OPTIMIZATION OF RESERVOIR OPERATION BY RULE CURVE ADJUSTMENT

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Abstract. A MATLAB model of reservoir operation was developed with historical data of Lake Okatibbee in Mississippi. A downstream flow requirement and reservoir operation rule were assumed for the reservoir. The rule curve was fed into the model as a parameter, and was optimized according to resultant lake elevation and downstream flow. The simulation results showed that by optimization of the rule curve, the lake elevation could be kept at an optimal level while the downstream flow requirement can be met with more reliability.

INTRODUCTION

For operation of a reservoir, there is usually more than one purpose, such as flood control, water supply, navigation, and recreation. In practice, the operation is mostly guided by operation rule and subjective judgments of operators (Ngo, 2006). Thus, much research has been conducted on optimization of operation rule (Tung et al., 2003; Ndiritu, 2003). Tung et al. (2003) optimized the operation zone of a Reservoir to increase water supply reliability. Ndiritu (2003) optimized a system of two reservoirs that supply monthly varying demands and environmental flows. In this research, we developed a MATLAB (MathWorks, 2008) model to simulate the reservoir operation, and used this model to optimize operation rule of a specific lake.

METHODS

Lake Okatibbee is located only seven miles northwest of Meridian, Mississippi. This project was authorized by Congress in 1962 primarily for flood reduction, and now provides excellent opportunities for boating, fishing, and other recreational activities (USACE, 2007). For this research, we assumed the reservoir has three functions: flood reduction, recreation, and flow augmentation. For the first function, we assume the release from this lake will not exceed 1225 cubic feet per second (cfs). For the second, we want to keep the lake level within reasonable range. For the last function, we assume there is a downstream minimum flow requirement of 120 cfs. The release from the lake is determined on the basis of current storage (see Table 1).

Table 1. Assumed Operation Rule

Storage	Operation
Above top of conservation pool	Outflow = total storage – conservation storage (≤1225 cfs)
Between top of conservation pool and top of inactive zone	Outflow = 0~120 cfs
Below top of inactive zone	No release

A MATLAB model was developed to simulate the operation of this lake. The model is in the following form:

[Elevation, release] = f(Rule curve, inflow)

When a different rule curve and inflows are fed into the model, the model will yield different elevations (storage) and releases. By this way, we can use the model to evaluate the impact of different rule curves. The current rule curve is shown in Figure 1. For the current research, we selected the top of conservation storage on January 1, April 1, May 1, October 1, and December 1 as the “nodes” of rule curve (the rule curve is created by linear interpolation of these nodes), and the observed inflow during January 1, 1984 to December 31, 1993 (USACE, 2008) as model inputs to evaluate the impact of the rule curve. According to preliminary screening, the range of the “nodes” is set to 339 feet to 346 feet. For each node, we selected 6 values. Thus, totally we did 7,776 evaluations. For the performance evaluation of the rule curve, we adopted the following utility function:

$$D = D_1 + D_2 + D_3$$

where D_1 and D_2 are the number of days when the lake level is below 335 feet and above 350 feet, respectively; D_3 is the number of days when the release from the lake is lower than 120 cfs. The purpose of the optimization is to minimize the value of D.

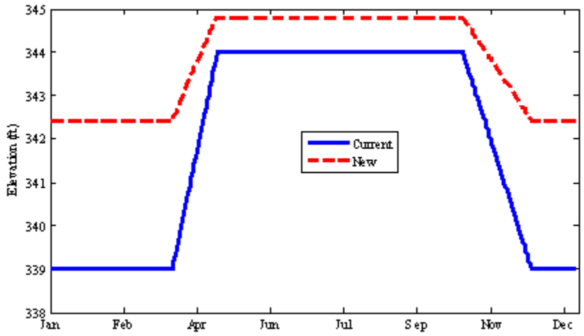

Figure 1. Current and New Rule Curve of Lake Okatibbee

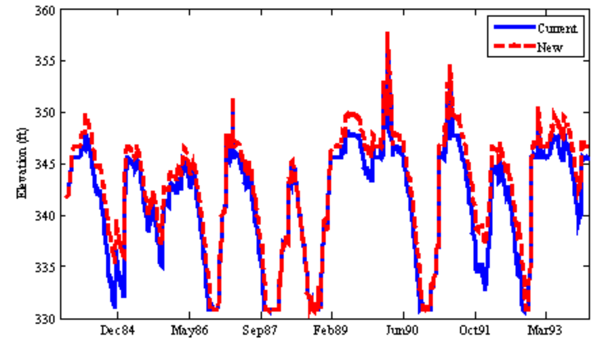

Figure 2. The resultant lake elevation from the current and new rule curve

RESULTS AND DISCUSSION

Through the performance evaluation of different rule curves, we got the optimum rule curve, which is shown in Figure 1. Compared with the current rule curve, the new curve is a bit higher thus more water can be saved. The performance comparison of this new rule curve and the current rule curve is listed in Table 2. The resultant lake level is also shown in Figure 2. From the results in Table 2 and Figure 2, it was demonstrated that with the new rule curve, the lake elevation could be kept at an optimal level. For example, during December 1984 to January 1985, with the current rule curve, the lake elevation would be below 335 feet for most of the time. However, with the new rule curve, the lake elevation would be above 335 feet, which would provide a better chance for recreation. Furthermore, for the duration of lake discharge below 120 cfs, with the current curve, the duration is 290 days, which would be reduced to 109 days with the new rule curve. Thus, with the new curve, we can expect a more reliable discharge from this lake.

Table 2. The Performance Comparison of Current and New Rule Curve

Performance	With new curve	With current curve
Days of elevation < 335 ft	390	722
Days of elevation > 350 ft	123	72
Days of outflow < 120 cfs	109	290

However, it should be noted that with the new rule curve, we might have less storage for flood reduction. From the results in Table 2, it was shown that the duration when the lake elevation is above 350 feet is increased from 72 days to 123 days. This needs to be evaluated on the basis of the flooding history of this area. Because currently we have no such data, we cannot do further optimization related to flooding reduction. If such data become available, they can be utilized to reduce flooding risk besides other targets.. For example, the duration of lake discharge beyond certain limit can be added as another performance indicator. Also, different targets of performance can be weighted according to their priorities, which might become the theme of our future research. Furthermore, currently Georgia is facing challenge of meeting various requirements with limited water resources, therefore similar models could be developed with various targets from stakeholders to improve water resource management in Southeast area including Georgia.

CONCLUSION

In this research, a MATLAB model was developed and used to optimize lake operation to get a better lake elevation and more reliable releases. It was demonstrated that with certain criteria of performance evaluation, an optimum rule curve could be obtained through optimization. This method could be modified to accommodate more performance indicators or with the weighted performance targets.

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