Digital River Basin and its Application to Reservoir Induced Seismic Risk Assessment

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Abstract: River basin is the cradle of the human civilization, and has been playing very significant roles in the social and economic sustainable development. In order to accumulate water and generate electric power, some reservoirs and hydropower stations are always constructed in a river basin, which may induce earthquakes. According to the vision of digital earth, this paper proposes the concept, content, function and framework of digital river basin. It is thought that digital river basin is one of the important branches or regional layers of digital earth, which is the high integration of modern digital, network and information technologies in river basin. It consists of three levels such as visual fundamental information platform, thematic application system and comprehensive decision-making support system, where each level is designed for its own corresponding users and has its special functionality. Being considered as one of the thematic application systems of digital river basin, the theory and method to predict and access the reservoir induced seismic risk based on digital river basin are discussed in details. It is shown that digital river basin not only provides a new way to implement the assessment of reservoir induced seismic risk in a river basin, but also improves the visualization of the processes and results. Reservoir induced seismic risk assessment in river basin is an important thematic application system of digital river basin.
Keywords: Digital River Basin, Digital Earth, Reservoir induced Earthquake, Seismic Risk Assessment, Hydropower Station, Spatial Information Science and Technology.

1. Introduction

Since Mr. Gore, the former Vice President of the United States, originally brought forward the concept of Digital Earth(DE) or Digital Global in 1998[1], a lot of countries and regions around the world have paid more attentions to it, and the related theories and technologies of DE have been widely studied. Some new versions of DE such as digital city, digital district and digital province have been come forth[2-4].

As the cradle of human civilization, river basins play very important roles in the social and economic development of a country or region. Since a river basin generally crosses over multi-administrative regions, it is best to manage the river basin as a whole so as to optimize the resources in the scale of river basin. So today, there have already been many watershed administrative organizations all over the world. In this situation, how to optimally manage the whole river basin has become an urgent issue. Digital River Basin provides a new solution for this problem[2-4].

In a river basin, many reservoirs and hydropower stations are always built, which not only provides the water for people's life, industrial and agricultural production, but also generate electric power. However, sometimes they may also cause seismic activities in the river basin, which is generally called reservoir induced earthquake. So, the prediction and assessment of reservoir induced seismic risk in river basin is a very important fundamental task among the river basin management[5-7].

This paper first proposes the concept, content, functionality and framework of digital river basin, and then discusses how to assess the reservoir induced seismic risk based on digital river basin.

2. Digital River Basin

2.1 Concept of Digital River Basin

Digital River Basin(DRB) is an important branch or regional layer of digital earth, Generally speaking, DRB is a large system which uses the modern technologies of remote sensing(RS), geographical information system(GIS), global positioning system(GPS), virtual reality(VR), database, network and multimedia to capture, store, manage, process and analyze the information on geographical background, fundamental facility, natural resource, cultural scene, ecological environment, population distribution, social and economic condition in the scale of river basin, constructs a visual fundamental information platform, provides thematic application systems for administrative departments of different fields in the river basin, and on the bases of these, then develops a comprehensive decision-making support system to optimize the management of the river basin. So, DRB can not only model a river basin in the computer and provide visual query of information, but also simulate the thematic and comprehensive management of the river basin[2-4,8-9].

From the above description, it is shown that DRB is the high integration of modern digital, network and information technologies in river basin. It provides a new way or tool to plan, design, build, manage and serve the river basin. The construction of DRB plays a very significant role in improving the management efficiency and increasing the modernization level of the river basin. In information era, DRB will become a new kind of basic facilities which should be organized by the government, requires the participations of all the thematic departments and serves for the public.

2.2 Content and Framework of Digital River Basin

Digital river basin is very huge system engineering. According to its concept, it can be divided into three subsystems: visual fundamental information platform, thematic application subsystem and comprehensive management and decision-making support system, which are independent but correlative with each other(Fig.1).

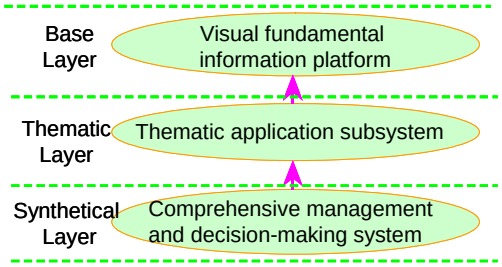


Fig.1 Layer division of digital river basin

(1) Visual Fundamental Information Platform—Base Layer

The visual fundamental information platform is the basic layer of a DRB. By using modern digital, information and network technologies, it collects different types of information in the river basin, constructs the spatial and attribution databases and makes up a visual fundamental information platform based on GIS, which models the river basin in the computer, realizes the visual storage, management, query and analysis of the information in the river basin and provides information services for the public. So, the visual fundamental information platform of DGB includes a fundamental information database, a three dimensional model of the river basin and a corresponding management and analyze platform(Fig.2).

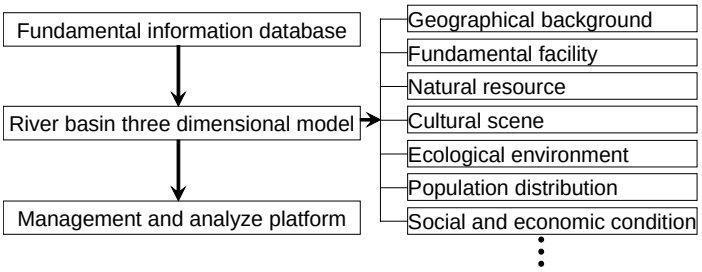


Fig.2 Content of visual fundamental information platform

(2) Thematic Application Subsystem—Thematic Layer

The thematic application subsystem is the applied layer of DRB. In a river basin, there are always many administrative and professional departments in different fields such as hydrology, natural resource, environment, transportation, communication and planning, which have their own corresponding requirements for automatic office and decision-making. On the base of the visual fundamental information platform, different thematic application subsystems should be developed for these professional departments so as to provide thematic application services. In addition, all these thematic application subsystems are integrated together onto the common visual fundamental information platform. Fig.3 shows some of the possible thematic application subsystems of DRB.

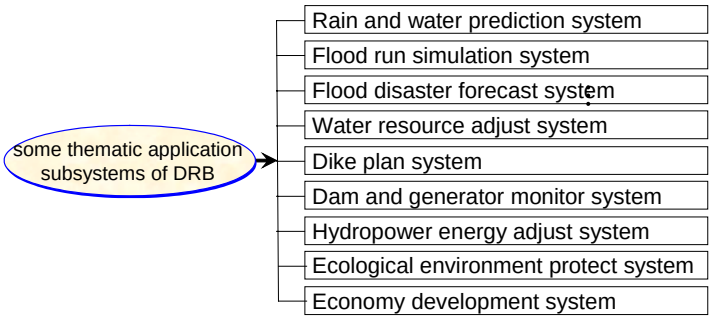


Fig.3 Some of the thematic application subsystems of digital river basin

(3) Comprehensive Management and Decision-Making Support System—Synthetical Layer

As the synthetical layer of DRB, the comprehensive management and decision-making support system is used to analyze different types of information in the river basin based on the visual fundamental information platform. In addition, it optimizes the macro management and policy-making of the whole river basin according to the integration of many different results obtained from all the thematic application subsystems.

Among the above three layers of DRB, each of them has its own special functionality and is designed for corresponding users. The visual fundamental information platform that is the basic layer of DRB is designed for everyone, including professional thematic users, as well as all public users. The thematic application subsystems that belong to the thematic layer of DRB are used by different administrative and professional departments in different fields in the river basin, while the comprehensive management and decision-making support system that is the synthetical layer of DRB is designed for the top administrators of the river basin.

3. Model of Reservoir Induced Seismic Risk Assessment

The causes and mechanisms of reservoir-induced earthquake are very complex. So far, many theories and methods of reservoir induced seismic risk prediction and assessment such as geological environment, gray system, pattern recognition, logic information and stochastic probability method have been given out and widely applied[5-7].

According to the stochastic probability method, the process of reservoir induced earthquake is hypothetically thought to be a function(F), where all the factors which may induce reservoir earthquake are considered to be the variables(X), while the induced seismic activity is the result(Y). The factors(X) and the corresponding induced seismic results(Y) in reservoirs where induced earthquakes have been occurred can be collected and analyzed so as to obtain the function(F) between them. Then, if these factors(X) in a new reservoir are known, they can be input into this function so as to calculate its seismic results(Y). Fig.4 is the sketch map of this stochastic probability method[10-14].

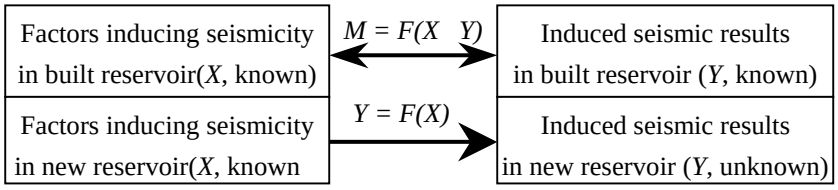


Fig.4 Sketch map of stochastic probability method of reservoir induced seismic risk assessment

4. Application of DRB in Reservoir Induced Seismic Risk Assessment

It seems that the above stochastic probability method of reservoir induced seismic risk assessment is very simple. In practice, however, it is not easy to be realized because there are too many parameters in a very large reservoir area. According to the concept of digital river basin, it provides a possible new way to implement this operation, Below is the procedures to assess the seismic risk of a reservoir based on DRB, with the Yangtze Three-gorge reservoir in China as an example,

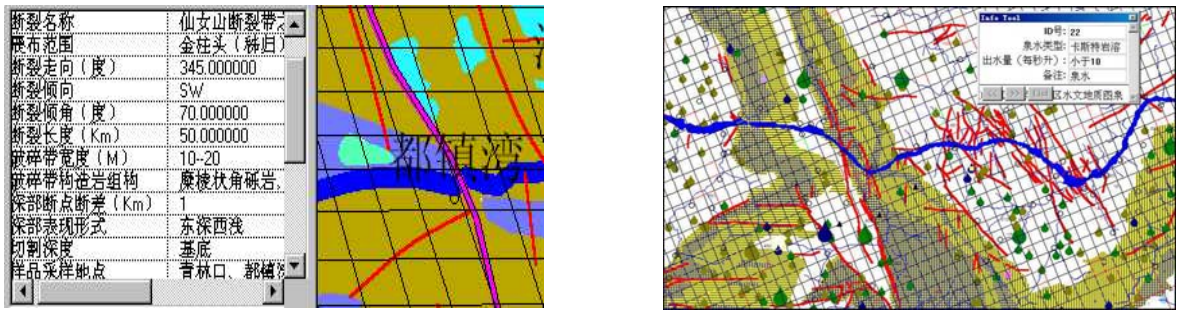
4.1 Construction of Fundamental Information Platform of DRB

In the fundamental information platform of DRB, all the information in the reservoir area are collected and digitized, and all kinds of thematic databases are built based on GIS, including the spatial information and their corresponding attribution data. In order to analyze the function(F) between X and Y, in the fundamental information platform of digital Qingjiang, the information on the factors which may induce earthquake and the induced seismicity data is digitized, while in digital Yangtze Three-gorge, only the factors are collected and digitized. All the information can be visually queried based on the fundamental information platform of DRB.

4.2 Units Division and Data Collection in Reservoir Area

On the fundamental information platform of digital Yangtze Three-gorge and digital Qingjiang, with the factors and seismicity thematic maps opened, the statistic units are visually divided and then the required data in each unit are collected by using the visually interactive query functions of DRB[15].

In digital Qingjiang(Fig.5A), it is divided into 323 units, both the factors(X) and seismicity data(Y) of each unit are obtained, while in digital Yangtze Three-gorge(Fig.5B), the reservoir is divided into 1330 units, and only the factors data(X) are collected(Fig.5) .



(A) (B)

Fig.5 Unit division and data capture based on digital Qingjiang(A) and digital Yangtze three-gorge(B). In the right map of (A), the strata layer and fault layer are overlaid onto the grid unit layer, and the data in the left table are the corresponding attributions of the double-lined fault feature in the right map. In (B), quadrangles are unit layer, and the layers of river, fault, strata and fountain are overlaid onto it. The upper right map in (B) shows the fountain attribution data in the selected unit.

4.3 Function Analysis and Seismic Risk Assessment

After obtaining the data of factors(X) which may induced earthquake and the corresponding seismic activity results(Y) in digital Qingjiang, we analyze their relationship and construct the mathematic function(F) between them . Then, the stored factors(X) in each unit of Yangtze Three-gorge reservoir are input into the function so as to calculate and assess the seismic risk in each unit. Because all the data are based on GIS, the assessed results can also be expressed in a visual manner. Fig 6 is one of the assessed results of the seismic risk in Yangtze Three-gorge reservoir. It shows that the induced seismicity risk of Yangtze three-gorge reservoir and its neighboring area is not uniform. The induced earthquake risks of most units are very low, but in the units between Jiuwanxi and Xiangxi, Shuitianba and Zigui, units of southern Jieya and units near Guojiaba and Guangzhuangping, it is possible to frequently induce small earthquakes or even induce moderately strong earthquakes.

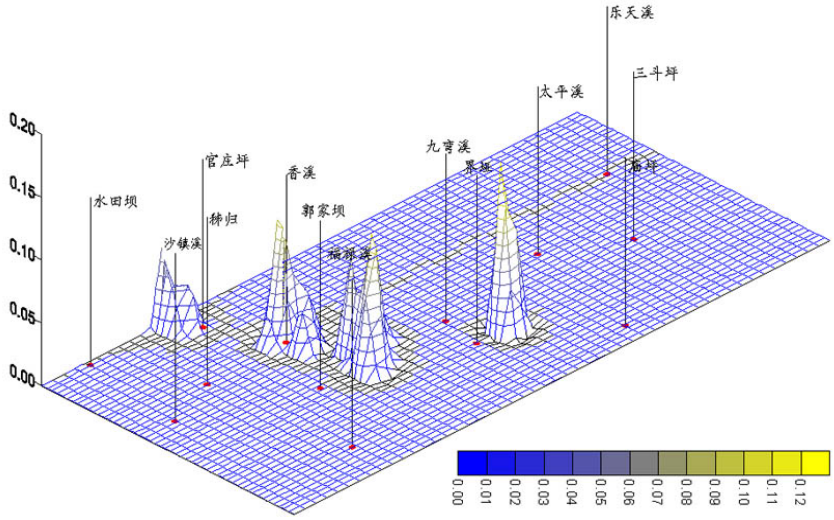


Fig.6 Probabilities to induce frequent small earthquakes or moderately strong earthquakes in Yangtze three-gorge reservoir

5. Conclusions

Digital river basin is an important regional branch of digital earth which is the high integration of modern digital, network and information technologies in river basin. Digital river basin is a very huge system engineering and can be divided into base layer, thematic application layer and synthetical layer. Each of them is designed for its own corresponding users and has its special functionality.

Reservoir induced seismic risk assessment is not easy to be realized by conventional ways because there are too many parameters in a very large reservoir area. Digital river basin not only provides a new way to implement the assessment of reservoir induced seismic risk in a river basin, but also improves the visualization of the processes and results. Reservoir induced seismic risk assessment in river basin is an important thematic application system of digital river basin.

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