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RESEARCH ON SYSTEM OF FLOOD DISASTER CONTROL AND REDUCTION SUPPORTED BY GIS IN MEDIUM AND SMALL BASINS

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ABSTRACT: Southeast China coastal areas belong to subtropical monsoon climatic zone, thus easily affected by floods resulted from typhoons and rainstorms. Since the areas of river basins are small, rivers flood regulation capacities are low, and therefore flood hazard is grave. In this paper, taking the Yongjiang basin in southeast China as an example, the approaches and methods of geographic information system (GIS) applied to flood disaster control and reduction research on small basin are explored. On GIS help the rainfall-runoff calculation model and the river channel flood routing model are developed. And the evaluating flood submerged area and the damage assessment models are built supported by digit elevation models. Lastly the decision support system on GIS supported for flood control in research basin has been set up. This greatly improves flood-proofing decision-making capacities in river basin, and provides valuable information and a mode for flood prevention and reduction in the medium and small basin. Meanwhile, the research indicates that technologies of GIS provide a powerful tool for flood disaster control.

KEY WORDS: geographic information system (GIS); system of flood disaster prevention and reduction; coastal medium and small river basins in southeast China

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1 INTRODUCTION

In southeast China coastal areas there are many rivers of medium or small size, which flow into the sea separately. Because the length of rivers is short and the area of basin is small, their flood regulation and storage capacities are low, duration of flow concentration is short, therefore flood hazard is grave. Since the founding of the People's Republic of China, continuously constructed water resources projects have contributed a lot to the area's flood hazard alleviation. However, being situated in China's developed regions, especially in recent years, with its rapid expansion in its economy, industy and city scale, as well as population, losses from flooding have also been drastically increased. Thus supported by geographic information system (GIS), the research of decision support system (DSS) in flood prevention and reduction is important. It may be enabled to collect and monitor display real-time hydrologic regimen of the river basin, to flood simulation forecasting, and to assess flood damage, etc. All these demonstrate the importance and apparent economic and social benefit of the system for flood control.

The Yongjiang River basin lies in the coastal area of southeast China, with drainage area of 4518 km^2, has two main tributaries of the Fenghua River and the Yaojiang River. the Yaojiang is the drainage net in flatlands, controlled by sluice gate in flow into the Yongjiang River. the Fenghua River consists of tributaries of Xianjiang, Chanjiang, Dongjiang, and Yinjiang, its lower reaches and the Yongjiang Rive are prone to be affected by tide. Four large and many medium and small reservoirs have been constructed there, with total storage capacity of $8 \times 10^8 m^3$, which have been playing a very important role in whittling down flood peaks and alleviating flood hazard. And to set up the system for flood prevention

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and reduction is just aimed to make the most of these projects, so as to decrease flood damage from non-structural measures.

2 RESEARCH OF THE SYSTEM FOR FLOOD PREVENTION AND REDUCTION

Geographic information system is a technological system that offers spatial data management and analysis. On the basis of geographical space database, and supported by software and hardware of computer system, GIS is able to gather and storege related spatial data, to simulate analysis and to show output these data. Using method of geographical analysis models, GIS may provide various spatial and dynamic geographical information as well as quantity analysis in space. Thus GIS is also a spatial data management system that possesses the function of geographic graph and spatial location. At present GIS has been widely applied to each branch of national economy. In flood control, it is enabled to monitor regimen of river, to simulate flood level, and to assess flood damage that is supported by spatial analysis of GIS. It improves obviously decision capacities for prevention and reduction flood damage (WANG *et al.*, 1998).

2.1 Structure of System for Flood Prevention and Reduction Supported by GIS

With the application of various information technologies and models, through the human-computer inter-action, the system for flood control is designed to assist decision-makers in solving complex problems in flood control. Supported by GIS, the decision system for flood prevention can better meet the demand for spatial information in flood prevention and reduction decision-making of a river basin. In accordance with the special features of medium and small river basins, the system should be simple, practical, swift and convenient. Thus the system should mainly include: river regimen information collection; transmission and monitoring system; spatial database system of GIS; rainstorm flood database management system (DBMS); social economy database system of the basin; flood simulation prediction; flood damage assessment and flood optimized regulation; flood control expert experience system; system integration and input/output interface system (XU *et al.*, 2000). Fig. 1 shows the components of the whole system.

The spatial database system of GIS stores elevation data of topographic maps and of flooded area maps as well as data of subject maps like of river systems, Besides the digital elevations model (DEM) of GIS is built, by which three-dimension solid display of the river basin, gradient calculation, dynamic display of flooded areas as well as printout of flood risk and subject maps of all kinds become possible, which provides spatial information supporting for decision of flood control.

In the real-time river regimen collection system, via automatic hydrologic remote survey technology, functions like automatic collection of rainfall and water level information and monitoring of variations in water level of key river sections and flooded areas have been realized. Rainstorm flood DBMS mainly deals with inquiries and searches of real-time river regimen and historical rainstorm flood, the dynamic renewal, and input/output etc., so as to provide information for rainfall runoff prediction and flood regulation. While the social economy database system generally keeps social economic data so as to provide information support for flood damage assessment. In the flood prevention and reduction model system, there are the rainfall-runoff calculation model, the river channel flood routing model, the calculation model of submergence range of the plain water systems, the forecast model of tide in the lower reaches of the river basin, the flood damage assessment model, the simulation and optimization model of multi-reservoir conjunctive regulation so on.

The spatial database system and the rainstorm flood attribution database may achieve organic connection of data whatever via the opening of database connectivity (ODBC), so that it can provide spatial information needed for flood simulation and prediction, flood damage assessment and flood regulation. By means of various supporting systems developing, and by system integration, inter-relation among different modules has thus achieved.

2.2 Built-up of GIS in Research River Basin

Based on topographic maps on scale of 1∶50 000 in combination with those on scale of 1∶100 000 and various subject maps, the database system of figure and spatiality are built in GIS. The system is to keep maps and spatial information of maps of river systems, reservoirs and lakes, vegetation and soil, land use, the distribution map of survey stations, the route map of typhoons in history, as well as elevation data from the topographic map of the river basin, and flood hazard figure information. The system has built DEM of topography and in submerged area.

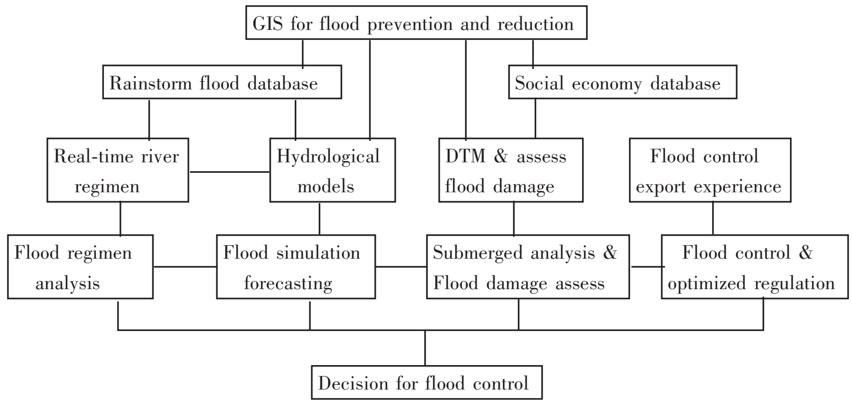

Fig. 1 Flow chart of system for flood prevention and reduction by GIS

The map system of GIS of the river basin takes MapInfo as its development supporting system. So the graph database adopts the data structure and mode of MapInfo, and the attribution data basically are the mode of relation data. Besides, TAB table organically links graph data and attribution data. A TAB consists of a group of data files, showing the data format, graph data, attribution data and the relation between graph and attribution data. As a result, the setup, inquiry, searches, amendment and addition functions of the graph database are expediently actualized. Using graph digitalization method, mainly factors such as water system, roads, lakes and reservoirs, soil and vegetation, and land use across the river basin, are input to the database via different graphic layers, along with corresponding attribution data. Besides, the graph database also keeps information on main historical typhoon route maps and the alike. Meanwhile, the topographic map of the river basin and submergence lines of plain water systems, together with their corresponding elevation value, are input also to the database. And based on it, the corresponding digital landform elevation model is created, laying a foundation for model analysis and flood damage assessment.

2.3 Research of Hydrological Database System

The attribution database of flood control in research area includes the real-time regimen database, the historical rainstorm and flood database, the feature of survey station, the water resources projects running status database and the social economy database of the basin. Real-time hydrologic regimen database mainly keeps: real-time information of various water levels of the river basin; rainfall information from survey stations; the opening status of reservoir sluices, inflow and outflow information; and other water resources projects operation information. The historical rainstorm flood database is to store typical data features of historical rainstorm floods and their process data. Information of routes and intensity of typhoons is also to be stored in respect of rainstorms and typhoons. The database of survey stations and water resources projects is used for the storage of characteristic such as types and locations of survey stations and alert water levels, and the storage of information about regulating rules, reservoir storage capacity and limit water level of flood. The social economy database is used for the agricultural layout and population status of the river basin, and social economy data such as industrial output value, so as to assist flood damage assessment.

The regimen database of river basin makes use of Microsoft SQL Servers' network database. The real-time regimen database is to keep real-time regimen information transmitted timely from each water level and rainfall remote survey station. The historical rainstorm and flood database keeps rainstorm flooding process data from major stations in the river basin since 1960. In terms of typhoon rainstorms, feature data such as typhoon landing sites, typhoon intensity are also stored in the database. The operation status database of water resources projects is for the storage of inflow and outflow of key reservoirs as well as reservoir gate process status data. The social economy database of the basin is to keep such social economy data such as population of each district, land use, industrial and agricultural output in typical years, which corresponds to the submergence graphic database, so as to provide information support in damage assessment.

3 RESEARCH OF THE SYSTEM MODEL UNDER THE SUPPORT OF GIS

Among flood simulation and prediction models, importance has been laid to rainfall runoff models of the basin as well as flood routing models in the rivers and submergence area. The rainfall runoff models of the study area selecting Xin′anjiang model (ZHAO, 1992). The model bears a physical notion to some extent and is mainly composed of the following four parts: evapotranspiration, runoff production, and runoff separation and runoff concentration calculations. In evapotranspiration calculations, three-layer evaporation mode has been applied. In runoff production calculations, the model has used the mode of runoff formation on repletion of storage. In runoff separation calculations, the total runoff has been divided into three kinds: surface water, underground water and soil water. And non-dimension unit line or lag and route have been adopted in concentration calculations. In the model parameter ascertainment, such parameter as impervious areas that reflects features of the basin is ascertained directly by the spatial database system of the GIS, however, parameters needed to be ascertained by rating should recur to the historical rainstorm and flood database. River channel flood routing, submergence borderline condition and the related parameters are provided by the spatial database system. With the rating parameters, model calculations can be more precise, and the error rate of flood simulation is generally below 10%. And these models are used in the system for flood simulation prediction both in the upper reaches and reservoir area of the basin. As to tide-affected river sections in the middle and lower reaches of the basin and flood simulation in submergence areas, the simplified unsteady flow calculation method is adopted, at the same time, water amount exchange has been taken into account. And river channel cross-section data and ground elevation data are supplied by the spatial database of GIS, typhoon and flood variation rules in different cases, such as tide upholding, should be analyzed as well.

Supported by DTM and social economy database, according to the above-mentioned simulation water level value prediction, in the damage assessment and flood regulation models of the study area, possible submerged areas and their depths are found out. In addition, according to the spatial information of the GIS, DTM models and information about population, industrial output value and crop growing type and season from the social economy database, possible damages are assessed. And then, by analyzing flood evolvement and incurred damages on the conditions of different reservoir regulation and the unlocking of flood gates on dams, and by using the calculation method of model optimization in system analyses, an optimized regulation scheme with more effective reservoirs and less damages in the lower reaches can be worked out.

4 APPLICATION OF THE SYSTEM FOR FLOOD CONTROL IN THE RESEARCHED RIVER BASIN

A computer network system for flood prevention has been set up in the study area up to now. There is a local area network (LAN) of flood prevention in the Flood Prevention Center, which is situated in the river basin. The wide area network (WAN) in long-distant connection with large reservoirs and with each city or county in the basin has been realized via microwave transmission and internet packet switching network. Therefore, rainfall, water table, waters resources projects conditions as well as flood control decision information within the basin can be passed on in no time. DSS for flood control in the studed area (centering on tributary of the Fenghua River) now is in a test-run in the network. The whole system can realize real-time regimen display and monitoring, historical flood inquiry, rainfall-runoff simulation prediction, flood damage assessment and flood regulation simulation. Flood prevention and reduction assistance decision in medium and small river basins has preliminarily been actualized. So far, the results are satisfactory.

Using automated hydrological remote survey technology, real-time regimen information can get to the regimen database via microwave communication and the computer network system, so the automation of regimen information collection has been realized. Using graphs display system of GIS, real monitoring is realized for large reservoirs and survey water-level changes in the key river sectors and potential submergence water network areas. In the same way, real-time water resources project information is transferred to the water resources projects database in the system. By means of open database connectivity, modules of the display system can realize such functions like inquiry display, above alert-line alarm and feature statistics, in forms of graphs, images and tables, for example, histogram, isoline, etc.

In flood simulation prediction, rainfall runoff simulation model is applied in the calculations of the upper tributaries without tied effect and reservoir areas in the basin. Flood routing in the lower tide-affected reaches and submergent areas adopts the simplified unstable flow calculation method (LIU *et al*., 1991). In estuary tide and storm tides forecasts, hydrologic department's model forecast results are introduced to system. Flood simulation forecasting can be divided into simulation prediction of rainstorm flood trend, rainfall runoff forecast and real-time revision forecast. Simulation prediction of rainstorm and flood trend is to be used before a flood. According to the current conditions of reservoirs, tide level and soil water, considering the typhoon intensity and route feature, using information on similar rainstorm in history, and after proper revision, go about the trend analysis of relatively long foreseen period, so that early stage decision-making analysis for flood prevention and reduction may begin. Rainstorm flood simulation forecasts are rainfall runoff forecast after a rainstorm and revision forecasts are real-time revision of forecasting results.

On the basis of the analysis of hydrologic characteristics in research area, flood frequency calculation analysis is carrying out. Supported by DEM of GIS for flood control in the river basin, and with analysis of varied topography and water resource projects in each district, as well as through flood routing of two – dimensional equation, the scope of flooding and inundation is decided. Meanwhile, considering land use and states of social economy, the flood damage assessment in submergence area is found out, then the flood risk maps subject to database system is built. The system module is link to decision support system of flood control. Based on regimen of river dynamic simulation and prediction, and combined with flood risk assessment system, flood submersion and flood risk are found out, and related flood possible damages are assessed. And then, by conjunctive regulating two or more reservoirs, possible submerged area and hazard evaluation under different schemes can be simulated and predicted. A multi-object optimized regulation scheme for decision-makers' reference may thus be mapped out via optimization calculation method, which allows better reservoir benefit and less damage in the submerged lower reaches.

The system has been running since 1998. The examination for several floods simulation indicates that the error rate of flood simulation is generally below 15%, and the flood damage assessments conform to reality. The research results are roughly satisfied. The system for flood prevention and reduction of the river basin by GIS supported has high automation and ability of spatial analys and is visualized and intuitionistic, swift and convenient. Meanwhile the precision of flood simulation prediction is very high. Through schemes of flood regulation, flood damage may obviously decrease. The benefit of system in flood control is evident.

5 CONCLUSION

Above research is to indicate that technique of GIS provides a powerful tool for flood prevention and reduction. It is advantageous to the application of hydrological models, especially in flood damage evaluation the advantages of GIS is more obvious. It provides favorable condition for quick decision in flood control, and greatly improves flood-proofing decision-making capacities in river basin. This paper provides some experience in this way.

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