Multiple-Criteria Decision Support System for Siemianówka Reservoir under Uncertainties

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Abstract This paper presents a Multiple Criteria Decision Support System for the optimal management of the Siemianówka reservoir. The reservoir is localized on the Narew River upstream the NNP. The river system under considerations consists of a storage reservoir and a 100 km long River Narew reach, at which end the NNP is located. The goal of the work is to provide decision makers with a tool that would allow the safety of the NNP environmental requirements within the reservoir management policy to be included. An important issue is the competition between many water-dependent systems and agents, e.g., agriculture, energy, wetlands, for limited water resources. The proposed system allows a trade-off between different reservoir users to be found, including protected wetland ecosystems of the Narew Nation Park. Unobserved inflows play an essential role in the river water balance and are dealt with use of *k-NN* technique. In addition, as the optimization problem requires numerous realizations of the river model, a numerically efficient Stochastic Linear Transfer Function was applied to flow routing.

1 Introduction

Mitigation of negative changes in natural ecosystems is one of the challenges of the water management. In case of riverine environments, the most noticeable matter is protection of wetlands, which are considered as the ecosystems of a very high biodiversity level. Therefore their existence is crucial for sustainable development

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of society. In this case such negative changes are especially seen in disruptions of river hydrological regime: long periods of droughts, shorter and smaller freshets. In result wetland areas often suffer from serious water shortages. The causes might be directly related to the human impact, but as well to some other inferences, like climate changes.

In this paper we would like to focus on adaptation of a management strategy of single reservoir system to include requirements of protected areas as one of the reservoir's main goal. This leads to the problem of a control of a multi-purpose reservoir which always takes a form of a supply/demand problem for a set of different, usually colliding users. The main difficulty comes when costs or benefits of certain users cannot be easily compared especially when economic terms are considered. For example, the benefits from energy production can be directly assessed, while introducing any economical measures for ecological or social requirements is rather a problematic issue.

There are many different approaches to this problem in water management. The most successful ones were based on such techniques like *Goal Programming* I.a. (Can and Houck 1984; Gandolfi and Salewicz 1991; Goulter and Castensson 1988; Yang et al. 1992, 1993), where optimization was constrained to a desirable value for each criterion. This allowed to obtain required trade-off between different criteria. An extension of this concept was proposed in form of interactive decision support systems, allowing the user to choose any appropriative solution form *pareto*-optimal surface. Such applications were presented by (Agrell et al. 1995; Berkemer et al. 1993; Makowski et al. 1995).

However, taking into account the stochastic character of reservoir management problem within multi-criteria analysis it is still a difficult task (Labadie 2004). In this paper we consider demands in stochastic way, in form of required safety levels of supply for each user. It was achieved by introducing special criteria functions, being similar to well known Value-at-Risk measures.

We consider here an application of Decision Support System for the multi-purpose Siemianówka reservoir. The reservoir is localized on the Narew River in North–East Poland. Downstream to it rich wetland ecosystem, enclosed within Narew National Park (NNP), is situated. The goal of the proposed system is to provide decision makers with a tool that would allow to control safety of the NNP environmental requirements within the reservoir management policy to be included. Important issues concern competition among many water-dependent systems and agents, e.g., agriculture, energy, wetlands, for limited water resources. Accounting for inherent uncertainties is a challenging key task. The control was performed in accordance with the Receding Horizon Optimal Control (RHOC) concept, where release amount is computed each time for a present inflow forecast.

The problem of reservoir management and water supply-demand under uncertainties and risks is formulated as a stochastic multi-criteria problem for preserving water mass balances.