SHORT AND LONG TERM OPTIMAL OPERATION OF A MULTIPURPOSE RESERVOIR

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1. INTRODUCTION

Mathematical models of optimization are techniques frequently used to support the planning and operation of reservoirs subject to multiple purposes. They help in finding an optimal set of policies that provide the best possible allocation of the available water.

In this study, an optimization model is developed and applied to the operation of the reservoir that supplies the city of Matsuyama in Ehime Prefecture (Figure 1). The reservoir, named Ishitegawa Dam, is responsible for half of the water supply of Matsuyama and is also used for the irrigation of an area of approximately 550 ha.

Short (real-time) and long term (monthly) operations are carried out and compared with fictitious simulations. A discussion is performed on the different outcomes from the short and long term approaches.

2. THE OPTIMIZATION MODEL

In principle, the main objective of the operation is to determine the best amount of water to be allocated for city supply and irrigation that meet their respective demands to the greatest extent possible without violating the constraints of the system. Besides, the water level of the reservoir should be kept as high as possible avoiding a collapse in periods of shortage. The objective function and constraints of the model are thus written as below:

$$\min \sum_{t=1}^{N} \left\{ \begin{array}{l} \left(\dfrac{Q_{rel}^{t} - T_{dem}^{t}}{T_{dem}^{t}} \right)^2 \\ + \left(\dfrac{Q_{irr}^{t} - T_{irr}^{t}}{T_{irr}^{t}} \right)^2 + \left(\dfrac{V_{stor}^{t} - V_{stor}^{\max}}{V_{stor}^{\max}} \right)^2 \end{array} \right\} \quad (1)$$

subject to

$$V_{stor}^{1} = V_{stor}^{0} + V_{inf}^{1} - Q_{rel}^{1} - Q_{irr}^{1} - V_{spill}^{1}; \quad (2)$$

$$V_{stor}^{t+1} = V_{stor}^{t} + V_{inf}^{t+1} - Q_{rel}^{t+1} - Q_{irr}^{t+1} - V_{spill}^{t+1}; \ \forall t \quad (3)$$

$$Q_{rel}^{t} \le T_{dem}^{t}; \ \forall t \quad (4)$$

$$Q_{rel}^{t} \le Q_{rel}^{\max}; \ \forall t \quad (5)$$

$$Q_{irr}^{t} \le T_{irr}^{t}; \ \forall t \quad (6)$$

$$Q_{irr}^{t} \le Q_{irr}^{\max}; \ \forall t \quad (7)$$

$$V_{stor}^{\text{dead}} \le V_{stor}^{t} \le V_{stor}^{\max}; \ \forall t \quad (8)$$

$$Q_{rel}^{t} \ge 0; Q_{irr}^{t} \ge 0; \ \forall t \quad (9)$$

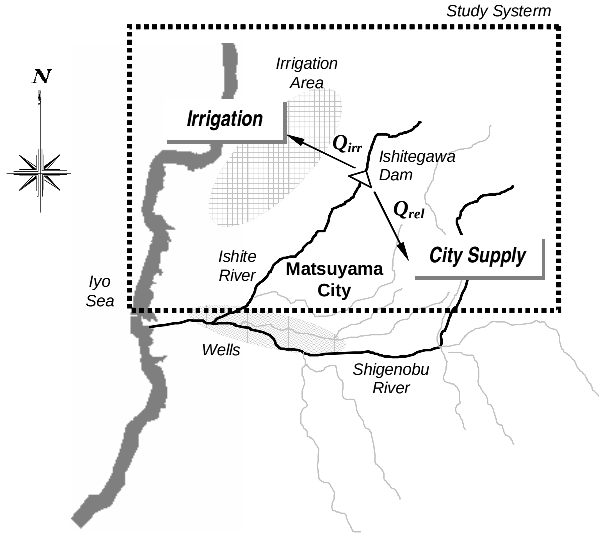

Figure 1. Location and layout of the system.

in which t is the time index; N is the operating horizon; Q_{rel}^{t} is the amount of water allocated for city supply from the reservoir; T_{dem}^{t} is the demand for city supply; Q_{irr}^{t} is the allocation for irrigation from the reservoir; T_{irr}^{t} is the demand for irrigation; V_{stor}^{t} is the reservoir storage; $V_{stor}^{\max}$ is the capacity of the reservoir; V_{stor}^{0} is the initial storage; V_{inf}^{t} is the inflow to the reservoir; V_{spill}^{t} is the amount of water that might spill from the weir; $Q_{rel}^{\max}$ is the total capacity of the surface water treatment plants; $Q_{irr}^{\max}$ is the capacity of the irrigation system; and V_{stor}^{dead} is the dead storage of the reservoir.

3. RESULTS AND DISCUSSION

Figures 2 and 3 present some results from the application of model (1)-(9) to the long and short term operations of Ishitegawa Dam, respectively. The average monthly data of inflows of 1997 were used for the deterministic optimization process. In the long term operation (monthly), the operating horizon N is equal to 12. As for the short term real-time operation, N is assumed to be equal to 5. Consequently, the values of inflows for five days counting from the current day are considered as forecasted inflows. Then, the model is run and the optimal allocations for the five days are found. However, only the

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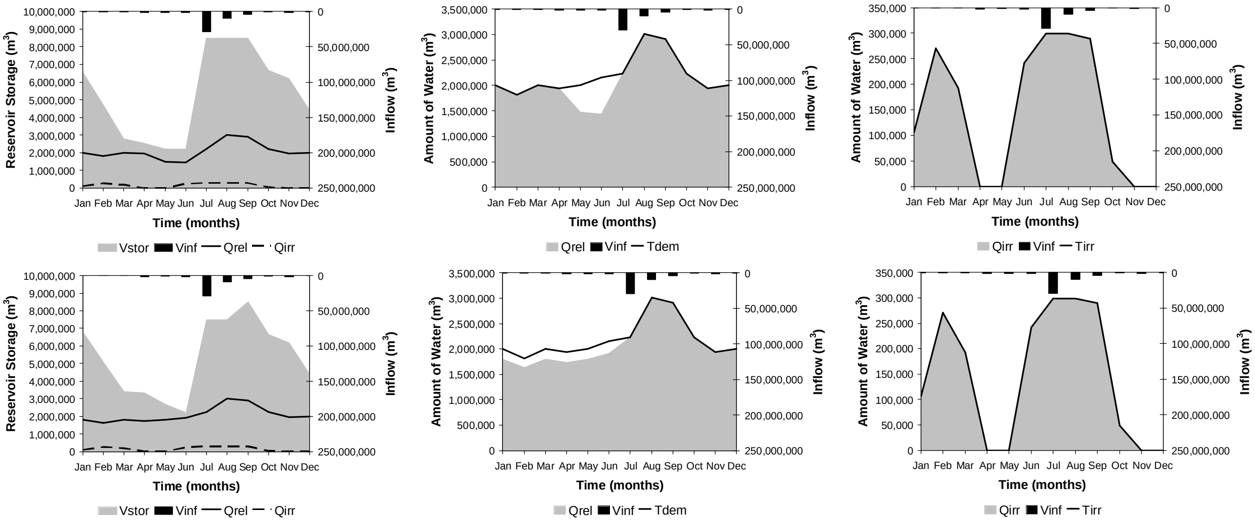

Figure 2. Results from monthly simulation (a, b, c) and long term (monthly) optimization (d, e, f).

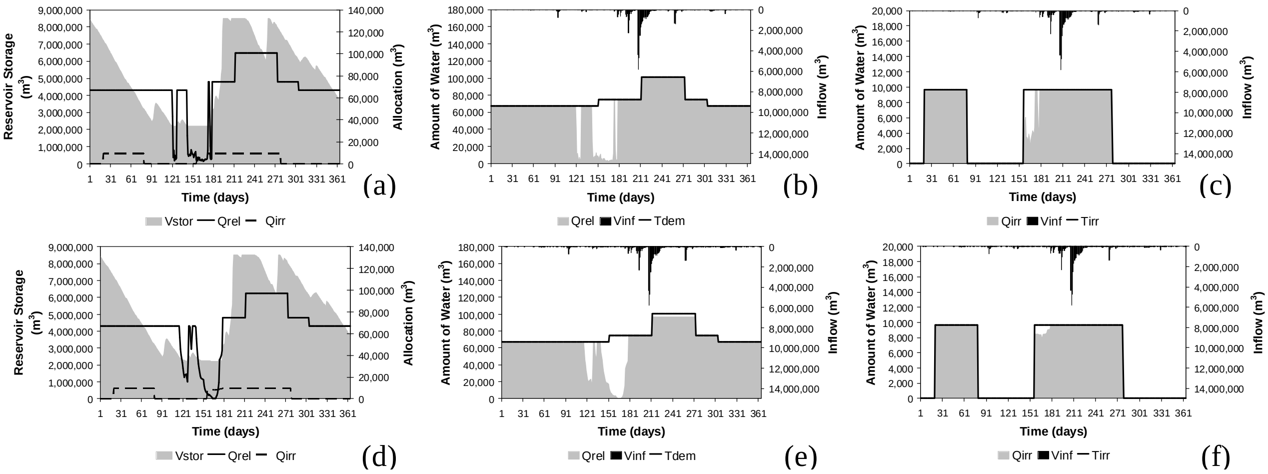

Figure 3. Results from daily simulation (a, b, c) and short term (real-time) optimization (d, e, f).

allocations for the present day are used. The procedure is repeated for the next day and so forth until the final day of operation (end of the year) is reached. For comparison purposes, fictitious simulations where all the demands should be met whenever possible, were considered and compared with the optimal operations. Figures (a), (b) and (c) show results from simulations while figures (d), (e) and (f) illustrate the outcomes from optimization. The model is solved by *Quadratic Programming* (QP). Figures on the left display the variation of the reservoir storage and the optimal releases along the year. Centered figures consider only the city supply and show how the allocations from the reservoir meet the target demands. Right-sided figures illustrate how the allocations from the reservoir for irrigation satisfy the demands.

For the case of the monthly operation, one can see from the results that the optimization process tries to alleviate the large difference between allocations and demands concentrated in some months (simulation) by decreasing the releases for other months. Thus, if the operation considers only fulfilling the demands without considering the future situation, the system may collapse when the period of shortage comes. The optimization process does not let this occur.

As for the real-time operation, the same situation happens but, in this case, since the operating horizon is relatively short, it becomes difficult to have a broader knowledge of the future inflows. Thus, the alleviation process does not produce a considerable reduction in the difference between allocations and demands for the critical periods.

4. CONCLUSIONS AND FURTHER STUDY

In this work, an optimization problem was applied to the short and long term operations of Ishitegawa Dam in Matsuyama, Ehime. The results showed that the optimization model found more reasonable operating policies than simulations that tried to meet all the demands without taking the future situation into account. In real-time short term operation, however, the operating horizon needs to be long which is not always possible due to the inaccuracy of the forecast information. The integration of short and long term information in real-time is an important topic for further studies.