Deltares

Enabling Delta Life

Project Description

Dam synchronisation and flood releases in the Zambezi River Basin

Assignment and consortium

The Zambezi river basin is a complex watershed, both hydrologically and institutionally. The Upper Zambezi (Western part) of the catchment consists of huge layers of deposited Kalahari sands, interspersed by vast wetlands, while the Middle and Lower Zambezi are generally more mountainous and fast responding on rainfall. Its water resources are shared amongst no less than eight riparian countries. Large reservoirs amongst which Lake Kariba and Lake Cahora Bassa have been built in the colonial period for electricity production. The dams are operated by different organisations and communication and information sharing between dam managers is limited. This has caused unneccesary floods downstream of the reservoirs, reduction of energy productivity and an unnatural runoff regime with negative impacts on the rich eco-systems within the Zambezi.

The Southern African Development Community (SADC) has initiated a project, to recommend on improved operations of the reservoirs in the Zambezi river basin. In particular the focus of the recommendations has been on feasibility of forecasting of floods, added value of synchronized operation, environmental flow releases and potential of new infrastructure. This project has been performed by a joint venture, consisting of SSI (South-Africa), WRNA (South Africa), SEED (Mozambique), Rankin Engineering (Zambia) and Deltares. The project has been financed by the Gesellschaft für Technische Zusammenarbeit (GTZ).

Client

Southern African Development Community (SADC).

Keywords:
Hydrology, ecology, disaster management, forecasting, dam operation

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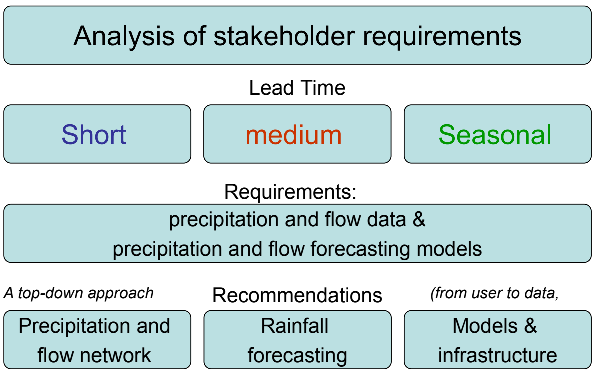
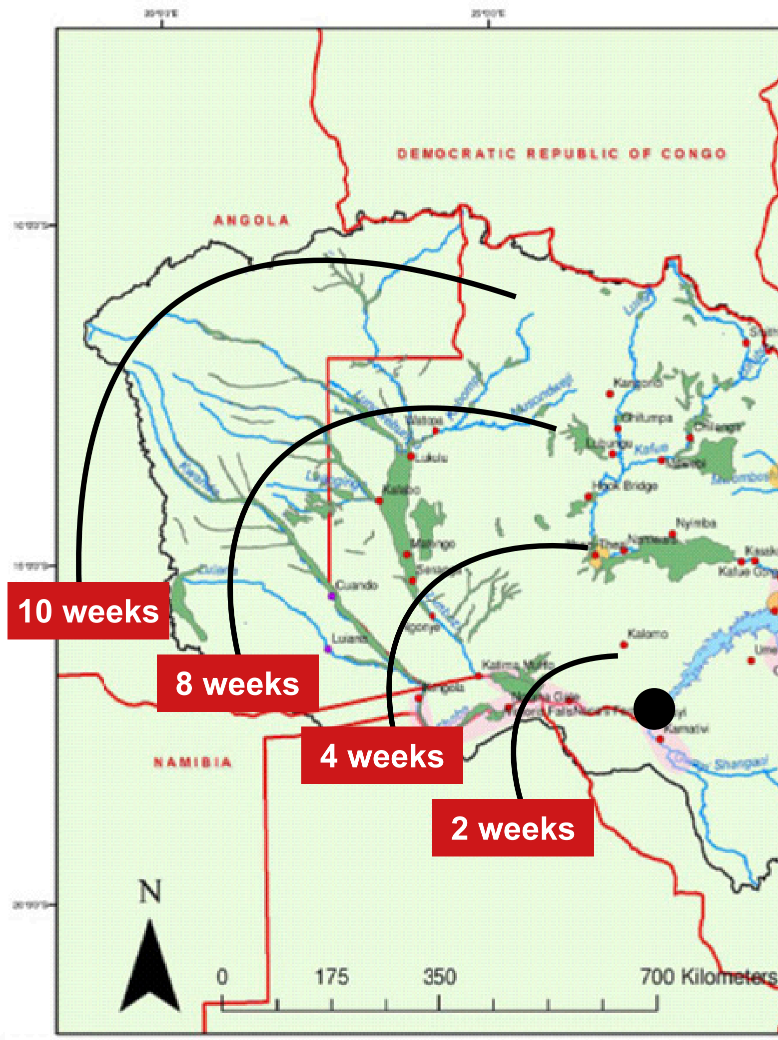
In this project Deltares' input was concentrated on the recommendations for a basin-wide flow forecasting system and expert inputs to the remainder of the consortium in all other tasks. The project is an example of an excellent collaboration between European and African experts, with concentration of the work on the ground in Africa.

Recommendations on flow forecasting

Flow forecasts are to be used by a multitude of stakeholders in the basin, all having different requirements in terms of forecast locations, lead time, and accuracy. The recommendations have been established following a top-down approach, starting from the perspective of the stakeholder's needs, and determining what (ground or satellite) data, models and precipitation forecasts are needed, given these forecast requirements. This approach ensures that the recommended forecasting system will consist of models and data that are exactly fit-to-purpose. The results of this top-down approach have been outlined below.



A top-down approach (from user to data, models and precipitation forecasts) to define the requirements of a flow forecasting system.

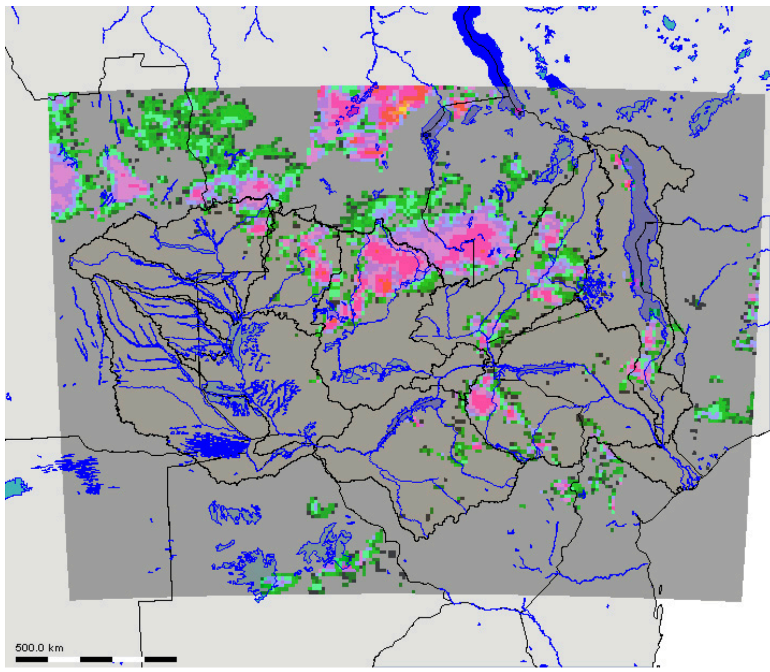


What do the users require?

Consultation with key stakeholders was undertaken to assess the user requirements of a flow forecasting system. Dam managers, power companies, disaster management agencies, water related state agencies and tourism and wildlife agencies were targeted as stakeholder within the basin member states and were interviewed. From these interviews, an inventory was made of forecast locations, lead time and accuracy, required by the different stakeholders. Short term, medium-range and seasonal lead times were considered.

What observations are required given the user requirements? What is already available on the ground?

Based on the forecast requirements, data requirements were established and an evaluation of the existing stream flow and precipitation observation network was performed. Data requirements were also linked to the lead time, provided by the natural response times of the basin. These have been identified from historical flow gauge records. For each forecast location, the required flow gauge network (locations upstream, measurement time scale) and precipitation network (density, required time scale) was determined. A gap analysis between the required networks and existing networks was performed in order to identify gaps in data availability. The potential of satellite rainfall estimates (SRE) was also investigated. At remote locations where a high density network was needed but infeasible, the use of SRE has been recommended.



Example of hourly Satellite Rainfall Estimate over the Zambezi region.

Example of natural lead times, provided by the response time of the basin. The upper part of the basin is particularly slow resonding due to the vast wetland areas, present.

Reliability, communication and sustainability of data

Recommendations for the design of a gauging network were given. It was recommended to use existing successful measuring campaigns such as SADC-HYCOS, a WMO initiative, as a foundation and further these networks, while learning from failures in the past. Recommendations were made in view of issues with reliability, communication and sustainability in the SADC-HYCOS project. Reliability can be significantly improved by using instruments from local vendors, which ensures timely deliverey of spare parts. Sustainability is a serious issue due to theft and lack of maintenance. Communication, performed through satellite transmission in SADC-HYCOS, can now be performed through the cell phone network due to the increase in cell phone coverage. This reduces costs and makes a solar panel for power redundant. This decreases the risk of theft as well.

What rainfall-runoff and hydraulic models are required? What existing models are suited for the job?

From the forecast requirements, required hydrological and hydraulic models could also be established. Similar to the observation network, an overview of existing model capabilities within the region was established and a gap analysis performed.

This resulted in recommendations, which existing models to include in a forecasting system, and which new models to acquire. The use of existing models was furthermore recommended as to increase the feeling of ownership and recognition of the forecasting system.

What precipitation forecasting is required? What forecasting capabilities are already established in the SADC region?

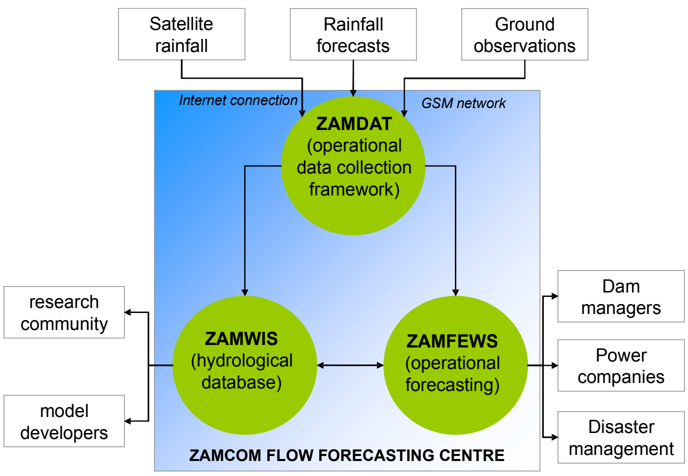
At a number of locations, short term, medium-range or seasonal precipitation forecasting is required. At seasonal lead time, this typically involves the forecasting of anomalies from the average climate rather than absolute numbers. It was found that there are sufficient regional capabilities to perform short term forecasting of rainfall, and that global centres such as the European Centre for Medium-Range Weather Forecasts can deliver medium-range to long-term forecasts. More importantly, a mandate to collect, interpret and transfer these data to the forecasting system and forecast users is required.

Integrating information in and end-to-end forecasting system

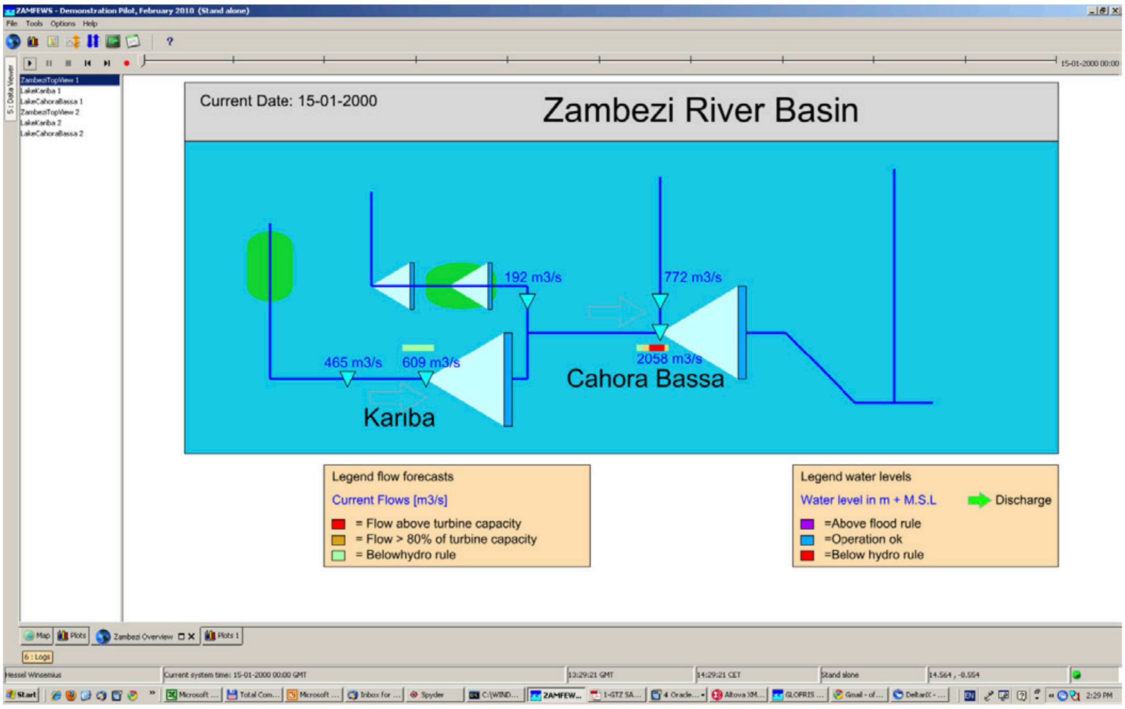
We have made recommendations on the technical implementation of a fully fledged forecasting system. This includes hardware requirements, staffing, (operational) cost estimates, structure of operational data collection platform, data archiving platform and forecasting platform, but also required institutional arrangement (see further below). We recommended the use of existing models, and in order to do so, the use of an open modelling shell, such as Deltares' Delft-FEWS.

Institutional aspects to forecasting.

Having recommended on technical implementation, Deltares also recommended on institutional aspects. In particular the requirements to the institutional establishment a flow forecasting centre have been investigated. The forecasting centre should be positioned at the Zambezi Commission (ZAMCOM), the foreseen river basin administration of the Zambezi. At the time of the project, ZAMCOM was not yet established, but the ZAMCOM agreement was in its ratification



Recommended structure of the forecasting system.



Impression of the top-view SCADA Display. The SCADA display can be configured such that it only provides information that is directly relevant to the end user.

phase. Forecasting should be done under the mandate of ZAMCOM. Therefore, recommendations were made to augment the ZAMCOM agreement with agreements on data sharing. Also recommendations on capacity building were made. It is proposed to establish the forecasting centre as a centre of excellence, where staff,operating the system is exchanged from stakeholders and trained at location. Furthermore connections with universities and knowledge networks are strengthened. This ensures recognition of the forecasting centre by the stakeholders and implementation of new developments in the forecasting system.

Delft-FEWS Pilot system

A pilot system has been setup and presented to stakeholders to give an impression of the look and feel of a flow forecasting system, and to demonstrate what kind of information could be provided by such a system. To this end, the pilot system has been equipped with a SCADA display. A number of real data sources and models were implemented in the system, simulating the behaviour of some of the Zambezi's tributaries and the large reservoirs based on satellite rainfall estimation, rainfall-runoff models and Muskingum routing models. A demonstration case study was shown of a historical flood situation in the year 2000. The pilot showed that with use of forecast information, floods due to spillage could have been prevented and power revenue considerably increased.

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Deltares is an independent institute for applied research in the field of water, subsurface and infrastructure. Throughout the world, we work on smart solutions, innovations and applications for people, environment and society.
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