Preliminary design of GIS-based integrated basin management and flood control information system for SWRC

WU CHAOJUN\textsuperscript{1}, ZHANG DEFU\textsuperscript{2} & YANG JIXING\textsuperscript{2}

\textsuperscript{1}Beijing Capital Information Science & Technology Pty. Ltd., Building A, Cyber Tower, Zhong Guan Cun Avenue 2, 100086 Beijing, China
\textit{ejunwu@public2.sta.net.cn}

\textsuperscript{2}Flood Control Department, SongLiao Water Resources Commission (SWRC), Gongnong Dalu 888#, Changchun 130021, China

Abstract In recent years, the Chinese Government has intended to move from an exclusive emphasis on structural solutions towards a balance of structural and non-structural measures in watershed management and flood control. In support of this intent, a comprehensive GIS-based information system, or Decision Support System (DSS), is necessary for the headquarters of the SongLiao Water Resources Commission (SWRC), the Ministry of Water Resources (MWR). The main objective of the project is to build a comprehensive and integrated information system based on GIS techniques. The system is designed as a practical tool for the daily water management and flood control of the Songhua River basin. The main features of this system are real-time data query and dynamic modelling.

Key words GIS; integrated information system; integrated watershed modelling; real-time data; Songhua River basin

INTRODUCTION

The Songhua River basin is one of the seven largest river basins in China. It lies within three jurisdictions: Heilongjiang and Jilin Province, and the Inner Mongolia Autonomous Region. The basin is located between 41°42' and 51°38' north latitude, and 119°52' to 132°31' east longitude, with a width of 920 km from east to west, and a length of 1070 km from north to south. It covers an area of 556 800 km\textsuperscript{2} that accounts for about 5.8\% of the entire country. Figure 1 shows the location of the Songhua River basin.

Several storage reservoirs exist in the basin. The top three are Fengman and Baishan reservoirs in the upper reaches of the Second Songhua River, and the Cha’ersen reservoir on the Tiang River, a major tributary of the Nen River. A major reservoir, Nierji, is under construction on the Nen River.

Major floods occur on average about once every 10 years in the basin. The 1998 flood had an average recurrence interval of about 100 years, and locally even up to 300 years. This flood affected some 16 million people in the Songhua and Liao River basins, caused the loss of 154 lives, and resulted in serious damage to infrastructure, agriculture, and personal properties of about $7.3 billion equivalent. Following emergency relief measures implemented during and after the floods, Local Government began an urgent programme to repair and upgrade damaged infrastructure. This programme is still ongoing in Jilin and Heilongjiang Province, and the Inner Mongolia Autonomous Region.
The management of flood control and disaster assessment was still carried out using traditional approaches, with low efficiency and accuracy, such as telephone and paper reports.

The Government realizes that there is a urgent need for a long-term programme to address the interrelated water resources problems in the Songhua River basin, particularly the escalating flood damage, water scarcity, increasing water pollution, soil erosion, and ecosystem degradation. It is recognized that solving these problems requires a shift from a sector focus towards integrated water management and its related natural resources. There are legal, institutional, and financial constraints that need to be overcome to achieve such integration. However, it is within this context that the Government initiated a programme in 1998 to improve the standard of flood protection and flood management in Songhua River basin.

**PRINCIPLES AND FUNCTIONS OF THE SYSTEM**

The design system is an open system, which will be flexible to meet different user’s requirements, and sustainable for future development. Therefore, the system consists of several function modules.
These modules are either based on the essential GIS functions, or on the combination of available models and special GIS functions. Some of the main functions and the possible future developments are:

(a) System administration—The module is designed specially for the administrator of the system, such as the user registration system safety control, linkage between the system and new applications, and database management, etc.

(b) Information query—This is a general query and display module. The application shall give users a simple graphic query and SQL query builder to query spatial features of interest, such as reservoir facilities and their attributes, environmental data, weather information, population data, hydrology station data, rainfall data, historic flood events etc. The module will display the query as two-dimensional (2-D) maps with highlighted features selected. Attribute information associated with the query will also be displayed on the screen as part of the 2-D map, or as attribute tables and graphs.

(c) Weather forecasting information—A function will be provided to display satellite images of clouds. Animation will be played for the images that are captured in a time interval. Weather forecast information can also be retrieved and displayed with the cloud animation. This module also provides access to, and display of, other weather information, such as historical rainfall distribution, and storm information that is stored in the geodatabase.

(d) Hydrology information—There are more than 700 hydrological stations located across the three provinces. They are 185 flow stations, 32 stage stations, and 514 rainfall stations. All the real-time data are transmitted to the central database via telephone cables, wireless, and China DDN. The hydrology information, such as real-time water level and river flow, should be displayed in different types of presentation. The presentation types may be a 2-D map with spatial distribution features, and may be time series plots at site stations. An animation function should be developed for the dynamic display of 2-D maps against time.

(e) Rainfall information—Rainfall information from numerous stations are collected and transmitted into the central database in SWRC. Most of them are real-time data, which it is convenient to retrieve directly from the central database. Two ways are designed to display the rainfall information. One is to display the spatial distributed data at the same time or in the same time period, another one is to show the rainfall information at a selected station. Some thresholds should be determined for warning purposes according to the flood control regulations in the Songhua River basin. A function for generating rainfall contour maps, or colour ranked images, by using spatial distributed data at a certain time, will provide useful information for decision-making.

(f) Works information—Information of infrastructure works are collected and transmitted into the central database of SWRC. Part of them are real-time, part are the current situation. Some special information, such as dangerous dike sections and low-grade infrastructure, should be displayed by warning signals, which may be sound, bright colour, or flashlight. Two ways are designed to display the works information. One is to display the spatial distributed information with different colour or symbols, and the other is to show the layout or cross section CAD map at a selected location.
Environmental information—There is a lot of environmental information that could be displayed in the system. Besides the common geographic information, social and economic information, as well as some special information and maps about the project impacts in the basin, can be presented.

Statistics—GIS provides sufficient statistic functions by which the user can make conventional statistics and analysis to meet the various requirements of water management and administration.

Data input and updating—The system should provide a GIS application to maintain all the map layers and other GIS spatial data in the geodatabase. The data will be maintained and updated by the source information.

Map and report generation—Map and report generation functions provide the user with tools for generating plots of the current map theme and extent, as well as a report for the database query results. A variety of scales, plot size, and plotter output should be provided. Inside the module, view selection functions support the selection of predefined map themes and user-defined map themes. A predefined set of thematic maps is also available, which can be modified afterwards by the user. The user may select from a list of tables containing attribute data to be joined to the active map theme. The attributes that are related to the map themes can be queried at any time by the user and printed in reports. A plot may be generated at any time for the current view, which may include a thematic map.

View—This module provides convenient view tools to view the spatial information in different ways, 2-D maps or 3-D models, and special GIS features. It allows users to retrieve macro information and detailed information within a special area by use of zooming.

Flood control—The flood control application is the most practical and important part of the system. Some applications need to be developed. For instance, the Flood Forecast Module should be interfaced with hydrology/hydraulic modelling. Some of the GIS data will be used as source information for the modelling, and the GIS will be used for post-processing of the modelling results.

SYSTEM STRUCTURE

The physical structure of the system is shown in Fig. 2. According to the software specifications, the technical support from local distributor and the available support from the original software developer, and the wide user group in China, ArcGIS, a series of GIS software, developed by ESRI (Environment Science Research Institute) in the USA, was selected as the GIS software platform.

The hardware applied in this system will be PC computers, a PC based database server, and a Web server. All the information will be stored in the central database.

GEODATABASE

The multi-user Geodatabase is the foundation of GIS, which consists of a map layer database, attribute information database, real-time database, non-GIS database, and historical database. The geographic data are stored in an intelligent DataBase
INTEGRATED DYNAMICAL MODELS

Flood models will enable flood routing and simulation for both the Nen and Songhua rivers, and form the core model for both the flood forecasting system and the decision support system. The flood forecasting system aims for a real-time prediction and forecasting of potential floods, and enables the government to take measures for flood reduction, flood diversion, the operation of flood detention/retention basins, and/or evacuation of threatened areas. The flood model will be running in so-called “real-time”, based on actual observed data of rainfalls, water levels and flows in the basin.
**Interface with the flood model (core model)**

Flood models can obtain the cross-section data from the Geodatabase of the system, and use these data to build the physical model of the Songhua River system. An interface is required to connect the GIS and model applications. The real-time data from the hydrology stations and the stage stations in the basin provide the necessary input to the model calculation. Figure 3 shows the flow chart of this application.

**Interface with the 2-D flooding model**

Two-dimensional (2-D) flood models will obtain the elevation and topography information from the Geodatabase of the system via the developed interface, and use these data to perform flood routings at a real site or a potential site according to the dyke broken model or detention model. Variation of the flooding areas is also calculated by these models.

The system’s GIS functions also provide a powerful capability for visualizing the flooding areas. The animation of flood routing overlaid on the DEM or DTM will be more interested by the decision-makers. Figure 3 shows the flow chart of this application.

![Figure 3 GIS and flood model (core model).](attachment:Fig_3_GIS_and_flood_model_Core_model.png)
Interface with flood regulation of the reservoirs

SWRC is carrying out a project to integrate flood regulation and flood prevention for the Baishan, Fengman, Nierji and Hadasan reservoirs. The individual flood prediction plans, as well as the integrated plan of the four reservoirs, are stored in the geodatabase as a unique system. As described above, for the real-time modelling it will be possible to obtain all necessary data from the geodatabase. The resulting maps and hydrographs can be displayed by the GIS functions.

CONCLUSIONS

Non-structural measures are very important components in management of the Songhua River basin. The GIS-based integrated basin management information system is the core of the non-structural measures. It will provide a systematic interface and various application functions for decision-makers and users outside of SWRC. The project will be accomplished in the coming years.

A comprehensive geodatabase should be established for the GIS-based system. In order to build this database more effectively and economically, information sharing between SWRC and the provincial governments and agencies is a key issue for the project implementation.

Real-time data acquisition and mathematical modelling are the bases of the dynamic information system. They will enable the leaders of SWRC and local governments to use this system as a decision support system. The interface between the system, real-time data, and flood modelling must be well designed.

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