

# 3D-GIS FOR BARRIER LAKE DISASTER REDUCTION AND RISK MANAGEMENT

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## ABSTRACT:

On May 12, 2008 a large earthquake occurred in Wenchuan, resulting in significant casualties and enormous property loss, and shocked the world. Then the Tangjiashan barrier lake caused by earthquake, made a serious threat to 1.3 million people living downstream. From its formation to being successfully disposed, the entire emergency management of Tangjiashan barrier lake lasted about a month. In this process, GIS has played an enormous role, for example, fast access precise coordinates of disaster areas by 3D-GIS. However, looking back to the entire process of emergency management, we can envision that GIS could do a better job. In this paper, we propose a comprehensive framework to integrate various GIS technologies in emergency management.

## 1. INTRODUCTION

A barrier lake (or landslide dam, debris dam, quake lake) is a lake or a dam reservoir formed by landslides, debris flows or volcanic lava flows impounding the river and storing water to a certain degree. It is usually caused by earthquake, windstorm, and volcanic eruption in nature (though there are human factors sometimes). Engendered by unstable geological conditions, barrier lakes often have no controlled spillway, so it frequently fails catastrophically and leads to downstream flooding, causing high casualties.

The earthquake occurred in Wenchuan, China, on May 12, 2008, resulted in over 50 thousand of landslides, collapses, as well as 35 barrier lakes in tributaries of some important rivers [Liu 2008]. The Tangjiashan barrier lake was one of them, simultaneously became the most threatening one owing to its large scale and geographic position. According to statistical data, 50 percent of the barrier lakes tend to break in ten days, and more than 90 percent break in a year [Nie et al. 2004]. Hence, the government should adopt efficient measures to solve the barrier lake problem as soon as possible to ensure the safety of people's lives and properties. Scientific methods and technologies are urgent needed to provide auxiliary support to the decision making in barrier lake disaster reduction.

3D-GIS is such a technology that has huge advantages in visual expression of disaster-related information, especially the 3D visualization of the topography (or the surface features) of the study area as well as the distribution and the trend of the disaster information. Benefiting from this, 3D-GIS has played an important role in the process of eliminating danger of the Tangjiashan barrier lake. However, there are still many obstacles in the application of the current 3D-GIS products because of the copyright limitation, the high cost or the lack of consideration about the special factors in barrier lake problems.

In this paper we take the Tangjiashan barrier lake as an example to analyze and summarize major issues in

conventional barrier lake's situation study and risk elimination. We attempt to explore the key technologies in construction of a management platform based on three-dimensional GIS to deal with the problems in barrier lake disaster reduction and risk management in order to develop the autonomous prototype system.

## 2. METHODOLOGY

In this section we explore special problems of the existing barrier lake emergency management GISystem, and discuss four key technologies in building a 3D-GIS based platform.

### 2.1 Multi-source data integration and management

The barrier lake, if caused by earthquake, is always located in remote valleys of mountains. The topographic and geological surveys and other related data are relatively inadequate or become imprecise after the earthquake. Therefore, emergency observations will be carried out in order to obtain post-quake situations in detail. Generally, in the entire process of emergency, researchers will receive a variety of information, including topographic surveys, geological surveys, hydrological monitoring, dam monitoring, aviation and space remote sensing, wireless video monitoring and other monitoring data. Ultimately it leads to massive data which are stored by many types of formats and derived from heterogeneous sources. As these data are essential, it is necessary to build a professional platform to realize efficient management which can be productive to make full use of these multi-source data.

To integrate the data in a unified system, we suggest classify the multi-source data first. The next step is to construct the integration of multi-source database. We try to examine the technologies to automatically establish the interrelationship between various types of data. More studies are on the rapid data-processing technology of the monitor data of various

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forms, different types and large amount.

## 2.2 Fast risk analysis by GIS

The barrier lakes, especially for those caused by earthquake, have a significant characteristic, which is serious lack of data before the earthquake and rich miscellaneous data afterward. Because the earthquake often changes topography of the region it affects remarkably, and previous data are no longer applicable, while new data collected need more time to process. In this case, numeric flood models are difficult to play a great role to decision and support of danger eliminating, but GIS can partially support some risk analysis services by using spatial analysis.

This paper attempts to use STEarth, a three dimensional spatio-temporal GIS, as the basis platform based on the theory of spatial analysis to study the rapid development techniques of risk analysis model, such as the fast calculation of cubic meter of stone and earth, the barrier lake storage capacity, flooding area of the barrier lake, backwater areas, the catchment basin areas, etc. Once the latest monitoring data has been introduced, the system should be able to conduct fast disaster evaluation calculation to assess the disaster condition.

## 2.3 Integration of 3D-GIS and numeric flood models

Hydrological model and hydraulical models are the most scientific and most authoritative to forecast the development of the floods, which is important for us to make right decision. At present, these models are usually independent and isolated, the data pre-processing is often undertaken using specialized tools, and the computation results also need to import into GIS to display and analysis [Zhao 2007]. Now there is still a lack of integration solutions, which will greatly impact on the efficiency of decision-making support.

## 2.4 Three-dimensional visualization of Barrier lake risk

As we all know, transitivity is an important characteristic of information, but different expression ways will greatly influence the efficiency of information transmission. Vision is the main channel for information transmission and reception, so visualization is at a special status in the Information world. As one of commonly used visualization methods, three-dimensional visualization can enable people to easily access to a variety of reality beyond the experience of space perception which originally are abstract concepts and difficult to directly perceive. Three-dimensional visualization need to apply for risk-elimination of barrier lakes in a wide range, in order to improve the scientific nature and efficiency of the emergency decision-making.

## 3. CASE STUDY AND PROTOTYPE SYSTEM

While there exist several 3D spatio-temporal GIS environments that support further development of the three dimensional visualization, we decided to use an existing environment named STEarth as our underlying 3D-GIS platform. In the Tangjiashan barrier lake case, we attained the multi-source data including the fundamental geographical data at 1:50,000 scale, water and rainfall condition, multiple remote sensing imagery, etc.

Referring to current fundamental geographical data, water and

rainfall condition, database standards, we designed and built the barrier lake risk management system database based on MySQL open source database. We studied the interrelations between the different types of the data base on the space information and the express process of the various forms, different types, and large amount of monitoring data. Furthermore, we developed the data transfer interfaces based on component technology. Data sharing mechanisms based on emerging computer and network technologies were evaluated. We also incorporated the hydraulical thematic model combined with data exchange technology of 3D-GIS. We finally built a barrier lake multi-source data management platform to implement the multi-source data integration, management, and sharing.

Then we built a fast flood analysis model based on the seed growth method, successfully achieving the goal to fast calculate the storage capacity and the flooding area under specified water levels. The paper focuses on the implementation of the rapid mutual assessment of the disaster in 3D environments, for instance, to obtain the water level and the elevation information of the barrier lake, to compute the cubic meters of the dam, the storage capacity curve of the barrier lake, the submerged area and so on.

We adopted above-mentioned data to build the three-dimensional scene of the Tangjiashan barrier lake, and then to analyze the change characteristics of the disaster data in space and time. On the basis of this, we can receive the dynamic response by means of 3D virtual simulation, and implement the 3D dynamic visualization of the model computation results, such as the fluctuation of the water level and flooding area changes of the barrier lake.

Finally, considering about the throughout process to build the barrier lake disaster reduction and risk management platform prototype system based on 3D-GIS, we design the workflow of the development (Figure 1).

Following the guideline and the workflow of our platform, we have successfully developed a 3D-GIS for Barrier Lake disaster reduction and risk management. The system is based on NASA Worldwind, developed in C# environment, using MySQL open source database.

In the prototype system, 3D DEM, remote sensing imagery, GIS vector data are integrated in a united interface, and data of multi-source are integrated seamlessly.

## 4. DISCUSSION AND CONCLUSION

In this paper, we present an example of barrier lake danger eliminating using 3D-GIS visualization. The paper focuses on the integration of the multi-source data about the barrier lake, and demonstrates a database system to manage the barrier lake risk. We successfully constructed the fast risk analysis model library, which could provide scientific decision-making support in emergency management when data was inadequate. We also attempted to explore the key technology in combining 3D-GIS with hydraulic thematic models in order to implement efficient data exchange between them and to derive the more valuable and intensively information. The goal is to implement the dynamic three-dimensional visualization of the hydraulic thematic information.

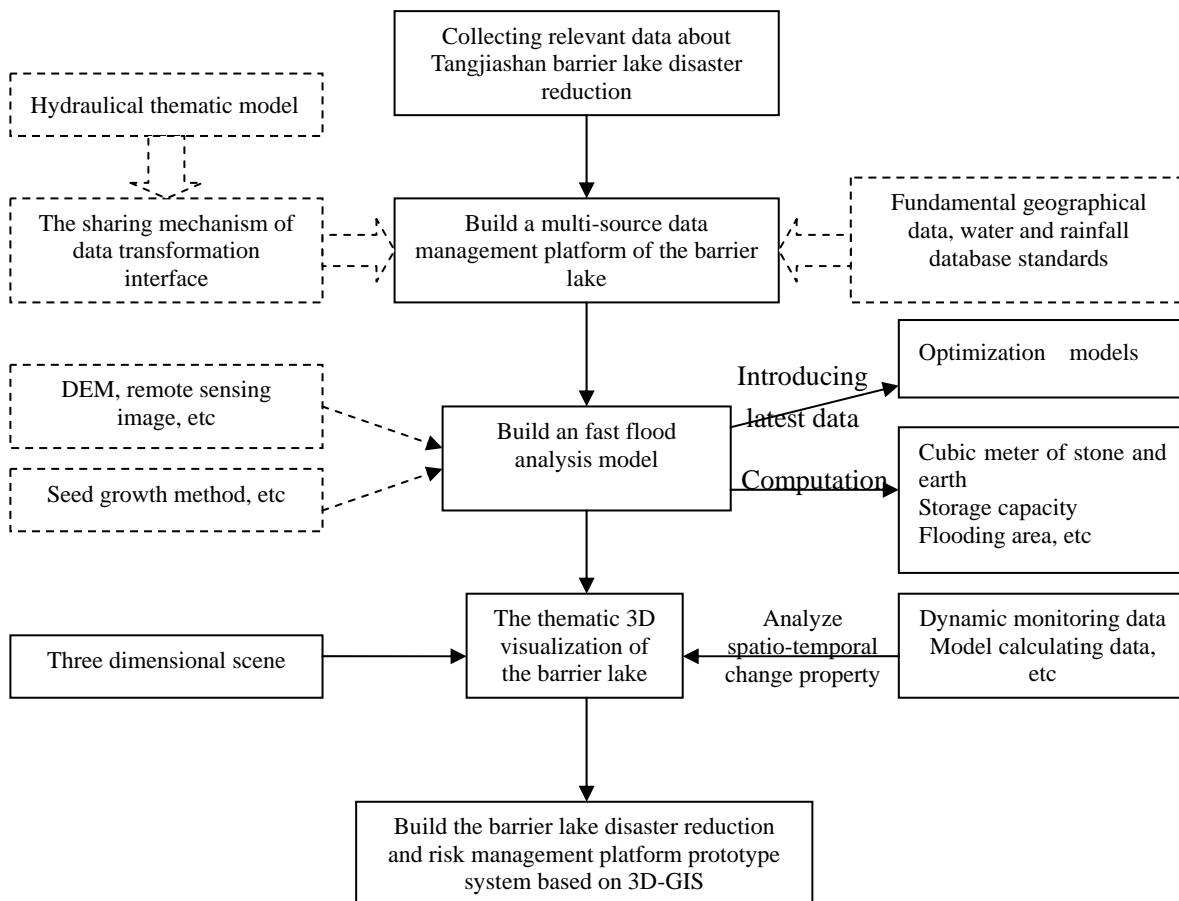


Figure 1. The workflow of the platform

A case study of Tangjiashan barrier lake was taken to demonstrate the efficiency of the prototype system based on 3D-GIS. The successful application of the prototype system verified the scientific and the practical value of results presented in the paper.

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#### REFERENCES

- [1] Ning Liu ,2008. Management project in Tangjiashan barrier lake disaster reducing, *China Engineering Science*, 10(12), 67-72.
- [2] Gaozhong Nie, Jianguo Gao, Yan Deng. ,2004. Preliminary study in barrier lakes caused by earthquake. *Quaternary Research*, 24(3),293-301.
- [3] Qiang Zhao. ,2007. GIS application in distributed hydrological mode. *Resources and Environment in Arid Areas*, 21 (3), 60-6