

USE OF HYDRAULIC, HYDROLOGIC AND WATER QUALITY MODELS IN THE INTEGRATED WATER RESOURCES MANAGEMENT: THE CASE STUDY OF LAKE IDRO

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ABSTRACT

A challenge for the next years is the improvement of the hydropower sustainability following the basic principles of the integrated water resources management issued by the WFD. Indeed, although WFD has been fully introduced within the national laws, a further period of experimentation and diffusion of best practice should be needed to put its basic principles into practice. In this frame a means to improve hydropower sustainability should pass through testing reservoirs operational modalities which take into account all the possible water needs at a wider scale. After having spent some years developing and applying tools to support hydroelectric reservoirs management issues, we decided to set up one case study where those tools could be used in combination, in an attempt to carry out an example of an integrated approach to the river basin management. The selected site was Lake Idro, a natural lake regulated through an artificial weir for agricultural and hydropower use, whose inflowing water depends on the management of upstream hydroelectric plants. Along with the quantitative aspect, water quality and ecological status of the lake are considered to have worsened in last years. Although the lake has been smoothly regulated for decades, conflicts among public and private stakeholders have arisen more recently, due to the increase in ecological requirements, public awareness of environmental issues and fragmentation of water exploiters and regulatory boards throughout the hydrographic basin. The project core is the simulation of water quality, hydrology and hydraulic of the watershed-lake system in order to identify firstly which changes of lake regulation could help to reduce nasty water conditions and then to study the consequences that such changes could have in relation to flood prevention, water availability and electrical production.

The following tools will be applied: a hydrological-hydraulic watershed modelling tool, a lake hydrodynamic and water quality model (using data from in-lake monitoring station), a simplified tool for the optimization of the management hydropower plant.

Prior to the start up, the project has been presented to the main stakeholders in order to share with them both the goal and the achievements of the research. Agreements have been reached with the main institutional subjects (Regione Lombardia and Provincia di Trento) for the sharing of data and information produced within each own institutional tasks. The present paper is aimed at the presentation of the start up of the Lake Idro project.

1 INTRODUCTION

The issue of the Water Framework Directive was one of the most significant events of the European environmental policy in the last decades and it has had a very important impact also on the energy sector. The higher attention to the protection of water bodies provided by the WFD has led to some constraints in water exploitation and, hence, in the development of the hydropower sector. Ever since, hydropower producers have moved much criticisms to the WFD asserting that it would inevitably hinder not only the further development of the sector but also the maintenance of the actual energy production. Nonetheless it is widely recognized that an effective water management, as promoted by the WFD with the Integrated Water Resources Management, can lead to the satisfaction of all the users while improving the overall sustainability of resources exploitation. According to the IWRM paradigm, which can be considered the key concept of the WFD, water resources have to be managed taking into account all the possible uses falling into the influence of the water catchment, which is the natural spatial scale for an effective water management (Davis, 2007).

This basic concept has been recently included in the Italian legal framework (legislative decree 152/2006), however, the transition to a practical application is still difficult. As a matter of fact the territorial organization has followed a far different, and in some ways opposite direction to that hoped for a real joint management of resources. While it is clear that the level of conflict is expected to rise in coming years, owing to both the increasing competition for water use, and a greater environmental awareness, fragmentation of administrative board as well as of electric utilities risks to make the adoption of the IWRM approach more and more remote.

In this context, we have started a research project aimed at exploring the possibility to approach a complex water system problem by using in a joint way some hydropower oriented modelling tools, with the scope to identify regulation agreement which satisfy the need of all the stakeholders.

For the selection of the site we considered several aspects such as, besides the prominence of hydropower use, the water quality status of the lake/reservoir to be studied, the data availability (operational, hydrological and water quality data). As a result we selected the Lake Idro water system because of the significant environmental issues and severe conflicts among the stakeholders.

2 STUDY AREA

Lake Idro is one of the Italian great lakes, situated in the Alps, although it is by far the smallest. The lake has a maximum capacity of about 850 Mm³, maximum depth of 124 m and a surface area of 11.5 km² (at 370 m a.s.l.). The lake is fed mainly by river Caffaro and river Chiese which is also the lake emissary; the outflow is regulated through an artificial weir since 1920's. Leaving the lake, the river flows through the Val Sabbia up to Roè Volciano and then, in the plains, flows north-south until merging with Oglio river, downstream Acquanegra sul Chiese.

Lake Idro catchment area covers about 617 km² and is situated at an average altitude of 1509 m a.s.l, with the lowest point at 360m and the higher one coinciding with Carè Alto mountain, at 3462 m a.s.l.

An area of 379 km² of the total Lake Idro catchment is represented by the Chiese

river catchment, another part of 149 km² by the Caffaro river catchment, while the remaining part of the basin drains directly to the lake.

In the upper Chiese basin river there is the Lobbia Glacier from which the river has its source.

From 2009 to 2010 the average total inflow to the lake has been 33 m³/s of which about 15 m³/s was the contribution of the river Chiese.

In the upstream watershed of lake Idro, there are six regulated reservoirs formed by dams, whose main use is hydropower production. About 55% of the area is influenced by these reservoirs. In the figure below a table is given with the volumes of each reservoir.

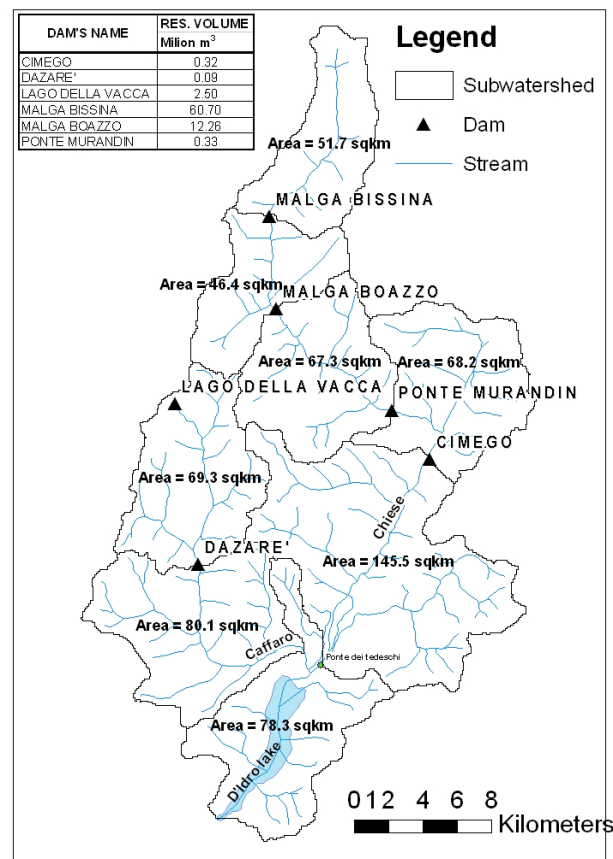


Figure 1. Lake Idro watershed and sub-basins.

As regards the ecological characteristics, lake Idro is a mesotrophic, naturally meromictic lake. A meromictic lake is characterised by the presence of a lower layer (monimolimnion) whose water is completely segregated from the upper layer (mixolimnion); being permanently excluded from winter recirculation, the hydrodynamic process which guarantees the oxygenation of deeper water, the

monimolimnion is normally completely anoxic. In lake Idro the monimolimnion extends from about 40-50 m depth to the bottom; the high conductivity showed by the lower layer contributes to make the separation more stable. Apart from the deep unmixing and naturally anoxic layer, the mixolimnion (upper mixing layer) is classified as “mesotrophic”. In general, lake conditions are considered to have worsened in the last decades, and a diminishing trend of the mixing layer depth has been observed (Garibaldi et al., 1996).

2.1 The regulation of Lake Idro

The lake is regulated through works built during the 20's and managed by Società Lago d'Idro (SLI). For years, the regulation of the lake was conducted in accordance with the regulations approved by the Royal Decree 9.28.1934, which guaranteed the appropriate water supply, with reference to the seasonal needs for irrigation in the downstream watershed, and established minimum and maximum water level threshold. During the 50's, some hydroelectric reservoirs were built in the upstream basin, for a total storage capacity of about 75Mm³. Operational rules have been established since then, to comply with the different water needs.

On expiry of the older water concession, the Ministry of Public Works, through the Po River Basin Authority, together with Regione Lombardia, Provincia Autonoma di Trento and Province of Brescia, promoted an experimental period (1996 - 2001) to identify new ways of managing water in Lake Idro - Chiese Basin. ([Http://www.ors.regione.lombardia.it/](http://www.ors.regione.lombardia.it/)).

At the moment the water management appears to be still problematic due to the fragmentation of local Authority who belong to the area and the existence of many different users (hydropower producers and farmers). The conflict situation among farmers and hydropower producers is similar to those described for other Italian great lakes, such as Lake Como (Anghileri, 2010), however, for Lake Idro the situation seems to be worse due to its ecological status.

The main lake water use is the irrigation of the downstream catchment, although hydropower plants are located both upstream and downstream. Downstream producers are not much involved in the conflict because they are subdued to the irrigation and normally this quantity is far enough to satisfy the hydropower request.

Hydropower reservoirs in the upstream catchment have a small capacity when compared to the lake volume. However the situation is quite different if reservoirs total storage is compared to the lake's operational capacity only -actually much reduced with respect to the former management- of about 35Mm³ (corresponding to the maximum level excursion of 3.25 m allowed by the rule in force).

3 THE LAKE IDRO INTEGRATED PROJECT

As a matter of fact at the moment the lake is still under the whirlpool of many contrasting interests among different users, public Authorities and citizens organization. Local organizations, expressing much concern about the worsening of water quality, make request for a more natural-like management of the lake and an overall restoration of its environmental conditions (included the recovering of hydraulic continuity between the lake and the outflowing stream).

The project core is a hydrodynamic-based study of the lake Idro water quality aimed

to identify possible operational changes to ameliorate its ecological status, and the subsequent evaluation of hydrological, hydraulic and energetic consequences that such changes could have on the upstream watershed.

The first step is thus to model the lake water quality in relation to its hydrodynamic. Once satisfactory simulations of the main ecological variables are obtained, the model will be used to test whether operational alternatives and/or different regulation rules can affect water quality conditions and which consequences the various regulation requests can have on the water quality.

The alternatives so defined will be in turn evaluated in relation to hydraulic/hydrological aspects (such as flood prevention, environmental flow and aquatic ecosystem continuity) and power production. In particular by globally modelling the hydropower scheme in the upstream watershed we will try to evaluate the effects that the different management scenarios suggested for the lake's health may have on production efficiency, but also on the hydrological status of the water system.

As operational alternatives we will consider either the in-lake withdrawal or the inflowing water (e.g. daily and yearly flow patterns), suggested by the involved actors.

Models and tools to be applied in this study-case have been developed under the framework of the Research for the Electric System Fund, aimed at the improving of the environmental performance of the electro-energetic national system. The tools implemented in previous researches are designed to support private and public operators in analysing important aspects of water resources, with regard to the hydroelectric management. The following tools would be applied in this study:

LDS-DYRESM/CAEDYM system (developed by Centre for Water Research, University of Western Australia): an integrated system composed of a floating monitoring station (LDS) whose data (meteo and water temperature) are supplied to an hydrodynamic model (DYRESM) coupled to a water quality model (CAEDYM). The system has been completed with a software interface (SIMOLAB) for data management (developed by RSE). The whole system has been set up in a previous research for the Fiastra hydroelectric reservoir (Garofalo et al., 2009).

HALTFLOOD (developed by RSE): software integrating meteorological data (measures and local forecasting) hydrological and hydraulic models for the real time management of dam withdrawal in complex hydropower schemes.

SOLARIS (developed by RSE): deterministic optimization tool that, given a network of interconnected hydroelectric reservoirs, given the rainfall time series and given the energy prices time series, determines a management policy that maximize the revenues from energy sales. As it is not a dynamic stochastic optimization tool, it is useful mainly to compare different management scenarios.

Due to the complexity of the study and, above all, to the critical relations among the stakeholders, we considered it fundamental to involve the main institutional subjects from the very beginning. A summary of the project was prepared, which served as a basis for the discussion with the main stakeholders. These are: Regione Lombardia (lake jurisdiction); Provincia Autonoma di Trento (upstream river basin jurisdiction); Società Lago d'Idro (lake regulatory body); Hydroelectric producers (owners of the main reservoirs in the upstream watershed).

4 PROJECT START-UP

The first phase of the project concern the setting up of the LDS/ DYRESM-CAEDYM system.

DYRESM (DYnamic REServoir Simulation Model) is a one-dimensional hydrodynamics model for predicting the vertical distribution of temperature, salinity and density in lakes. The model needs water balance data (initial lake volume, inflows and outflows) and meteorological data (to simulate the surface heat, mass and momentum exchange), during the simulation period and returns vertical profile of temperature and salinity. It can be run either in isolation for purely hydrodynamic studies or coupled to CAEDYM (Computational Aquatic Ecosystem Dynamics Model) for investigations involving biological and/or chemical processes (Imerito, 2007; Hipsey at al., 2006).

The Lake Dyagnostic System (LDS) is a floating monitoring station meant for the acquisition of data environmental necessary for the modelling. It consists of a floating meteorological station installed at 2m above the surface (measuring wind direction and velocity, air temperature, relative humidity and short-wave and net radiation) and submerged sensors for temperature, oxygen and conductivity measurements along the water column. Data are registered every 30 seconds and transmitted via mobile telephone to a shore computer running the acquisition software. Data are then processed with SIMOLAB, on-purpose software interface developed by RSE, which performs data quality check, graphic display, statistical computing, creation of the library of climatic and hydrological conditions and finally preparation of input files for the numerical codes.

The installation site and the configuration of LDS (type and position of the sensors), have been established after a preliminary analysis of previous data, provided by ARPA Lombardia. The final LDS set-up is illustrated in figure 2.

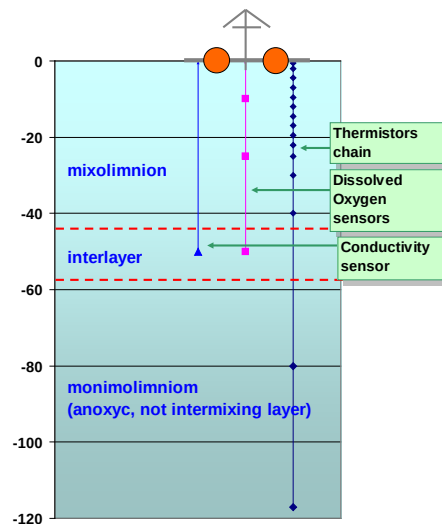


Figure 2. Schematization of the submerged sensors configuration

The system is designed to be installed at 120 m depth and to compensate water level excursion up to 10 m. Beside a complete meteorological station, it is equipped with a 15 node thermistor-chain distributed along the water column, 3 dissolved oxygen sensors and 1 conductivity sensor, fixed at the most significant depth. Other fundamental data for the DYRESM-CAEDYM modelling are:

- Lake morphology, in particular the volume-depth and area-depth curves
- Water level variation, in-out flow data (daily basis)
- Chemical and physical characterisation of the inflow
- Chemical and biological characterization of the water column (seasonal basis)

Data supply is granted by Provincia di Trento, as regards river Chiese, and Società Lago d'Idro, as regards daily lake regulation and river Caffaro.

As to the in-lake chemical and biological characterization, our Project will benefit of the results of a parallel research on the ecology of lake Idro, carried on by the University of Parma, Department for Environmental Sciences. The research is committed by Regione Lombardia, and co-funded by FESR within the framework of the European Project-Alpine Space 2007-2013 "SILMAS - Sustainable Instruments for Lake Management in the Alpine Space".

The LDS has been installed in the lake during a field campaign in March 2011. Since March 24th, data are transmitted every 2 hours to the shore-station located at RSE head office, automatically controlled and processed by SIMOLAB.



Figure 3. The Lake Diagnostic System newly installed in Lake Idro.

The data set elaborated by SIMOLAB has been used to perform a test simulation on lake Idro, in order to verify first if the system configuration (LDS position and depths of the sensors, lake morphometry and water balance data provided to Dyresm) is able to

output with good approximation the thermal structure of lake Idro. In the figure below the output of the test simulation is showed. In agreement with monitoring data, it shows the thermal segregation between the upper layer and the deep anoxic water.

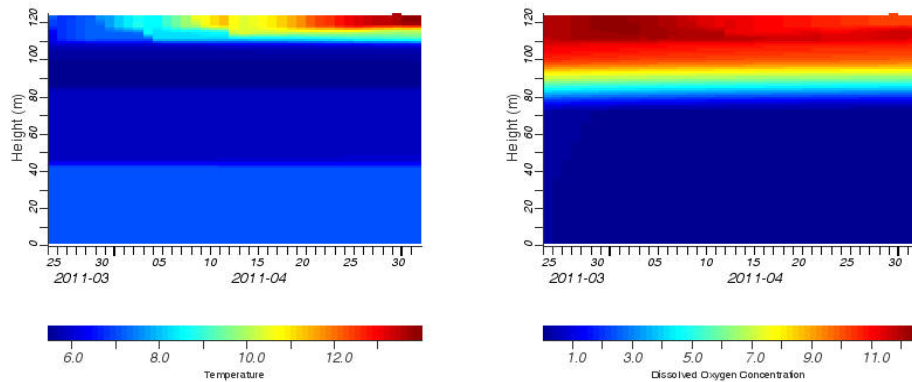


Figure 4. Simulation results: vertical distribution of temperature (on the left) and oxygen (on the right) over the simulation period.

5 CONCLUSIONS

The conflict situation for the lake management implied a period of preliminary discussions with the stake holders, before even starting with the experimentation, and until now the project has had a very satisfactory kick-off. Although the goal of the project is ambitious and will need a much longer period to be achieved, some important middle term results can be obtained by the end of 2011.

The preliminary test simulation showed that the implemented system configuration is capable to reproduce energetic and hydrodynamic process governing the lake: by the end of the year we expect that a preliminary seasonal Dyresm-Caedym simulation will put in evidence more details about time evolution of vertical water stratification, with particular regard to the critical season (summer, early autumn) and to the anoxia of deeper layers.

We expect as well to assess in detail the possibility of analyzing all the aspects concerning water management by integrating different and very specialized tools. In particular, the schematization of the water system (upstream catchment and lake regulation) will allow us to identify principal conflicts as regards water quantity.

This is fundamental for the best setting of the hydrological, hydrodynamic and management analysis which will be performed to identify regulation optimization.

Finally, particular attention would be given to communication initiatives and to consolidate the involvement of the main stakeholders.

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