RANA-ICE, a methodology to estimate compensatory runoff in Costa Rica

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INTRODUCTION

Sustainability in the development of water resources is not limited to only safeguarding healthy aquatic habitats and acceptable water quantity and quality, but also includes a wise use of the water resources in human activities, balancing the interests of different uses with a proper consideration of the natural environment. Confronting the natural demands for water in order to maintain aquatic habitats, and those of different water users in a holistic way is a prerequisite for the sustainable use of water resources.

The "compensatory runoff" (as used to refer to the river runoff that can sustain the natural biological functioning of a river) (Laporte *et al*., 2006), can only be developed by considering the social, biological and hydrological constraints. As these vary with the environment, it is hardly possible to obtain some "universal" value for such constraints. Krasovskaia & Rodriguez (2007) stressed that it is not possible or desirable to propose national standards for setting minimum acceptable flow (MAF); the requirements should be site-specific and may vary from one river basin to another. It can be mentioned that the number of approaches used to determine "environmental flow" is very big, but essentially three main groups can be distinguished (Dunbar *et al.* 1998): look up approaches ("Rule of thumb"); discussion-based approaches and hydrological analysis; biological response modelling.

The RANA-ICE methodology is a combination of "look up", discussion-based approaches and biological response modeling, and can be characterized as a hybrid methodology combining the "best" of existing methods, including hydrological, ecological, as well as socio-economic factors.

OBJECTIVE

The principal objective was to develop a methodology for the determination of the compensatory runoff that is feasible to apply in developing countries, to optimize the use of water resources in Costa Rica.

METHODOLOGY

In this study we apply a hybrid approach to estimate compensatory (environmental) runoff. The steps in the analysis are: start with a thorough hydrological analysis; apply a discussion-based approach (Expert Panels) to establish natural biological and socio-economic constraints; investigate natural biological and socio-economic conditions in case study areas with respect to the demands to low flow; follow the steps in biological response modeling; and, finally, work with interactive scenario methods as a tool to apply the findings to a particular case (Krasovskaia & Rodriguez, 2007). Scenario testing offers a framework for negotiating to reach an acceptable compromise between needs that historically were seen as conflicting.

Advanced statistical methods were applied for the characterization and analysis of minimum flow conditions in Costa Rican rivers (Krasovskaia *et al*., 2006; Pacheco *et al*.; 2006). The methodology was developed using two catchments with diametrically different socio-economic and biophysical conditions: the Savegre River catchment on the Pacific slope of Costa Rica, and the Reventazón River catchment on the Caribbean slope. Both cases required field data that provided basic information to validate the environmental constraints.

RESULTS

Ecological and socio-economic constraints introduced in a simple hydraulic model allowed the testing of different minimum flow scenarios for hydropower project developments and other water uses. In the hydrological component the hydrostochastic approach (Gottschalk *et al*., 2006) was applied to the runoff data from the database of the Instituto Costarricense de Electricidad for the whole of Costa Rica to estimate low-flow conditions at any point along the river in the country. These data were completed with the hydraulic characteristics of the key cross-sections of the two studied rivers. The effects of particular meteorological patterns, as well as ENSO, were also analysed.

Socio-economic information is based on analyses of consumptive and non-consumptive uses in the river sections under study, evaluation of the relative importance of different uses, and their respective demands in terms of flow depth and velocity. These demands are used as socio-economic constraints.

Ecological constraints are based on the expression of habitat preferences for flow indicator organisms in terms of flow depth, velocity and substrate (Chaves *et al.*, 2006).

The methodology is supported by a specially developed software (RANA). It includes five modules: information management (Abeja), two analysis modules (Túngara and Machaca), a mapping module, a regionalization module (Fregata), a hydraulic module (Martín Pescador) and a scenario modelling module (Búho).

CONCLUSIONS

The RANA-ICE methodology integrates hydrological, biological, and socio-economic information, related to river sections where the impact of hydropower developments is envisaged. Natural hydrological patterns are studied first and different water use demands are identified, including those of the ecosystem, to determine a minimum acceptable flow satisfying these demands. These demands are used as constraints and are evaluated against different flow regulation scenarios to recommend the environmental flow pattern that provides a sustainable use of water resources.

The application of this methodology in the environmental impact assessment for the Reventazón Hydropower Project meant the inclusion of a mini powerhouse at the base of the dam to ensure environmental flows in the critical river section. It also meant modifications in the powerhouse design and operation, so that environmental flows could be guaranteed in the river section affected by regulation.

Acknowledgements The study has been performed in the frame of The Compensatory Runoff Project, Instituto Costarricense de Electricidad (ICE) with financial support from the Swedish International Development Agency, SIDA), whose generous cooperation is acknowledged.

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