Incorporating inflow uncertainty into risk assessment for reservoir operation

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Abstract: An attempt of using stochastic hydrologic technique to assess the intrinsic risk of reservoir operation is made in this study. A stochastic simulation model for reservoir operation is developed. The model consists of three components: synthetic generation model for streamflow and sediment sequences, one-dimensional delta deposit model for sediment transport processes in reservoirs, and simulation model for reservoir operation. This kind of integrated simulation model can be used to simulate not only the inflow uncertainty of streamflow and sedimentation, but also the variation in operation rules of reservoirs. It is herein used for the risk assessment of a reservoir, and the simulation is performed for different operation scenarios. Simulation for the 100-year period of sediment transport and deposition in the river-reservoir system indicates that the navigation risk is much higher than that of hydropower generation or sediment deposition in the reservoir. The risk of sediment deposition at the river-section near the backwater profile is also high thereby the navigation at the river-segment near this profile takes high risk because of inadequate navigation depth.

Key words: Risk, uncertainty, reservoir operation, sedimentation, computer application.

1 Introduction

In the middle of this century, with the development of economics in the world, the demand for water increases promptly. The temporal and spatial randomness of water distribution has obligated to humans to build reservoirs. A multipurpose reservoir may have many beneficial uses: hydropower generation, navigation, flood control, water quality, fish and wildlife maintenance, municipal water supply, low flow augmentation, etc. However, several of these particular uses may bring deep conflicts basically related to the water release and storage. For example, if a reservoir is operated mainly for hydropower generation, the water control manager would like to have as much water head as possible in order to generate higher amounts of power. On the other hand, if the reservoir is operated mainly to decrease floods, the regulators would try to maintain lower volumes of water for containing high floods. If the same reservoir is operated under both purposes, flood control and hydropower generation, conflicts may appear during the operation of the reservoir. At the stage of
planning, regulation rules of reservoir operation are usually predetermined trying to avoid future conflicts. However, before the reservoir start its operation, rules already determined are only guidelines. Many elements, most of them never even be thought before, start influencing the operation of the reservoir because there is no detailed knowledge of future inflow of water and sediment. Reservoirs are usually managed on water volumes provided by the uncertain natural processes. This is why the operation risk is unavoidable and the reservoir sometimes becomes operational failures.

In order to guide the reservoir operation more effectively, the need of combining mathematical tools with the computer techniques in the planning and operation of reservoirs has well been realized by researchers and practitioners. Reservoir operation research has been conducted for more than three decades and many mathematical models or systems have been developed (Simonovic and Savic, 1989). These models are representation of systems, used to predict the behavior of the system under a given set of conditions. Model executions are generally made to analyze the performance of systems under varying conditions, such as for alternative operating policies. A reservoir simulation model reproduces the hydrologic and, in some cases, economic performance of a reservoir for a given inflows and operating rules. It is also a technique that is understandable, and becoming increasingly more comprehensive and easier to use in practical management. Another active research field is the risk and uncertainty analysis, which has been studied intensively in recent years, and significant achievements have been made. Especially beginning from the research conducted by Yen (1970), flood risk has been widely studied (Todorovic and Zelenhasic, 1970; Rosbjerg, 1985). Recently, reservoir operation risk also has been investigated in the literature (Loaiciga and Mariano, 1986; Simonovic et al. 1992). Risk, as it stands, may be measured in numerous ways. In flood analysis, risk is generally defined as the probability that a exceedance flood occurs (Rasmussen and Rosbjerg, 1991; Xu, 1993). In the planning and operation of water resources, risk is generally measured in the following ways: (1) probability of occurrence of a specified undesirable outcome; and (2) the number of occurrences of a specified length of time. The definition and application of reliability, resiliency and vulnerability are also studied in the literature in recent years (Jinno et al. 1995). In this paper, the first definition of risk is adopted. For example, hydropower risk is defined as the probability that the target hydropower can not be satisfied. Flood risk is defined as the probability that overflows are larger than the safety capacity of the spillway.

When reservoirs are analyzed with a historic data record at the project site, a single estimate of the capacity, hydropower generation, and other indexes is obtained. However, such an approach does not give a measure of risk for these indexes caused by natural uncertainty from inflow or operations. Some of the traditional techniques merely design for the worst drought or serious flood in the historic record. In this paper, the stochastic hydrologic approach for assessing the risk of target indexes estimated from single historic record, is presented. This technique overcomes the limitations of the traditional simulation approach. On the basis of the specified or estimated parameters of the underlying streamflow processes, the likely hydrologic sequences are generated by using stochastic models firstly. These sequences are then used to analyze different operation policies of reservoirs, from which the statistical properties of reservoir operation indexes and risk are estimated. Several scenarios for reservoir operation are analyzed in the present paper. At the last section, some significant conclusions are made.