Optimization Technique for Determining Reservoir Capacity

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Abstract- **Sustainability of reservoirs implies a need for the control and adjustment of reservoir planning and operation characteristics, resulting in optimal, or near optimal system performance throughout the life time of the reservoir. However, the construction of a reservoir has need of large costs; optimum dimensioning of such storage facilities is very significant together with the optimal operation. The main objective of the present study is to find out the active storage capacity and operate the reservoir in an optimal way. Because of the complications in water resource systems and various constraints, it seems essential to develop mathematical models and optimization techniques to calculate the reservoir capacity in an optimal way. In this study, to find the optimum active storage capacity of Mula reservoir, a deterministic linear programming is introduced. The developed model is solved by LINGO 17.0 software that gives the minimum reservoir volume of 457.71 MCM.**

.Keywords — Linear Programming (LP), Optimization techniques, Reservoir planning, LINGO. 17.

I. INTRODUCTION

Today's world is very concerned with water problems. As the water eligible for different human usages became scare in terms of quality and quantity, more attention is given to sustain the available water resources, and that can be achieved by adopting more efficient water utilization methods and optimal planning and operation of water resources projects. As water resources have been inadequate in India and constructing hydraulic structures expenses more, so there is requirement to have optimal capacity and operation for reservoir system. Because of the complication in water resources systems and the existence of various constraints and restrictions, applications of mathematical models and optimization methods for determining the optimum reservoir storage volume are needed.

The reservoir scheduling and operational studies, which had made progress in current decades, were depends on Rippl's graphical method. The limitation of this technique, which could only consider a constant need, was corrected by Thoma's Sequent Peak algorithm. The designing of capacity of water reservoir systems and their operation are multi-variable decision problems. Dorfman firstly proposed the idea of Linear Programming (LP) optimization model to resolve the complications. Afterward Yeh's [1] study developed a Linear Programming (LP) and Dynamic Programming (DP) models have been widely used for solving the problems in water resource engineering. Sattari and Kodal [2] proposed a concept of deterministic mathematical model's applications in optimizing the capacity of small irrigation reservoir. Susom Dutta [3] developed a mathematical LP model to determine the reservoir capacity. Asvini and Amudha [4] proposed a deterministic optimization technique for optimal release from the Thirumurthi and Amravathi reservoirs. Hurst H. E [5] also evaluated the model for long- term storage capacity of reservoir. P. Krishan and Durgunoglu Ali [6] developed a new optimization method for deciding reservoir storage for future uses. Yeh and W.G [7] developed a simulation model for the management and operational of reservoir in failure years. Sawunyama et al. [8] estimated the storage capacity of small reservoir in Limpo river basin using the GIS.

In the present study, a model is formed for minimizing the active storage capacity to meet given demands from the available historical deterministic inflows. Linear programming (LP) is successfully applied to the models i.e., model for the minimum storage capacity.

II. METHODOLOGY

Linear programming (LP) is one of the greatest broadly used practices in the field of water resources management. It is related to solve a special type of difficulties: one in which all relations between the variables are linear, both in

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constraints and in the objective function to be optimized. Linear Programming is a substitute and more elegant routine to sequent peak method and Ripple method. One hypothesis is being taken in this study that the inflows are deterministic, In Linear Programming model, the rate of evaporation loss function can be simply integrated into the storage continuity relationship by the linearity assumption. There are two basic set of constraints that to be satisfied here, first one relates to storage continuity and the other one is related to capacity.

A. Model Formation

The operating model comprises of:

1. Continuity constraint.
2. Release restriction constraints.
3. Variable restriction constraints
4. Objective function.

B. Objective Function

The objective function of the model is to determine the minimum storage capacity.

Minimize, K_a. (1)

C. Continuity Constraint

The necessary condition of an optimization model to determine the reservoir storage capacity is the mass balance or continuity equation.

$$S_t + Q_t - R_t - L_t = S_{t+1} \qquad \forall t \qquad (2)$$

D. Maximum Storage Constraint

Reservoir capacity will not be exceeded in any time duration.

$$S_t \le K_a \qquad \forall t$$
(3)

E. Variable Restriction Constraints

$$S_t \ge 0; \;\; K_a \ge 0$$
(4)

Where, R_t is release at time, t, Q_t is known inflow at time, t, L_t is estimated storage loss at time, t, S_t is storage at the beginning of period, t, S_{t+1} is the storage at the end of period, t, K_a is active storage and dead storage capacity respectively.

III. Incorporation of Evaporation Loss

In case that evaporation volume is a function of surface-area of the reservoir which, in turn, depends on the reservoir storage, one can integrate the storage-area relationship in the optimization model. The storage-area correlation is computed by performing topographical investigations so as to determine the storage capacities and surface area for different elevations. Practically for all the reservoir sites, the correlation between storage capacity and surface area is nonlinear in nature. Consequently, the model represents non-linear optimization model. The non-linear storage-area correlation can be approached by a linear function to make easy implementation of linear programming. Thus, loss can be simplified using the linear approximation.

Total Evaporation rate in period 't' is given by the following equation.

$$E_t = e_t\left[A_0 + a\left(\frac{S_t + S_{t+1}}{2}\right)\right]$$

$$E_t = L_t + a_t\,(S_t + S_{t+1}) \qquad \forall t \qquad (5)$$

Where, L_t is the fixed evaporation loss = $A_0\ e_t$, e_t is the rate of evaporation in period t in meters, 'a' is the area per unit active storage above A_0, A_0 is the water surface area at the top of the dead storage level

IV. Study Area: Mula Project

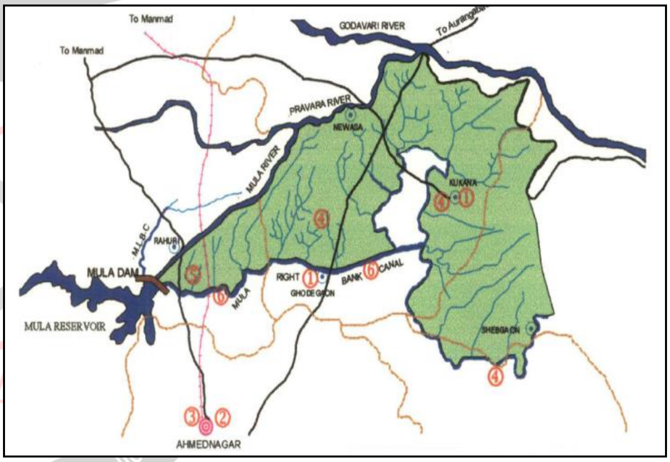

Figure 1: Image shows Mula project location

The Mula project is a significant irrigation system project on the stream Mula, a stream of Paravara that is a sub-tributary of Godavari. The multipurpose undertaking gives water system, water supply to Ahmednagar city, water supply to businesses and towns. The total annual water requirement is 748.52 million cubic meters (MCM) out of which the annual water supplies requirements is 73.92 MCM and annual irrigation water requirement is 674.6 MCM.

In this study the required data (18 years' average inflows to the reservoir, various demands from the reservoir i.e., Demands for village water supply (VWS), demands for city water supply (CWS), demands for industrial water (IWS), water supply for sugar factory (SF), water supply for Mahatma Phule Agricultural university (MP), water supply for Lift irrigation (LI) and water supply for major

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irrigation (IR)), water spread area vs. storage relationship and monthly evaporation rates) are used.

V. Parameters Required

The slope of the storage-area line indicates the area per unit active volume, A_0, above the dead storage. Area per unit active storage volume multiplied by average annual depth of evaporation indicates the average annual vaporation volume loss rate per unit active storage volume, E.

The parameters i.e., water spread Area at dead storage level, A_0 (Mm^2) and slope of the area-capacity curve beyond dead storage, a. which are required for solving the model are listed in the Table 1. The linearization of water storage area and storage levels in reservoir is shown in Figure 2.

Table 1: Parameters (water spread Area at dead storage level, A_0 (Mm^2) and slope of the area-capacity curve beyond dead, a)

Water spread Area at dead storage level, A_0 (Mm^2)	Slope of the area-capacity curve beyond dead storage, a
17.4532	0.0663

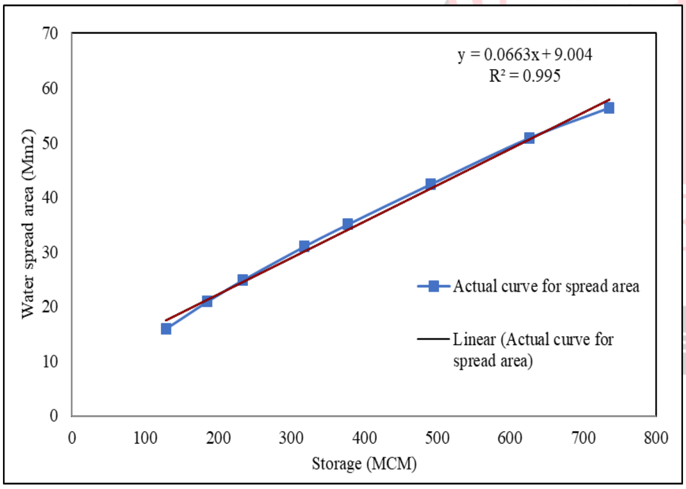

Figure 2: Reservoir Linear Storage-Area relationship

VI. Results and Discussion

The analysis of the results for the minimum storage capacity required to fulfill the various demands (demands for village water supply (RVWS), demands for city water supply (RCWS), demands for industrial water (RIWS), water supply for sugar factory (RSF), water supply for Mahatma Phule Agricultural university (RMP), water supply for Lift irrigation (RLI) and water supply for major irrigation (RIR)) from the known inflows which is found out on the basis of linear programming model.

The result of the model shows that the value of minimum active storage capacity, Ka is 457.71 MCM. The total capacity of the reservoir is 585.16 MCM. Meanwhile, the volumes of all the decision variables are given in the Table-1. Reservoir operation curve for all the months in a year is drawn in Figure-4. The curve shows that in October, storage has the highest amount and total demand is moderate in that month and full filing all the demands required for the different purposes in all the months.

The volume of evaporation loss is maximum in month of May which is 6.62 MCM. The detailed tabular and graphical representation of the result is shown below.

The detailed tabular and graphical representation of the result is shown in Table 2 and Figure 3.

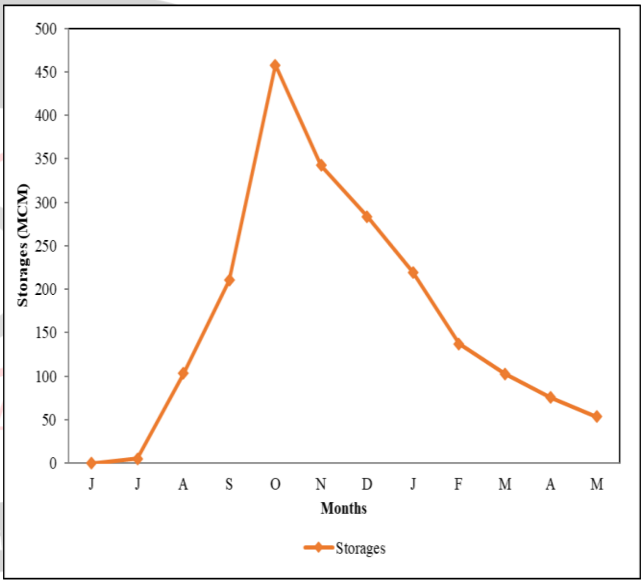

Figure 3: Reservoir Operation Curve for all the months

Table 2: **Result for minimum capacity** (**All volumes are in MCM**)

Months	Inflow	RVWS	RCWS	RIWS	RSF	RMP	RLI	RIR	E_t	S_t
Jun	65.51	0.354	1.062	1.932	0	1.231	1.27	50.60	3.98	0
Jul	199.67	0.354	1.062	1.932	0	1.231	1.76	90.972	4.23	5.3663

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Aug	226.52	0.354	1.062	1.932	0	1.231	2.34	106.58	6.24	103.492
Sep	216.18	0.354	1.062	1.932	0	1.231	1.41	57.34	5.41	210.273
Oct	52.5	0.354	1.133	1.932	0.531	1.571	1.34	53.97	6.59	457.718
Nov	14.87	0.354	1.133	1.932	0.531	1.571	1.48	61.39	5.35	342.798
Dec	8.21	0.354	1.133	1.932	0.531	1.571	1.48	61.39	4.34	283.925
Jan	8.43	0.354	1.133	1.932	0.531	1.571	1.82	79.26	3.89	219.408
Feb	7.5	0.354	1.133	1.932	0.531	1.205	0	33.06	3.99	137.343
Mar	8.48	0.354	1.133	1.932	0.531	1.205	0	25.3	5.23	102.639
Apr	9.7	0.354	1.133	1.932	0.531	1.205	0	20.57	5.72	75.432
May	7.32	0.354	1.133	1.932	0.531	1.205	0	49.24	6.62	53.691

VII. ENVIRONMENTAL & SOCIO-ECONOMIC BENEFITS OF OPTIMIZING RESERVOIR CAPACITY

- Accounts for appropriate water quality and quantity to ensure environmental needs, in view of the environment as a key water user.
- Reduce the environmental dangers of water scarcity and flooding.
- Aids in achieving management objectives while providing optimum benefit to all users.
- Assists in the better management of climate-induced water variability and decreases the risk of economic activities (depending on water releases).
- Lowers operating costs while increasing the economic advantages of water use.

VIII. CONCLUSIONS

The following conclusions from the present study are as follows- an optimum policy has been developed for the reservoir, on solving the model we get the optimum reservoir capacity, Ka for the proposed reservoir is 457.71 MCM. The maximum evaporation loss from the reservoir is found to be 6.62 MCM in the month of May.

The model shows that in the month of October, storage has the highest water level and total demand is moderate in that month and full filing all the demands required for the different purposes in all the months.

REFERENCES

[1] Yeh, W., 1985. Reservoir management and operation models: a state-of-the art review. Water Resources Research, 21(12): 1797-1818.

[2] Sattari, Mohammad Taghi, Kodal, Suleyman and Ozturk, Fazli, "Application of deterministic mathematical method in optimizing the small irrigation reservoir capacity", Journal of Irrigation and Drainage Engineering, 2006, 19(2), 261-267.

[3] Dutta, Susom, "Determination of Reservoir Capacity Using Linear Programming". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 4, Issue 10, October 2015.

[4] Asvini, M. Sakthi, and T. Amudha. "Deterministic optimization technique proposed for optimal reservoir release of Thirumurthi and Amravathi reservoirs", 2014 IEEE International Conference on Computational Intelligence and Computing Research, 2014.

[5] Hurst H.E., Long-term Storage Capacity of Reservoirs, Trans. ASCE, Vol. 116, pp. 770-808, 1951

[6] Singh. P. Krishan, Durgunoglu ali; "A new method for estimating future reservoir storage capacity" Volume.25, No. 2, water resource Bulletin, pp. 263, April 1989.

[7] Yeh, W.W.G., "Reservoir Management and Operations Models: A State of- The-Art Review", Water Resources Research, 21(12), pp. 1797–1818, 1985.

[8] Sawunyama, T., Senzanje, A., Mhizha, A., 2006. Estimation of small reservoir storage capacities in Limpo river basin using geographical information systems (GIS) and remotely sensed surface areas: Case of Mzingwane catchment. Physics and Chemistry of the Earth 31, 995-1002.

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