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A web-based tool for operational decision making and IWRM

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Abstract

This article presents a web-based tool for operational decision making and water management planning. The tool was designed and implemented to address the management and modelling stakeholder's needs of Bogotá river basin. In general, the system is composed by two entities: a backend and a frontend, which are loosely coupled by an API. The backend incorporates the management, processing and storage of the water data. Within this component the water data will flow through a set of modules, such as: processing routines, water models and a multi criteria analysis module. Moreover, the backend steers a set of exiting water models, such as: Water Balance model, hydrological and hydrodynamic models, water quality and groundwater model. The frontend is the platform component visible and accessible to the user (stakeholder). With it, the users will be able to see monitored data, partially configure the water models, run model trains and see their results and evaluate different planning strategies. The frontend was implemented on a web-based environment, this is advantageous as the frontend component is platform independent. This means, the stakeholder will only need web browser to access the platform. Moreover, it will be possible to benefit from cutting-edge web technologies to produce visualizations and displays, and in this way offer the stakeholder a suitable user experience. After the implementation, the stakeholders made use of the system operationally and their experiences are also present.

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1. Introduction

Nowadays, river basin water resources management is carried out by a set of stakeholders with different, and sometimes conflicting, objectives. Decision support System (DSS) have been widely used for helping stakeholders make decisions. Decision support platforms are systems that incorporate a considerable amount of data from various sources and disciplines. This data is composed mainly of time series, spatially distributed data and metadata. Moreover, these systems transform and process raw data, such as measurements, into valuable information to the system user. Additionally, this information is displayed in graphic visual representations to make it presentable and easy understandable to the user. Regardless of these advances, DSS sometimes are deficient in dealing with collaborative decision making as much of the software it is encapsulate in single physical entity (a PC) as a standalone system. In an attempt to overcome with these issues, developers and engineers have tried to implement a web-based environment as user interface, or frontend component for this platform this frontend will be platform independent. In other words, it will only require a web browser to view the displays and the results of the scenarios. Moreover, it will be possible to take advantage of the web technologies to produce visualizations and displays, and in this way offer the stakeholder a suitable user experience. The intention of this article is to implement such an approach in the conceptualization and design of a Decision Support Platform for the Integrated Water Management of the Rio Bogota Basin.

1. Conceptualization of the DSS system

1.1. Gathering Information

The first step for successfully design and implement a modelling platform for decision support is to have a deep understanding of the water system, from a process and management perspective. This was achieved by looking to different sources of information. This was accomplished by carrying out first hand interviews and complementing it with a literature review. The first consisted on performing semi-structured technical interviews with experts and stakeholders of the system (the platform end-users). Then, it was used reports, management and adaptation plans of the River Basin System for reviewing and literature study.

1.2. Overview of the Rio Bogotá Water System and its Management

The Rio Bogotá water system is a complex one. The system provides water for consumption and energy to the people, industries and irrigation. The sources of water come from both surface and groundwater. Along the whole basin there is an important set of reservoirs that are used for storing water for domestic and energy generation purposes. Also there is direct extraction of water from the Rio Bogotá for domestic purposes and irrigation. When there is no enough surface water for irrigation, this is obtain from the groundwater.

The Río Bogota Basin system is managed by an environmental institution named "Corporación Autónoma Regional de Cundinamarca" (CAR) and the water resource of the basin is used mainly by a set of institutions, both public and private, in charge of the providing water for consumption and generating energy. The system's manager, CAR, and the rest of users get together on a normal basis in what it is called a Hydrological Committee. This committee takes joint general decisions of how the water will be used, solve inconveniences in the operation of the system and adapt the operations to foresee changes in the hydrological patterns which could affect normal operations of the system.

After all the workshops, it was noticeable that CAR and the rest of the stakeholders have a deep understanding of the Rio Bogotá water system. Moreover, all of them understand deeply the roles and responsibilities of each stakeholder. And, they are aware of the current system problems, from a physical processes and from a management and operation point of view.

Furthermore, in the meetings, it was highlighted how the Hydrological Committee is in a weak position toward future hydrological changes, due to the lack of a set of tools, methodological and computational, which will help them take informed and technical substantiated decisions. Moreover, they say "these type of situations are particularly critical when there is a lack of water. And then the stakeholders must compete for the access to the water resource". In the future, this could be aggravated when the pressure over the water resources increase due to a rise in the demand.

Nevertheless, the stakeholders still manage to provide fast response for operational decision making, because of their broad knowledge of the basin system and the clear understanding between stakeholders.

1.3. Requirements

The Río Bogotá Hydrological Committee requires informatics tools and numerical models for making timely, certain and substantiated decisions. In this way guarantee adequate use of the resource, guarantee enough water to the supply system and environmental sustainability.
Moreover, the tool should provide information for:

- Guaranteeing an adequate distribution of the water resources in the long, middle and short term,
- Optimizing the operation of Bogotá system, especially in extreme events,
- Taking technical substantiated decisions for operational management and planning

Therefore, the system manager and its stakeholders require a platform/system that will help them provide assertive decisions in the daily operation of the system. Moreover, it needs to provide support for long term planning evaluation. And What is more, the platform will engage the Committee to follow a structured methodology for decision making.

The stakeholders understand that at the beginning the platform will not be able to cover all the management needs. Hence, they foresee the platform as an expandable and configurable system. The system should be capable of adding new tools, using the same software as the ones already configured, and gradually extend the river system schematization through time.

From a visualization perspective, the stakeholders plan the interfaces as a set of UI composed of interactive maps with layers (base maps, grids, land uses, stations, etc.), schemas, bar charts, time series graphs, pie charts, metadata information, etc.

1.3.1. Specific Needs

The platform should work as a planning tool for:

- Optimizing the use of the water resource to guarantee to the basin users the water resource,
- Identifying the water accessibility for future users,
- Establishing the monthly water resource availability for the water supply system,
- Scheduling the reservoirs operation,
- Defining the maintenance plan of the water infrastructure,
- Estimating the long and midterm energy production in the power plants,
- Minimizing energy rationing and maximizing energy generation.

The platform should work as an operational system for:

- Evaluating the water level conditions during an extreme event,
- Assessing the wave travel time in the river for flood assessment,
- Assessing the water quality of the river, especially in the water treatment intakes,
- Detecting the water quality critical points along the river,
- Optimizing the short term reservoir operations concerning energy production,
- Optimizing the operation of the pumping stations along the river,
- Optimizing the use of the control gates along the river,
- Identifying sources of pollution along the river,
- Evaluating the seasonality of the water quality parameters in different river reaches,
- Evaluating water quality conditions in the river and take actions by adjusting the operation of the water treatment plants or the reservoirs.

2. The Río Bogota DSS system and Modeling Platform

2.1. Concept

In very general terms, it has been planned to implement a system that displays and manages water information. In very general terms, the system will be compound by two entities: a backend, and a frontend which are loosely coupled by an API. The backend incorporates the management, processing and storage of the water data. Within this component the water data will flow through a set of modules, such as: processing routines, water models and a multi criteria analysis module. The frontend is the platform component visible and accessible to the user (stakeholder), it is composed mainly of visual displays.

2.2. Architecture

2.2.1. Backend

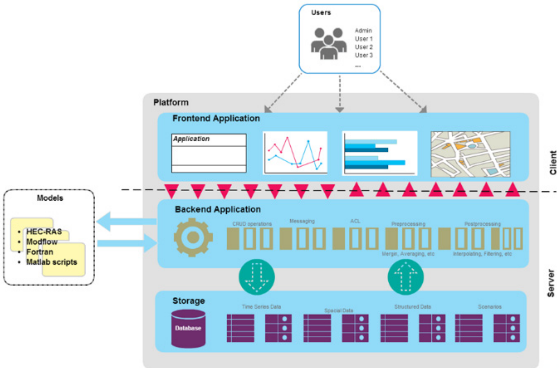

Figure 1 Platform's Architecture

Currently, CAR possesses a set of uncoupled 'water' models, see Table 1. Each model describes a well-defined process within the Bogotá basin. It was planned to couple these models in a cascade workflow, when possible. This type of workflow creates many advantages: 1) it is relatively simple to configure; 2) it allows for easy expansion; 3) it is efficient; 4) it is easy to understand for new system managers and users; and 5) If it is required, it forms a sound basis for operational forecasting system.

Table 1 Water Models Available

Models	Aim	Software Package
Water Balance Model	Assess Availability of the surface water resources along the basin, operate the reservoirs,	HecResSIM
Hydrological Model	Compute volumes of water along the subbasins of the system	HEC-HMS
Hydrodynamic Models	Evaluate water levels and discharges along the river streams	HEC-RAS
Groundwater Models	Evaluate ground water table and its changes due to extractions	Modflow
Water quality Model	Evaluate water quality along the river streams	CAR's internal Model

The steps below, show a very general overview of the processes the decision support platform will carry out:

- First, the platform will retrieve data from an external source. This could be a folder, a server URL, ftp, etc.
- Once the raw data is in the system's local database or after a model run has finished, the system will carry out processing routines to transform the data and make it appropriate to be exported to another of the model. Processing routines comprise of:
  - Gap filling for the imported raw data. This will be carried out with linear interpolation.
  - Hierarchical data merging, when there is more than one source of information, to merge hindcast and forecasted data and to fill gap with alternative sources of data.
  - Spatial interpolation for flood mapping.
  - User defined transformations, such as eg. Rating curve transformation for calculating water levels into discharge; calculation of the theoretical generated power of a hydroelectric plant based on the discharge and the head in the reservoir. This type of information will transform the model output data into valuable information to decision makers.
- Each model will be coupled to the platform by an adaptor. This adaptor will be in charge of the exchange of data between the platform and the software.
- Afterwards, the platform will perform final post processing activities, these include:
  - Deployment of the multi criteria analysis engine.
  - Transformation of data to other formats.
  - Producing additional information which could be important for the end users
  - Reporting
  - Exporting information to external sources.

Moreover, it is envision a modelling platform that is able to provide support for collaborative decision making. This platform will convey uniform information to all the stakeholders through an accessible common interface, leading to the reduction of conflicts and implementation of common and agreed alternatives. To accomplish the above, it was foresee a system which works in two modes. In an operational environment, carrying out scheduled simulations. And in an evaluation environment, where simulations takes place for the assessment of alternatives under specific scenarios. Within the platform the platform operator would be able to partially configure the models for simulating different alternatives. For collaborative decision making, the stakeholders expect a multicriteria assessment tool, in which there is a comparison of alternatives. During the Hydrological Committee, they will weight a group of evaluations and finally the members will find the most suitable decision.

2.2.1.1. Operational Mode

The operational mode objective is to evaluate the current conditions of the river system, and make operational decisions. For this, the stakeholder will require monitored and forecast information. The information will be displayed in an interactive map, see Figure X. Through the map it will possible to observe measure and forecast information. Additionally, there will be a chance of displaying alarms for thresholds crossings.

Moreover, to help the decision makers take operational informed solutions. There is an option of carrying out partial modifications to the model configuration. So the users test diverse alternative and finally they make informed and technical substantiated decisions.

2.2.1.2. Evaluation Mode

The evaluation mode main objective is to assess alternative strategies facing a specific scenario. Specifically, the idea is that the stakeholders elaborate a set of alternative strategies for solving an issue. The user administrator will implement these strategies by partially configuring the models through the frontend or implementing a new model train. Then, these strategies will be evaluated against a specific scenario. Finally the results will be compared in a multicriteria analysis method.

2.2.2. Model Trains

After a deep analysis and evaluation of all the available models. It was concluded that it was not possible to carry out a single model train structure. Mainly because the platform needs to address different processes which are describe in different time scales. Therefore, there will be 4 model trains. Three of them will be in the evaluation mode and one of them in the operation environment. These are describe below:

- Evaluation Mode – Water System and Management train: composed of a hydrological method for estimation of monthly average runoff and of the Water Balance Model. This train will run with a monthly time step. Its objective will be for long term integrated planning assessment, this means assessments of at least 1 year. It will give as outputs:
    - The reservoirs states
    - Energy production
    - The ability of the system to guarantee the demands (water supply, energy, irrigation).
- Evaluation Mode – River system train: composed of a Rainfall-runoff model, the HEC-RAS river model and the ADZ water quality transport model. This model will run in an hourly time step. The objective of this train is to evaluate the operation of the system in a small temporal scale, such as: Increase or decrease of reservoir discharge, or opening and closing gates, and evaluate its repercussions on the river's flow and quality.
- Evaluation Mode – Groundwater train: composed of the Modflow model. It will run of monthly time steps. The idea is to make a regional assessment of the groundwater repercussions, eg. Piezometric level descent, due to aggregated extractions. The pumped water will be aggregated to an area scale, there will not be a well detailed analysis.
- Operational Mode – River system train: this train is composed similarly to the one in the evaluation mode. However, this will be running operationally with a specific schedule, most probably on a daily basis. The train will be running with the objective of forecasting water levels and discharges along the river.

2.3. Frontend

Normally, the classical decision support platforms are available as stand-alone systems, and in very few cases they are set up as client-server systems. Although this classical approach handles the backend processes without any problem (processing and storage), they often lack important features that cater for user needs, in our case the stakeholders; such as:

- The user requires a specific software, even in client-server systems.
- The user, in a client-server system, is usually bound to the software's platform, in other words, they need specific computer requirements, such as: locally installed software, (which could be bound to a license), and specific operating system requirements.
- The user experience is bound to the visual capabilities of the software.

In an attempt to overcome these problems, it was decided to implement a web-based environment as user interface, or frontend component for this platform this frontend will be platform independent. In other words, it will only require a web browser to view the displays and the results of the scenarios. Moreover, it will be possible to take advantage of the web technologies to produce visualizations and displays, and in this way offer the stakeholder a suitable user experience.

For displaying the information in the user interface, it was proposed the implementation of dashboards. This will be composed by spatial, time series, metadata visualizations, and log information. High end-users will have the possibility to setup scenario cases and trigger the workflows. Results are provided to the users for strategic evaluation.

3. Conclusions

A web based DSS concept has been developed. The conceptualization and design process consisted in gathering all the needs of the stakeholders and preparing a requirements list. In a joint effort between River experts and IT developers it was designed a platform that adapt to the needs of Rio Bogotá water managers. A platform such as the one they request will help them provide assertive decisions in the daily operation of the system. It will provide support for long term planning evaluation. What is more, the platform will engage the managers to follow a structured methodology for decision making.

The design of this platform is part of a project for the Management of the Rio Bogotá Basin. Currently the involved staff are working on the implementation of the platform (processing modules, post processing modules, API's, web dashboards, database, etc.). For this, the team of developers decided to use as much as possible open source technologies, this are listed below:

- Python 2.7
- Django Framework
- Django Rest Framework
- Django Res Swager
- PostgreSQL
- HTML - HTML5
- Javascript (leaflet, react.js, Angular.js)
- Geoserver

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