ANALYSIS OF OPTIMISATION OF SINGLE & MULTI RESERVOIR SYSTEM USING LINEAR PROGRAMMING MODEL

A dissertation submitted in partial fulfilment of the requirement for the award of degree of

MASTER OF TEHCNOLOGY

IN

HYDRAULICS AND WATER RESOURCES ENGINEERING

BY

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JULY 2017

CANDIDATES'S DECLARATION

I do hereby certify that the work presented is the report entitled **"ANALYSIS OF OPTIMISATION OF SINGLE & MULTI RESERVOIR SYSTEM USING LINEAR PROGRAMMING MODEL**" in the partial fulfillment of the requirements for the award of the degree of "master of technology" in hydraulics & water resources engineering submitted in the department of civil engineering, Delhi Technological University, is an authentic record of our own work carried out from January 2017 to May 2017 under supervision of Dr.Rakesh Kumar(professor),department of civil engineering.

I have not submitted the matter embodied in the report for the award of other degree or diploma.

Date:30/06/2017 AkashAnand

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Certificate

This is to certify that the work embodied in the dissertation entitled "**analysis of reservoir planning using linear programming mode**" by Akash Anand (2K15/HFE/04) in partial fulfilment for the award of degree of Master of Technology in hydraulics & water resources engineering, is an authentic record of student's own work carried out under my guidance and supervision.

It is also certified that the report has not been submitted to any other institute/university for the award of any degree.This is to certify that above statement made by the candidate is correct to best of my knowledge.

Dr. Rakesh Kumar Arya (Professor)
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ACKNOWLEDGEMENT

I take this opportunity to express my profound gratitude and deep regards to Dr. Rakesh Kumar Arya (Professor, Civil Engineering Department,DTU) for his exemplary guidance, monitoring and constant encouragement throughout the course for this project work. The blessing, help and guidance given by him from time to time shall carry me a long way in life on which I am going to embark.

I would also like to thank Dr. Nirendra Dev (Head of Department, Civil Engineering Department, DTU)for extending his support and Guidance.

Professors and faculties of the department of Civil Engineering, DTU, have always extended their full co-operation and help. They have been kind enough to give their opinions on the project matter; I am deeply obliged to them. They have been a source of encouragement and have continuously been supporting me with their knowledge base, during study. Several of well-wishers extended their help to me directly or indirectly and we grateful to all of them without whom it would have been impossible for me to carry on my work.

ABSTRACT

Now days, computational modeling has gained much importance for the determination of several phenomenon in the field of Hydrology. Artificial intelligence are now being used for prediction of rainfall, runoff etc. This dissertation depicts that how linear programming can be applied for the determination of reservoir capacity.

Reservoir capacity depends on the inflow available and demand where inflow in the river is always greater than the demand, there is no storage required and if the inflow in the river is small but the demand is high, a large reservoir capacity is required. Here, two sets of constraints to be satisfied, one relates to storage continuity and the other to capacity. These two constraints are employed to define the linear equations and to develop the model. To get accurate results evaporation loss is also accounted for constructing the model. After the development of the model, it is analyzed using LINGO software in which values of the reservoir are provided and the reservoir capacity is determined.

We have discussed about the storage yield relationships to provide the engineer engaged in planning and design of reservoir projects.It is useful for single-purpose and multipurpose reservoir.

Multi reservoir operating policies are defined by either individual reservoir target storage volumes or desired releases depends on time of year and existing total storage volume in all the reservoirs.Multireservoir system serves the purpose of water supply, flood control and hydropower generation.

There are also other methods available to solve the linear, nonlinear variables like genetic algorithm, discrete dynamic differential programming. And they may be comparable with the lingo software with a small difference in the value of global objective function.

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LIST OF SYMBOLS

Symbol	Title
R_t	pre-specified (known) release.
Q_t	known inflow.
L_t	estimated storage loss.
S_t	storage at beginning of period t.
K_a	active storage capacity.
K_d	dead storage.
A_0	surface area at dead storage.
A	area per unit active storage above ao
$E_t a_o$	lt i.e. fixed evaporation loss
Et	evaporation rate in period t.
α_1, α_2	Fraction of release that joins the downstream reservoir from reservoir Tilaiya Dam and Konar Dam
$\mathbf{B_1^*}$	Benefit Obtained From Irrigation in Mm^3
$\mathbf{B_2^*}$	Benefit Obtained From Flood control in Mm^3
$\mathbf{B_3^*}$	Benefit Obtained From Hydropower in Mw

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CHAPTER 1

INTRODUCTION

1.1. INTRODUCTION TO RESERVOIR

A reservoir is a natural or manmade lake, storage pond, or impoundment from a dam which is used to store the water. Reservoirs may be established in river valleys by the dam construction or may be constructing by excavation in the field or by conventional construction methodology & techniques like as brickwork or cast concrete. Reservoir may be also called for those water having bodies formed by modification of human activity for specific purpose .Reservoirs are also said, in order to give a reliable an full controllable resource.

Reservoirs are generally searched in areas of water lack or excess, or may where there are agricultural or technological concepts to keep a controlled water provision. Where water is mitigate, for example, reservoirs are mainly work to keep available water for use during those periods in which it is most useful & needed for irrigation or drinking water supply purposes. When water in excess may be the problem, then a reservoir can be specified for flood- control to prevent entire downstream areas from being flooded during periods of rainfall or snow-melt from glacier. Particular activeness such as power generation, fish-farming land, paddy-field management or general wet-land development, for example, these are also got by constructing reservoirs. By entailment, they are also water bodies which are potentially act to proper human control, besides of any other impact.

Reservoirs size in range varies from pond-like structure to large lakes structure, but in favor to natural lakes the range of reservoir types and geomorphic change is probably much greater. For example, the most definite, and the most irregular, water bodies are likely to be reservoirs. This unevenness in reservoirs, related to management interference, and it ensures that their water quality and process be deceptive to make any normal statements about them without proper making as to their type & class. Reservoirs do, nonetheless, deal with a number of dimensions with natural lakes and some are even related to river in their nature. Normally, all reservoirs are act to water quality necessity in relation to a assortment of human uses. The fluctuation in design and operation of controlled structures in reservoirs can provide greater flexibleness and potential for human interference than in natural lakes (and, therefore, significant range for management and control) with the aim of getting a desired water quality. However, the nature of the intercession or control can perplex the development and operation of water quality. Yield or discharge is the volume of water in Mmm^3 which can be withdrawn from a reservoir in a fixed time period. Safe yield or discharge is the optimum quantity of water which can be provided from a reservoir in a fixed period of time during a critical dry year. Auxiliary yield is the amount of water which is available during the period of peak flow in the rivers when the yield or discharge is more than the safe yield or discharge. Mean yield is the arithmetic average of the firm yield and the auxiliary yield over a long period of time. Design yield is the yield followed in the design of a reservoir. The design or safe yield is usually fixed after pointing the necessity of the water needs and the amount of hazard involved. Reservoir capacity depends on the inflow discharge available and demand or outflow where inflow value in the river for full time period is always greater than the demand, there is no storage needed.

1.2.1Single Pool Operation

The main aim of a reservoir is to restraint a resolute amount of water during some period of time. The quantities that are restrained depend on the properties of the reservoir system, which include components of the reservoir such as the dam, outlet, facility of inflow, and spillway. Figure 1 denotes a simple example of a basic reservoir system. Inflow to a reservoir is unrestrained if the reservoir is on the river. Some dams are built where stream is off and water is delivered to the reservoir in a restrained manner. Usually, the controls on inflows to the reservoir are a valued function of the level of water in the reservoir.

As the reservoir starts to achieve an upper limit, the flow into the reservoir is turned as an off if the inflows are able to be restrained. For reservoirs that are settled on a stream, the inflows cannot be restrained so the reservoir must operate a control of flood system that usually comply an outlet works and an unrestrained spillway. When the works of the outlet are not able to discharge proper water to down the reservoir level, then the water level will rise continuously above the spillway.

Many times the system of reservoir operations requires to be simulated in a computer or mathematical model. In general, a model of the reservoir must cover the major parts of the system of reservoir in order to measure the reservoir system operations. The fundamental facet of reservoir modeling is the water routing. This is done in various methods & ways, depending on the situation arises and requirements of modeling. All methods of routing are based on the volume continuity.

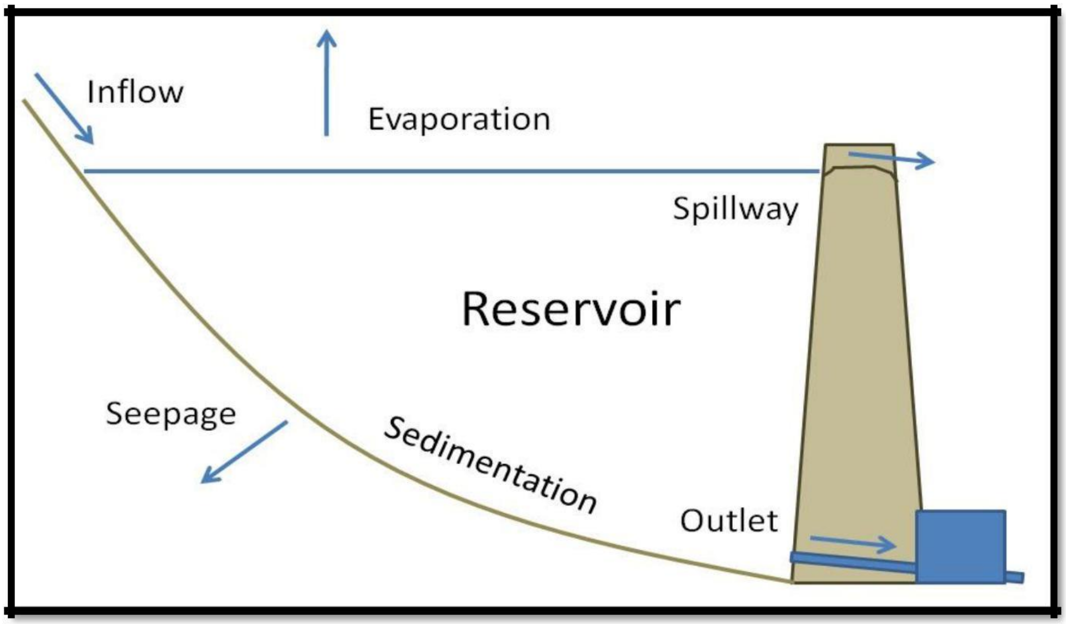


Fig1:Simple Reservoir Diagram

1.2.2. Multiple Pool Operation

In general, reservoirs are run based on policies that regard multiple pools that are stated to be used for distinct purposes for analysis. An example of multiple pool of reservoir is denoted in Figure 2, where the reservoir is divided into surcharge, conservation, control of flood, and pool of dead zones. Many of the times, the pool of conservation is denoted to as the multiuse zone because water needs to be conserved in this pool for multiple and many times conflicting uses.

The flood control area is to stay empty except during the times next a flood event upstream side of the reservoir. Flood control area many of the times include a surcharge area, which is the unrestrained storage volume above a spillway summit. Normally, it is not in the keen of reservoir operators to water spill over the spillway because it is unrestrained and create a risk to the channel downstream side of the reservoir. The flood area is generally drained in a restrained manner through use of a works of outlet with a gate operated or valve.

The conservative pool is used to store water temporary manner for downstream side of reservoir and uses such as generation of power, navigation, irrigation, recreation, municipal and industry water supply, and inflows for habitat. This pool is only drawn if any request is made on behalf of any one of these uses.

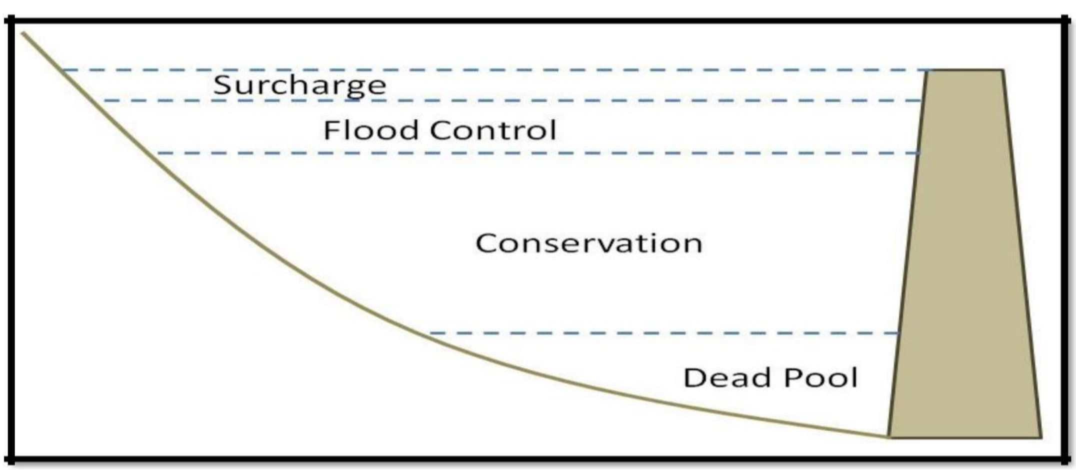


Fig1.1:Reservoir Pool

1.3 BENEFITS

- Local supply of water
- water supply for distant, if water is delivered to cities, villages by aqueducts
- Local boating & fishing source
- Wildlife habitat
- Enhanced water pressure for those residing in the valley
- Power generation
- Irrigation
- Control of flood water

1.4 RESERVOIR SIZING

In many cases, yearly demand may be lesser than the total annual inflow to a specified site. However, the distribution of time of demand or discharge and inflows may not be matched, which in turn give the result in surplus or excess in some time periods and deficit or mitigation in some other time periods. Therefore, there is a need of structure of storage that is, reservoir to collect water in time periods of excess flow & make it available when there is any deficit. In order to active storage regulation to best meet of the specified demands or discharges, the storage capacity of the reservoir should be sufficient. The reservoir sizing problem involves finding of the required reservoir storage capacity when inflows and demands or discharges in a step of time periods are given. Reservoir capacity can be finding using of two methods: Mass curve method and Sequent peak algorithm method. The reservoir sizing problem involves finding of the required reservoir storage capacity when inflows and demands or discharges in a step of time periods are given. there is a need of structure of storage that is, reservoir to collect water in time periods of excess flow & make it available when there is any deficit.

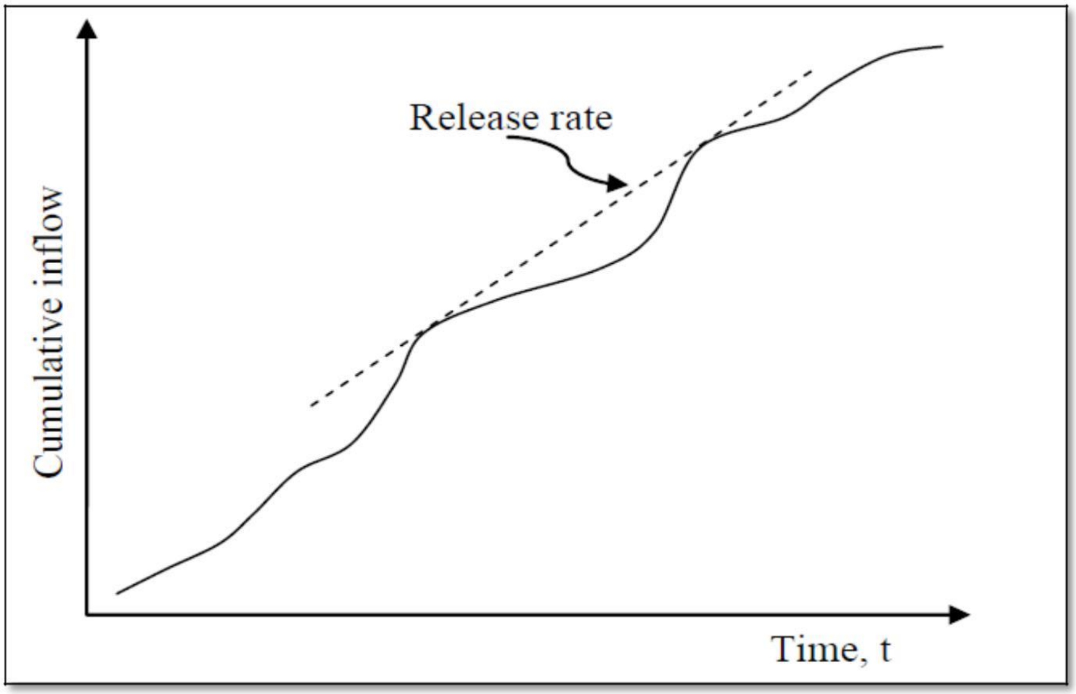


Fig1.2: Typical Mass Curve

1.5 MULTIRESERVOIR OPERATION

Multi reservoir operating policies are defined by either individual reservoir target storage volumes or desired releases depend on time of year and existing total storage volume in all the reservoirs. Multi reservoir system serves the purpose of water supply, flood control and hydropower generation.

There are 5 reservoir here .Reservoir 1 & 2 receives its own inflow through its catchment. Reservoir 3 receives not only the natural flows from the catchment, but also controlled flow that have coming from reservoir 2.Same reservoir 4 receives from natural flow and controlled flow from reservoir 1&3.Finally reservoir 5 receives from natural reservoir and reservoir 4. Multi reservoir operating policies are defined by either individual reservoir target storage volumes or desired releases depend on time of year

Typically you can imagine this to be return flows from the irrigation or you will let some amount of water into the hydro power tail race comes and joins the stream. There is certain amount that is lost or is already used from the releases that you made and only the remaining amount of water comes and joins the stream and therefore joins the downstream.

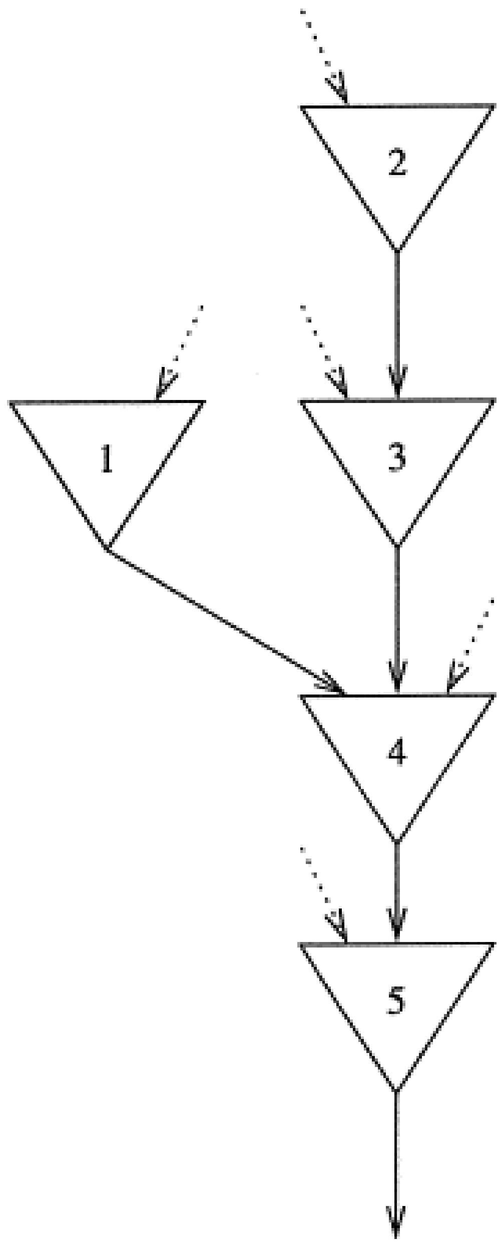


Fig1.3: Example of Multi reservoir System

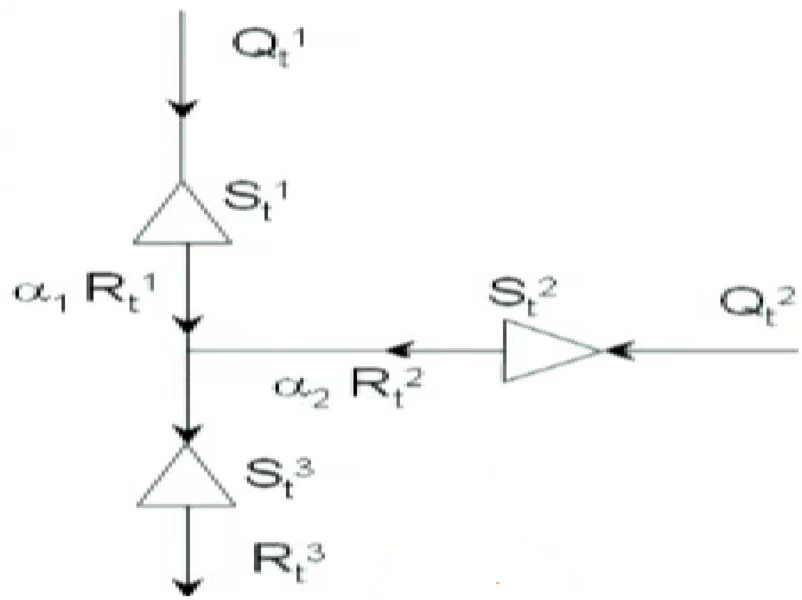


Fig1.4: Schematic view of multi reservoir

Here α_1 is the fraction of control flows that contribute to reservoir 3 from reservoir1 that means $\alpha_1 R^1{}_t$ comes to reservoir 3 in period t

α_2 is the fraction of control flows that contribute to reservoir 3 from reservoir1 that means $\alpha_2 R^2{}_t$ comes to reservoir 3 in period t

When you are deriving reservoir operating policy at reservoir 1, you are also looking at the consequences of this reservoir policy on the reservoir 3; similarly consequences operating policy on the operation of reservoir 3 itself.

1.6 PURPOSE OF MULTIRESERVOIR AND TERMINOLOGY

Each of the reservoir serves the purpose of water supply, flood control, hydropower etc.

Here we have taken these three purposes at each of these reservoirs.

Now we introduce the terminology used in multi reservoir are B_{1t}^i, B_{2t}^i, B_{3t}^i

i refers to the reservoir

t refers to the time period

B_1 refers to unit net benefit (net benefit corresponding to unit release or irrigation)

B_2 refers to unit benefit (net benefit corresponding to unit available flood freeboard)

B_3 refers to unit benefit (net benefit corresponding to unit storage)

Here storage directly determines the hydropower which means that the benefits associated with the hydropower may be in terms of the amount of power that you can generate is directly related to storage itself in reality.

Hydropower also depends on the release through the penstocks because the power generated is proportional to Q into H where Q is the discharge and H is the head; head is determined by the storage and discharge is determined by release policy. And therefore we associate benefits with the storage and these benefits can be typically hydro power generator, at particular reservoir storage in particular time period t.

Now for the flood control we specify a minimum buffer storage to be available in each of the reservoir .During the flood season there must be a free storage space available at reservoir I and that we specify that F_{min} of i, this is the flood free board to be made available at reservoir i during the flood season, then the release that we are making from each of these reservoirs

is limited by canal capacity itself or the river capacity and so on.

So you may put a higher bound on the release that is to be made from the reservoir.

So these are the conditions, one is that you want to meet the hydropower to the best extent possible, you want to maximize that the power is generated, you would like to at the same time maintain the flood free board to absorb the flood waters, and you would also like to make sure that your release are such that they don’t exceed the maximum value.

Net benefit associated need not be just economic minority returns, but it may be in terms of the physical output that you may be get in terms of crop yield, in terms of hydropower that is generated, in terms of that you know, the flood control volume that you could achieve and so on.

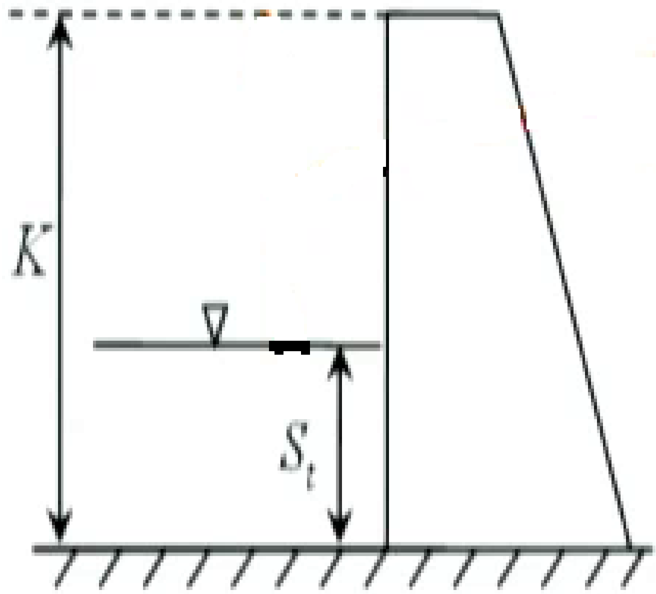


Fig1.5: Reservoir with storage capacity

1.7 CONNECTION OF MULTIRESERVOIR SYSTEM

Connection of these reservoirs can be categorized in two ways

1. Series Connection
2. Parallel Connection

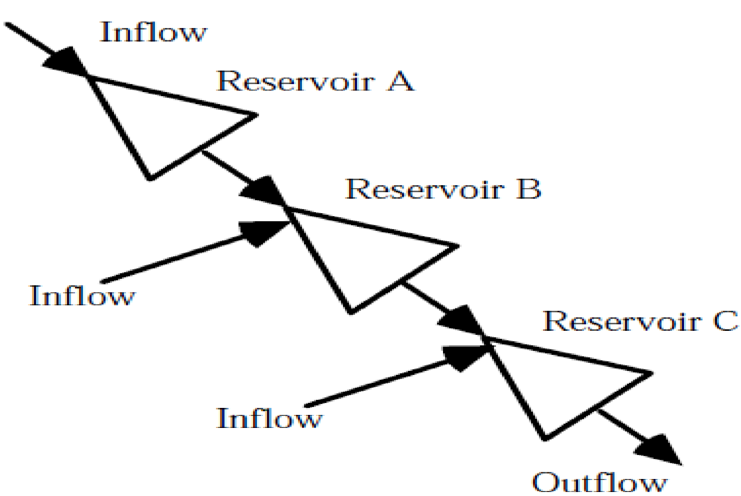


Fig1.6: Reservoirs in series

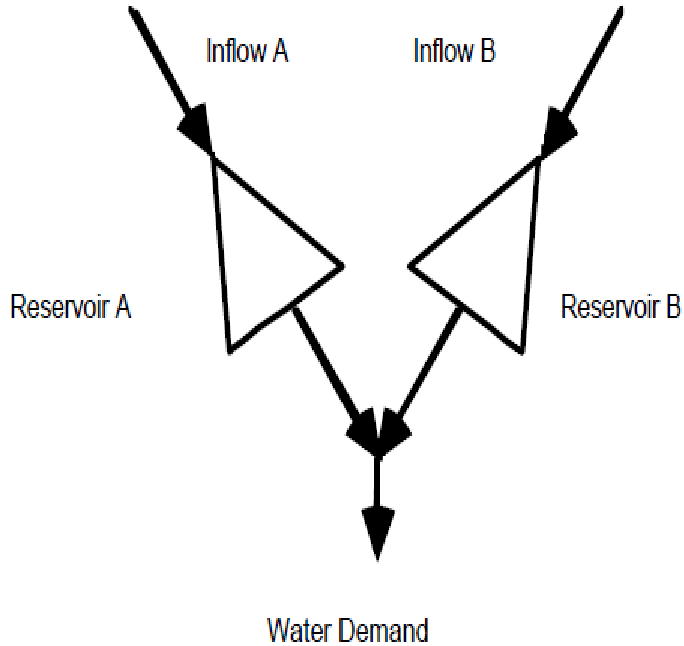


Fig1.7: Reservoirs in parallel

1.8 OPERATING RULES FOR RESERVOIRS

Single purpose operating policies for reservoir in series and in parallel for water supply, flood control, hydropower, water quality and recreation are useful in real time operation and understanding the working of multi reservoir systems.

Practical real time operations are necessary for the specification of reservoir operating rules. These rules determine release and decision storage.

Reservoir in series new policies can be derived for the case of optimal short term operation for hydropower production and energy storage.

Reservoir in parallel, special rules can be derived for water quality, water supply, and hydropower production.

These are derived rules can be supported by conceptual or mathematical deduction from principles of engineering optimization.

The presumption in these rules is that a system of reservoir can be operated produce benefits than operating the individual reservoirs.

1.8.1 RULES FOR RESERVOIR IN SERIES CONNECTION

Table1: Operating Rule for Reservoir in Series

Purpose	Season/Period Refill	Drawdown
Water Supply	Fill upper reservoirs first	Empty lower reservoirs first
Flood Control	Fill upper reservoirs first	Empty lower reservoirs first
Energy Storage	Fill upper reservoirs first	Empty lower reservoirs first
Hydropower Production	Maximize storage in reservoirs with greatest energy production	
Recreation	Equalize marginal recreation improvement of additional storage among reservoirs	

For reservoir in series giving water supply, & objective is to maximize the amount of water available, & same as minimizing water spilled .The rule for single purpose water supply reservoirs in series is to fill up the higher reservoir first and lowest reservoir last.

With intermediate inflows the chances of spill from the reservoir is minimized by filling first the topmost reservoirs and maintaining storage capacity in the lower reservoir.

For reservoir in series with intermediate inflows and storage and providing for flood control, it is optimal for regulate floods by filling top reservoirs first and empty the lower reservoirs first. The main objective is to balance as much control upon flows going into the system above the critical flood possible reach.

Hydropower rules for reservoirs in series changes between refill and drawdown periods. At the time of refill period, generally it is to maximize the storage energy at the end of the period. At the time of drawdown period, the objective is to maximize hydropower discharge for a given total storage quantity.

The main objective of the storage energy rules for reservoirs in series is to optimize the total energy stored at the last of refill periods.

Refill season is stated as the time when system inflows exceed for those needed supply of water or demands of hydropower production. The rule of energy storage for reservoirs in series is to always fill the first upper reservoir.

Water at many times is stored first in small reservoirs, where head generally enhances more per unit volume of extra storage than in most of the large reservoirs. Where the water volume required enhancing head by an amount x in the lower reservoir, V2, is less than that required to get an equivalent enhance in head for the upper of reservoir, V1

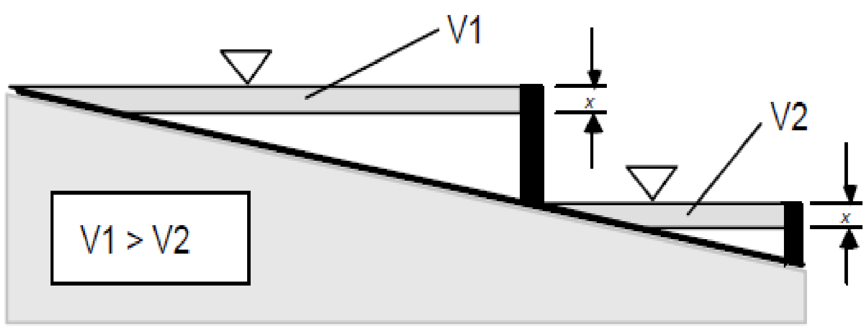


Fig1.8: Change in Head with Varying Capacities

At last reservoirs with higher efficiencies generated should be maintained at high level of the storage. The combination of capacity of the reservoir, total amount of inflows, and generation efficiencies of power determines the potential of the reservoir to produce the water.

The connection of these factors is checked mathematically. The obtained result is to find the following ratio for each of reservoir i at each time-step simulation

$$V_i = a_i e_i \left(\sum_{j=1}^{i} I_j \right)$$

Where,

V_i increased production of power per unit increase in the storage

a_i unit change in head of hydropower per unit change in the storage

e_i the generation efficiency of power of reservoir i

I_j the direct inflows and discharges into reservoir j, for all the reservoir

Here reservoir 1 is the topmost reservoir in the reservoirs series. For this state of steady rule of Hydropower production, reservoirs are maintained in terms of their values of V_I, and are filled from high to low value of V_i till the total amount of the water storage target is got.

For periods of drawdowns, these rules can be applied for production systems of hydropower of reservoirs in parallel & in series, & in mixed systems

1.8.2 RULES FOR RESERVOIR IN PARALLEL CONNECTION

The reservoirs operation in parallel changes from reservoir in the series in such that like downstream reservoirs cannot be used to accept extra water from unacceptable flow.

Table1.1: Operating Rule of Reservoir in Parallel

	Season/Period	
Purpose	**Refill**	**Drawdown**
Water Supply	Equalize probability of seasonal spill among reservoirs	Equalize probability of emptying among reservoirs
Flood Control	Leave more storage space in reservoirs subject to flooding	N.A.
Energy Storage	Equalize expected value (EV) of seasonal energy spill among reservoirs	For last time-step, equalize expected value (EV) of refill season energy spill among reservoirs
Water Quality	Equalize EV of marginal seasonal water quality spill among reservoirs	For last time-step, equalize EV of refill season water quality spill among reservoirs
Hydropower Production	Maximize storage in reservoirs with greatest energy production	
Recreation	Equalize marginal recreation improvement of additional storage among reservoirs	

For purpose of water supply, rule of space consists of by setting the target storages by each of the reservoir in such the way the proportion of the space maintain at the end of recent period to the target value of remain refill season inflow for each of the reservoir is same.

When stopping energy spills, the rule of space an equation used for water supply is renewed by replacement reservoir capacities, storage available and margined inflows with their potential energy.

The taken process for control of flood in reservoirs in parallel is to keep a balance between reservoirs in terms of captured capacities and runoff flood from areas of drainage. When an enhance in releases is possible, it is made from the reservoir with the capacity in greatest form occupied. The plan of the control of balancing rule is to maintain the parallel reservoir to manage the amount of control of flood storage available.

For water supply drawdown reservoirs in parallel, the chances of each of the reservoir and being empty at the season of drawdown. For reservoir systems in parallel with side discharge & demands, focusing on releases from a reason of specific individual reservoir, such of the operation is mean to ignore the possibility of having side discharge & demand when availability of water to meet other discharge or demands.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A mathematical model is a description of a system using mathematical concepts and language. The process of developing a mathematical model is termed mathematical modeling. Mathematical models are used in the natural sciences as well as in the social sciences. Physicists, engineers, statisticians, operations research analysts, and economists use mathematical models most extensively. A model may help to explain a system and to study the effects of different components, and to make predictions about behavior. Mathematical models can take many forms, including dynamical systems, statistical models, differential equations, or game theoretic models. In general, mathematical models may include logical models. In many cases, the quality of a scientific field depends on how well the mathematical models developed on the theoretical side agree with results of repeatable experiments. Lack of agreement between theoretical mathematical models and experimental measurements often leads to important advances as better theories are developed.[1]

Since the 1960s water resources management policy and practice have shifted to a greater reliance on improving water use efficiency. Water research teams in many countries have conclusively demonstrated the value of adopting the modern tool of operations research or systems analysis for assisting in the development, operation, planning and management of the water resources project.There are many analysis techniques and computer models available in the real world for developing quantitative information for use in evaluating storage capacities, water allocation, and release policies. Yeh (1985), Wurbs (1996) and McKinney (1999), in their state-of-the-art review, discuss different optimization techniques that are used in water resources system analysis at the basin level and reservoir operation. This chapter consists of five sections and presents the most relevant research developed in the last two decades in the optimization of reservoir operation. The first section introduces the concepts of reservoir operations. The second section presents the ideas and concepts of main conventional optimization techniques (linear programming, dynamic programming) and simulation used in this area of water resources planning and management. The third section speaks about the concepts and application of rule curves and hedging rule for fulfilling the primary demand with reduction in supply to other requirements. The fourth section deals with the robust search technique-genetic algorithms for the optimization of reservoir. The fifth section presents the importance of simulation-optimization model used in the reservoir operation.[2]

2.2 DISCRIPTION OF LINGO SOFTWARE

Software used: LINGO 14.0 x64

By LINDO CORP. CHICAGO, IL, USA

LINGO is a comprehensive tool designed to make building and solving Linear, Nonlinear (convex & nonconvex/Global), and Quadratic, Quadratically Constrained, Second Order Cone, Stochastic, and Integer optimization models faster, easier and more efficient. LINGO provides a completely integrated package that includes a powerful language for expressing optimization models, a full featured environment for building and editing problems, and a set of fast built-in solvers.[3]

2.3 APPLICATION OF SOFTWARE[4]

1) Available for modeling linear, nonlinear and integer stochastic programs (SP).

2) Supports most standard distributions, e.g., Normal and Poisson, as well as user defined.

3) Full solutions for each of the possible scenarios are available at the scripting level (calc sections) allowing for the creation of custom reports on variable values over the full range of scenarios.

4) Sampling scenarios through statistical sampling.

5) Ability to generate statistically dependent samples based on Pearson, Spearman or

Kendall’s correlation measures.

6) Ability to generate and display the underlying deterministic equivalent used to optimize SP models. Storage yield function plotting

7) To find the demand in the particular month of year and corresponding reservoir storage capacity.

8) To find the constant maximum release with particular storage capacity

2.4 LITERATURE REVIEW

There are lot of papers were studied followed by review. Some of them have been described below:

Jery R. Stedinger et.al. wrote the book on water resource systems, planning and management. This book contains the introduction to methods, models and application. This book builds on a text titled Water Resources Systems Planning and Analysis by Loucks, Stedinger and Haith published by Prentice Hall in 1981. The present work updates much of what was in that text, introduces some new modelling methods that are proving to be useful, and contains considerably more case studies. It benefits considerably from the experiences of WL | Delft Hydraulics, one of the many firms involved around the world using the approaches and methods discussed in this book.[5]

Larry W. Mays et.al. wrote the book water resource engineering and management and it is an introduction to methods used in hydro systems for upper level undergraduate and graduate students. The material can be presented to students with no background in operations research and with only an undergraduate background in hydrology and hydraulics. A major focus is to bring together the use of economics, operations research, probability and statistics with the use of hydrology, hydraulics, and water resources for the analysis, design, operation, and management of various types of water projects. This book is an excellent reference for engineers, water resource planners, water resource systems analysts, and water managers.[6]

Singiresu Rao et.al. wrote the book on engineering optimization. Covering both the latest and classical optimization methods, the text starts off with the basics and then progressively builds to advanced principles and applications. This comprehensive text covers nonlinear, linear, geometric, dynamic, and stochastic programming techniques as well as more specialized methods such as multiobjective, genetic algorithms, simulated annealing, neural networks, particle swarm optimization, ant colony optimization, and fuzzy optimization. Each method is presented in clear, straightforward language, making even the more sophisticated techniques easy to grasp[7]

Hamdy A.Taha wrote about the operations research and told we don't have single technique to solve the optimization problem. Instead, the type and complexity of the mathematical model dictate the nature of the solution method.He told that linear programming is most prominent technique it is designed for linear model with objective function and constraints function.[8]

P.P Majumdar et.al. wrote paper is to develop the irrigation planning model and to apply the same in the form of Multi Objective Fuzzy Linear Programming (MOFLP) approach for crop planning in command area of Jayakwadi Project Stage I, Maharashtra State, India. To formulate MOFLP model various Linear Programming (LP) models are developed to optimize the Net Benefits (NB), Crop/Yield Production (YP), Employment Generation (EG) and Manure Utilization (MU) for which the objective function and constraints are crisp in nature.[9]

Rippl., W wrote about the capacity of storage reservoirs for water supply. He told about the purpose of storage reservoir is to equalize the fluctuation of supply and demand during indefinitely long period of time.[10]

Susam Datta wrote about determination of reservoir capacity using linear programming model in international research paper.He talked about the how linear programming can be applied for the determination of reservoir capacity. Reservoir capacity depends on the inflow available and demand where inflow in the river is always greater than the demand, there is no storage required and if the inflow in the river is small but the demand is high, a large reservoir capacity is required. Here, two sets of constraints to be satisfied, one relates to storage continuity and the other to capacity. These two constraints are employed to define the linear equations and to develop the model.[11]

Shavkat Rakhmatullaev et.al. wrote about geostastical approach for the assessment of water reservoir capacity in arid region. The paper presents results of the application of a geostatistical approach to assess the water resources availability of the Akdarya reservoir in Uzbekistan. The simulation enables to have a range of reservoir volumes and surface areas with the same probability in comparison to the kriging and traditional methods. [12]

Evrad . J et.al. Water reservoir, irrigation and sedimentation in central Asia. They told about Water reservoirs play an important role in areas with limited and erratic precipitation where water is stored and re-distributed later for different purposes. Irrigation is primarily a major water consumer in arid countries of Central Asia for the economic development, employment and food security of the region. The major rivers of Central Asia (e.g., Amu Darya, Syr Darya, and Zerafshan) are turbid watercourses. The aim of this paper is first to review the present conditions and the role of man-made water reservoirs for irrigation in Central Asia with special focus on Uzbekistan, second to document past and current reservoir sedimentation conditions in Uzbekistan and third to discuss research carried out by Soviet and present-time local research community in the domain of erosion.[13]

Furnans J, Austin B wrote about comparisons of methods to asses reservoir volume and sedimentation based on bathymetric surveys. This paper presents two different terrain modeling techniques to assess sedimentation employing single-beam bathymetric data, using as a case of study a Peruvian reservoir located in the Andes Mountains. Both methods used the same input data. The first method employed was the traditional method and the second was Insertion of Mesh Points (IMP). In agreement with previous findings, the IMP method produced lower sedimentation values but proved to be satisfactory by this case. [14]

William L. Graf discussed in the research paper about downstream hydrologic and geomorphic effects of large dams on American rivers. Regional variation in rivers, dams, and responses are substantial: rivers in the Great Plains and Ozark/Ouachita regions have annual maximum/mean flow ratios that are 7 times greater than ratios for rivers in the Pacific Northwest. At the same time, the ratio of storage capacity/mean annual water yield for dams is greatest for Interior Western, Ozark/Ouachita and Great Plains rivers and least for Pacific Northwest streams. In many cases those rivers with the highest annual variability have the greatest potential impact from dams because structures can exert substantial control over downstream hydrology. [15]

Palmieri A, Shah F et.al. wrote about Optimizing the operation of a hydraulic dam for ecological flow requirements of the You-shui River due to a hydropower station construction. The typical annual flow rates were determined, and Chinese sucker (*Procypris rabaudi*) was chosen as the target fish with 4 life stages to represent the habitat suitability situation under the environmental discharge. The optimal model was designed to be a function of the maximum value of the sum of the power generating function and the overall suitability index (OSI) function.[16]

Rakhmatullaev S wrote about Improvement of operational methods for the assessment of the water reservoir useful storage capacity using geoinformation systems. Case study of the Akdarya Reservoir, Samarqand Province, Uzbekistan. This study deals with the use of a geostatistical approach to assess the reservoir sedimentation in the Akdarya reservoir in Uzbekistan. Geostatistical approach includes (semi-) variogram analysis and interpolation (kriging and simulations (turning bands)) techniques predicting values at unsampled locations for generating digital bathymetric surface models of reservoir bottom conditions in order to calculate volume and surface area at given water elevation.[17]

Mitsuo Gen, Runwei Cheng wrote to solve the genetic algorithm problem. Genetic algorithm developed by Goldberg was inspired by Darwin's theory of evolution which states that the survival of an organism is affected by rule "the strongest species that survives". Darwin also stated that the survival of an organism can be maintained through the process of reproduction, crossover and mutation. Darwin's concept of evolution is then adapted to computational algorithm to find solution to a problem called objective function in natural fashion[18]

Rodrigo Oliveira wrote about Multireservoir operating policies are usually defined by rules that specify either individual reservoir desired (target) storage volumes or desired (target) releases based on the time of year and the existing total storage volume in all reservoirs. This paper focuses on the use of genetic search algorithms to derive these multireservoir operating policies. The genetic algorithms use real-valued vectors containing information needed to define both system release and individual reservoir storage volume targets as functions of total storage in each of multiple within-year periods. Elitism, arithmetic crossover, mutation, and "en bloc" replacement are used in the algorithms to generate successive sets of possible operating policies[19]

Abbas Afshar et.al. wrote A mixed integer linear optimization model for river basin development for irrigation is presented. The model is a chance-constrained optimization model that considers the interactions between design and operation parameters (reservoir capacity, delivery system capacity, hectares of land to be developed and planted to different crops, etc.). The model is capable of integrating all decision variables in the design phase, thus accounting directly for any interdependency between the design variables. [20]

Millie Pant et.al. wrote about the Estimation of optimal crop plan using nature inspired metaheuristics. Irrigation management has gained significance due to growing social needs and increasing command for food grains while the available resources have remained limited and scarce. Irrigation management includes optimal allocation of water for irrigation purposes, optimal cropping pattern for a given land area and water availabilities with an objective to maximize economic returns. In the present study we consider an optimization model based on linear programming for determining optimal crop plan for command area of Pamba-Achankovil-Vaippar (PAV) link project.[21]

Ralph A. Wurbs wrote about Simulation Modeling of River/Reservoir System Water Allocation and Management. The Water Rights Analysis Package (WRAP) is a generalized modeling system for simulating and analyzing water resources development, management, allocation, and use in river basins located anywhere in the world. WRAP is designed for assessing reliabilities in meeting water supply, hydroelectric power, and environmental flow needs. Reservoir operations for flood control can also be simulated. The modeling system is routinely applied in Texas in the United States to support administration of water allocation systems, regional and statewide planning, and other water management activities. The Texas Water Availability Modeling (WAM) System consists of WRAP and input datasets for all the river basins of the state.

WRAP has also been applied in several other countries but not to the extent as in Texas. WRAP capabilities continue to be expanded to address an expanding range of water management concerns.[22]

Jay R. Lund wrote about derived operating rules for reservoirs in series & parallel. This paper reviews a variety of derived single-purpose operating policies for reservoirs in series and in parallel for water supply, flood control, hydropower, water quality, and recreation. Such rules are useful for real-time operations, conducting reservoir simulation studies for real-time, seasonal, and long-term operations, and for understanding the workings of multireservoir systems. For reservoirs in series, several additional new policies are derived for special cases of optimal short-term operation for hydropower production and energy storage. For reservoirs in parallel, additional new special-case rules are derived for water quality, water supply, and hydropower production. New operating policies also are derived for reservoir recreation.[23]

Joel Guzman wrote about derived power production and energy drawdown rules For reservoirs. Theoretical hydropower operation rules are derived and discussed for reservoirs in parallel, in series, and single reservoirs for cases where reservoirs typically refill before they empty and for parallel reservoirs when reservoirs are expected to draw down to empty. These hydropower rules offer a simplified economic basis for allocating storage and energy in multireservoir hydropower systems. The approach is demonstrated for an illustrative example and should be helpful for making decisions regarding hydropower releases over time, subject to the limited conditions under which these rules hold.[24]

CHAPTER 3

METHODOLOGY

3.1. LINEAR PROGRAMMING MODEL

An alternative and more frequent method to sequent peak method. There is one assumption that we take that is inflows are deterministic. In LP, the linearity assumption simplifies mixing the function of evaporation loss generally into relationships of continuity of storage.

Two sets of constraints which to be satisfied here, one to storage continuity and the other to capacity. Let, R_t be the release and D_t is the specific demand or release.

Model of Optimization for active storage, K_a.

Minimize K_a.

Linear Equations:

Mass balance:

$S_t + Q_t – R_t – L_t = S_{t+1}$ (1)

Maximum active storage: $S_t < K_a$

Non-negativity: $S_t > 0$; $K_a > 0$ Where,

R_t is known release.

Q_t is known inflow.

L_t is storage loss estimated.

S_t is beginning storage of period t

K_a is (active) storage capacity.

In this, continuity, with loss of evaporation has been taken as consideration.

K_d is dead storage of reservoir.

A_0 is the area surface at dead storage.

a is the area per unit active storage above A_o.

Total rate of evaporation in period t is given by

$E = A_O e_t + a(S_t + S_{t+1}) / 2e_t$ (2)

Where,

e_tA_o is L_t i.e. fixed

loss of evaporation e_t is the evaporation rate in period t.

A_o is surface area of water at top of the dead storage level.

a is the surface area per unit active storage (slope of the area-capacity relationship beyond the dead storage)

Continuity, with evaporation loss considered,

$S_t + Q_t – R_t – E_t = S_{t+1}$ (3)

Put in E_t continuity equation,

$S_t + Q_t – R_t – E_t = S_t + 1$

$E_t = L_t + a_t (S_t + S_{t+1})$

$L_t = e_t A_o$ (4)

On solving we get,

$S_T + Q_t – L_t – R_t = S_t + 1$

The storage in each period is restrict by the capacity, K,

thus

$S_t < K$

Also,

$R_t < D_t$

The reservoir capacity K is a changable, which should be minimized. The objective is to minimize K

The formulation of model reduces

to, Minimize K,

$(1 – a_t)S_t + Q_t – L_t – R_t = (1 + a_t)S_{t+1}$ (5)

$S_t < K$

$R_t < D_t$

$S_{T+1} = S_1$, where

T is the last period in sequence of time interval

The last constraint means that when putting a sequence of monthly inflows in a year, T = 12, S_{13} in the formulation is fix equal to S_1.

The main purpose is to reliable that the storage at the end of the final period in the year is same as the storage at the starting of the first period because the sequence of inflow is considered to be repetitive. In the continuity equation of storage spill if any in period t, is engrossed in the term $R._t$

For storage yield:

A favorable problem to capacity of reservoir estimation can be done by optimizing the yield. Firm yield is the largest quantity of flow that can be flow or released at all the times. It is the magnitude of flow that is equaled or may be exceeded 100% of time for a historical flows sequence. Linear Programming can be used to optimize the yield, *R* from a reservoir of given capacity *(K).* The optimization problem can be formed as

Maximize *R* Subject to

(i) Equation of Storage continuity

$$S_{T+1} = S_t + I_t - EV_t - R_t \text{-} Q_t \quad \text{for all t}$$

(ii) Reservoir capacity

$S_t \leq K_a$ for all t $S_{T+1} = S_t$
where T is the last period.

3.2 STEP INVOLVED FOR MODEL FORMULATION OF LP IN LINGO SOFTWARE

1. Equality form of constraints

$(1 - a_t)S_t + Q_t - L_t - R_t = (1 + a_t)S_{t+1}$

The constraint should imply that Rt includes the demand to be met and possible spill in the period. Ensure demand in every period is satisfied in full.

2. Inequality constraints

Use ‗ > 'instead of ‗ = ' and substitute Dt in place of Rt.

Forms in flexibility to alert of spills. Excess water over release or demand and evaporation is stored within the reservoir till the capacity.

The problem structure is

Minimize K

$(1 - a_t)S_t + Q_t - L_t - D_t > (1 + a_t)S_{t+1}$

$S_t < K$

The spill in period t is

$(Spill_t) = (1 - a_t)S_t + Q_t - L_t - D_t - \text{at } S_{t+1} - K$ …if positive (7)

$(Spill_t) = 0$ … otherwise

3. Other equality form of constraints:

Stipulate additional term for spill in each constraint and spills penalization in the equation

$(1 - a_t)S_t + Q_t - L_t - D_t - Spill_t = (1 + a_t)S_{t+1}$ (8)

Yield function of storage: To determine the maximum constant yield that is constant release in all periods within a year from a reservoir

Formula drawn is,

Maximize R

$(1 - a_t)S_t + Q_t - L_t - R > (1 + a_t)S_{t+1}$ (9)

and $S_t < K$

With $S_{T+1} = S_1$, where T is the last period

Mixed integer LP formulation for optimizing yield is an graceful way to solve a problem with equality constraints calculating for spills is by the use of variables of integers in LP formulation. Formulation of mixed integer confirms that spill will not exist until reservoir is full.

A favorable problem to capacity of reservoir estimation can be done by optimizing the yield. Firm yield is the largest quantity of flow that can be flow or released at all the times. It is the magnitude of flow that is equaled or may be exceeded 100% of time for a historical flows sequence. Linear Programming can be used to optimize the yield, *R* from a reservoir of given capacity *(K).* The optimization problem can be formed as

Forms in flexibility to alert of spills. Excess water over release or demand and evaporation is stored within the reservoir till the capacity.

The main purpose is to reliable that the storage at the end of the final period in the year is same as the storage at the starting of the first period because the sequence of inflow is considered to be repetitive.

An alternative and more frequent method to sequent peak method. There is one assumption that we take that is inflows are deterministic.

4. Introduce additional constraints using integer variables:

Constraints may be denoted as:
$Spill_t < B_t*M$

$B_t < (S_{t+1})/K$ (10)

B_t is integer < 1 (11)

When S_{t+1} is less than K, then $B_t = 0$ and Spillt = 0

When S_{t+1} is higher than K, then $B_t > 1$

B_t is pushed to be equal to 1 ($S_{t+1} = K$) in respect to make spill positive (+ve).

• Total annual inflow in all periods is much greater than the sum of release or demands and evaporation losses; or else the problem will be impossible.

• The problem of finding K for a given R cannot be solved using formula of mixed integer , the constraint.
$B_t < (S_{T+1})/K$ or $B_T*K < S_T$ Becomes nonlinear when both are variable

5.Inequality constraints for multiple reservoir:

$S_{t+1}^{i}=S_t^{i}+Q_t^{i}-E_t^{i}-R_t^{i}$ i=1,2,4,5,……n t=1,2,3,4,5,…..n

$S_{t+1}^{i}=S_t^{i}+Q_t^{i}-E_t^{i}-R_t^{i}+\alpha_1 R_t^{1}+ \alpha_2 R_t^{2}$ i=3 t=1,2,3,4,5,…..n

$S_t^{i}< K_t$ i=1,2,3,4,5,……n t=1,2,3,4,5…...n

$(K_t- S_t^{i})>=F_{min}^{i}$ i=1,2,3,4,5,……n t=1,2,3,4,5……n

$R_t^{i}<= R_{max}^{t}$ t=1,2,3,4,5…….n

$R_t^{i}>=0$ t=1,2,3,4,5…….n

$S_3^{i}= S_1^{i}$

i denotes the no of reservoir

t denotes the time interval may be yearly,seasonly,monthly

K denotes the storage capacity of different reservoir

S denotes the storage of the reservoir for different reservoir at different time

R denotes the release from the different reservoir at different time

$\alpha_{1,}$ α_2 denotes the fraction of release that joins downstream reservoir from upstream reservoir.

CHAPTER 4

OBSERVATION

4.1 OBERVATION FOR SINGLE RESERVOIR

Deriving a maximum constant release for a reservoir of UKAI DAM located in GUJRAT state to meet a long-term objective.[25]

This is Single **reservoir operation** with deterministic inflows

ATTRIBUTE	VALUE
NAME OF THE DAM	UKAI DAM
STRUCTURE PURPOSE	FLOOD CONTROL,HYDROELECTRIC,IRRIGATION
STATE	GUJRAT
STATUS	COMPLETED
TYPE OF SPILLWAY	OGEE
CREST LEVEL OF SPILLWAY	91.4
NO OF SPILLWAY GATE	22
LENGTH OF THE DAM	4927(m)
RIVER	TAPTI
TYPE OF DAM	EARTHEN,GRAVITY & MASONARY
DESIGN FLOOD	46269(cumec)

These are the attributes of the UKAI Dam in which design flood, type of spillway and crest level of spillway,lenth of spillway are shown. This is the gravity dam mainly on located on the bank of Tapti River.It has 22 spillway gate.

Fig4: Location Map Of UKAI Dam

Dark red point denotes the location of the Ukai Dam **.**It is located on GUJRAT State. Length of this dam is 4927m on the bank of TAPTI River.

The purpose of this reservoir is for control of flood, hydroelectric power, and Irrigation

The design flood of this reservoir is 46269 cumec

4.1.1 DATA OBTAINED FOR SINGLE RESERVOIR

Table4.1: Data of Inflow and Evaporation of Dam

MONTH	Q_t (Mm3)	E_t (mm)	A_t=a*e/2	L_t=A_0*e_t (Mm3)	(1-a_t)	(1+a_t)
Jun	70.61	231.81	0.01357	8.58	0.9864	1.0136
Jul	412.75	147.57	0.00864	5.46	0.9914	1.0086
Aug	348.4	147.57	0.00864	5.46	0.9914	1.0086
Sep	142.29	152.14	0.00891	5.63	0.9911	1.0089
Oct	103.78	122.96	0.00720	4.55	0.9928	1.0072
Nov	45	121.76	0.00713	4.51	0.9929	1.0071
Dec	19.06	99.89	0.00585	3.70	0.9942	1.0058
Jan	14.27	97.44	0.00571	3.61	0.9943	1.0057
Feb	10.77	106.14	0.00622	3.93	0.9938	1.0062
Mar	8.69	146.29	0.00857	5.41	0.9914	1.0086
Apr	9.48	220.97	0.01294	8.18	0.9871	1.0129
May	18.19	246.75	0.01445	9.13	0.9856	1.0144

$\mathbf{Q_t}$ is the average inflow of 20 year data

$\mathbf{E_t}$ converted to ‘m’ is evaporation at time t

$\mathbf{L_t}$ is the evaporation loss due to dead storage

$\mathbf{A_t}$ is the evaporation loss due to active storage

$\mathbf{A_0}$ =Area Corresponding To Dead Storage Level

a=slope of the area capacity curve beyond dead storage

$\mathbf{s_t}$ is the storage at the beginning

$\mathbf{s_{t+1}}$ is the storage at time t

A_0 =37.01Mm^2 a=0.117115m^2/m^3 K=600Mmm^3

4.1.2 AREA CAPACITY CURVE OF RESERVOIR

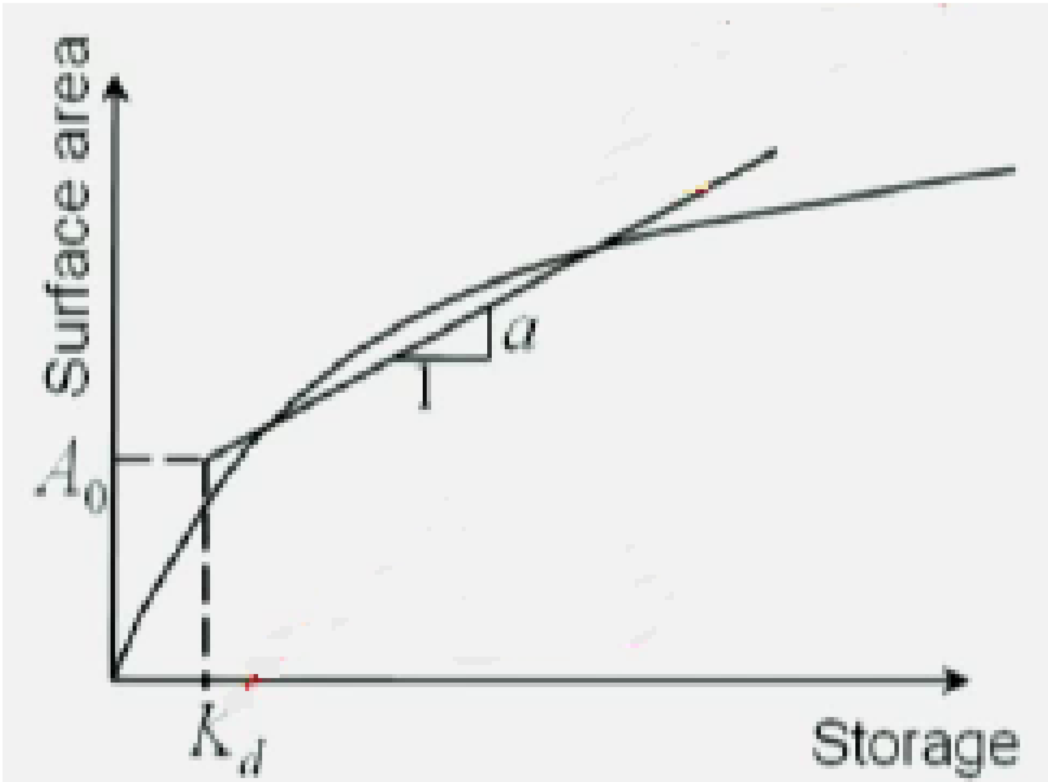


Fig4.1: Area Capacity Curve of the Reservoir

Area capacity curve is given when we analyze the reservoir. It depends on the contouring of the upstream side of the reservoir because at upstream level contouring is different from bottom to top hence surface area of water will be different from bottom to top.

The analysis of area capacity curve is done separately for active and dead storage.

Area capacity curve increases from bottom to top means from dead storage to active storage. The variation in dead storage is minute hence can be considered constant means not changing with storage but for active storage can be assumed variation linearly for calculation point of view.

Dead storage is provided to accumulation of sediment deposition. It can be considered as volume of sediment deposited (to be expected) in the reservoir at the time of design life of reservoir

Active storage is the volume of water stored between minimum pool level & full level of reservoir. It is also called useful level of storage. It specifies the supply of water for particular period and gives the full demand.

Evaporation loss depends on the area capacity curve and calculated by average of storage at beginning and at time t for active storage but for the dead storage evaporation rate is multiplied with area of dead storage to find the loss.

For active storage:

$A_t=[a(s_t+s_{t+1})/2]e_t$

$A_t=a_t(s_t+s_{t+1})$ $a_t=(a*e_t)/2$

For dead storage:

$L_t=A_0e_t$

Total evaporation loss= $L_t+ A_t$

$\mathbf{L_t}$=Evaporation loss due to dead storage

$\mathbf{A_t}$=Evaporation loss due to active storage

T=Total evaporation loss

e_t is the evaporation rate with unit of depth in mm.It will be different for all the months. Active storage & dead storage depend on this evaporation rate.

4.1.3 LINEAR PROGRAMMING FORMULATION

LP FORMULATION

Maximize R

$(1-a_t)S_t+Q_t-L-R>=(1+a_t)S_{t+1}$ t=1,2,3……12

$S_t<=K$; $S_{13}=S_1$

S1<=600; S2<=600; S3<=600; S4<=600 ; S5<=600 ; S6<=600 ; S7<=600; S8<=600; S9<=600; S10<=600; S11<=600 ; S12<=600;

0.9864*S1+70.61-8.58-R=1.0136*S2

0.9914*S2+412.75-5.46-R=1.0086*S3

0.9914*S3+348.4-5.46-R=1.0086*S4

0.9911*S4+142.29-5.63-R=1.0089*S5

0.9928*S5+103.78-4.55-R=1.0072*S6

0.9929*S6+45-4.51-R=1.0071*S7

0.9942*S7+19.06-3.7-R=1.0058*S8

0.9943*S8+14.27-3.61-R=1.0057*S9

0.9938*S9+10.77-3.93-R=1.0062*S10

0.9914*S10+8.69-5.41-R=1.0086*S11

0.9871*S11+9.48-8.18-R=1.0129*S12

0.9856*S12+18.19-9.13-R=1.0144*S1

Storage continuity equation for the reservoir for all the months has been written above.

Storage for all time will be less than or equal to reservoir capacity.

Storage after last month storage of reservoir will be initial or first month reservoir because this is the deterministic approach.

This 12 equations cannot be solved by manually .It will be very tough to handle with these equation with manually with considering inequality condition.

4.1.4 SOLUTION (SOLVED BY LINGO SOFTWARE)

This above equation is solved by this software with no of iteration to get the more & more appropriate value

INPUT:

```
Lingo Model - RESERVOIR MAX
MAX=R;
S1<=600; S2<=600; S3<=600; S4<=600; S5<=600; S6<=600; S7<=600; S8<=600; S9<=600; S10<=600; S11<=600; S12<=600;
0.9864*S1+70.61-8.58-R=1.0136*S2;
0.9914*S2+412.75-5.46-R=1.0086*S3;
0.9914*S3+348.4-5.46-R=1.0086*S4;
0.9911*S4+142.29-5.63-R=1.0089*S5;
0.9928*S5+103.78-4.55-R=1.0072*S6;
0.9929*S6+45-4.51-R=1.0071*S7;
0.9942*S7+19.06-3.7-R=1.0058*S8;
0.9943*S8+14.27-3.61-R=1.0057*S9;
0.9938*S9+10.77-3.93-R=1.0062*S10;
0.9914*S10+8.69-5.41-R=1.0086*S11;
0.9871*S11+9.48-8.18-R=1.0129*S12;
0.9856*S12+18.19-9.13-R=1.0144*S13;
```

Fig4.2: Input Given to the lingo software

Input given to the software is just put the equation and when we execute then get the output.

OUTPUT:

```
Solution Report - RESERVOIR MAX
  Objective value:                              93.32397
  Infeasibilities:                              0.000000
  Total solver iterations:                            12
  Elapsed runtime seconds:                          0.05

  Model Class:                                        LP

  Total variables:                     14
  Nonlinear variables:                  0
  Integer variables:                    0

  Total constraints:                   25
  Nonlinear constraints:                0

  Total nonzeros:                      49
  Nonlinear nonzeros:                   0


                          Variable           Value
                                 R        93.32397
                                S1        46.17115
                                S2        14.05805
                                S3        325.1073
                                S4        567.0507
                                S5        600.0000
                                S6        597.2856
                                S7        536.4024
                                S8        452.7016
                                S9        365.3746
                               S10        274.9208
                               S11        180.9563
                               S12        85.49510
```

Fig4.3: Output Obtained by the lingo software

Matrix form:

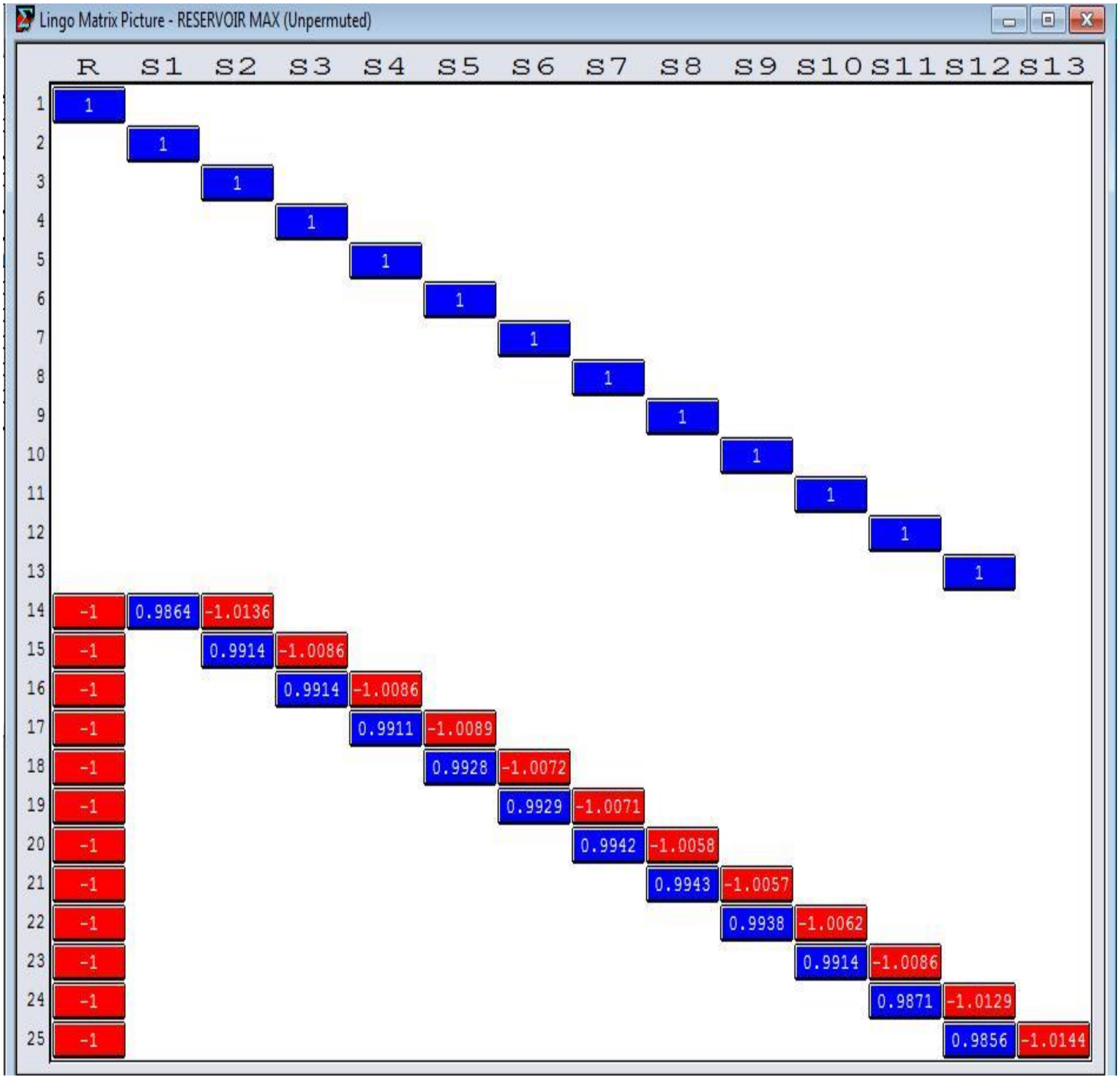


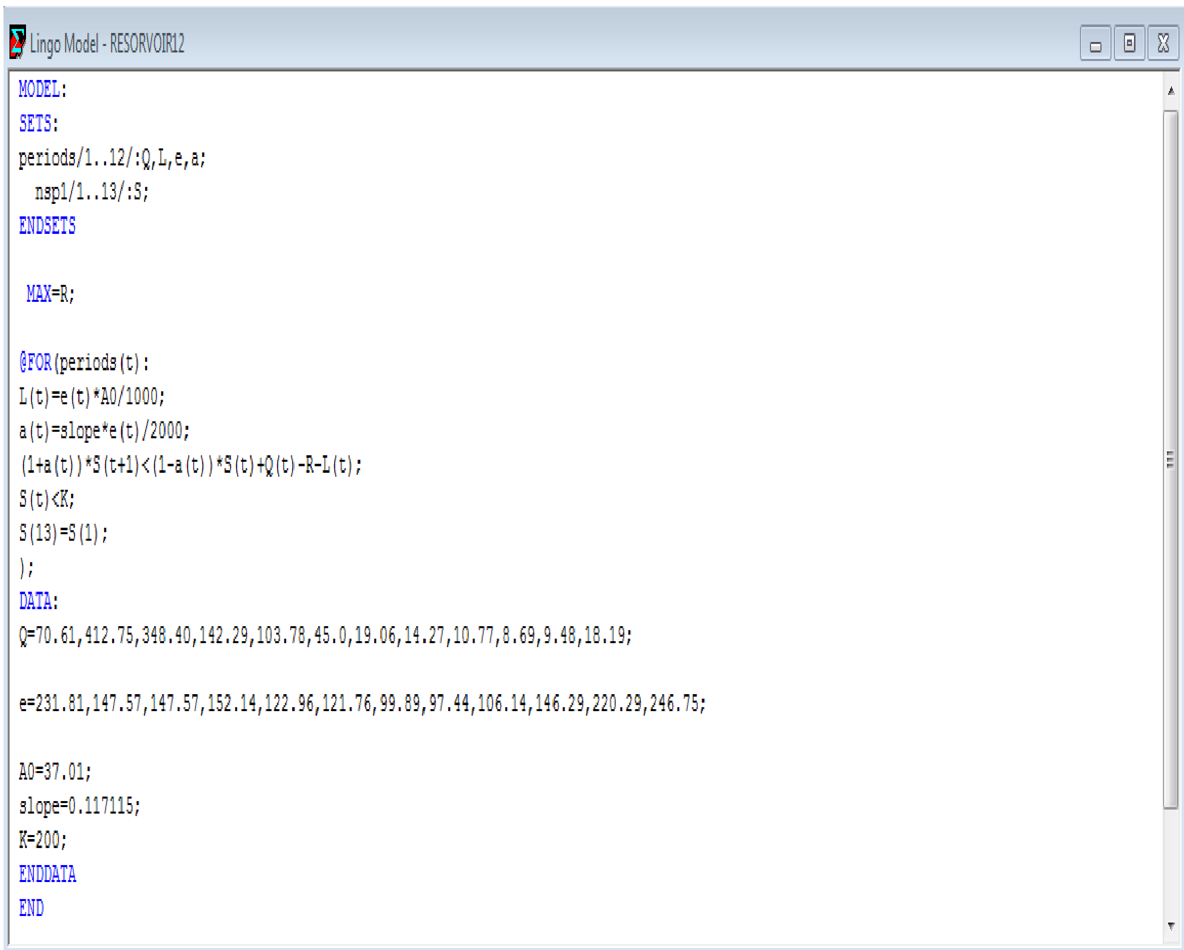
Fig4.4:Matrix form of the storage equation

In real stage the storage capacity of the reservoir 600 but when we design any of the reservoirs we don’t look only for this storage capacity even look for the value less and more from the stated value. Because yield from any reservoir depends upon the active storage capacity and inflow value. The inflow value summation for all month must be greater than constant release summation for all months.

It means if there is scarcity of the reservoir then no need to give more capacity and it will be uneconomical. In other sense we can say if we increase the reservoir capacity then the value of maximum constant release value will not increase hence the system will be uneconomical.

This statement can be proved by the help of lingo software .In software we have taken the release value for storage capacity 200,250,350,400,450,500,550,600,650 and checked it till maximum constant storage reaches and then stop checking.

INPUT (K=200)




```
MODEL:
SETS:
periods/1..12/:Q,L,e,a;
  nsp1/1..13/:S;
ENDSETS

 MAX=R;

@FOR(periods(t):
L(t)=e(t)*A0/1000;
a(t)=slope*e(t)/2000;
(1+a(t))*S(t+1)<(1-a(t))*S(t)+Q(t)-R-L(t);
S(t)<K;
S(13)=S(1);
);
DATA:
Q=70.61,412.75,348.40,142.29,103.78,45.0,19.06,14.27,10.77,8.69,9.48,18.19;

e=231.81,147.57,147.57,152.14,122.96,121.76,99.89,97.44,106.14,146.29,220.29,246.75;

A0=37.01;
slope=0.117115;
K=200;
ENDDATA
END
```

Fig4.5: Lingo Coding for Storage Capacity k=200

OUTPUT

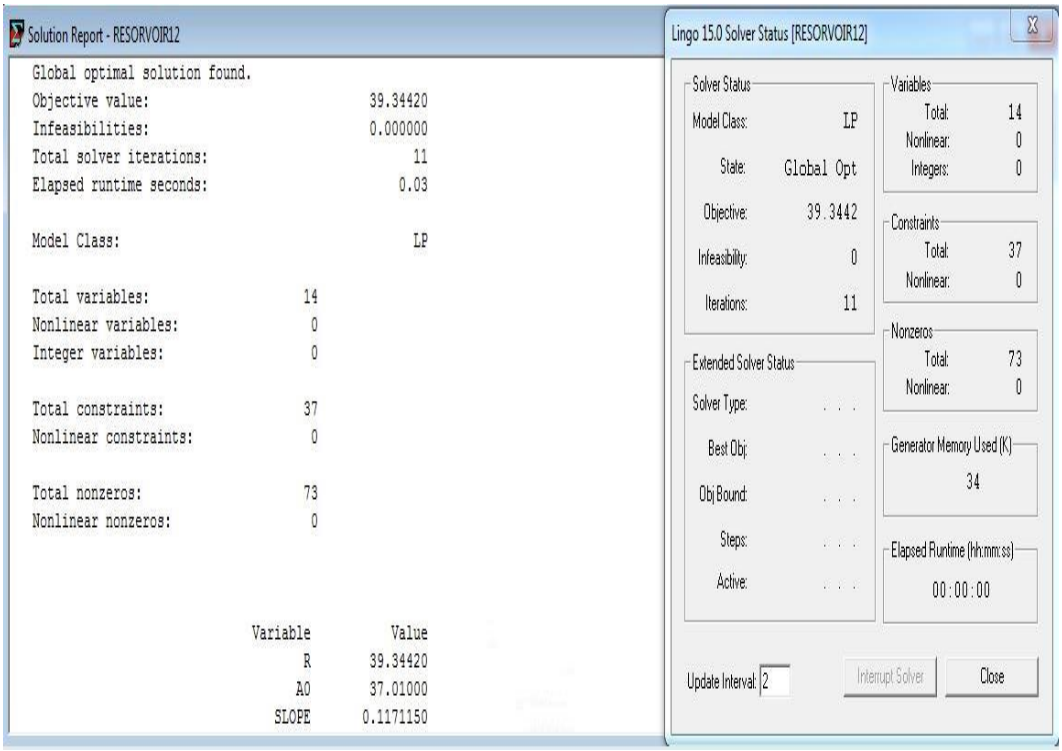


Fig4.6: Lingo coding output for release

This is the coding of lingo software at storage capacity of 200 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 39.34 with 11 no of iteration.

INPUT (K=250)

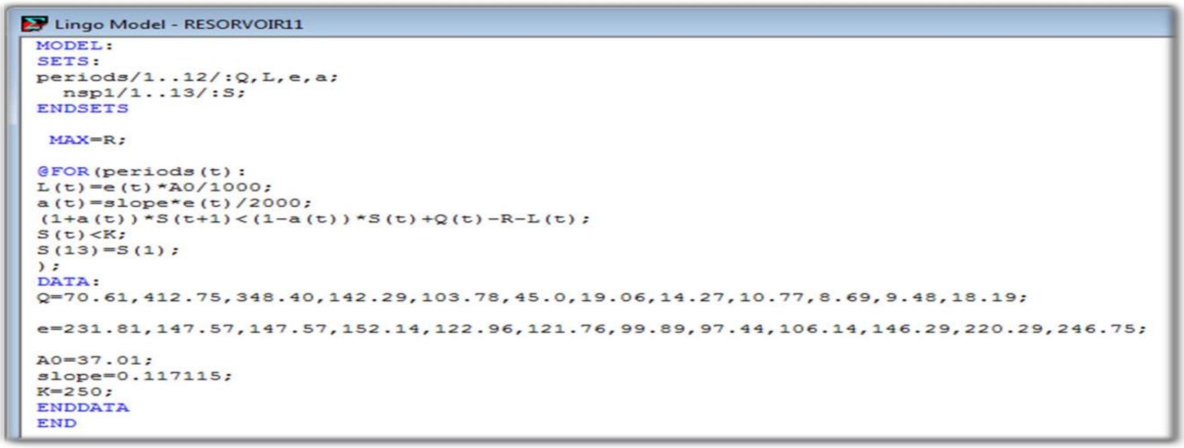


Fig4.7: Lingo Coding for Storage Capacity k=250

OUTPUT

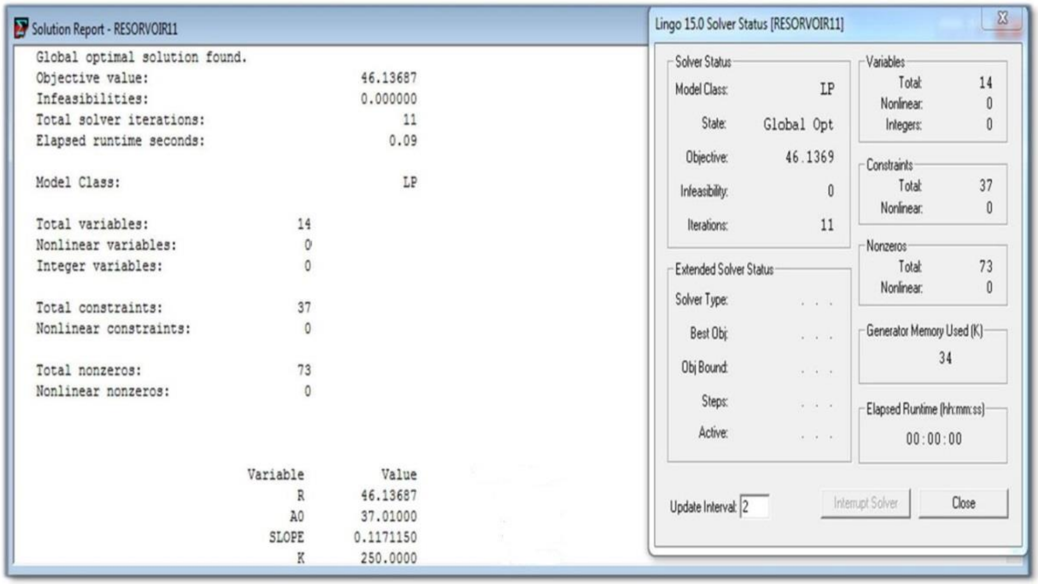


Fig4.8: Lingo coding output for release

This is the coding of lingo software at storage capacity of 250 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 46.13687 with 11 no of iteration. It takes the total elapsed time of .09sec

INPUT (K=300)

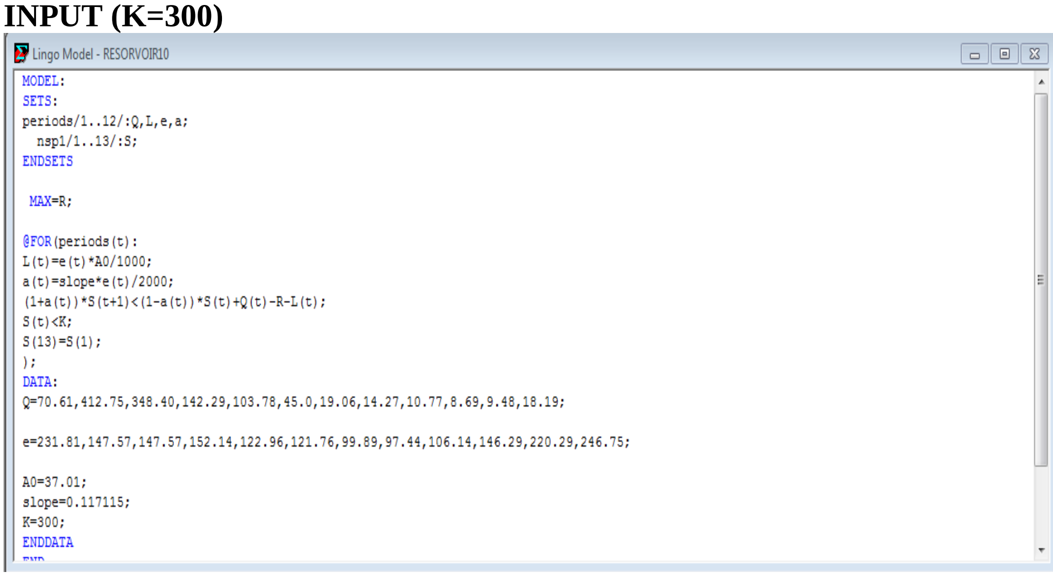


Fig4.9: Lingo Coding for Storage Capacity k=300

OUTPUT

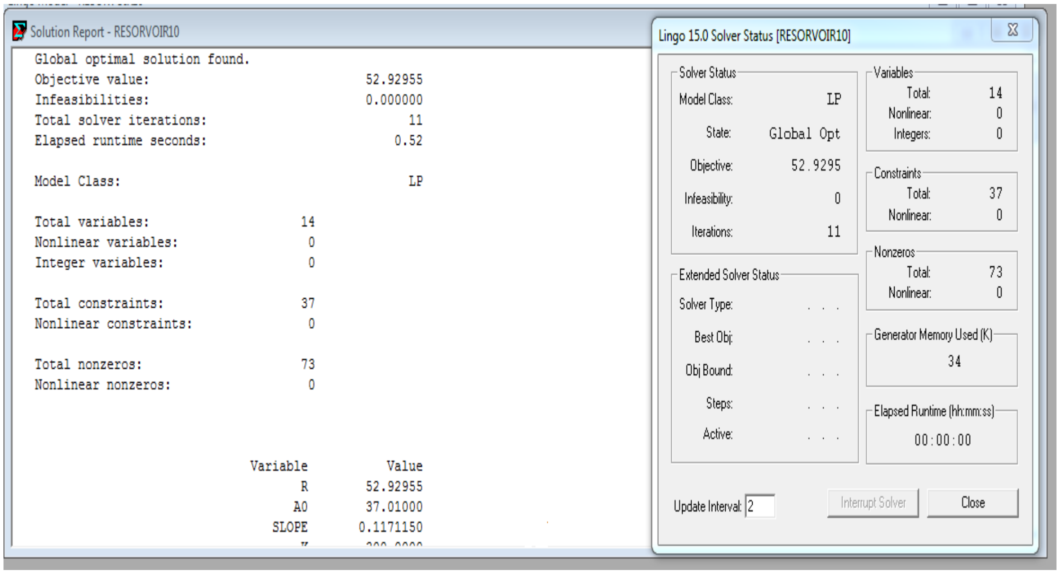


Fig4.10: Lingo coding output for release

This is the coding of lingo software at storage capacity of 300 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 52.92955 with 11 no of iteration. It takes the total elapsed time of .52sec.

INPUT (K=350)

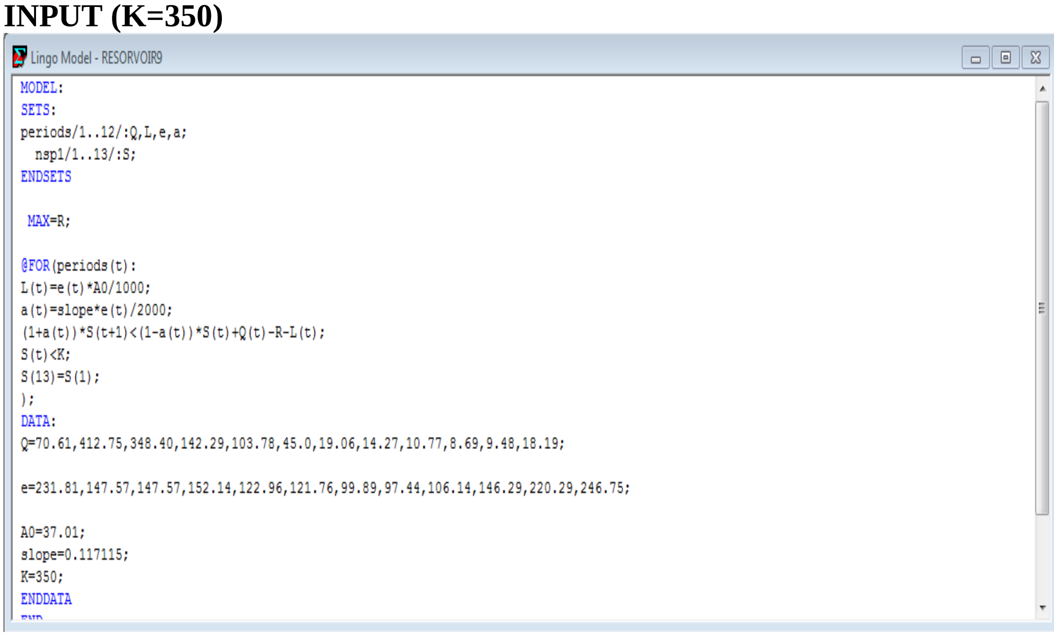


Fig4.11: Lingo Coding for Storage Capacity k=350

OUTPUT

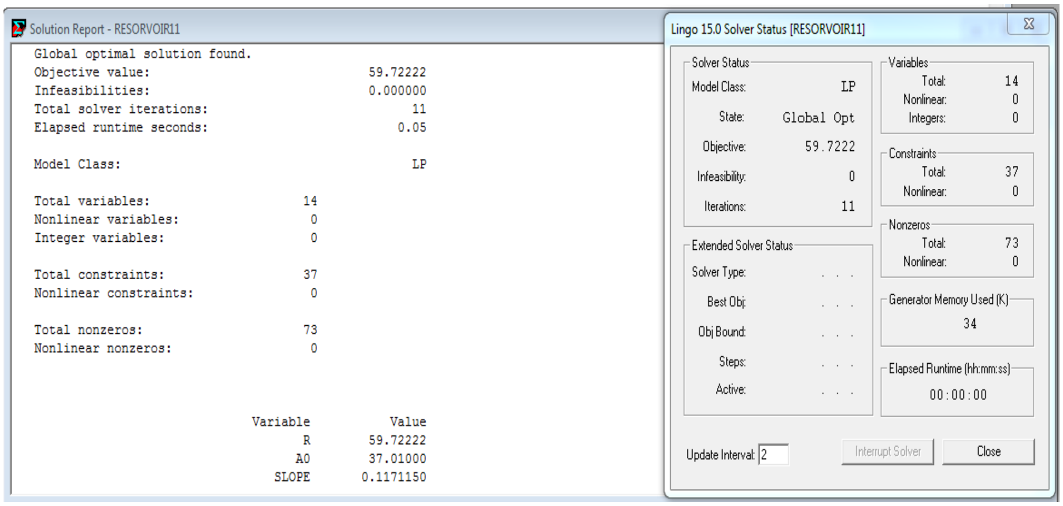


Fig4.12: Lingo coding output for release

This is the coding of lingo software at storage capacity of 350 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 59.7222 with 11 no of iteration. It takes the total elapsed time of .05sec

INPUT (K=400)

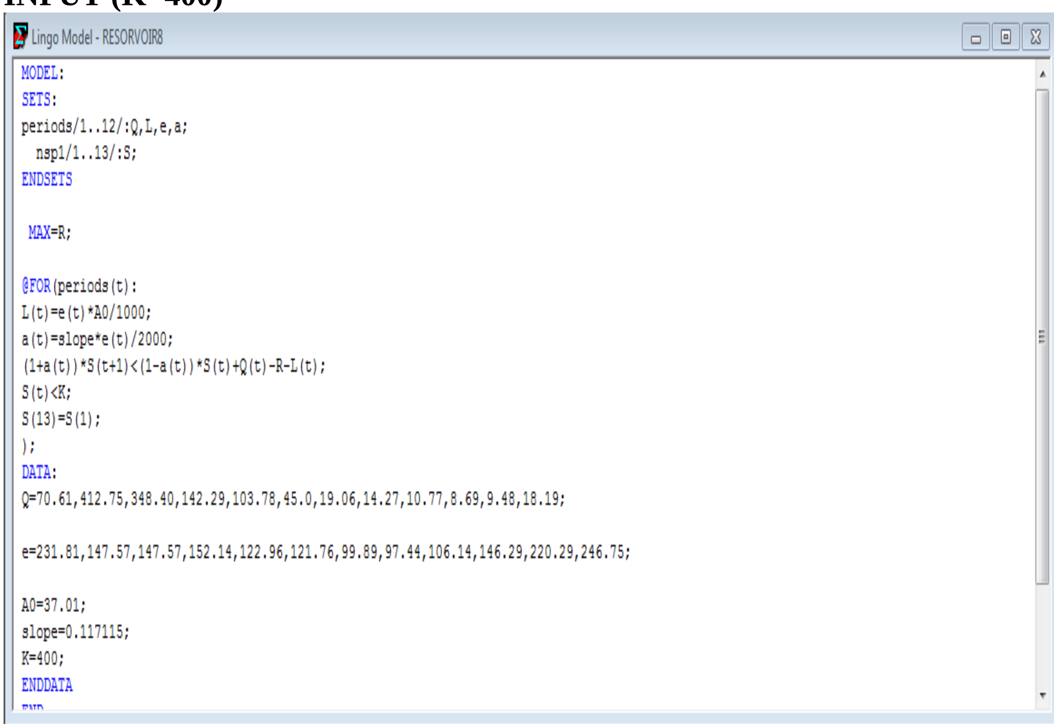


Fig4.13: Lingo Coding for Storage Capacity k=400

OUTPUT

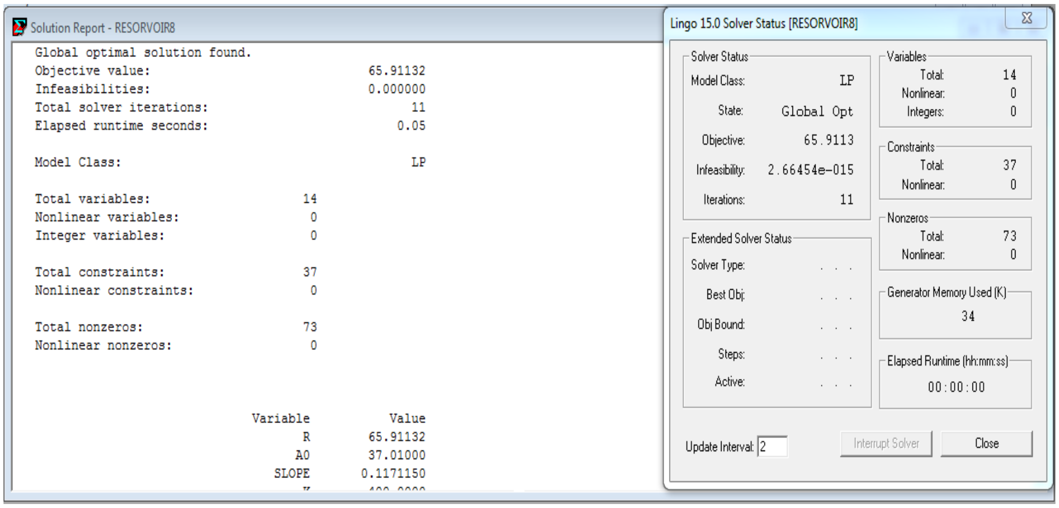


Fig4.14: Lingo coding output for release

This is the coding of lingo software at storage capacity of 400 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 65.922 with 11 no of iteration. It takes the total elapsed time of .05sec

INPUT (K=450)

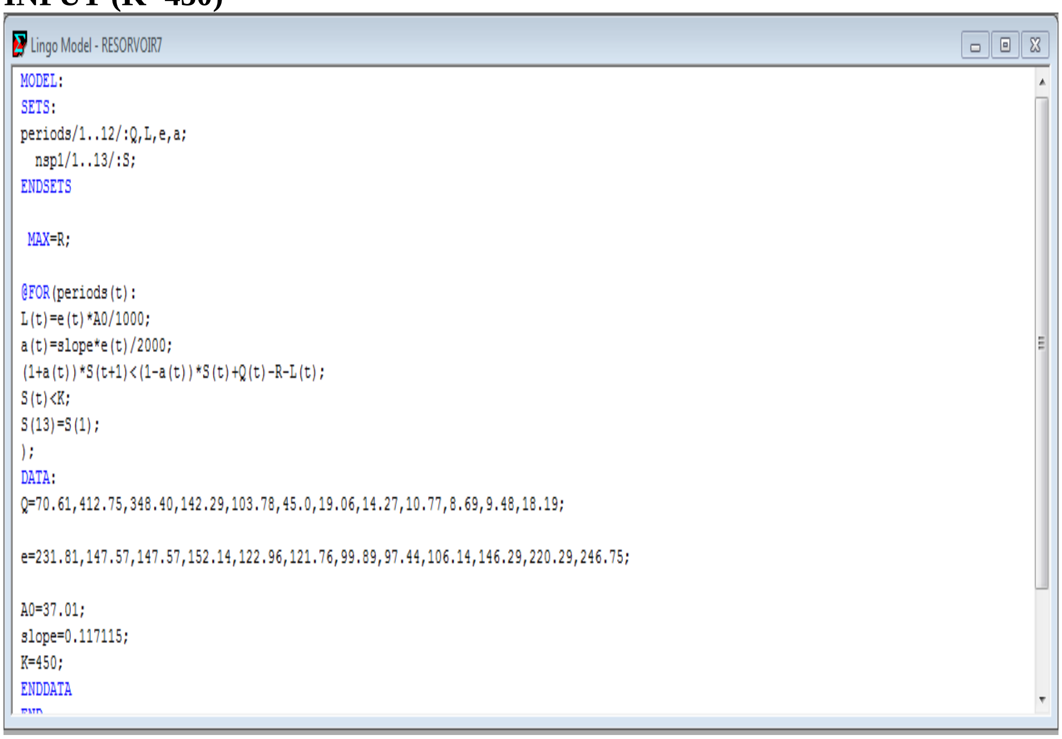


Fig4.15: Lingo Coding for Storage Capacity k=450

OUTPUT

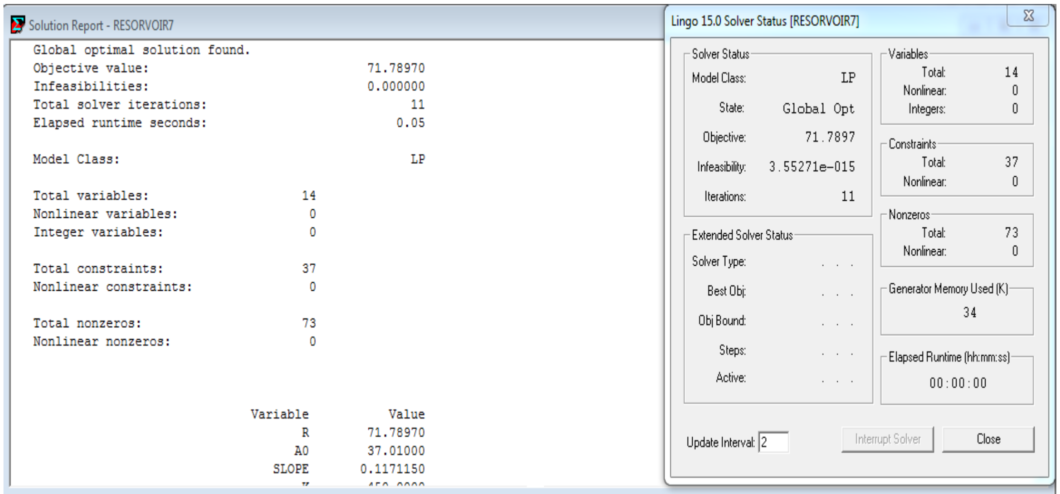


Fig4.16: Lingo coding output for release

This is the coding of lingo software at storage capacity of 450 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 71.78970 with 11 no of iteration. It takes the total elapsed time of .05sec

INPUT (K=500)

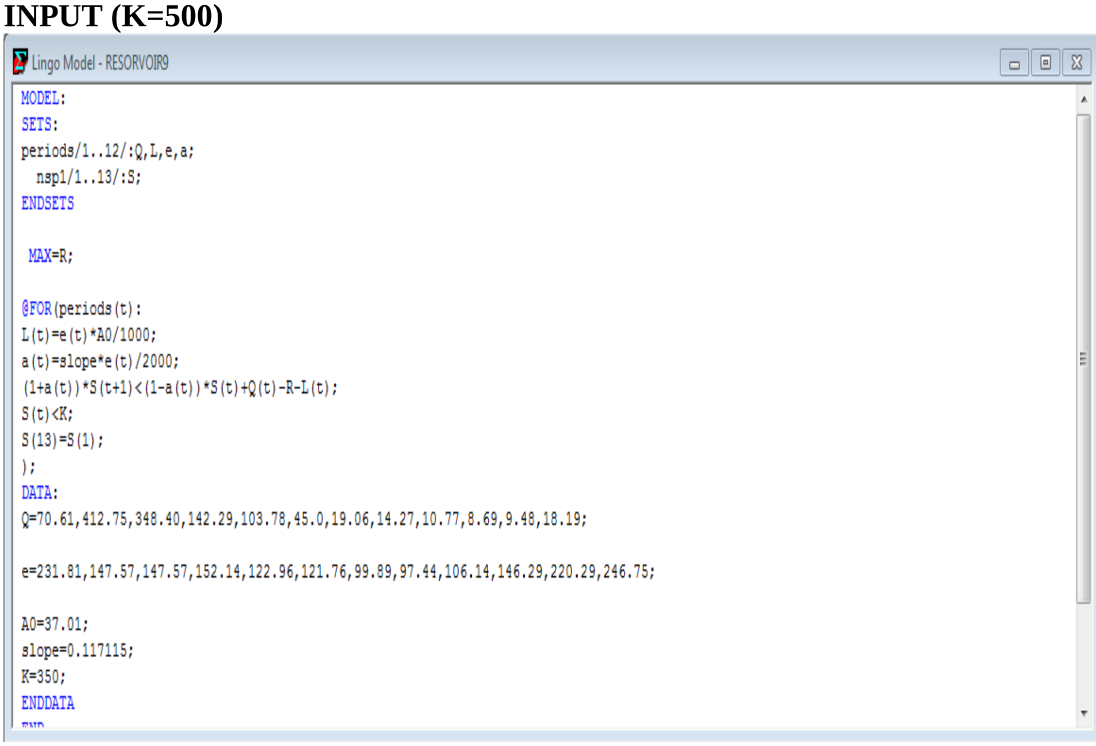
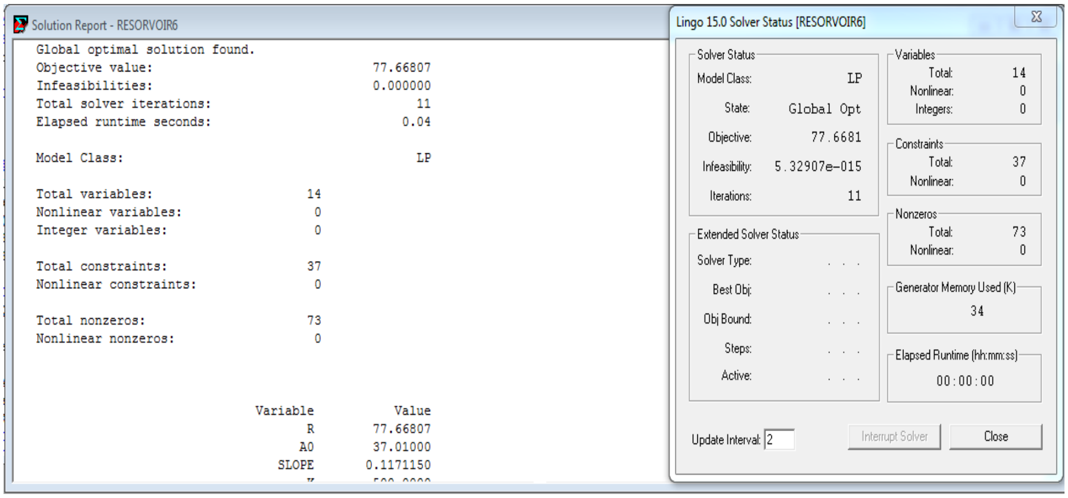


Fig4.17: Lingo Coding for Storage Capacity k=500

OUTPUT



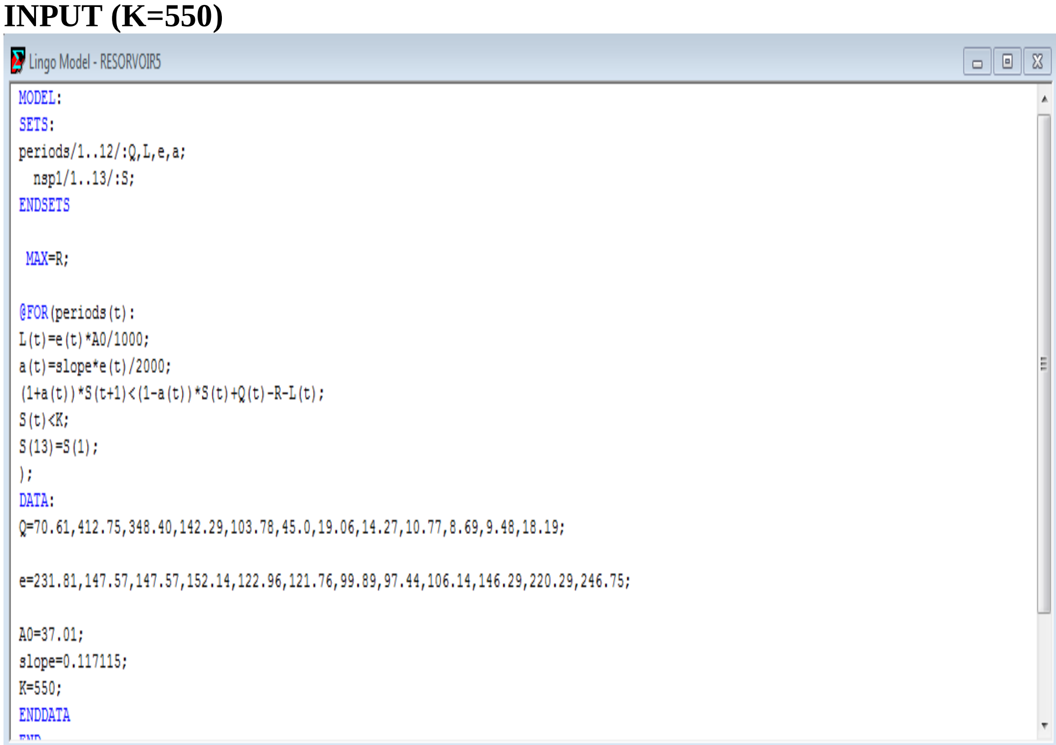
```
Solution Report - RESORVOIR6
Global optimal solution found.
Objective value:                              77.66807
Infeasibilities:                              0.000000
Total solver iterations:                            11
Elapsed runtime seconds:                          0.04

Model Class:                                        LP

Total variables:                     14
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   37
Nonlinear constraints:                0

Total nonzeros:                      73
Nonlinear nonzeros:                   0

                                Variable           Value
                                       R        77.66807
                                      A0        37.01000
                                   SLOPE       0.1171150
```


Fig4.18: Lingo coding output for release

This is the coding of lingo software at storage capacity of 500 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 77.66807 with 11 no of iteration. It takes the total elapsed time of .04sec.

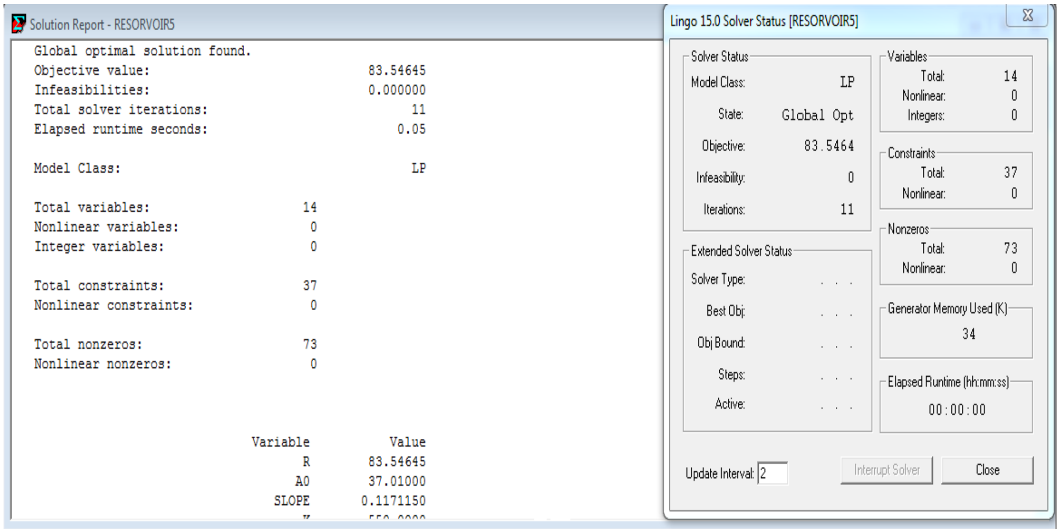
INPUT (K=550)



```
Lingo Model - RESORVOIR5
MODEL:
SETS:
periods/1..12/:Q,L,e,a;
  nsp1/1..13/:S;
ENDSETS

 MAX=R;

@FOR(periods(t):
L(t)=e(t)*A0/1000;
a(t)=slope*e(t)/2000;
(1+a(t))*S(t+1)<(1-a(t))*S(t)+Q(t)-R-L(t);
S(t)<K;
S(13)=S(1);
);
DATA:
Q=70.61,412.75,348.40,142.29,103.78,45.0,19.06,14.27,10.77,8.69,9.48,18.19;

e=231.81,147.57,147.57,152.14,122.96,121.76,99.89,97.44,106.14,146.29,220.29,246.75;

A0=37.01;
slope=0.117115;
K=550;
ENDDATA
```

Fig4.19: Lingo Coding for Storage Capacity k=550

OUTPUT



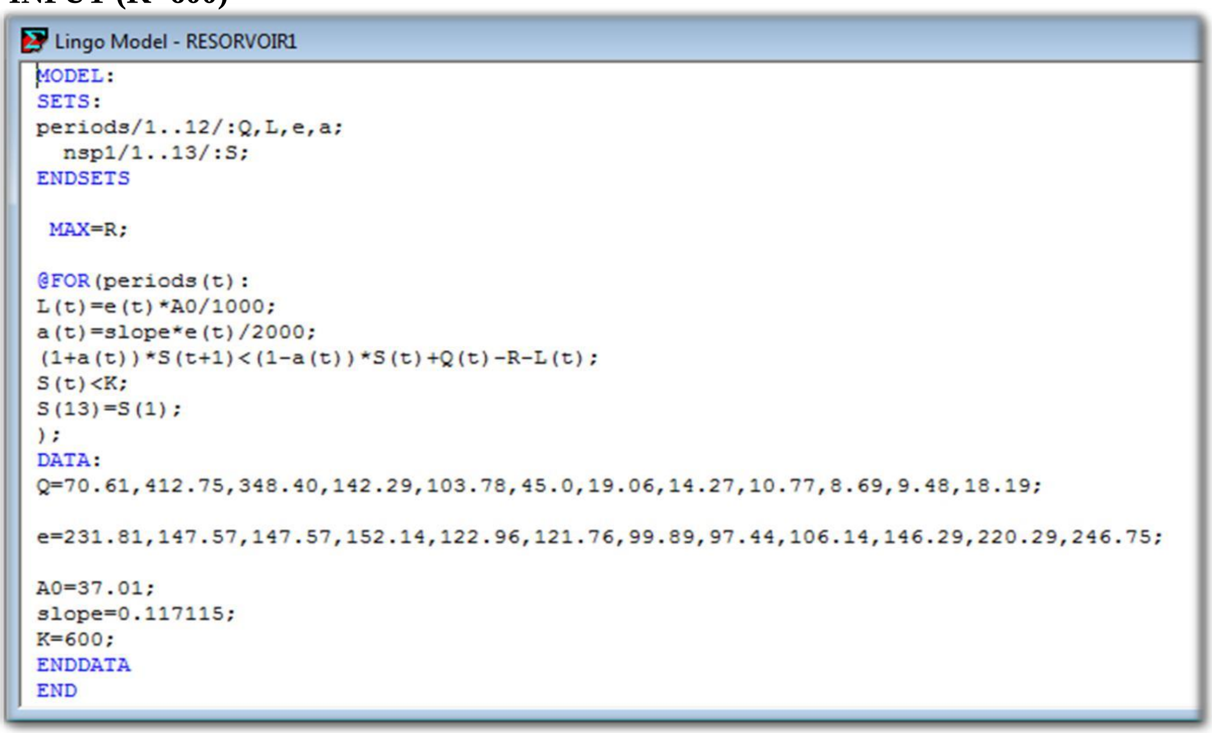

```
Global optimal solution found.
Objective value:                              83.54645
Infeasibilities:                              0.000000
Total solver iterations:                            11
Elapsed runtime seconds:                          0.05

Model Class:                                        LP

Total variables:                    14
Nonlinear variables:                 0
Integer variables:                   0

Total constraints:                  37
Nonlinear constraints:               0

Total nonzeros:                     73
Nonlinear nonzeros:                  0

                          Variable           Value
                                 R        83.54645
                                A0        37.01000
                             SLOPE       0.1171150
```

Fig4.20: Lingo coding output for release

This is the coding of lingo software at storage capacity of 550 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 83.54645 with 11 no of iteration. It takes the total elapsed time of .05sec

INPUT (K=600)




```
MODEL:
SETS:
periods/1..12/:Q,L,e,a;
  nsp1/1..13/:S;
ENDSETS

 MAX=R;

@FOR(periods(t):
L(t)=e(t)*A0/1000;
a(t)=slope*e(t)/2000;
(1+a(t))*S(t+1)<(1-a(t))*S(t)+Q(t)-R-L(t);
S(t)<K;
S(13)=S(1);
);
DATA:
Q=70.61,412.75,348.40,142.29,103.78,45.0,19.06,14.27,10.77,8.69,9.48,18.19;

e=231.81,147.57,147.57,152.14,122.96,121.76,99.89,97.44,106.14,146.29,220.29,246.75;

A0=37.01;
slope=0.117115;
K=600;
ENDDATA
END
```

Fig4.21: Lingo Coding for Storage Capacity k=600

OUTPUT

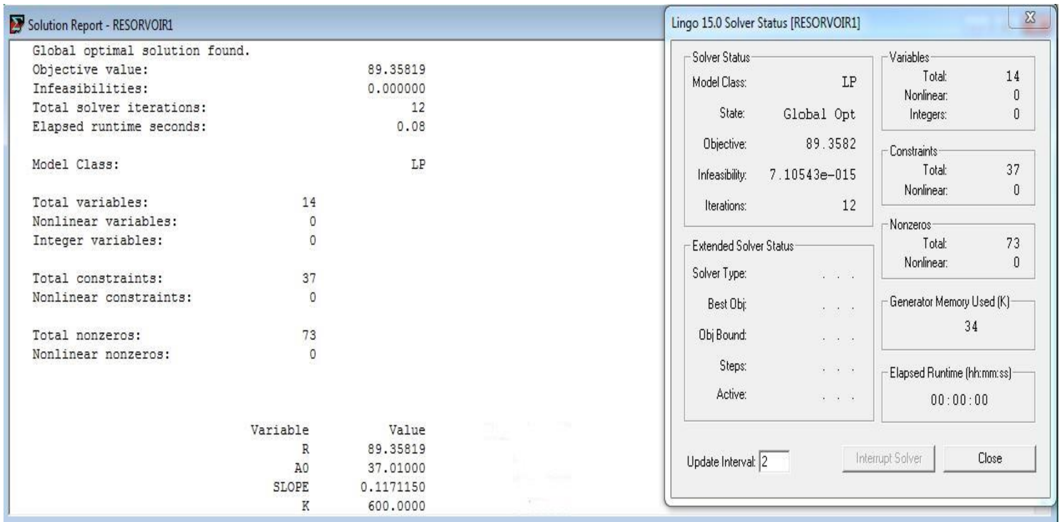
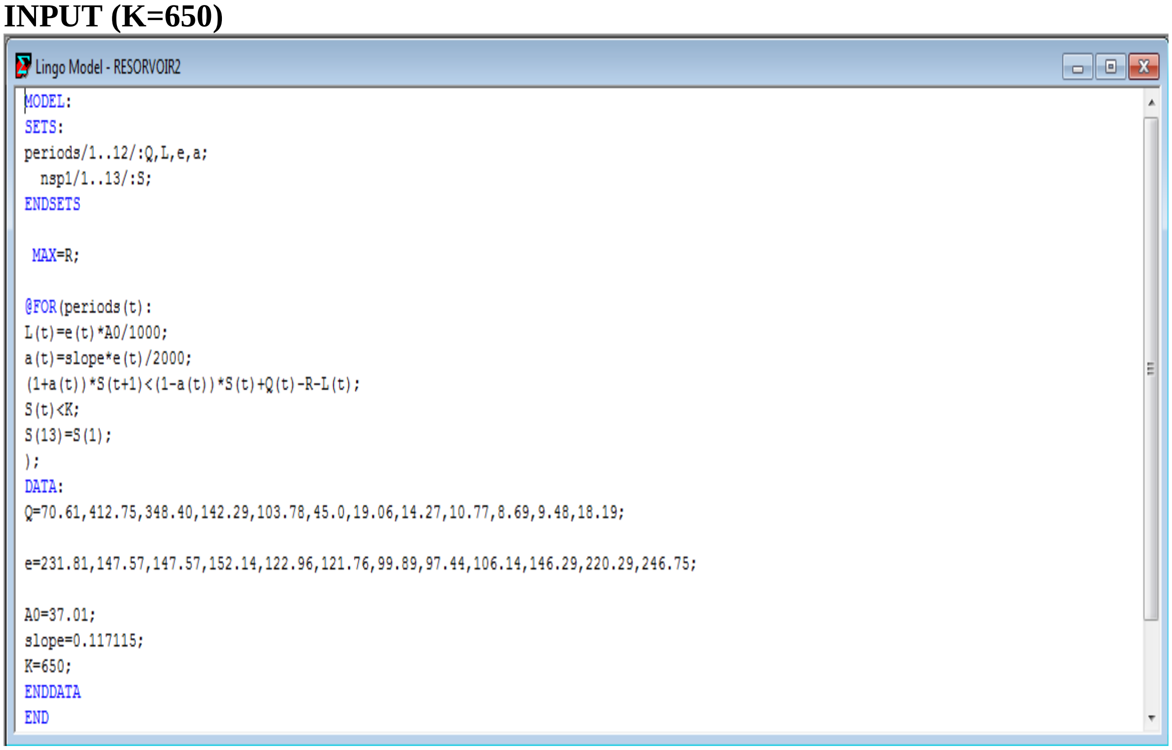


Fig4.22: Lingo coding output for release

This is the coding of lingo software at storage capacity of 600 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 89.35819 with 12 no of iteration. It takes the total elapsed time of .08sec

INPUT (K=650)




```
MODEL:
SETS:
periods/1..12/:Q,L,e,a;
  nsp1/1..13/:S;
ENDSETS

 MAX=R;

@FOR(periods(t):
L(t)=e(t)*A0/1000;
a(t)=slope*e(t)/2000;
(1+a(t))*S(t+1)<(1-a(t))*S(t)+Q(t)-R-L(t);
S(t)<K;
S(13)=S(1);
);
DATA:
Q=70.61,412.75,348.40,142.29,103.78,45.0,19.06,14.27,10.77,8.69,9.48,18.19;

e=231.81,147.57,147.57,152.14,122.96,121.76,99.89,97.44,106.14,146.29,220.29,246.75;

A0=37.01;
slope=0.117115;
K=650;
ENDDATA
END
```

Fig4.23: Lingo Coding for Storage Capacity k=650

OUTPUT

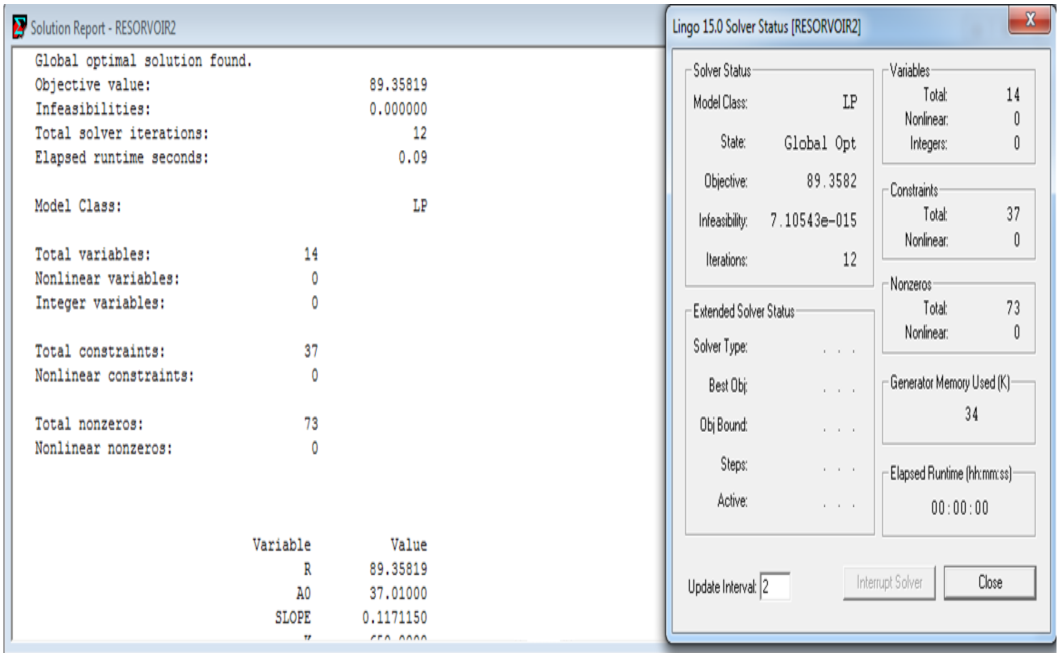


Fig4.24: Lingo Coding for Storage Capacity k=600

This is the coding of lingo software at storage capacity of 600 to find the appropriate value of release with no of iterations and get the solution.

According to software objective value means release value comes 89.35819 with 12 no of iteration. It takes the total elapsed time of .09sec.

By use of software we are getting the release value 39.34,46.13,52.93,59.72,65.91,71.78,77.66,83.54,89.35,89.35,89.35 for storage capacity value of 200,250,300,350,400,450,500,550,600,650,700 respectively.

By the observation we have found that after storage capacity value 600, release value is not changing means it shows constant maximum release value used for irrigation purpose. After storage capacity 600 there is no need to further any increment. If we do so then system will be uneconomical. Here it proves that it depends on storage capacity and inflow value.

4.1.6 CONCLUSION POINT OF MODEL

4.1.6.1 TABLE B/W STORAGE CAPACITY & YIELD

Table4.2: Storage Capacity Corresponding to yield

STORAGE CAPACITY,K (Mm3)	YIELD,R (Mm3)
200	39.34
250	46.13
300	52.93
350	59.72
400	65.91
450	71.78
500	77.66
550	83.54
600	89.35
650	89.35
700	89.35
750	89.35

Storage capacity vs. yield table is shown above .Yield value is increasing from up to down and constant from storage capacity 600 and no value will increase after that it means this is the maximum constant storage value of 89.35 and effective storage capacity is 600.

4.1.6.2 GRAPH B/W STORAGE CAPACITY & YIELD

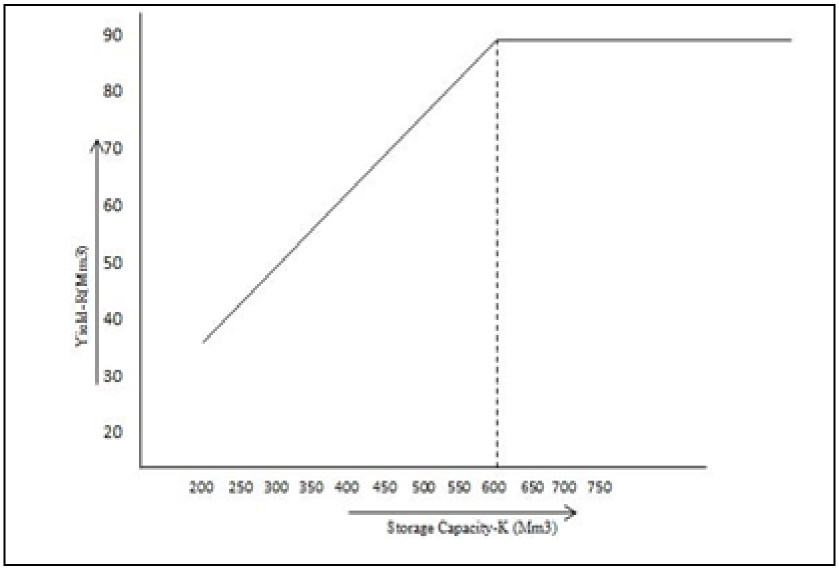


Fig4.25: Yield vs. Storage Capacity Relationship

Graph between yield and storage capacity is shown above .First it comes linear and after one point it goes constant means there is no change in yield with storage capacity. Practically it is not linear that is showing non linearity but performance and execution will be same when using linear programming model. This yield is used for the irrigation purpose.

This software proves that reservoir discharge maximum constant release because it has possible storage capacity that is critical storage capacity.

Maximum Constant Release =**89.35**Mmm^3 K=**600**

4.1.6.3 TABLE B/W STORAGE CAPACITY & RELIABILITY

Table4.3: Storage Capacity Corresponding to Reliability

STORAGE CAPACITY,K	**YIELD**	**RELIABILITY(%)**
200	39.34	
250	46.13	(39.35÷46.13)×100 =85.28
300	52.93	(46.13÷52.93)×100 =87.15
350	59.72	(52.93÷59.72)×100 =88.63
400	65.91	(59.72÷65.91)×100 =90.60
450	71.78	(65.91÷71.78)×100 =91.82
500	77.66	(71.78÷77.66)×100 =92.42
550	83.54	(77.66÷83.54)×100 =92.96
600	89.35	(83.54÷89.35)×100 =93.49
650	89.35	(89.35÷89.35)×100 =100

4.1.6.4 GRAPH B/W STORAGE CAPACITY & CHANGE IN RELEASE

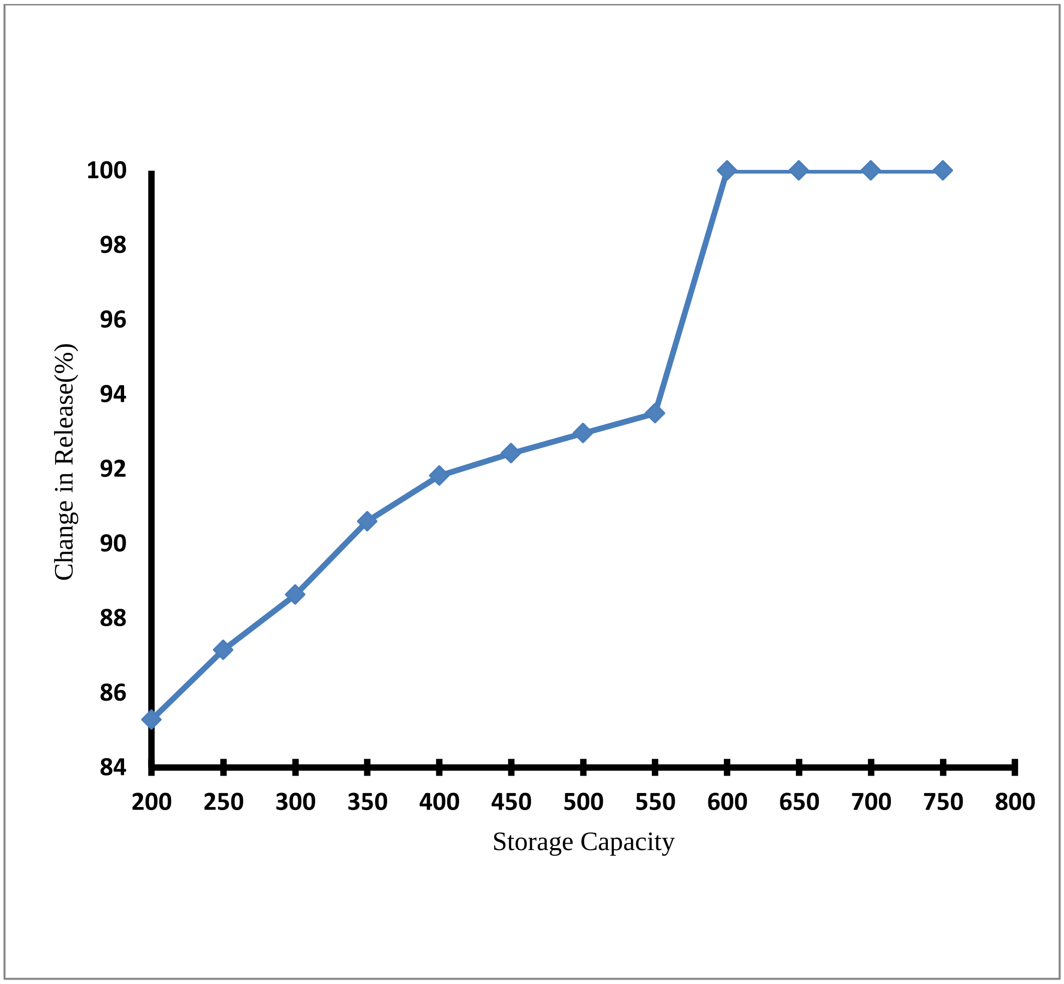


Fig4.26: Change in release vs. Storage Capacity Relationship

We can plot the graph between storage capacity and reliability to check the reliable release value from the previous release.And then graph obtained is a increasing graph and will constant after a certain storage capacity value.

Reliability value will increase according to the storage capacity increase and after the particular storage it will be constant means 100% as a maximum constant release.So according to the storage capacity & reliability we can design the reservoir for year to year .

4.1.6.5 TABLE B/W STORAGE CAPACITY & ECONOMIC VALUE

Storage capacity	Economic value(%)
200	19.67
250	18.45
300	17.64
350	17.06
400	16.47
450	15.95
500	15.53
550	15.18
600	14.89
650	13.76
700	12.76
750	11.91

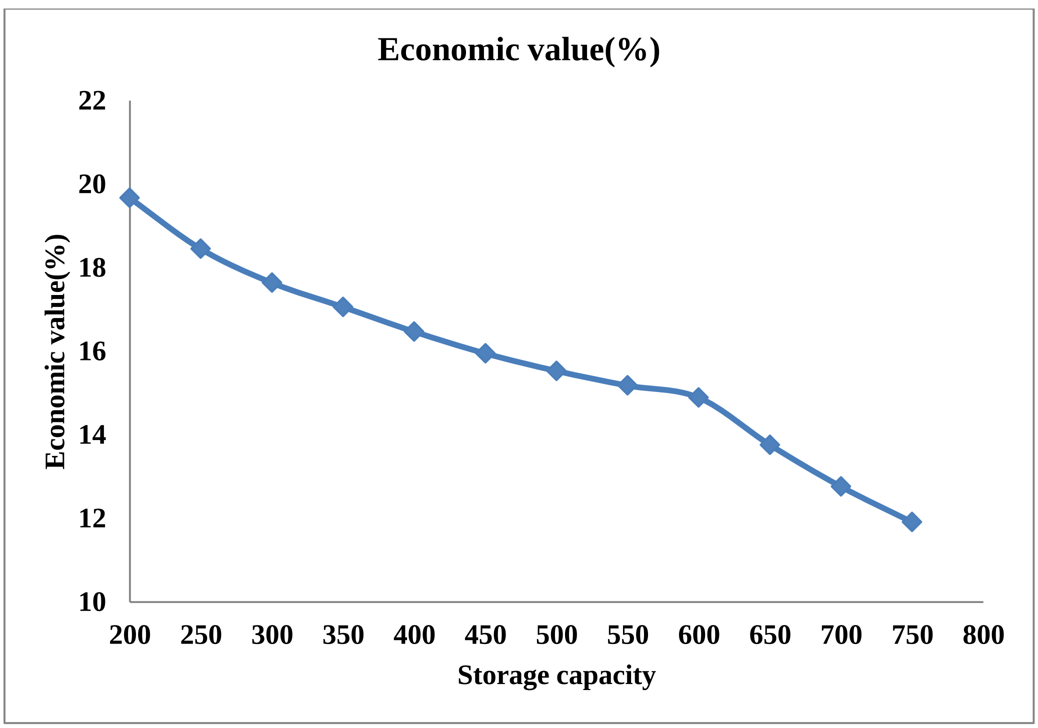


Fig4.28:Graph between economic value vs. storage capacity

4.2 OBERVATION FOR MULTI RESERVOIR

For observation of multi reservoir we observed the data of Damodar Valley Corporation .It is also known as DVC.This is a governmental organization. It operates many power stations in Damodar river and are covers the Jharkhand & West Bengal. It operates both thermal & hydel power station. The head quarter of Damodar Valley Corporation in west Bengal, Kolkata.

It has four multipurpose multi reservoir

- Maithon Dam
- Panchet Dam
- Tilaiya Dam
- Konar Dam

Talaiya Dam and Konar Dam are in parallel and panchet dam are in series with both dams.That's why analysis of Tailaiya Dam & Konar Dam are done simultaneously then after this results from these both reservoir are merged with Panchet Dam. These Dams are multipurpose used for irrigation, flood control, and hydropower purpose. Positions of these reservoirs have been shown in below map and diagram.

Flood reserve capacity has been given 1292 mcm by these four reservoir it can moderate a flood(peak) 18395 cumec.and it has a safe carrying capacity of 7076 Cumecs.

It has command area 24235 km^2 expand across Damodar river used to generate and transmit the power. These Dams are multipurpose used for irrigation, flood control, and hydropower purpose. Positions of these reservoirs have been shown in below map and diagram.

4.2.1 DATA OBTAINED FOR MULTI RESERVOIR[26]

Table Seasonal Data for Multi reservoir with benefits

RESERVOIR	INFLOW			K	F_{min}			B_1^*	B_2^*	B_3^*
	Rainy	Winter	Summer		Rainy	Winter	Summer			
Tilaiya Dam	25	10	15	10	3	2	7	50	10	25
Konar Dam	10	30	15	15	2	3	4	60	10	30
Panchet Dam	20	12	15	20	2	3	5	70	10	35

$\alpha_1=0.2$ $\alpha_2=0.3$

α_1, α_2=Fraction of release that joins the downstream reservoir from reservoir Tilaiya Dam and Konar Dam

INFLOW in Mm^3

K=STORAGE CAPACITY in Mm^3

$\mathbf{F_{min}}$ = MIN FLOOD FREE BOARD in Mm^3

$\mathbf{B_1^*}$ =BENEFIT OBTAINED FROM IRRIGATION in Mm^3

$\mathbf{B_2^*}$ = BENEFIT OBTAINED FROM FLOOD CONTROL in Mm^3

$\mathbf{B_3^{*}}$ = BENEFIT OBTAINED FROM HYDRO POWER IN MW

The above data has been taken from DVC (Damodar Valley Corporation) under the commission of central water.

DVC has the network of four dams:

TILAIYA dam & MAITHON dam on BARAKAR River

PANCHET reservoir on DAMODAR River

KONAR reservoir on KONAR River

In the table three reservoir data is given in which seasonal(rainy,winter,summer) inflow value are mentioned corresponding flood free board value and benefits in all the season is given. Flood free board is decided to provide the buffer storage. It is used during the flood control to fulfill the criteria of excess inflow

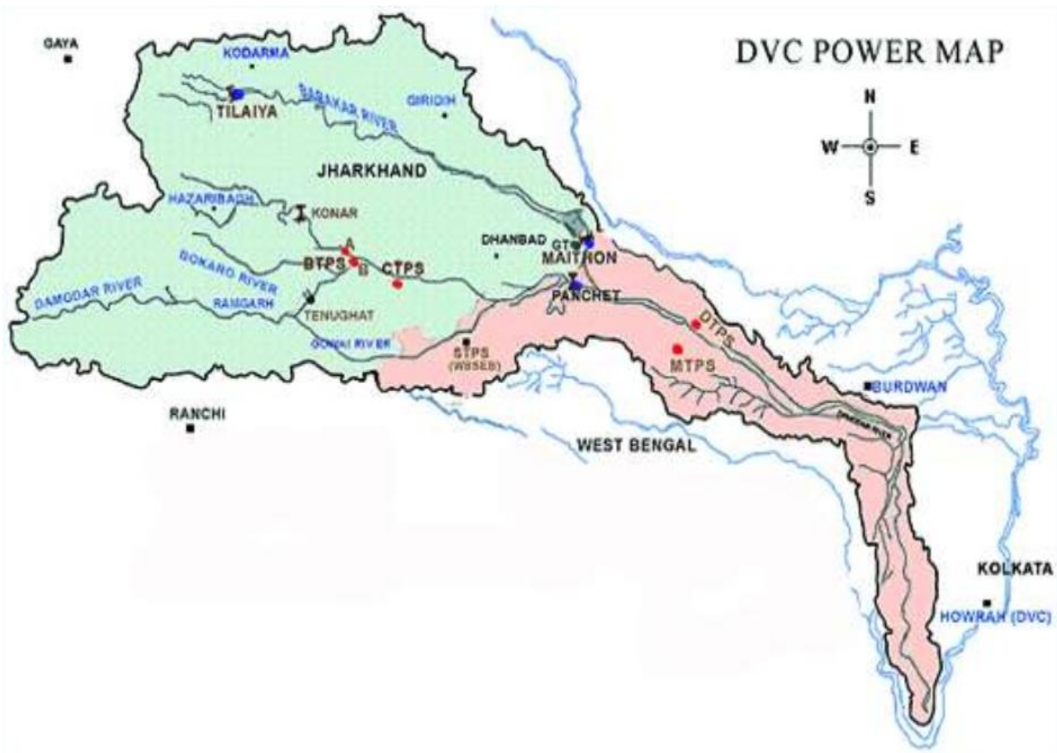


FIG4.27: DVC MAP

This is mapping of DVC shows the location of the entire four reservoirs and finally these rivers meets on Bay of Bengal.

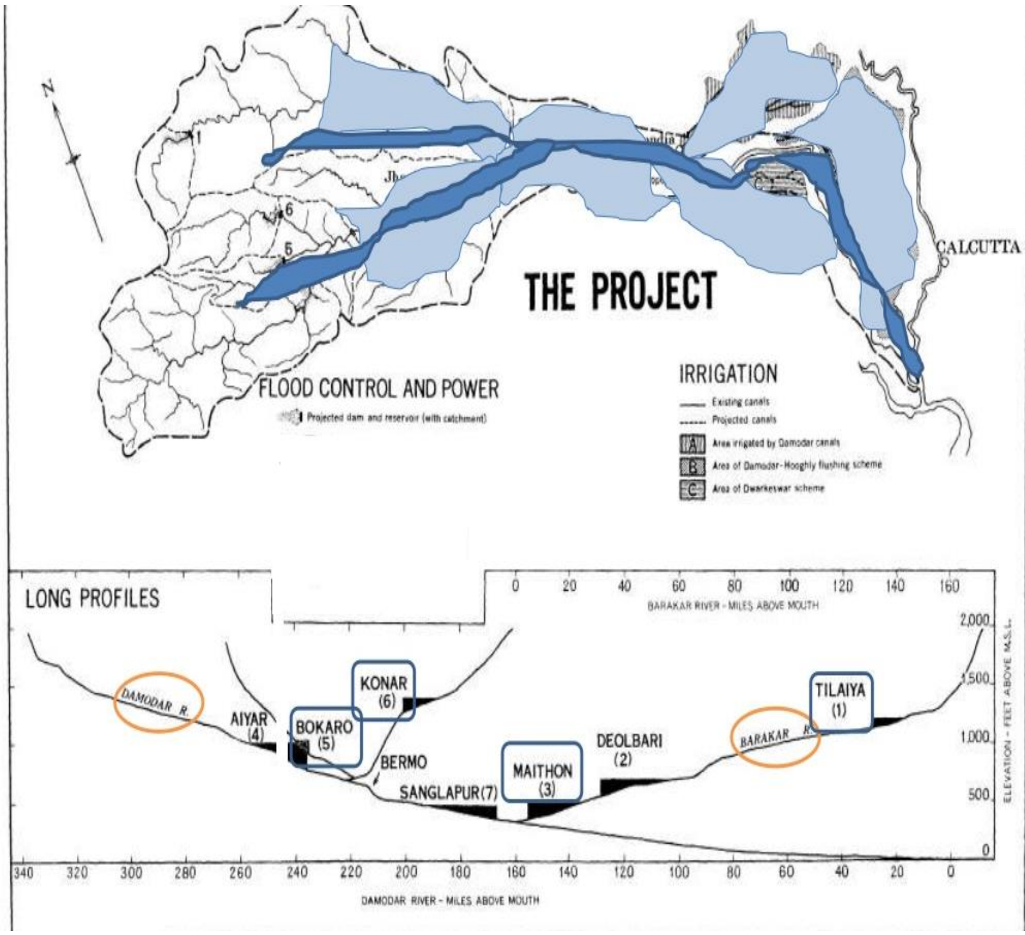


Fig4.28: Positions Of Dams With Long Profiles

Talaiya Dam and Konar Dam are in parallel and panchet dam are in series with both dams.

That's why anlaysis of Tailaiya Dam & Konar Dam are done simultaneously then after this results from these both reservoir are merged with Panchet Dam.

These Dams are multipurpose used for irrigation, flood control, and hydropower purpose.

Positions of these reservoirs have been shown in above map and diagram.

In the above diagram positions of dams with long profiles has been shown.

In figure dark blue shows the Talaiya dam & Konar dam are in parallel and Panchet dam are in series with both.

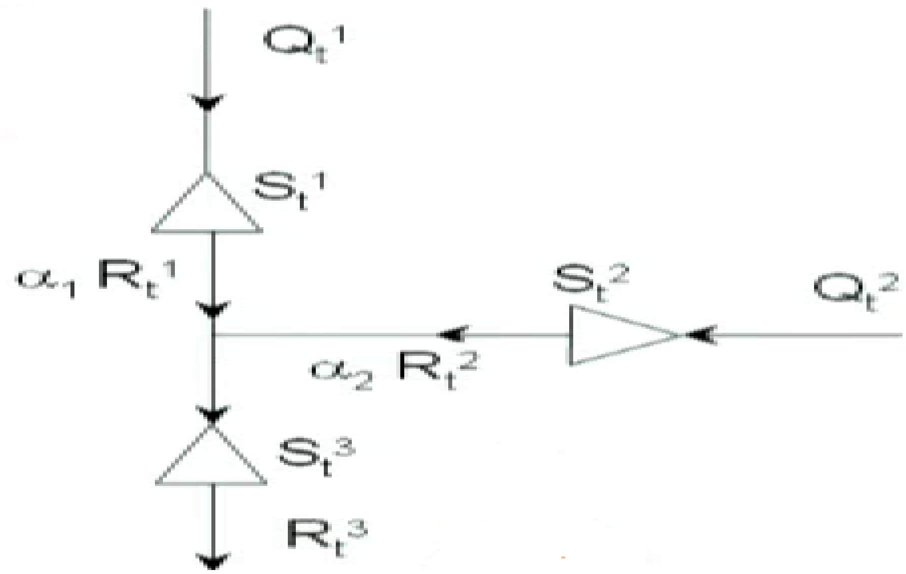


Fig4.29: Schematic view of multi reservoir

This is the schematic view of multi reservoir where two reservoirs in parallel and last one is in the series of these two according to the arrow notation.

Inflow, storage value have been shown in the diagram and release coming from reservoir 1&2 is taken by reservoir 3 in the fraction part of release .It is the coefficient α_1, α_2 multiplied by release 1 and release 2.

Then it is combined with reservoir 3 and its own catchment and then we make the inequality constraint.

4.2.2 OBJECTIVE FUNCTION & INEQUALITY CONSTRAINT

It is also called aggregated or comprehensive objective function for entire system together

$$\text{Max} \sum^{i=3}\sum^{t=3}[B_1 * R_t^i + B_2 * (K_t - S_t^i) + B_3 * S_t^i]$$

$$S_{t+1}^i = S_t^i + Q_t^i - E_t^i - R_t^i \qquad i=1,2 \quad t=1,2,3$$

$$S_{t+1}^i = S_t^i + Q_t^i - E_t^i - R_t^i + \alpha_1 R_t^1 + \alpha_2 R_t^2 \qquad i=3 \quad t=1,2,3$$

$$S_t^i < K_t \qquad i=1,2,3 \quad t=1,2,3$$

$$(K_t - S_t^i) >= F_{min}^i \qquad i=1,2,3 \quad t=1,2,3$$

$\mathbf{R_t^i <= R_{max}^t}$ **t=1,2,3**

$\mathbf{R_t^i >= 0}$ **t=1,2,3**

$\mathbf{S_3^i = S_1^i}$

The flow of water from one point to any other point is given by storage continuity equation.

For Konar and Tailiya dam we write together equation because they don't have any control structure of it.So we write for first and second for time period t .It give straight forward continuity equation.

When we come for Panchet dam then it matters that what is coming from konar and tailiya dam that is $\boldsymbol{\alpha_1}$ **&** $\boldsymbol{\alpha_2}$ taken as consideration .It has the meaning what fraction of release is coming from up reservoir. It also has the natural flow contributed by the catchment also called free catchment.

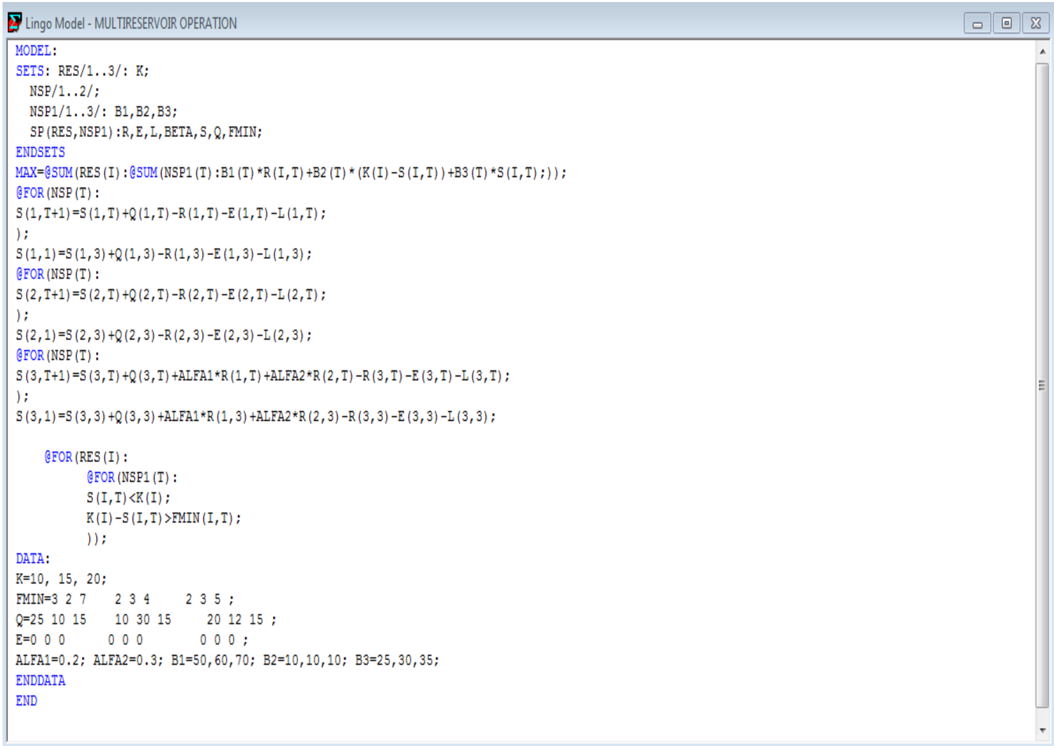
A minimum flood free board is provided and for each of these time period this term must be greater than this min value.

We are looking for optimal combination of storage as well as releases.

This is the linear programming model because objective function is linear and all the constraints are linear. So we can use Linear Programming Model.

4.2.3 RESULTS FROM SOFTWARE

INPUT



```
Lingo Model - MULTIRESERVOIR OPERATION
MODEL:
SETS: RES/1..3/: K;
  NSP/1..2/;
  NSP1/1..3/: B1,B2,B3;
  SP(RES,NSP1):R,E,L,BETA,S,Q,FMIN;
ENDSETS
MAX=@SUM(RES(I):@SUM(NSP1(T):B1(T)*R(I,T)+B2(T)*(K(I)-S(I,T))+B3(T)*S(I,T);));
@FOR(NSP(T):
S(1,T+1)=S(1,T)+Q(1,T)-R(1,T)-E(1,T)-L(1,T);
);
S(1,1)=S(1,3)+Q(1,3)-R(1,3)-E(1,3)-L(1,3);
@FOR(NSP(T):
S(2,T+1)=S(2,T)+Q(2,T)-R(2,T)-E(2,T)-L(2,T);
);
S(2,1)=S(2,3)+Q(2,3)-R(2,3)-E(2,3)-L(2,3);
@FOR(NSP(T):
S(3,T+1)=S(3,T)+Q(3,T)+ALFA1*R(1,T)+ALFA2*R(2,T)-R(3,T)-E(3,T)-L(3,T);
);
S(3,1)=S(3,3)+Q(3,3)+ALFA1*R(1,3)+ALFA2*R(2,3)-R(3,3)-E(3,3)-L(3,3);

    @FOR(RES(I):
         @FOR(NSP1(T):
         S(I,T)<K(I);
         K(I)-S(I,T)>FMIN(I,T);
         ));
DATA:
K=10, 15, 20;
FMIN=3 2 7    2 3 4     2 3 5 ;
Q=25 10 15    10 30 15     20 12 15 ;
E=0 0 0      0 0 0        0 0 0 ;
ALFA1=0.2; ALFA2=0.3; B1=50,60,70; B2=10,10,10; B3=25,30,35;
ENDDATA
END
```

Fig4.30: Coding of Lingo to Maximize Release

OUTPUT

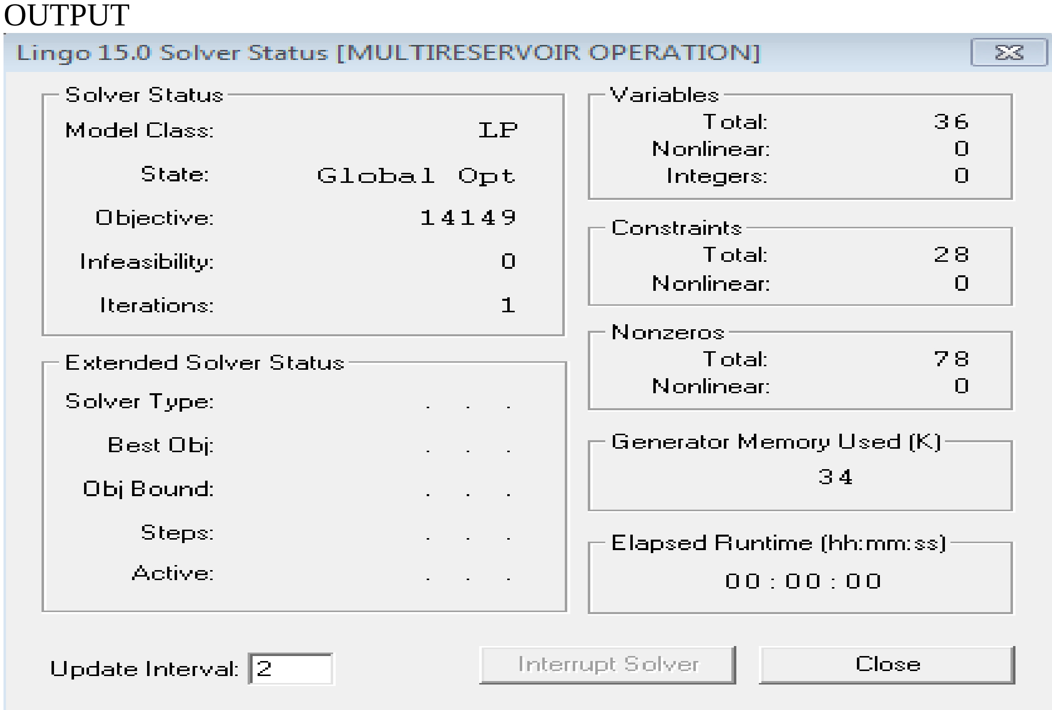


Fig4.31: Output for Global Objective Function

Global optimal solution found.

Objective value:	14149.00
Infeasibilities:	0.000000
Total solver iterations:	1
Elapsed runtime seconds:	0.09
Model Class:	LP
Total variables:	36
Nonlinear variables:	0
Integer variables:	0
Total constraints:	28
Nonlinear constraints:	0
Total nonzeros:	78
Nonlinear nonzeros:	0

Variable	**Value**
ALFA1	0.2000000
ALFA2	0.3000000
K(1)	10.00000
K(2)	15.00000
K(3)	20.00000
B1(1)	50.00000
B1(2)	60.00000
B1(3)	70.00000
B2(1)	10.00000
B2(2)	10.00000
B2(3)	10.00000
B3(1)	25.00000
B3(2)	30.00000

B3(3)	35.00000
R(1, 1)	17.00000
R(1, 2)	15.00000
R(1, 3)	18.00000
R(2, 1)	0.000000
R(2, 2)	31.00000
R(2, 3)	24.00000
R(3, 1)	6.400000
R(3, 2)	26.30000
R(3, 3)	40.80000
E(1, 1)	0.000000
E(1, 2)	0.000000
E(1, 3)	0.000000
E(2, 1)	0.000000
E(2, 2)	0.000000
E(2, 3)	0.000000
E(3, 1)	0.000000
E(3, 2)	0.000000
E(3, 3)	0.000000
L(1, 1)	0.000000
L(1, 2)	0.000000
L(1, 3)	0.000000
L(2, 1)	0.000000

L(2, 2)	0.000000
L(2, 3)	0.000000
L(3, 1)	0.000000
L(3, 2)	0.000000
L(3, 3)	0.000000
BETA(1, 1)	0.000000
BETA(1, 2)	0.000000
BETA(1, 3)	0.000000
BETA(2, 1)	0.000000
BETA(2, 2)	0.000000
BETA(2, 3)	0.000000
BETA(3, 1)	0.000000
BETA(3, 2)	0.000000
BETA(3, 3)	0.000000
S(1, 1)	0.000000
S(1, 2)	8.000000
S(1, 3)	3.000000
S(2, 1)	2.000000
S(2, 2)	12.00000
S(2, 3)	11.00000
S(3, 1)	0.000000
S(2, 3)	11.00000
S(3, 1)	0.000000
S(3, 2)	17.00000
S(3, 3)	15.00000
S(3, 3)	15.00000
Q(1, 1)	25.00000

Q(1, 2)	10.00000
Q(1, 3)	15.00000
Q(2, 1)	10.00000
Q(2, 2)	30.00000
Q(3, 1)	20.00000
Q(3, 2)	12.00000
Q(3, 3)	15.00000
FMIN(1, 1)	3.000000
FMIN(1, 2)	2.000000
FMIN(1, 3)	7.000000
FMIN(2, 1)	2.000000
FMIN(2, 2)	3.000000
FMIN(2, 3)	4.000000
FMIN(3, 1)	2.000000
FMIN(3, 2)	3.000000
FMIN(3, 3)	5.000000

By use of lingo software we get the solution of this multipurpose multi reservoir.
Here release and storage after integrity of the reservoir get its optimize value.
Software calculates objective function value 14149.It provides the Global Optimal solution with infeasibility zero. It also shows total no of variables 36 with total no of constraints 28 and total no of non-zeros is 78.It gives the data with one solver iteration and elapsed runtime .03 sec.
Software iterates the variable and gives the appropriate value already shown above in the form of table of variable & value.
In the table the value closed in the bracket denotes the reservoir and season respectively.

Like R(1,1)=17.0000,it shows first reservoir in rainy season gives the optimize release of 17 Mmm^3

Q(1,2)=10,it shows first reservoir in winter season has the average inflow value of 10 Mmm^3

S(2,3)=11.000,it shows second reservoir in summer season after optimization gets the value 11 Mmm^3

F_{min}(3,2)=3.0000,it shows third reservoir in winter season min flood free board in Mm^3

B1(1)=50.0000,it shows benefit corresponding to first reservoir

K(1)=10.0000,it shows storage capacity of first reservoir

ALFA1=0.2000, it shows fraction of release coming from reservoir1 goes to reservoir3

E(3,1)=0.0000,it shows evaporation loss of third reservoir in rainy season gives value 0

This is the meaning of material written in tabular form.

Objective function is also called aggregated or comprehensive function for entire System together.

4.2.4 OUTPUT IN TABULAR FORM

Table output for multi reservoir system in different season

	Tilaiya Dam			Konar Dam			Panchet Dam		
	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer
S_t	0	8	3	2	12	11	0	17	15
R_t	17	15	18	0	31	24	6.4	26.3	40.8
$(K-S_t)$	10	2	7	13	3	4	20	3	5

Above tabular form shows the optimization of multi reservoir system with respect to release, storage, possible flood free board with exact value. For Tilaiya dam the storage for all the season comes in optimized form .Same the process for Konar dam and Panchet dam in rainy,winter,summer.

The corresponding release value is also optimized for the entire reservoir in different season .This is the release used for irrigation purpose and obtained storage is used for hydropower to make a head.

In problem flood free board we are taking as a min but were not sure how the proper value is when we optimize with the help of software the we get exact value for all reservoir in different season.

Now at last it is necessary to check the result whether it is correct iterate by the software and accuracy of the software.

If we use the continuity equation then add the inflow and storage and subtract release then the value obtained will be the storage value of next season and from the table it is showing correct whether it is Konar dam or Panchet dam or Tailiya dam for different season.

4.2.5 GRAPHICAL REPRESENTATION

FOR TILIAYA DAM

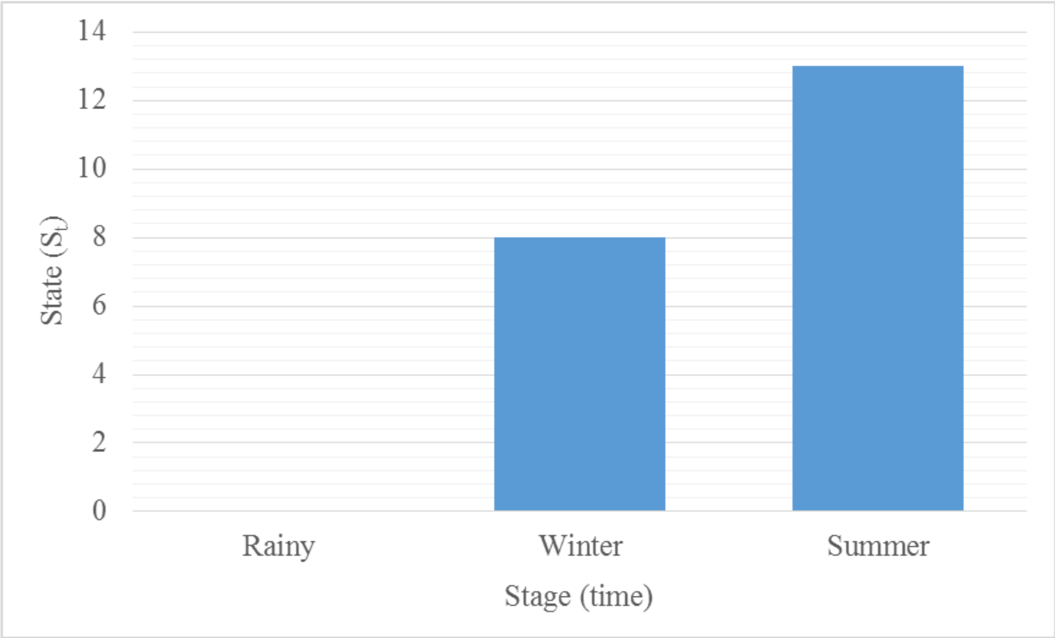


Fig4.32:Graph Time vs. Storage for Tiliaya Dam

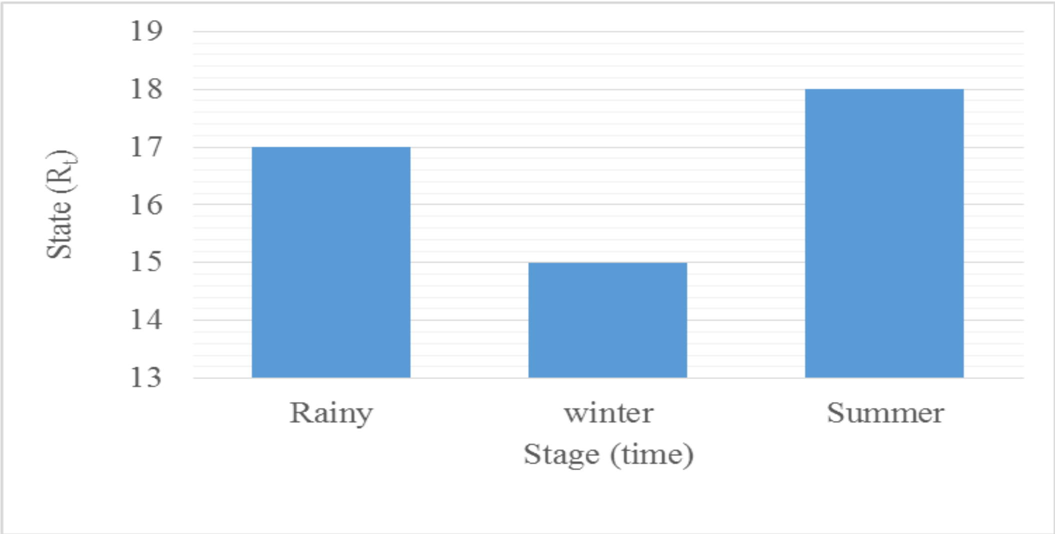


Fig4.33:Graph Time vs. Release for Tiliaya Dam

Above graphs are shown between time vs. release & time vs. storage .This is the optimized value of storage & release when it comes in integrity with other reservoir. At rainy season the reservoir is empty. All release & storage value is in Mmm3

FOR KONAR DAM

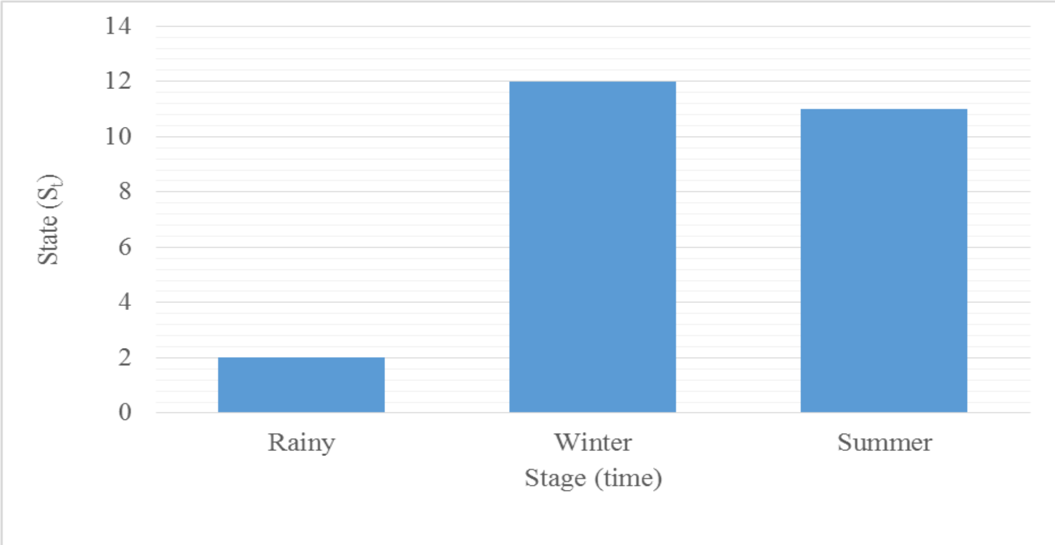


Fig4.34:Graph Time vs. Storage for Konar Dam

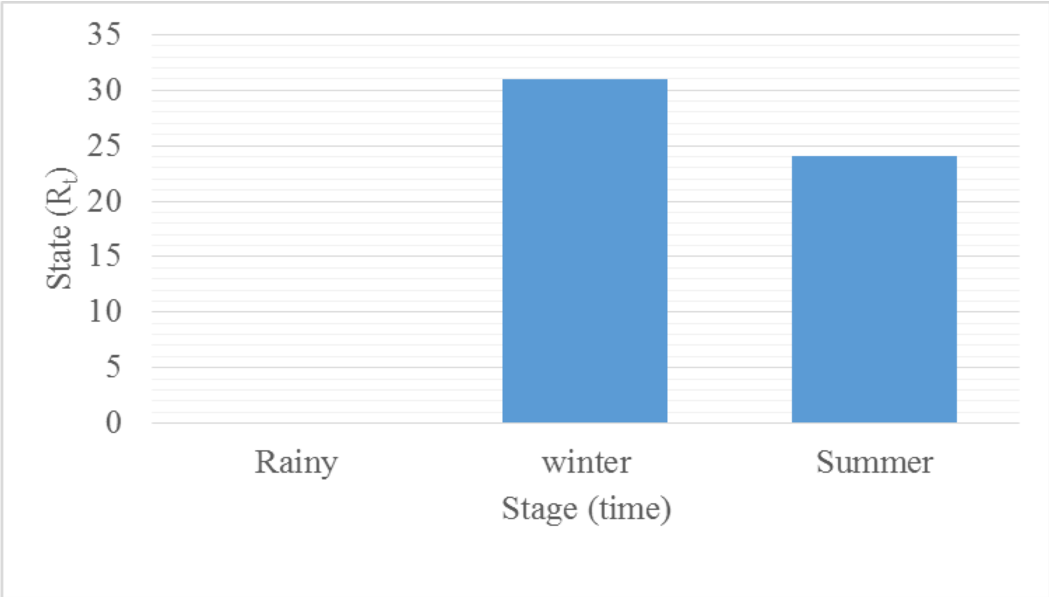
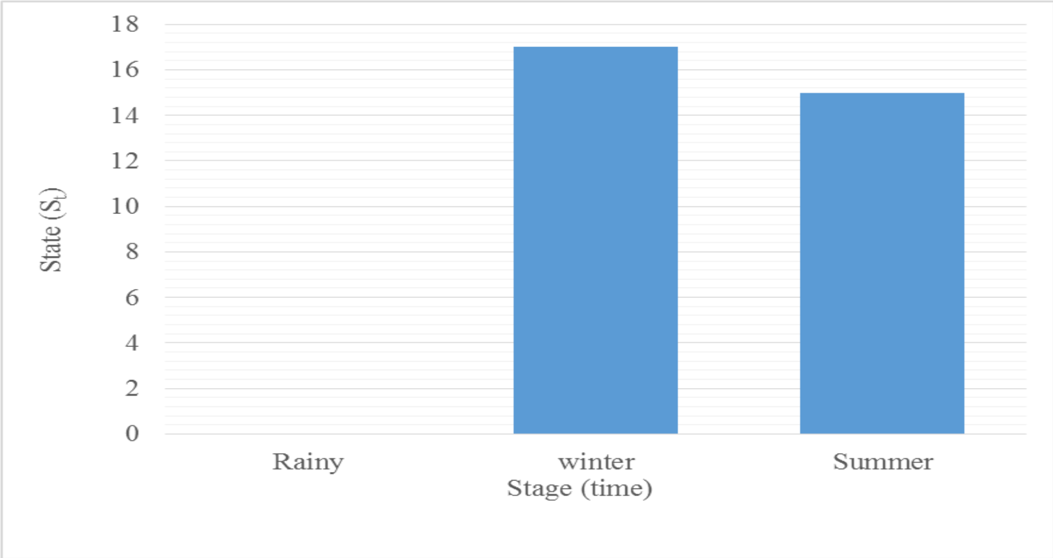


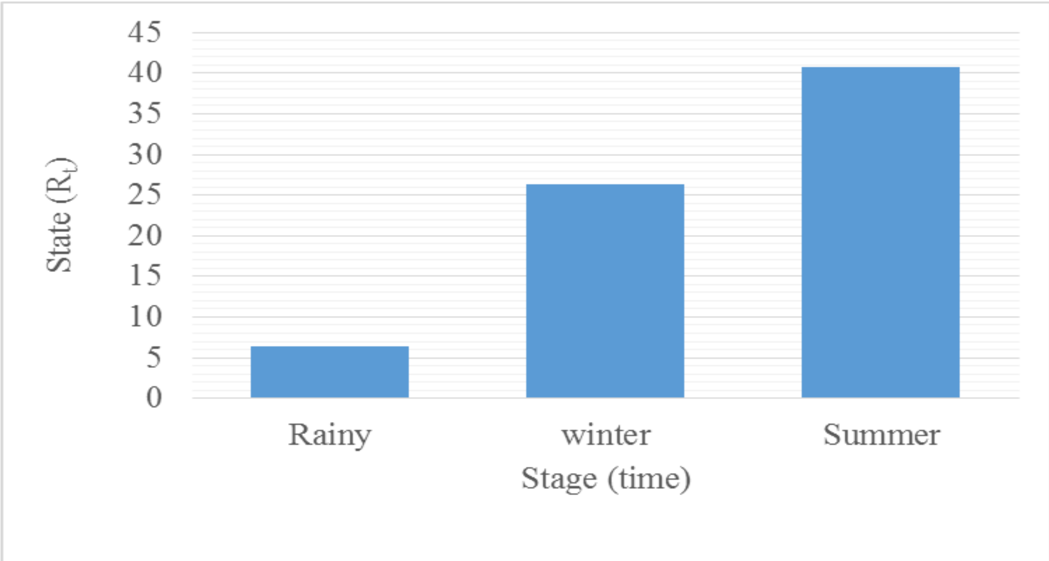
Fig4.35:Graph Time vs. Release for Konar Dam

Above graphs are shown between time vs. release & time vs. storage .This is the optimized value of storage & release when it comes in integrity with other reservoir. At rainy season storage is partially full and there is no release. All release & storage value is in Mmm3.

FOR PANCHET DAM



Graph Time vs. Storage for Panchet Dam



Graph Time vs. Release for Panchet Dam

Above graphs are shown between time vs. release & time vs. storage .This is the optimized value of storage & release when it comes in integrity with other reservoir. At rainy season reservoir is empty. All release & storage value is in Mmm3.

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