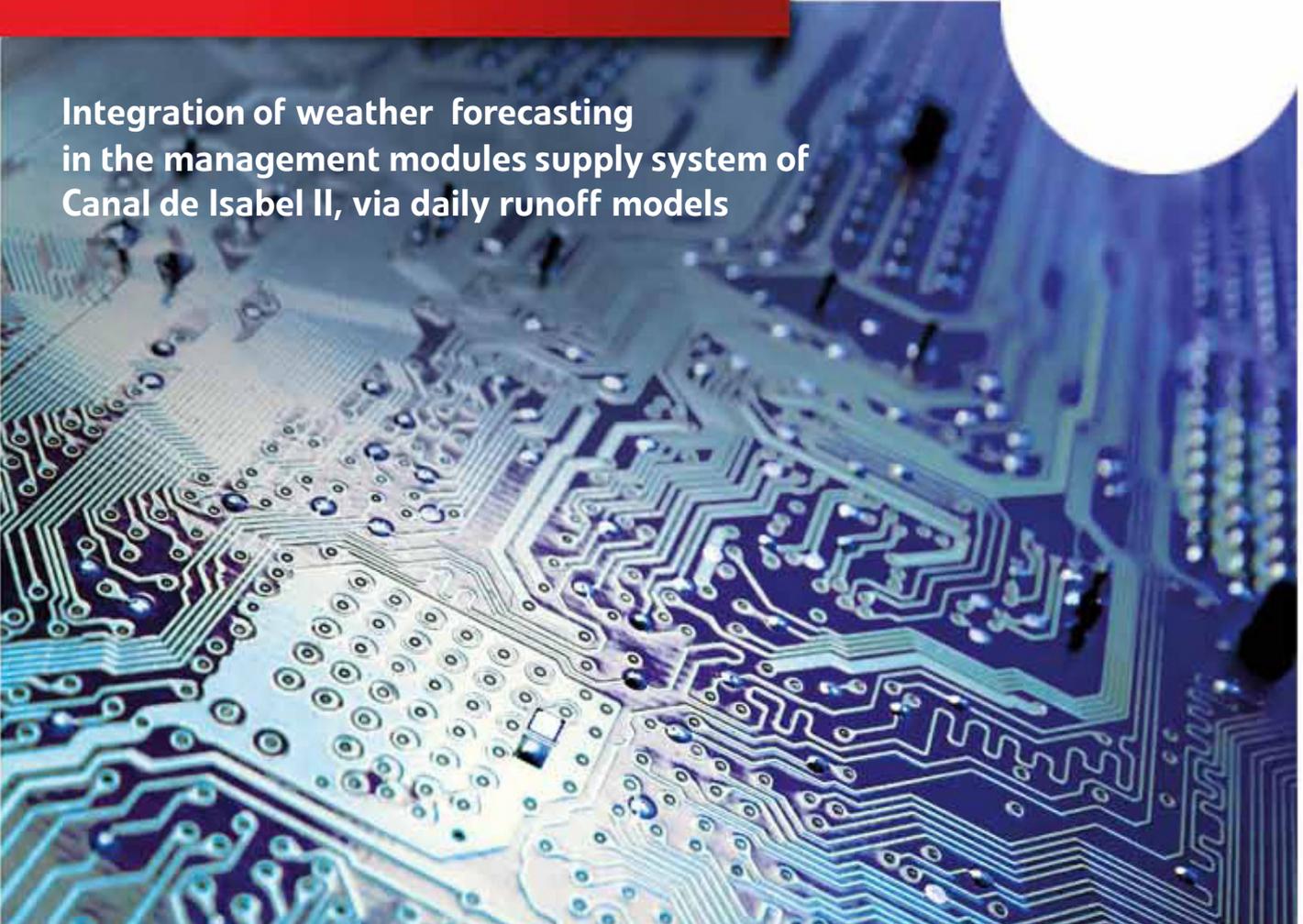


## BOOKLETS

Research + Development & Innovation

# 16

Integration of weather forecasting  
in the management modules supply system of  
Canal de Isabel II, via daily runoff models



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# Introduction

Canal de Isabel II's Research, Development & Innovation Booklets form part of the company's Knowledge Management Strategy and of the development involved in the Research, Development and Innovation Plan.

These Booklets represent an element for diffusion of projects and initiatives that are developed and sponsored by Canal de Isabel II for innovation in those areas related with water service in the urban environment.

A series of different problems that have been undertaken in each project are put forward in the Booklets, along with the results that have been obtained. The intention behind their diffusion by means of these publications is to share the experiences and knowledge that has been acquired with the entire water services sector, with the scientific community and with all those working on investigation and innovation tasks. What is aimed with the publication of these Booklets is to contribute to improvement and efficiency in water management and, consequently, in the quality of service that is provided to the citizens.

The R&D&I booklets published to date are as shown below by their titles in the following table.

**Table a. Titles published in the collection**

Collection Number	Research, Development and Innovation Booklets published
1	Transferences of Water Rights between Urban and Agrarian Demands. The case of the Community of Madrid
2	Identification of Hydrometeorological Runs and Tendencies within the scope of the Canal de Isabel II system
3	Contribution of Canal de Isabel II to the International Demand Management Project (IDMF)
4	Micro-components and Explanatory Factors on Domestic Water Consumption in the Comunidad de Madrid
5	Virtual Water and Hydrological footprint in the Comunidad de Madrid
6	Study on the saving potential of water for residential uses in the Comunidad de Madrid
7	Potentials of efficiency in using dishwashers in the Comunidad de Madrid
8	Accuracy in the measurement of individual water consumption in the Madrid Region
9	Research project to define and assess the applicability of a Bioassay Test to determine the toxicity of water using Zebra Fish embryos
10	Water Use Efficiency in Gardening in the Region of Comunidad de Madrid
11	Remote sensing techniques and geographical information systems for assessing water demand for outdoor uses in the Comunidad de Madrid
12	Cyanotoxin Dynamics Study in two of the Canal de Isabel II's supply reservoirs in the autonomous region of Comunidad de Madrid
13	Development of a validation, estimation and prediction of hourly consumption by sector, for the distribution network of Canal de Isabel II
14	Monitoring urban consolidation evolution in the Autonomous Region of Madrid using remote sensing techniques
15	Experiences for phosphorous recovery from wastewater as struvite in Canal de Isabel II

# Project Outline

Project title	Integration of weather forecasting in the management modules supply system of Canal de Isabel II, via daily runoff models
Research line	Guarantee strategic continuity of service
Canal de Isabel II areas involved	R+D+i Deputy Direction
External participation	ECM, Ecología y Tecnología del Medio Ambiente
Aim and justification of the project	To establish a system to forecast runoff into Canal Isabel II reservoirs, with a few days scope. Additionally, to test different modelization strategies for daily runoff in the river basins of Canal Isabel II reservoirs, assessing their capacity for forecasting runoff.
State of the art contribution	Original formulas were proposed and tested, to simulate daily runoff, like a metric model based on recursive filters to separate the base flow; or include a snow simulation algorithm to balance model GR4J. Furthermore, an error feedback technique has been successfully defined and tested based on correcting simulated moisture status, enabling inclusion of an information balance model on immediate past flow data.
Project development summary and milestones	Model GR4J, extensively proven in France, has been tested successfully in catchments of different geographical areas. The model was completed with an algorithm for the simulation of snow processes, absent in the original formulation. Furthermore, this model was used as a base to define and test the original error feedback formula.  The project carried out provides another comparison among conceptual and metric models.
Obtained results summary	A daily runoff model has been designed and tested successfully, adapted to the reservoir basins managed by Canal de Isabel II, and extremely useful given the currently available hydrometeorological information.  Furthermore, there is trial software of a runoff forecast system, based on that model, for three reservoir basins of Canal de Isabel II. The system allows weather predictions and feedback with past flow data.
Research lines open for continuing the work	<ul style="list-style-type: none"> <li>• Research extension to other reservoir basins managed by Canal de Isabel II.</li> <li>• Inclusion of weather forecast probabilities (current version only includes deterministic predictions).</li> <li>• In-depth research on flows feedback systems in balance models.</li> <li>• Improve simulation of processes associated with snowfall, especially insofar as specific contrasting data are available.</li> </ul>

# Executive Summary

The weather forecast integration project in the supply system management models of daily runoff, presented in this R+D+i booklet is an experimental study whose aim is to assess several modelization strategies for daily runoff to Canal Isabel II reservoirs, choosing the most appropriate and efficient in its forecasts.

Canal de Isabel II achieved preliminary works on the hydrological modelization. In 1991 a runoff model, with daily resolution for each of its reservoirs, was implemented and calibrated to estimate future runoff based on hypothetical weather scenarios for the following days, and particularly to assess expectable runoff from snow melt. The SYGA application was developed in 1997 on a preliminary hydrological modelization and reservoir operation during the flood, aimed at real time flood management, incorporating current situation data and hypothetical future rainfall data. In 2003 runoff models were developed based on regression adjustments of simple equations without physical base relating the flow with weather variables, and immediate past flows. These models have a daily resolution and are designed to accept forecasts as input data, as a predictor variable.

Due to obsolescence or different approach none of the previous actions fully responded to the needs of the modelization tasks posed in this study, which aims to design a system whereby from data available, it provides information on expectable runoff for forthcoming days. Said system will be based on the basin hydrological model with temporal daily resolution.

The hydrological and weather data provided by Canal de Isabel II's information systems are:

- The series of daily runoff data to reservoirs are available at least from 1986.
- There are also weather data of the most important variables (daily rainfall, minimum and maximum daily temperatures). These values are measured in the dams and can be considered representative of the basin conditions by virtue of their relatively small sizes. The automatic systems of data capture and transmission that Canal de Isabel II has installed virtually update these series in real time.
- Canal Isabel II has had for some years quantitative daily weather forecasts of sufficient quality, covering several days.

Study scope was limited to three reservoir supply basins, as a model representation of all the reservoirs managed by Canal de Isabel II, due to their size, and their greater or lesser hydrological importance of snow. The basins studied were: Pedrezuela, La Jarosa, and El Vado. Justification of their incorporation in the pilot study is developed in the document contents.

Initially, use of a continuous or balance hydrological model was considered like the HSPF, already tested by Canal de Isabel II in the 90s. Given its conceptual character, this type of model provides consistent interpretable results in hydrological terms. Furthermore, it seems essential the model try to explain the processes associated with the snow evolution, which also indicates continuous models. The aim is to design a system which provides information on expectable runoff for forthcoming days. Said system would be based on a river basin hydrological model with daily temporal resolution. Modelization strategy should respond to certain requirements: input data must be available, all relevant data available must intervene in the model, its implementation should be reasonable.

Nevertheless, continuous models present the disadvantage of not allowing incorporation of flows from immediate past as an input variable, thus defaulting on one of the requirements, since the immediate past flows are known and clearly important. On the one hand, the time scale of the recession is greater than the model resolution (today's flow will be felt tomorrow as a recession flow); and on the other, the flow is an indicator of the basin moisture (the response to rainfall will very likely be greater in a high water situation). The need for a model whose formula was relatively simple impeded the use of HSPF, and others equally sophisticated. Thus, two easier formulas of fairly recent development were tested, known as GR4J, and SIMHYD. Furthermore, other alternative strategies were tested in the line of statistical models to have an expectable accuracy level reference with different continuous type models.

## Results

The results achieved in this study are summarized in the following points:

- There is a simple formula to build models of daily runoff to Canal de Isabel II's reservoirs operable with daily data available. The formula is based on the balance model GR4J which incorporates an algorithm to represent the processes associated with snow cover. The combination of both elements is original and is called GR4JN.
- The previous system incorporated an error feedback system of the model, enabling introduction of information provided by recent daily flow data. This feedback type is original in the balance models and has shown notable efficacy in improving flow estimations in short forecast scopes.
- The model was tested to simulate daily runoff in three reservoirs managed by Canal de Isabel II: Pedrezuela, La Jarosa and El Vado. The model included a series of daily hydrological and weather data from 1986. Satisfactory results were obtained.
- The predictive capacity of the models was assessed for different prediction scopes (from 1 to 10 days) via the hydrological efficiency concept, model efficiency in the supposition weather data are known. In this supposition, prediction with n days' scope means rainfall and evapo-transpiration are known for the forecasted day and the previous; however, the last known flow data is prior to n days to the datum we wish to estimate.

As expected, hydrological efficiency reduces as prediction scope increases, whose limit is the non-feedback or free functioning model efficiency (representing the case where the model is not supported by any prior flow data).

- Other alternative modelization strategies were studied (SIMHYD model, regression models, Qb+Qf model). The GR4JN model generally provides better results in terms of predictive efficiency, in addition requiring fewer parameter adjustments.
- Channels for operational exploitation of models have been explored and identified, in particular estimation of future runoff for forthcoming days. Said estimation is obtained via an updated representation combination of the humidity status of the basin provided by the model, information available on the weather expected for the forthcoming days (climatology statistics, weather predictions) and the hydrological simulation capacity of the model.
- An application was developed implementing the model and a set of functions for its operation integrated in the Canal de Isabel II's information systems with data update, inclusion of weather forecasts, navigation by calendar and visualization of results. These functions enable updated maintenance of the model and its operational application in the prediction of future runoff.

A tool capable of translating hydrological, and weather information daily available in Canal de Isabel II, with information on runoff for forthcoming days has been obtained. The process rests on a balance hydrological model providing representation of the state of humidity of the basin. Furthermore, the state of simulated humidity is corrected via feedback with flow data from previous days.

The works carried out were a pilot study centered on the selection of three river basins. Therefore, the results obtained should likewise be interpreted from the perspective of seeking promising channels to continue the research. An immediate continuation channel of the works is an extension of the analysis to the rest of the basins supplying the reservoirs managed by Canal de Isabel II. An assessment phase of the results provided by the current tool in operation conditions may be natural preliminary condition to start this activity. In the current development, conceived for a limited number of river basins, the application developed treats each basin separately. Extension to other basins would involve the need to achieve integration of them all, in some way, to form a single prediction tool.

With focus more directed at researching new possibilities, other continuation channels are proposed for works to:

- a) Inclusion of weather forecast probabilities.
- b) Testing new feedback systems.
- c) Improve simulation of processes associated to the snow cover.

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