Applied Research on Flood Control and Disaster Reduction based on GIS Technology

Mem. Muroran Inst.Tech., 59（2009）73～76

特　集

Applied Research on Flood Control and Disaster Reduction based on GIS Technology

Xiaohuan QIANG* and Liujuan ZHU*

(Received 27 May 2009, Accepted 20 November 2009)

Geographic Information System is able to collect, manage, analyze and send out various geo-spatial information, very spacious and dynamic. Based on GIS technology, applying Digital Elevation Model, Flood Evolution Models, Humane and Economic information the scope of flooding and flood-stricken area, simulate flooding process, development trend and flood losses to provide timely information of towns, roads, water conservancy facilities, distribution of rivers and lakes can be confirmed. The best route and solution for personnel retreat, material transfer, minimize the losses caused by flood can be confirmed, and offer decision-making data to flood control and disaster reduction can be offered.

Key words: Floods, GIS, DEM, Flood Simulation, Flood Assessment

1　INTRODUCTION

Flood, one of the most common and the largest one in all natural disasters, is not only harmful to society, but also to the adjacent basin resulting in changes in water distribution. But flood is still defensible. It is impossible to eradicate the flood completely, but with more efforts, human can reduce the impact of flood disaster as much as possible(1).

For a long time, the flood prevention strategy mainly relied on engineering measures such as construction of embankments, reservoirs etc all over the world. However, with the development of social economy, science and technology, people came to realize that flood is a natural phenomenon, adopting engineering measures alone is impossible to resist it. In 1970s, the concept of Non-structural measures was firstly proposed by USA, namely, flood forecasting, flood control, water diversion, detention, scheduling legislation, water and soil conservation, afforestation and flood insurance can be used to reduce flood disaster and Strengthen flood control management.

Geographic Information System is able to collect, manage, analyze and send out various geo-spatial information, very spacious and dynamic. Sources of information is diversified, remote sensing, surveying, maps, GPS, and a written report all can be used to provide data for GIS. The computer system support the spatial data management, computer program simulate Geo-Analysis models, GIS has regional spatial analysis, multi-elements of a comprehensive and dynamic predictive capability. In addition, according to the needs of users, you can send out a variety of products such as text reports, thematic maps, electronic maps, multimedia messaging etc(2). In practice, GIS can provide timely information of towns, roads, water conservancy facilities, distribution of rivers and lakes, and undertake flood disaster early warning effectively and can estimate flood scope and flood losses through the data collected by remote sensing and measurement. Disaster mutative trends can be simulated dynamically and displayed visually so as to provide dynamic, real-time, accurate information for disaster reduction

* School of Surveying & Land Information Engineering, Henan Polytechnic University, China 454000.

and decision-making.

2 APPLIED DEVELOPMENT OF GIS IN FLODD CONTRAL AND DISASTER REDUCTION

The application of GIS in water began in the late 1980s. Initially it was mainly applied in the construction of flood control information system, and then expanded to water resources, soil and water conservation, water conservancy project management etc. The flood control information system is mainly the database construction, such as database search, query, overlay analysis, buffer analysis etc. After 1990s, GIS began to act as a decision-making, analysis, simulation and forecasting tools in some fields, and reflect the significant social, economic and ecological benefits [(3)].

"3S" technology has been extensively adopted in some countries to predict the evolution of flood, to assess flood disasters and to carry out risk assessment program. Since 1980s in our country, a series of studies have been launched such as flood control, flood damage assessments etc. The Yellow River hydro-conservancy committee has constructed flood control and disaster mitigation information system in Yellow River Delta, and established "GIS system in the Lower Yellow River" in 1995, which has played a positive role in Remote Sensing detection of the "96.8" Yellow River flood. Nanjing Institute of Hydrology and Water Resources have completed the "Yangtze River flood control and decision-making system", in which graphic information input, editing and the generation of spatial topological relations was achieved by using GIS. Geography of the Chinese Academy of Sciences and Hunan remote-sensing center has established “flood warning GIS in Dongting Lake ". Hehai University and other units use GIS as a development environment to build distributed watershed hydrological model of rainfall for hydrologic simulation and hydrological forecasting. Using GIS and Hydraulic model to simulate flood evolution has also made significant progress [(3)].

Application of GIS technology makes it possible to carry out disasters warning, disaster analysis and disaster loss evaluation; and plays a leading role in decision-making and management in flood control and disaster reduction.

3 THE CURRENT SITUATION OF FLOOD CONTROL AND DISASTER REDUCTION AND ITS BASIC NEEDS FOR GIS TECHNOLOGY

According to the Statistics of the National "Tenth Five-Year Plan" in flood disaster reduction，the land area threatened by Flood in our country is about 106 million square kilometers, covering 11.2% of a total area where 840 million people live, 66% of the total national population, among which including 407 cities, and representing a total cities area of the country's 61% and the generated gross domestic product accounted for 80% of the country [(4)]. The guiding ideology of "Tenth Five-Year Plan" in flood prevention and disaster reduction is the transition from the disordered, fighting for land with water unlimitedly to an ordered, sustainable coordination with each other[(5)]. Flood control and disaster reduction aim to realize a transformation "from flood control to flood management" in order to promote harmony between man and nature.

To achieve this strategic shift, the state flood control headquarters and other departments set out to build the relevant policies and regulations system, management systems, engineering systems, technical support system, as well as the social security system. Many demands for GIS technology were given, mainly in the following aspects:

1.Construction of basic database. "Rainfall, water, work situation" is extremely important information in flood control and disaster mitigation. This information has significant spatial and time distribution characteristics. Managing and displaying visual information timely, accurately, vividly and intuitively is one of the basis needs for GIS in flood prevention and disaster reduction.

2. Graphical management of basis information. With the support of GIS spatial database, the terrain, topography, elevation and other geographical information in different basins was to be provided service by graphical approach, and to be provided fast and convenient browsing, query and other functions.

3. Flood process analysis and dynamic simulation. According to the law of flood formation and flood movement, using hydrological and meteorological information to analyze and simulate the flood process and changes dynamically, is also an important needs for GIS.

4. Flood risk map making and displaying. The goal of building risk maps is for flood control departments to provide data for flood control program, flood plans and flood risk management, and to determine the maximum flood inundated area, water depth, flow rate and other information in different magnitude, so as to evacuate the masses and transport relief materials by choosing the correct route in event of emergency [(6)]. How to display this information efficiently and intuitively is also an important requirement for GIS.

5. Flood emergency command and decision-making system. At the time of the flood, the task of rescue, risk, evacuation and resettlement demand the space and time characteristics highly. A flexible space-time information management and rapid extraction of GIS is an important needs for emergency and decision-making .

6. Post-disaster damage assessment system. Based on real-time flood information, combined with the flood

routing models of hydraulic and the economic situation of the regional, the flood damage assessment model can determine the water level in flooded areas, scope, and lasting time to count the actual loss of the disaster.

4 GIS APPIICATION ON FLOOD CONTROL AND DISASTER REDUCTION

4．1 Graphical Information Management

Various hydrological information, engineering information, geographical information, as well as a variety of thematic map information can be stored in form of electronic maps by tiered. With Support of spatial database, the records of a variety of basic information database can be matched with the attribute information of maps object in the spatial database each other. Through the connection between the electronic map and database, the map object can be located accurately and dynamic linked with real-time data and calculation model.

4．2 Flood Forecasting

Flood forecasting is the scientific basis for the flood control and decision-making, optimization of water resources, and also an important non-engineering measures of flood control. It mainly studies the generated runoff by given rainfall and spatial and temporal distribution of flooding. According to the hydrological conditions of the upper reaches and the rainfall landed on the ground, using the fluid dynamics and water balance principle in the river basin, combining with the soil, topography, river network characteristics for the runoff and convergence calculus, the water level and flow in the downstream section can be calculated. In process of establishing distributed flood forecasting model based on GIS, the terrain is the first dominant factor, followed by rainfall, soil, and vegetation and so on. With the help of the DEM, the water flow can be set to determine the catchment area, calculate the mesh runoff and the end draining runoff.

4．3 Flood simulation

Flood simulation system is an important subsystem of "digital watershed" engineering system. Flood routing model simulate the whole process of flood forward, including the promotion from upstream to downstream, as well as the flood peak changing in shape because of the fluctuations in terrain (7). Using Hydraulic model the evolution of flood and the water level, velocity, and other flooded conditions in the different times and location of the flood can be calculated.

GIS-based flood simulation must firstly achieve the terrain simulation, because ups-and-downs of the terrain, slope, and slope direction not only affect soil and vegetation growth, but also control runoff flow and river development. First of all, using GIS technology digital elevation models can be generated, and then using three-dimensional features of GIS three-dimensional graphics can be generated. Or by transforming the DEM data into data files, processing triangle mesh by code, and combining with OpenGL three-dimensional graphics can be generated. The landscape effect is achieved by reading the texture mapping database of OpenGL (8). Based on 3D terrain, landscape, and flood routing model, it can simulate flooding surface in different water level and get the numerical simulation of the flood process, development trend, submerged areas etc.

4．4 Flood Risk Map Making

Flood risk maps can describe the risk-stricken regions and flood damage quantitatively and directly. In the GIS software platform, based on regional flood flow, water depth, lasting period and other parameters, we can extract geographic information such as elevation points and rivers information in the region to build DEM. According to different magnitude of floods, the largest submerged range, the maximum water depth distribution, the largest floods flow and other natural attributes can be simulated. According to the data statistics, the region affected by the floods is divided into dangerous areas, hard hit areas, light disaster areas and security areas, which is designed as different colored code indicating the extent of the disaster. Map should be marked with the important departments and units, engineering and transport facilities, but also with a transfer of personnel, evacuation routes to formulate emergency plan for flood control in case of emergency.

4．5 Flood damage assessment

Flood damage assessment model is highly characterized by non-linear, time-varying and the differences in spatial distribution, because it must take into soil infiltration, flooded water depth, submerged scope, population, economic conditions and other conditions by the different affected region. Combining meteorological data with hydrological models to determine the flood-causing factors, using GIS to establish the DEM for calculating the terrain factor, combining with the information of flood control projects and socio-economic factors, flood damage assessment model can be established(9). Using GIS software tools losses caused by floods and spatial distribution can be estimated.

Determining flooded scope is the core aspects of flood damage assessment. GIS-based flood analysis involves the flood face simulation and calculation of inundated scope. Seed filling is the most widely used method of flood analysis algorithms, which can be achieved by recursive or iterative algorithm. Based on the DEM we can seek for the flooded area under the conditions of a given level. When the flooded area as "passive submerged", all points lower than given level point in elevation, are included in flooded areas, which is equivalent to a large area of precipitation throughout the region, all low-lying areas can likely hold water to make disaster; when the flooded areas as "active drowned", the "flow" of water must be considered. Subjected to the impact of the surface of ups and downs, water flow may be blocked, as a result, some low-lying terrain will not be submerged.

Flood disaster loss in economic is an important part of damage assessment, it include direct losses and indirect losses. Direct loss is mainly the collective and personal property losses by direct flood inundation; Indirect losses refers to the increased product cost and the breach of contract caused by the damage to traffic and electrical equipment in the flood period, as well as these costs for the evacuation of victims and Disease Control and Prevention. According to damage assessment model, direct loss can be demonstrated based on GIS tools. Indirect losses generally can be estimated by the percentage of indirect loss in direct loss based on the findings of typical examples or empirical estimate.

5 CONCLUSION

Hydrological system has the characteristics of spatial distribution and dynamic changes. As a multi-source of information science and technology with spatial, dynamic and multi-disciplinary, GIS is one of the key technologies in hydrological system (10). With the development of economy in our country, new and higher demands on flood prevention and disaster reduction has been given, and flood control and disaster reduction has proposed higher demands for GIS constantly. Application of GIS technology, combined with remote sensing technology, computer technology, numerical methods, mathematical modeling, three-dimensional simulation and so on, multidisciplinary and comprehensive study applied into non-engineering flood control measures is the direction of future efforts for hydro-workers.

REFERENCES

(1) Xiquan HUANG, Hydrology. Beijing, Higher Education Press, 1993.6 (2000 reprint)

(2) Shupeng CHEN, Introduction to Geographic Information System. Beijing, Science Press, 2000.5.

(3) Weimin WANG, Geographic Information System and Its Application in Water Industry, Microcomputer Applications, No.3, (1998), p12-15.

(4) Changzhi LI and Jinchi HUANG, The applications demand and examples for SuperMap GIS in flood prevention and disaster reduction, China water resources, No.19, (2008), p 65-67.

(5) Jian DENG, Kungang LI and Linzhu XU, Establish and improvement of flood control and disaster mitigation system for the protection of economic and social sustainable development, China water resources, (2001), p29-31.

(6) Yongqiang WEI, Baoshun YAO, Ge XIN and Hua YANG,. ArcGIS applications on Flood Risk Map System in the Yellow River beach area, Yellow River, Vol 31, No.3, (2009), p16 +99.

(7) Wenfeng DONG, Yanbin YUAN, Yingze DU and Jiping LIU, Simulation of 3D Terrain and the Dynamic Simulation of Flood Routing Method, International Journal HydroElectric Energy, Vol.19, no.3, (2001), p37-39

(8) Yanzhao ZHANG, Jie DONG and Min HAN, Research of flood routing simulation system based on GIS, Chinese Journal of Scientific Instrument, Vol.27, No.6, (2006), supplements, p936-938.

(9) Xiaosheng LIU and Haofeng YU, Research on assessment model for flood losses based on GIS and BP neural network, Geotechnical Investigation & Surveying, No.4, (2009), p72-74.

(10) Xueqin ZHU, Shibing PAN and Jianli ZHANG, Review of the integration of Watershed Hydrological Model and Geographic Information System, Geography and Geo-Information Science, Vol.19, No.3, (2003), p10-13.