EDITORIAL

Integrated hydro-economic models as a tool for the sustainable management of water resources

Zoran Nakic Ph.D.

Nakic Z. Integrated hydro-economic models as a tool for the sustainable management of water resources. J Environ Geol 2017;2(1)11:12.

Implementation of the complex analysis of the effectiveness of application of various instruments and measures for water use and protection can be done through the integration of technical, economic, environmental, legal and social indicators of water status. For this purpose, integrated decision-making and management modeling systems can be used, with the aim of defining effective and sustainable water management strategies. In this respect, integrated hydro-economic models can play a key role, primarily at river basin level.

Throughout history, the underlying ideas and concepts of engineering and economics were often intertwined (1). The complexity of the interaction between water resource management and economic indicators can be demonstrated through integrated mathematical [hydroeconomic] models that link hydrological and biogeochemical processes to economic supply and demand laws (2). The use of hydro-economic models in water management implies defining the physical behavior of the system, with a realistic representation of surface water and groundwater resources, including their interaction, and estimating the spatial and temporal variability of their availability (3).

The basic and first step in the development of the hydro-economic model is to define the main components of the model. Most hydro-economic models include hydrological data, water infrastructure, economic water demand, operational costs, and operational rules (4). The hydrological data, in the broad sense, include hydrological [surface water] and hydrogeological [groundwater] parameters, rainfall, inflow and drainage or supply of the observed area. The water infrastructure consists of natural and constructed facilities [rivers, pipelines, reservoirs, canals, aquifers, waterworks, water treatment plants, water drainage facilities, water supply sites etc.] for the storage, transportation, treatment and use of water. Defining economic water demand can be done with functions that provide information on gross economic revenue within a certain timeframe of modeling (5). Operating costs include pumping, treating, artificial power, and any other costs related to water transport (4). These main components of the hydro-economic model can be supplemented by complementary elements of the model, such as polluting emissions, environmentally sensitive areas, but also institutional and legislative elements, such as constraints stemming from national and international agreements and national legislation.

The main features of the model [hydrological, economic, etc.] are defined within separate modules, which are integrated into a unique hydro-economic model. There are two main approaches to the integration of individual modules: modular and holistic (2,4). Modular approach implies the use of multiple models, i.e. the output data of one model represents the input of another model. The main advantage of the modular approach is that it mainly involves a higher probability of convergence towards the optimal solution, as well as the ability to use more detailed modules that can be independently developed. The holistic approach is based on an integrated model that can more effectively display relationships and interdependencies. In the holistic approach the greatest problem is finding a solver that can use all given variables and take into account simplified hydrological, economic and other model components.

The integration of individual modules [hydrological, economic] can be carried out by simulation and/or optimization methods. In fact, it is a choice between simulation of the behavior of water resources in relation to the previously defined set of rules regarding water distribution and infrastructure operation and optimization of water distribution over a certain period of time based on the function of the target that is subject to defined limitations (3). Simulation and optimization actually give answers to different questions. Simulation gets an answer to the question "what if?", while optimization gets an answer to the question "what is the best?" (4).

When developing a hydro-economic model, it is extremely important to define the model scale, because it depends on both the spatial and temporal domains of the model as well as its discretization (6). The most common spatial domain in hydro economic models is regional, although diverse scales can be used, from local [one household] to global scale. It should be emphasized that most hydro-economic models are developing at river basin level and less on aquifer level. Specifically, River Basin Analysis [RBA] enables the definition of a comprehensive framework for determining the measures that create an efficient, equitable and sustainable distribution of economic costs and benefits caused by certain programs of measures (7). The time discretization of the model depends mostly on how the management questions are to be answered. If one wants to analyze and evaluate management plans at river basin levels, it's enough to use monthly intervals (3). However, in cases related to dynamic, no stationary systems [e.g. groundwater], models must be based on daily or hourly intervals.

Integration of individual modules within a single hydro-economic model can be accomplished through various software packages, such as GAMS, AIMMS or AMPL. These packages have the ability to connect algebraic equations and solvers by using linear or nonlinear programming (4). Also, the user can arbitrarily define and develop his mathematical formulation that he will then test on a particular system. There are also other specific software that can be used. For example, Harou et al. (8) developed a geographically-based platform [Hydro Platform] that works with existing hydro-economic models, which are made in mathematical modeling systems such as GAMS. In addition to the above-mentioned applications, there are many integrated decision support systems used in water resource management, for example: AQUATOOL (9,10), OASIS (11), AQUARIUS (12) and MIKE BASIN (13).

REFERENCES

1. Lund JR, Harou JJ. How to build a regional hydro-economic engineering model. International Workshop on Hydro-economic modeling and tools for the implementation of the EU Water Framework Directive 2006, Valencia, Spain. 2006.
2. Brouwer R, Hofkes, M. Integrated hydro-economic modelling: Approaches, key issues and future research directions. Ecological Economics 2008;66:16-22.
3. Pulido-Velazquez M, Andreu J, Sahuquillo A, et al. Hydro-economic river basin modelling: The application of a holistic surface-groundwater model to assess opportunity costs of water use in Spain. Ecological Economics 2008; 66:51-65.
4. Harou JJ, Pulido-Velazquez M, Rosenberg DE, et al. Hydro-economic models: Concepts, design, applications, and future prospects. Journal of Hydrology 2009;375:627-43.
5. Bear J, Levin O. Optimal utilization of an aquifer as an element of a water resources system. P.N. 5/66, Hydraulic Lab, Technion – Israel Inst. of Technology, Haifa, 1966.

Faculty of mining, geology and petroleum engineering, University of Zagreb, Zagreb, Croatia.

Correspondence: Zoran Nakić, Faculty of mining, geology and petroleum engineering, University of Zagreb, Zagreb, Croatia. Telephone +385 1 5535 701, e-mail zoran.nakic@rgn.hr

Received: January 22, 2018, Accepted: January 24, 2018, Published: January 30, 2018

6. Jakeman AJ, Letcher RA. Integrated assessment and modelling: features, principles and examples for catchment management. Environmental Modelling and Software 2003;18:491–501.

7. Ward FA, Pulido-Velázquez M. Efficiency, equity, and sustainability in a holistic water quantity - quality optimization model in the Rio Grande basin. Ecological Economics - Special Issue: Integrated Hydro-Economic Modelling, 2008.

8. Harou J, Pinte D, Hansen K, et al. HydroPlatform.org – an open-source generic software interface and web repository for water management models. In: International Symposium on Environmental Software Systems 2009, Venice, Italy. 2009.

9. Andreu J, Capilla J, Sanchís E. AQUATOOL, a generalized decision-support system for water-resources planning and operational management. Journal of Hydrology 1996;177:269–91.

10. Andreu-Álvarez J, Pulido-Velázquez M, Collazos G. Methodology and tools for integrated assessment of resource and environmental requirements costs. In: Second International Workshop on Implementing Economic Analysis in the Water Framework Directive 2005, Paris, France. 2005.

11. Randall D, Cleland L, Kuehne CS, et al. Water supply planning simulation model wing mixed-integer linear programming "engine". Journal of Water Resources Planning and Management 1997;2:116–24.

12. Diaz GE, Brown TC. Aquarius: an object-oriented model for efficient allocation of water in river basins. In: Warwick, JJ. (Eds.), Symposium Water Resources Education, Training, and Practice: Opportunities for the Next Century, Keystone, CO 1997:835–44.

13. Jha MK, Das Gupta A. Application of Mike Basin for water management strategies in a watershed. Water International 2003;28:27–35.