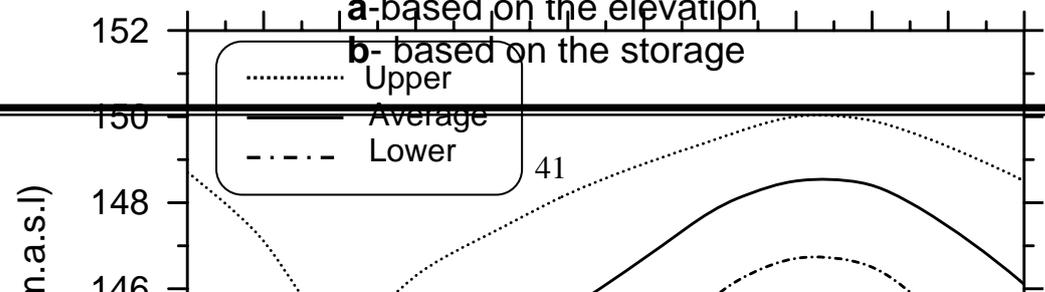


-b-

**Fig. (4-2): Optimum operation rule curves of Makhool Reservoir when Bekhma Dam is not exist:**

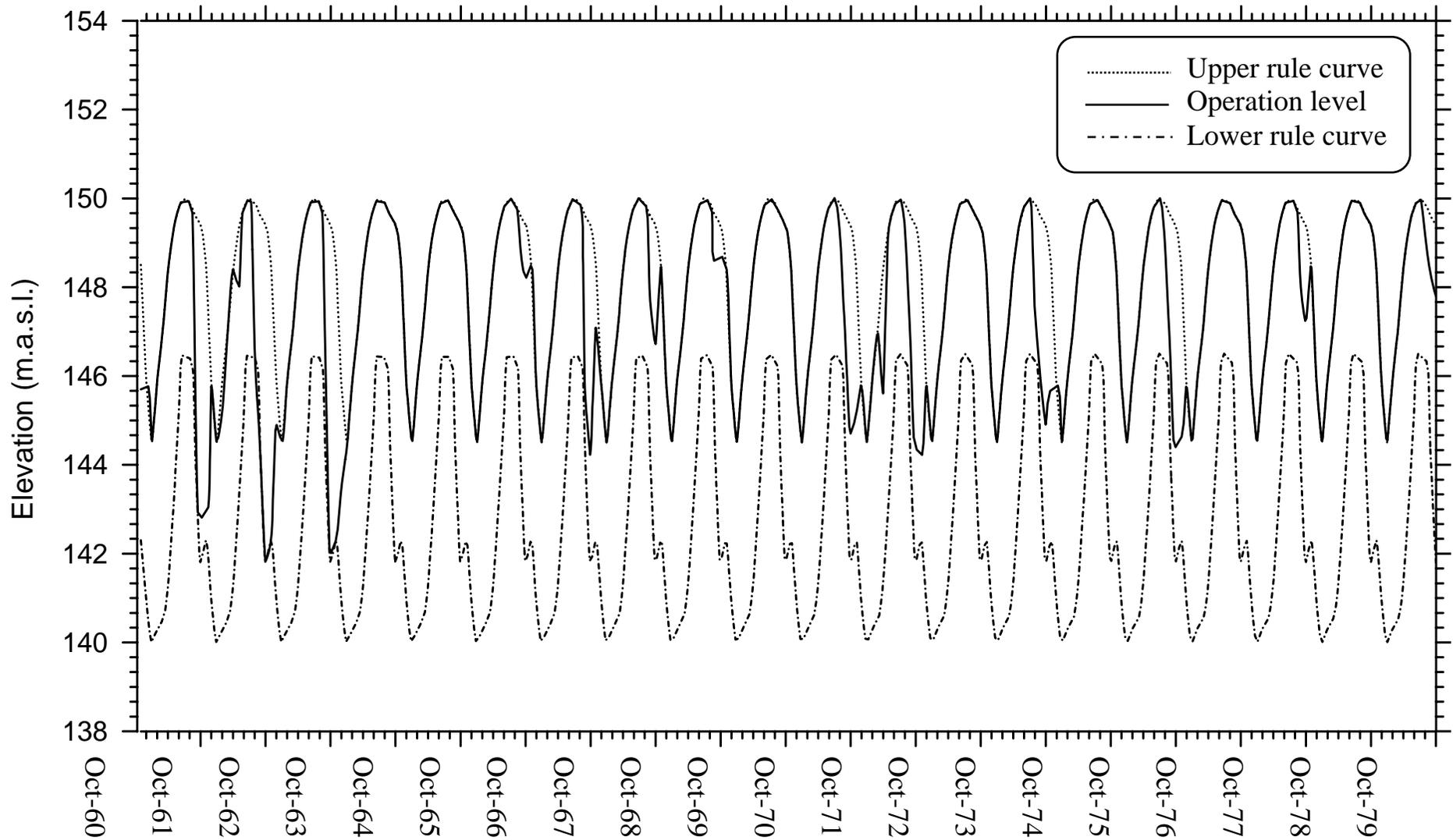
**a-** based on the elevation

**b-** based on the storage



Storage (MCM)

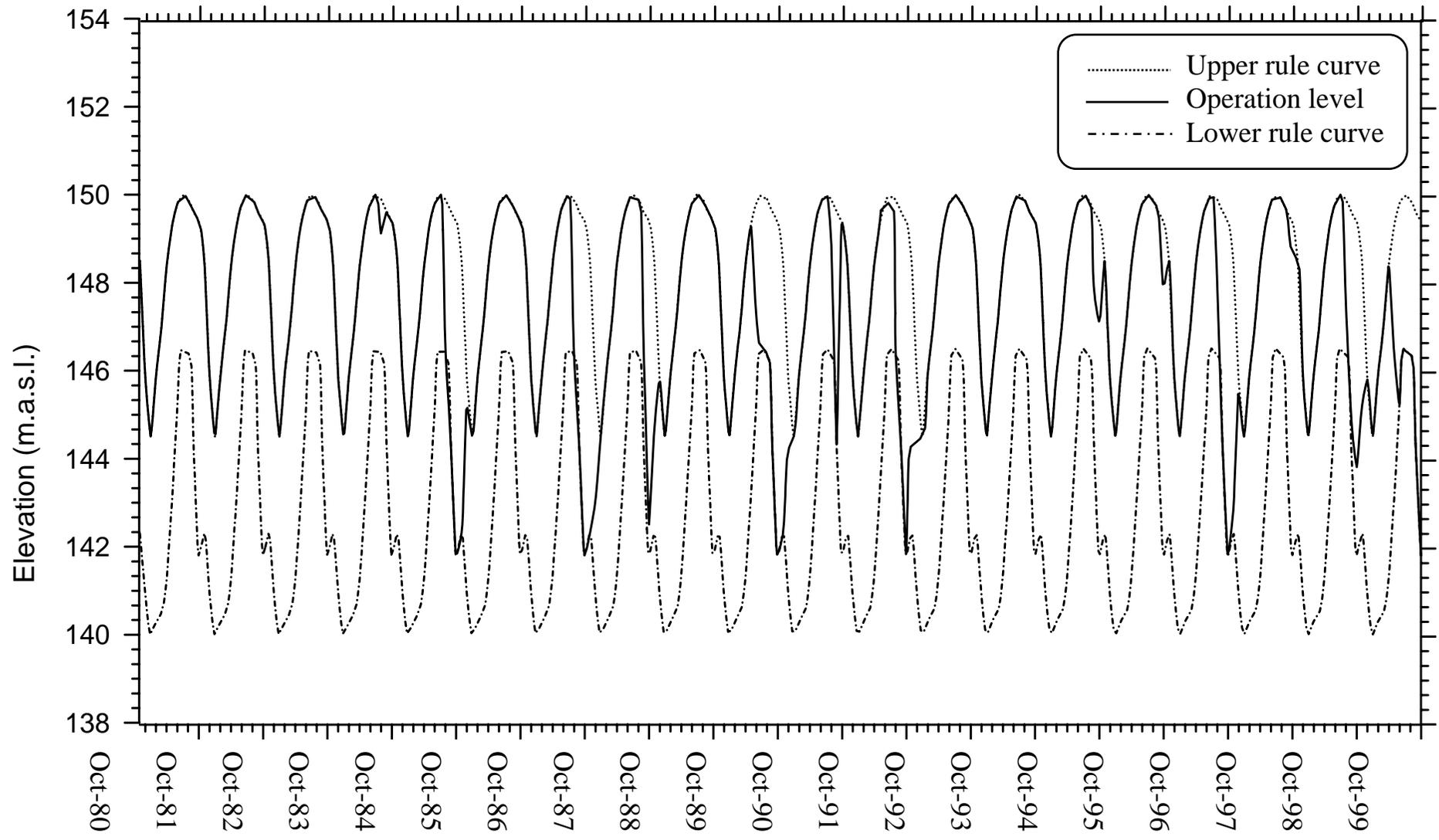
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep



**Fig. (A-3): Water level at Makhool Reservoir resulting from simulated operation**

**When Bekhma Dam is not existing**

**(Cont.)** →



(Cont.) →

Fig. (A-3)

## الخلاصة

استخدمت البرمجة الديناميكية التفاضلية المنفصلة في هذا البحث لإيجاد التشغيل الشهري الأمثل لسد مكحول بعد تهيئة دالة الهدف للوصول إلى اقل الخسائر المتعلقة بالإطلاق والخزين. البيانات الهيدرولوجية التاريخية لمدة (480) شهراً من (تشرين أول (1960) إلى (أيلول (1999)) شكلت بيانات الإدخال لنموذج ألا مثلية.

لغرض المحافظة على الحالة المنطقية للخزين وذلك بتوفير اقل خزين للتشغيل قبيل البدء المتوقع للفيضان المؤشر وتوفير أعلى خزين للتشغيل عند انتهاء موسم الفيضان) فقد ادخل محدد جديد في البرنامج وقد آمن هذا الشرط انسيابية منحنيات التشغيل الحاكمة المثلى المشتقة بموجبة (الأعلى والمعدل والأدنى). وبالاعتماد على منحنيات التشغيل تم إعداد نموذج محاكاة تشغيل المنظومة .

إضافة إلى ذلك فقد اعتبرت بيانات الجريان المرصودة للسنتين المائيتين (1988) و(1999) ممثلة لسنة مائة رطبة وسنة مائة جافة، على التوالي . وبناء على ذلك تم تشغيل نموذج ألا مثلية المطور لهذا البحث في حالتين افتراضيتين لتمثيل حالات قصوى وكانتا سنتين رطبتين متواليين وسنتين جافتين متواليين .

نتائج البحث تشير إلى:-

### أ- نموذج المحاكاة

1. للحالة القائمة حيث لا وجود لسد بخمة، فان التشغيل الأمثل بين عجزاً في تلبية الاحتياجات المائية مؤخر سد مكحول خلال (30) شهراً من فترة التشغيل الكلية المعتمدة في هذا البحث والبالغة (480) شهراً".
2. باعتبار سد بخمة شغالا" فان التشغيل الأمثل بين عجزاً في تلبية الاحتياجات المائية مؤخر سد مكحول لكن العجز لوحظ خلال (21) شهراً من فترة التشغيل الكلية.
3. تمت السيطرة على الفيضان بالكامل خلال فترة التشغيل المعتمدة عند عدم وجود سد بخمة أو عند وجوده واشتغاله.

4. محطة الطاقة الكهربائية تعمل بطاقتها القصوى بمعدل (124) يوماً بالسنة عند عدم وجود سد بخمة و(166) يوماً بالسنة عند تشغيل سد بخمة خلال فترة التشغيل الكلية و البالغة (40) سنة..

#### ب- سينار يوات التشغيل

1. مكن تلبية احتياجات الماء بالكامل في حالة سنتين رطبتين متتابعين عند عدم وجود سد بخمة أو عند تشغيله.
2. عند عدم وجود سد بخمة، فان التشغيل الأمثل يبين عجزاً في تلبية الاحتياجات اسفل سد مكحول لسنتين جافتين متتابعين . لقد لوحظ العجز خلال (6) اشهر في كل سنة من سنوات التشغيل. لقد لوحظ نفس الأمر في حالة اعتبار سد بخمة في حالة اشتغال لكن العجز المائي النسبي (كمأ) كان اقل وبشكل ملموس.
3. تمت السيطرة على الفيضان بالكامل خلال فترة التشغيل للسنتين الرطبتين المتتابعين وللجافتين المتتابعين عند عدم وجود سد بخمة أو عند وجوده واشتغاله.

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