Optimal Water Allocation: Sustainable Management of Dam Reservoir

Afshin Jahangirzadeh, Shatirah Akib, Babak Kamali, Sadia Rahman

***Abstract*—**Scarcity of water resources and huge costs of establishing new hydraulic installations necessitate optimal exploitation from existing reservoirs. Sustainable management and efficient exploitation from existing finite water resources are important factors in water resource management, particularly in the periods of water insufficiency and in dry regions, and on account of competitive allocations in the view of exploitation management. This study aims to minimize reservoir water release from a determined rate of demand. A numerical model for water optimal exploitation has been developed using GAMS introduced by the World Bank and applied to the case of Meijaran dam, northern Iran. The results indicate that this model can optimize the function of reservoir exploitation while required water for lower parts of the region will be supplied. Further, allocating optimal water from reservoir, the optimal rate of water allocated to any group of the users were specified to increase benefits in curve dam exploitation.

***Keywords*—**Water resource management, water reservoirs, water allocation, GAMS, Meijaran dam

I. Introduction

A relative expand limitation of water resources in Iran, increasing requirement to water for agricultural cases and great cost to establish dams and water reservoirs, has necessitate making use of the methods of optimization in design, execution, and exploitation from water resources.Because of diversity in aims and bonds, the problem of programming in water resources is complicated and in the case of systems investigation, appropriate mathematical models are required. The first suggestion of linear planning has been presented by Maas [3] to exploit and design a water reservoir. Revelle [5] have designed and managed by linear planning and by a linear decision regulation. Loucks et. all (1981) have presented different subjects in planning water resources by making use of linear, non-linear and dynamic methods. Yeh [11] has presented different models for reservoir function including NLP, non-linear, linear (LP).

Most dams in Iran are for supplying agricultural water. Existing water in dam reservoir is not sufficient to meet water for plants in lower part of the region and in peak months, usage is not completed. Therefore, plants are suffering from water tension and finally farmers face to product insufficiency.

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As a result, it is required to optimize the manner of exploitation from dam reservoir and the way of allocating water in farming plants. On the other hand, there are a few studies in optimal water supply from dam reservoir in its lands. Dariane and Hughes [1] have used from a dam regardless water balance in soil, by making use of an optimized model of maximizing net benefit from lands.

Vedula and Negesh Kumar [10] have traced soil moisture and they used cost and income of different products from total relative manufactured product as a target function regardless differences in the level of culture. The present essay is compiling a mathematical model in order to exploit from Meijaran dam reservoir and the manner of allocating water between garden and farming plants.

II. Technical Specifications of Meijaran Reservoir Dam

Meijaran dam that has been exploited in order to use water resources of Ramsar river in the year 2007 that its capacity is 80 million cubic meter and useful volume of 75 million cubic meter and dead volume of 5 million cubic meter. This dam is able to regulate about 10 million cubic meter water per annum.

The water regulated by this dam is used for agricultural and drinking cases after passing natural route of the river in approximate length of 60km through irrigation and drainage network.

III. Definition of Subject and Objectives of Research

The following cases have been evaluated in this study:

1. Estimating functional coefficients to describe specifications of reservoir of dam
2. Optimal program of reservoir exploitation that meet the requirement of the lower parts.
3. The program of water optimal allocation

A. Estimation of reservoir-height relations

The aim is finding coefficients of a and b in the relationship between height of surface and volume of reserved water in reservoir. Curve equation of reserve-height is shown as equation (1):

$$S(H) = a(H - H_0)^b \quad (1)$$

In which S is reserve volume in reservoir (L), H is water surface height in reservoir (L) and output height of reservoir is (L). In the process of estimation, the method of least squares was used. Error in the value of S (as equation 1) and observe rate of S is written as follows (equation 2):

$$e_i = S_i - \hat{S}_i = a\left(\hat{H}_i - H_o\right)^b - \hat{S}_i \quad (2)$$

In which, I is the scale of measurement, 1 is total number of measurements equal to the volume of reserve volume of I in reservoir, observe reserve of I in reservoir and water height in reservoir. Rate of coefficients has been estimated through a non-linear program (equation 3):

$$\text{Objective Function} = \text{Minimize}\left\{\sum_{i=1}^{I} e_i^2\right\} \quad (3)$$

Relationship between storage volumes against height of water surface for Meijaran dam has been drawn in Figure 1.

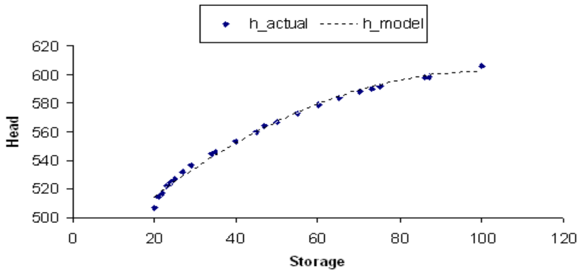

Fig. 1 Storage (million cubic meters) against water surface height (meter) in series 1 and real state (series 2)

B. Reservoir exploitation

Exploitation from dams' reservoirs is a very important and complicated subject that the designers of water resources systems are faced with them. Selecting a correct method of studies and applying appropriate techniques and standards of engineering are important cases in solving such problems. Systems engineering is a science in which there are techniques to be used as the best option due to total limitations (Cervellera et. al 2006). Diversity of calculating algorithms in these techniques, increasing development of computer software, hydrology, hydraulic and engineering economics have produced valuable and liable methods to design water resources systems that are used mainly in optimization of works. Optimization is a method that is defined due to a specified aim and limitations and as mathematical relations. This method gives the best possible answer to a subject. The most important section of an optimization model is equation (4):

$$S_{t+1} = S_t + Q_t - R_t - EV_t \quad (4)$$

In this way, arising calculations from reservoir surface has been obtained by making use of relations between storage volume and area of surface in the function No.2. Linear definition has been used to explain relations of volume-area of surface between dead volume and total storage surface (Rosa et. al 2004).

The aim of exploitation model is minimizing deviations square between monthly releases of reservoir and monthly demand of water. (Equation 5):

$$\text{Objective Function:} \quad \text{Minimize}\left\{\sum_{t=1}^{T}(R_t - D_t)^2\right\}$$

$$\text{Subject To:} \quad \begin{aligned} &(1+\alpha_t)S_t = (1-\alpha_t)S_{t-1} + Q_t - R_t - \beta_t \\ &\alpha_t = A_a e_t/2 \\ &\beta_t = A_0 e_t \end{aligned} \quad (5)$$

In which storage at the end of time series is equal to storage at the beginning of time series equal to entrance volume within the time period equal to releasing volume within the lengths of time series equal to rate of evaporation equal to demand equal to total capacity of reservoir (Soncini-Sessa et. al 2007).

Optimal volume of storage in different months of exploitation has been obtained through non-linear program into GAMS language and by making use of historical data of water input and water demand in lower parts and is presented through the results of model, drive curve of reservoir exploitation (Figure 2-3).

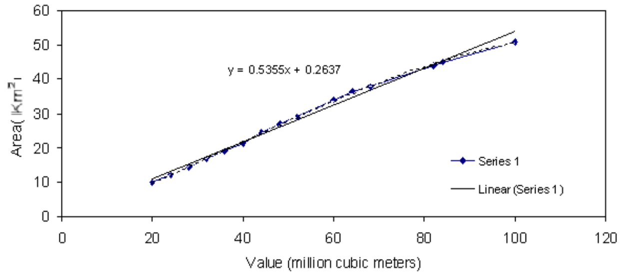

Fig. 2 Linear system of surface volume-area relations

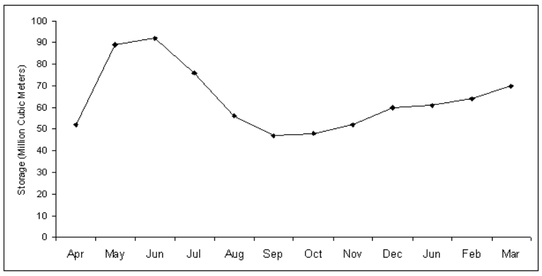

Fig. 3 Curve of reservoir exploitation of Meijaran Dam

C. Water optimal allocation

Irrigation and drainage network of the region, by having more than 2,000 hectare lands and Ramsar river as a liable supplier resource has been exploited within the period of two years which is one of the best networks of irrigation and drainage in Iran, and it has been performed due to the considerable investments. Strategic decision making in the way of management and optimal usage in this network can be accompanied with useful achievements for economic development of the region and finally Iran. In this way, a linear program in GAMS language has been presented that its target function is maximizing net benefit of the product, benefit minus water tariffs and other costs (equation 6)(Brooke et. al 1998):

$$\text{Objective Function:} \quad Z = \max\left[\sum_p \left(C(p)\times X(p)\right) - \sum_p \left(R(p)\times X(p)\right)\right] \quad (6)$$

$$\text{Subject To:} \quad \begin{aligned} &\sum_p \left[Wr(p)\times X(p)\right] \le Wo \\ &Wr(p) = D(p)/Ea \end{aligned}$$

In which, p is type of product, $C(p)$ is benefit arising from product in Rials per hectare, $R(p)$ is water hectare tariff, $Wr(p)$ is released water for product, $Wo(p)$ is annual water fee in Iran, Ea is total scale of irrigation, $D(p)$ is net demand of irrigation water for products and $X(p)$ is area of culture of product.

In this model, due to strategic products and water requirement for different plants of the region, references of Agricultural Soil and Water Research Institute has been used.

Through this model, rate of water and allocated lands to any one of the products and as a result, the profit has been maximized. The results arising from this model has been explained in Table 1.

TABLE I
RESULTS ARISING FROM WATER ALLOCATION TO DIFFERENT PRODUCTS

Name of product	Area of land	Released water
Rice	913.88	7037.84
Oranges	72,06	791.111
Kiwi	684.88	1028.93
Tea	35.296	449.1
Melon ground	86.136	485.961

In the state of optimal allocation of water to different products according to the table No.1, objective function has been increased 14 million dollar comparing with allocations that is a considerable figure. Coefficients of monthly distribution of required water for plants, published by Ministry of Agriculture Soil and Water Institute publications has been used to calculate. Comparison of monthly changes of water exploitation has been presented for issued allocations and optimal allocation of irrigation network in Meijaran Dam and is presented in Figure 4.

Due to Figure 4, allocations of water in the months of April and September, is as optimal allocation. From October to April, water supply has been more than requirement of the lands and from April to September, this supply has been less than requirement of the lands. This situation has been as a result of unnecessary allocations to agricultural cases. For this reason, it is better to execute projects to water pump age, and surplus water storage in artificial reservoirs to make use of surplus water in the months of less consumption rate in the said storage reservoirs and to be used in peak months of consumption.

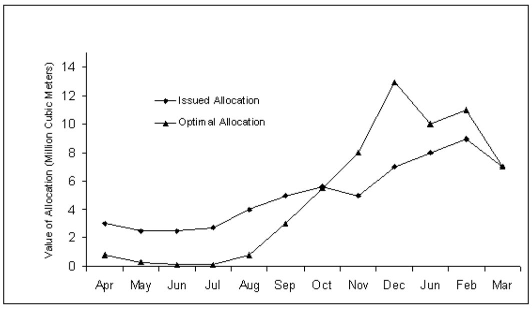

Fig. 4 Comparison of monthly changes of water exploitation for issued and optimal allocation (2000-2004)

IV. CONCLUSIONS

1. Figure 3 indicates the best situation of exploitation from Meijaran dam reservoir under special conditions that the manner of exploitation from dam is specified for the authorities.
2. According to Figure 3, in the months of May and June, because of more input and less consumption, maximum rate will be available in Meijaran Dam and in the month of November, minimum rate of storage will be available in the month of November because of input decrease and increasing water consumption.
3. Optimal exploitation from water in lower parts of Meijaran has been introduced in table 1. Non optimal usage in lower parts of dam, optimal function of reservoir exploitation has been under question.
4. According to table 1, increasing efficiency and optimal usage of water in the related region, is related to the cultivation of rice and then kiwi, because of their economics value.
5. By optimal allocation of water, the benefits arising from the region will be increased one million dollar per annum.

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