A Hydrological Monitoring, Forecasting and Warning System for Poland

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Abstract

One of the main issues of the Emergency Flood Recovery Project in Poland is to develop a Hydrological Monitoring, Forecasting and Warning System for the entire country, which will be implemented subsequently by the Institute of Meteorology and Water Management (IMGW) at the Headquarter in Warsaw, and regional branch offices. The main tasks are to provide effective management of the hydro-meteorological monitoring network, promote uniformity of data carrying, streamline and formalize the access to the information used for flood forecast preparation, digital presentation of current meteorological conditions and forecasts. The System of Hydrology (SH), which is going to be developed for the IMGW, is presented in this paper.

1. Introduction

In 1997 serious flooding has occurred on major rivers covering the total territory of the Republic of Poland causing 54 deaths and tremendous, basin-wide material damages costing the country some $3 billion. The main challenges today are to protect the flood prone areas reducing flood risks and to provide sustainable data management and telecommunication capabilities. This will additionally support the development of a Hydrological Monitoring, Forecasting and Warning System, which is badly in need for River Basin Management in Poland. This will be one of the main issues of the Emergency Flood Recovery Project in Poland, as a World Bank financed project.

Within this framework, a concept has been prepared, which encompasses the technical design of a Hydrological Monitoring, Forecasting and Warning System (referred to as “System of Hydrology”) to be implemented subsequently by the Institute

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of Meteorology and Water Management (IMGW) at the Headquarter in Warsaw, and at the corresponding seven Regional Branch Offices.

The System of Hydrology (SH), which will be developed, is aimed at the development of a comprehensive and integrated data transfer, management and analysis system. The main tasks were to provide effective maintenance and update of information coming from the hydro-meteorological monitoring network, promote uniformity of access to all observation results, streamline and formalize the access to the information used for forecast preparation during floods enabling full access to the digital presentation of current meteorological conditions and digital forecasts.

Additionally to the SH, a modern system for Operational Hydrological Forecasting is going to be implemented taking advantage of the powerful tools provided by the SH applications that complement data analysis capabilities of real-time monitoring systems, as well as combine a variety of water resources and hydrological modeling tools. This concept arose from several studies, e.g. Oder-Lisflood (Malek et al., 1999), Vistula River (Niedbala et al., 1999) carried out in Poland after the flood hazards in 1997.

2. System of Hydrology – the approach

The data management is directed towards the development of a hydrological information system (SH) that has to provide analytical support to data processing of measured data, monitoring network and other river basin related information. The SH concept is based on a client-server principle with ORACLE as a database platform, a Geographical Information System (GIS), and external programs with embedded SQL-functions. A MS-Windows based program serves normally as the user interface. The SH is equipped with the following basic tools and applications in order to make these tasks secure, efficient, and user friendly: (1) System management; (2) Data Management; (3) Data Import/Export; (4) Data analyses; (5) Reporting, and (6) Flood Forecasting System. According to Farley & Hecht, 1999, in order to provide the requested services, such system has to fulfill the following requirements:

1. Timelines – data delivery in time to drive decisions (data acquisition in real time);
2. Consistency – uniformity and consistency of all observations (plausibility checks, gap filling);
3. Understandability – data and information delivery in an understandable and appropriate manner (data attributes, description and visualization);
4. Accuracy – precision of measurements (calibration, QA, QC);
5. Flexibility, adaptability to multiply situations – supporting development of a multi-modeling platform required throughout the forecasting process.
3. **System of Hydrology – data storage and viewing concept**

Taking into account the requested flexibility of the SH-database for data analysis, data retrieval and other evaluation analysis options, a sophisticated data storage concept has been proposed. In general, all the measurements and information are stored in the database as independent units, referred to as “data points”. Each of these units is unambiguously defined through identifiers: (a) naming of the monitoring station, (b) meaning of the measured parameter, (c) time of measurement and (d) version of the measurement. The last identifier allows for storing in the database more than one measurement of a given parameter, at a given station, and at a given time (e.g. several runs of forecasting calculations). Retrieval of groups of Data Points can be done dynamically during data processing using rules defined by a set of four groups containing the appropriate indicators.

![Image of 4-D Cube of data access, analysis and presentation](image)

**Fig. 1.** The 4-D Cube of data access, analysis and presentation. The three axes represent stations, the measured parameters, and the time. The fourth dimension represents the version of measurements or simulation results.

Such an approach allows, e.g., comparing and visualizing time series values, measured at predefined time intervals, at a set of stations, including different versions, etc (Figure 1). The 4D data cube in the diagram represents the data extraction and data analysis concept.

The proposed approach allows presentation and investigation of data, providing a wide scope of information related comparisons (water quality, air quality, and water quantity measurements, station descriptions, other environmental data, non-standard data types, documents, etc). As a result, the system allows for flexible modification of the data sets for analysis using the SH tools.
For more efficient data retrieval of time related data (for flood forecasting calculations in real time), a time-series data structure concept has been also proposed. This improves the performance considerably.

4. System of Hydrology – data network and replication

The Regional Branches of the IMGW will be equipped with an appropriate computer network and peripherals and are connected to the central server of the IMGW Central Office in Warsaw. This configuration secures common usage of the central database as well as autonomous operation of each of the IMGW Regional Branches. This organizational scheme requires: (a) local data availability and (b) central data management. To fulfill these requirements following concept of database replication has been proposed: the data is stored in the Central Database (however, replications of the database are kept in the local databases). Local data queries and updates are performed at the regional levels. Manipulation and/or correction of data (central and local) are regularly updated causing all replicated databases storing the same information.

5. Data Acquisition System – Planned Telemetry System

A Telemetry System installed within the frame of another project component will be comprised of about 1000 monitoring stations. Up to approximately five parameters will be measured in each station every 10 minutes and the data have to be transmitted to the Data Collection Units within user defined transmission time intervals. Hydro-meteorological data transfer within the system will be carried out through a sophisticated communication net to the Regional Branch Offices.

In order to accommodate the user requirements to the requirements concerning data to be transferred from and control commands sent to the Telemetry System, a detailed concept for the data transmission protocols has been made. The corresponding interfaces will be implemented in the proposed database system (SH-Database).

The wide scope of functions that have to be available within the proposed System of Hydrology provides a database for management and analysis of collected information. In order to make these tasks secure, efficient, and user friendly, the database will be equipped with a package of appropriate tools and applications for:

1. System management (Station, Parameter, Data Selection, User Privileges, etc.)
2. Manipulation of the data (searching, editing, deleting, inserting, etc.),
3. Data input and output (data exchange, reporting, etc.),
4. Data analyses (graphical visualization and comparison, calculation, statistics)
5. Decision making (during flood forecasting, alarming, etc.),
6. Data security, backup, archiving, protocolling, etc.

Designing the future shape of SH, following information sources are taken into account: (a) on-line monitoring data, (b) off-line measured data, (c) meteorological forecasts and remote sensing data, (d) hydrological modeling scenarios (Chapter 6), (e) results of hydrological forecasting, (f) images and maps from Geographical Information System (GIS), (g) description of monitoring stations, etc.

In order to ensure an effective and user friendly handling of the data, SH will consist of following main components: (a) data manager, (b) telemetry manager, (c) import/export modules, (d) reporting, (e) data analyzer, (f) SH navigator,

6. Operational Hydrologic Forecasting System

The proposed multi-modeling system for operational hydrologic forecasting is built on a modular framework, conceptually based on existing modeling systems, like HEC-HMS (Hec, 1999), and the concept described by Cunge et al. (1992); Cunge et al. (1994).

It is conceived as a modeling platform, allowing integration of various models, providing a variety of options for simulating precipitation runoff processes. This platform will be comprised of a graphical user interface (GUI), which provides the means for an object-oriented specification of the watershed model elements using GIS capabilities, which are useful tools for integrated river basin modeling because of its capability to effectively assimilate different sources of information (Maidment, 1993). Data storage will be performed in the central SH-database allowing for retrieval of model input data as well as other model specific parameters and basin related attributes.

Through the proposed user interface, model objects (watershed elements whose runoff process can be described by a hydrological model), can be easily placed within the basin area and are configurable to a network (in a generic and a model specific layer) using node objects as links to other model objects (Fedra & Jamieson, 1996, Gunatilaka et al., 2001). This allows for effective analysis of the hydrological behavior of the whole catchment.

Prescriptions and rules stored in the central database enable integration of model components like the required input data, data processing information (pre-processing for regionalization and interpolation of meteorological forecasting data and other transformation procedures), model objects, modeling methods and their parameters, time related data and model output. Error correction modules use input data from downstream the model object and are processed in the so-called Node Objects.
Fig. 2. Modeling Methods proposed and the corresponding Model Objects

Several meteorological scenarios may be represented as historical time series standing for representative meteorological conditions and are stored in the SH-Database system. Hypothetical meteorological situations allow for modeling of ex-
extreme weather conditions in the river basin. These scenarios have to be adequately managed for easy retrieval and classification.

6.1 Multi-method approach

Taking into account the present state of the art in hydrological modelling, as well as the specific environmental conditions in Poland, comprising mountainous catchments, and in order to allow the use of a variety of input data sources, a semi-distributed conceptual to physically based model structure is proposed for the hydrological modelling and forecasting system (Maidment, 1992; Beven, 2001). The methodologies favoured are based on continuous modelling. In addition the model provides for optional use of event-based approaches, as well as process-oriented methodologies for specific tasks.

The primary hydrological units would be basins and sub-basins, delineated according to the river and station network, which are further subdivided into secondary hydrological response units representing major land use classes (e.g. forests, open land, agricultural areas, urban areas, lakes) and elevation zones. The response units are the basic model objects, which will be connected with other elements (reach objects, junctions, reservoir objects etc.) to form a river basin model. As shown in figure 2, for each object a variety of methods ranging from sophisticated to simple approaches are provided. The left side of diagram in Figure 2, characterizes the different hydrological modelling methods in different blocks, corresponding to the watershed elements (objects) depicted on the right side of the diagram. Within each block, there are boxes defining the proposed methods that can be applied optionally. The pre-processor in the top of diagram administers the meteorological data (weather radar, meteorological forecasted data, and rainfall data) for rainfall runoff calculations.

7. Conclusion

An integrated Hydrological Monitoring, Forecasting, and Warning System for whole Poland is going to be developed for the Institute of Meteorology and Water Management in Poland. The proposed system is a response to the disastrous floods occurred in 1997 and is composed of a database system incorporating the various data analysis tools, input and output interfaces, and the software for operational forecasting in real time, which is configurable to any river network. This system is designed to operate corresponding to local geographic and socio-economic conditions. This means, integration with other flood reduction strategies, such as complementary engineered structures developed to protect flood prone areas where the highly concentrated risks of life and property offer good opportunities for losses reduction by adequate procedures and favourable cost-benefit ratios.
Bibliography


