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Development and application of a GIS database for the Miyun Reservoir water quality protection

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Abstract: A high quality database is the starting point for any GIS application. For the Miyun Reservoir, a large amount of spatial data has been accumulated by numerous studies. This paper introduces a GIS database development in support of these studies. And some applications of the GIS database, include integration with GPS, view and management of data, and integration with WASP5 model, are also introduced.

Key words: GIS; database; ARC/INFO; Arcview; Miyun Reservoir; water quality

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1 Introduction

1.1 Miyun Reservoir and associated studies

The Miyun Reservoir (Fig. 1), situated in Miyun County, 90 km to the northeast of Beijing City, is one of the most important reservoirs in the suburbs of Beijing, serving as the source of drinking water for the people of the capital. It has a total pondage of 4.375 billion m^3 and a corresponding water surface area of 188 km^2. As industry and agriculture develop rapidly, the water supply in Beijing is getting in short. To relax the problem of water supply for people's life, the municipal government of Beijing has decided to make Miyun Reservoir as a surface water source to supply water for the capital. Thus the main function of the reservoir has turned from flood preventing to drinking water supplying, along with flood prevention and electricity generation. So the protection of the water quality of the Miyun Reservoir has become an important issue concerning the life and health of the people in the capital.

As the water quality of the Miyun Reservoir has been the concerns of the public, several studies have been accomplished by different institutes, sponsored by different government agencies, such as Beijing Water Resource Bureau (BWARB), Beijing Environmental Protection Agency (BEPA), Beijing Waterworks Bureau and so on. Many data have been accumulated through these projects, however, owing to the independent between these agencies and lack of the communication, many works are iterated.

In order to implement the share of the accumulated data, the development of a common database is needed.

1.2 Why GIS is adopted?

A geographic information system (GIS) is a computer-based tool for mapping and analyzing things that exist and events that happen on the earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and privates enterprises for explaining events, predicting outcomes, and planning strategies.

Spatial data are common in the reservoir water quality study, so GIS was identified as an important tool. The objective of this task is to develop a set of tools (models and GIS databases) that integrates the data from various tasks in this project and other projects to provide predictive capabilities, with which the decision makers can evaluate the consequences of various water management options on the watershed of Miyun Reservoir.

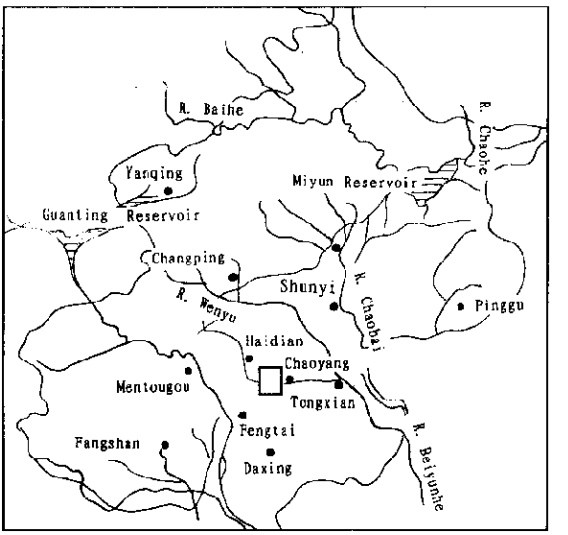

Fig. 1 Location of the Miyun Reservoir

2 Development of the GIS database

2.1 Primary data collection

2.1.1 The basic data of Miyun Reservoir watershed

The basic data include the administration zoning, soil type, land-use, production value of agriculture and industry, natural resource, population, annual precipitation and so on. These data are related with pollutant sources, and thus have influence on the water quantity and quality in Miyun Reservoir. These data are collected from the yearbooks of the county in the watershed.

2.1.2 The reservoir operation and flow data

The reservoir operation and flow data were provided by the Management Branch of Miyun Reservoir, BWRB. These data include the reservoir's inflow, outflow, water surface elevation and precipitation, along with other information.

2.1.3 The reservoir historical water quality data

Since the construction of the reservoir, the water quality have been monitored by many organizations, including the Management Branch of Miyun Reservoir, BWRB; the Center for Environmental Monitoring, BEPA; and some institutes and colleges. Some of these data are collected and organized in the database.

The location of each sample stations in the database was coded by an identification number.

ARC/INFO was used in the initial analysis of the historical water quality status. The reservoir and its sample stations were digitized into ARC/INFO converages. Data of the selected variables were transferred to INFO files and the water quality measurements were illustrated by ARCPLOT map outputs.

2.1.4 The tributary and non-point sources loading data

A parallel project of non-point source loading assessment was conducted by the Center for Environmental Monitoring, Beijing Environmental Protection Agency (BEPA). The objective of this project is to estimate the monthly loading from the tributary watershed to the reservoir and to provide data to calibrate non-point source models used to assess future watershed land-use scenarios.

2.1.5 The point source discharge data

The point source discharge data were collected from various sources, including EPA's

wastewater discharge permit records and city/county wastewater discharge monitoring data.

2.1.6 Cage fishery data

In Miyun Reservoir, there are about 1.35 hm^2 cage fisheries. These cage fisheries contribute lots nutrients. The nutrients data from cage fishery are provided by a project which was conducted by the Center for Environmental Monitoring, Beijing Environmental Protection Agency(BEPA).

2.2 GIS database construction

2.2.1 Geographical reference system

The geographic reference system used in GIS database of this study is the Beijing Coordinates System. The advantage of the system is that it is convenient for further manipulation when depth values(also in metric units) are involved, and convenient for data share with other projects.

2.2.2 Base map of the reservoir

Three sets of base maps are used in this study. The first is the 1∶50000 reservoir bottom elevation contour map(Fig. 2). The second is the 1:95000 Miyun County map that contains the administration zoning, water system land-use, road system, and so on(Fig. 3).

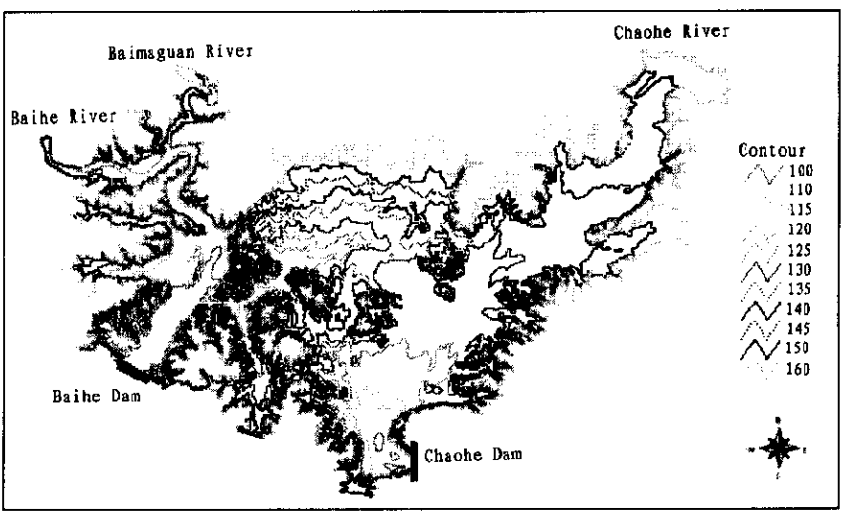

Fig. 2 Reservoir bottom elevation contour map

The third is the 1:200000 topographic map of Miyun Reservoir's watershed(Fig. 4). The first and second base maps are digitized using ARC/INFO system in Beijing Environmental Science Institute. The third base map is digitized using Mapinfo system in Tsinghua University, and then exported into ARC/INFO system. Separate coverages are generated for different topographical features, sample station, point and non-point source loading.

2.2.3 Transformation of multi-source data

Data in various formats must be pre-processed before merging into the GIS database. The processing procedure can be summarized into the following steps(Fig. 5): (1) affixing location information. Data of sample stations are registered with the station location; data of point source discharge are registered with the discharge outlet location; data of non-point source loading are registered with the reservoir segmentation polygon which receives the loading; data of inflow and outflow are registered with the location where the flow is measured; (2) change into format of matrix records, so that each column contains one variable and each row represents one point or one polygon in the GIS coverage; (3) transfer into ASCII text file; (4) add data to INFO file; (5) joint the data with coverage.

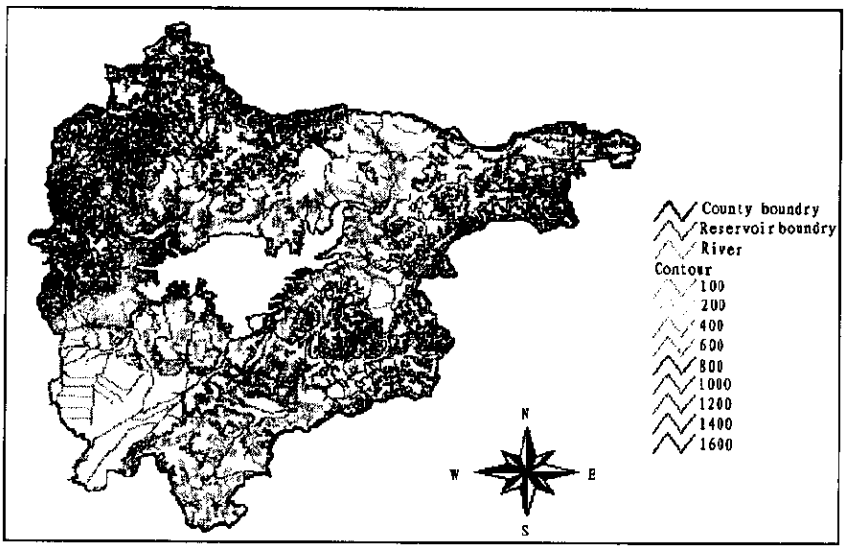

Fig. 3 The relief map of Miyun County

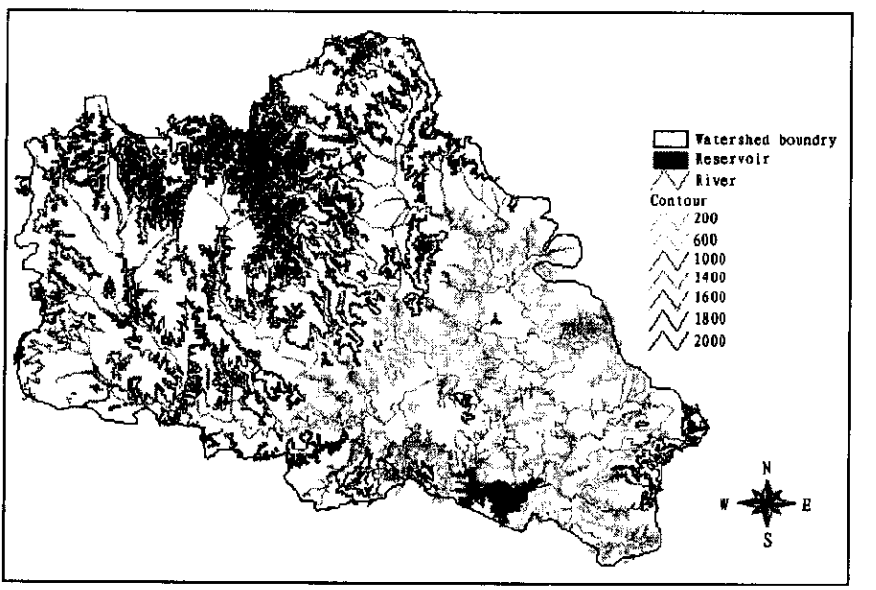

Fig. 4 The relief map of Miyun Reservoir watershed

3 Applications of the GIS database for Miyun Reservoir water quality protection

3.1 Integration with GPS

Water quality monitoring is important in reservoir water quality management. However, it is difficult to identify the sample station's location in the open water. Global positioning system (GPS), built by United States, has been widely used in determining the coordinates of objects on

the earth. Using the GIS database and high accuracy GPS equipment, it is easy to locate the sample station and relate the sample data with the GIS database.

Another use of GIS is in the investigation of pollutant sources and other information related to the management of the reservoir watershed.

3.2 View and management of data

The amount of data we collected are large and very specialized. It is very dull for decision-maker to read these data, and also difficult to understand it. The GIS provide a powerful tool to map and analyze these data. This makes it easier for decision-maker to understand these data. In Arcview, the attribute data (include water quality data, pollutants sources, and so on) are related with the geographical data, and then be viewed in the unique visualization form defined by users. Here is an example: Fig. 6 illustrate the location of the water quality sample station and cage fishery in the Miyun Reservoir, which can indicate the distribution of the cage fishery and their potential influences on the water quality in reservoir's outlet.

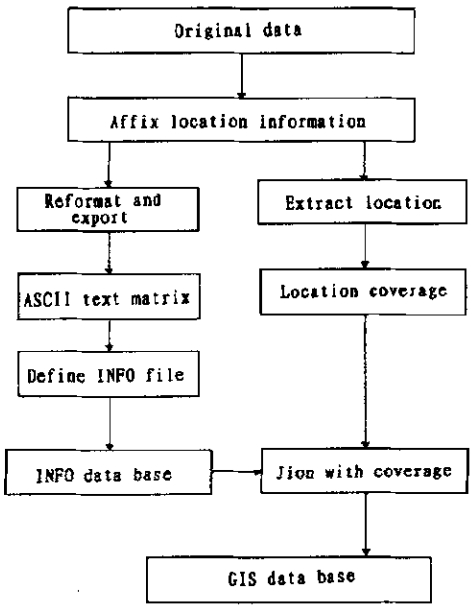

Fig. 5 Data transformation flow diagram

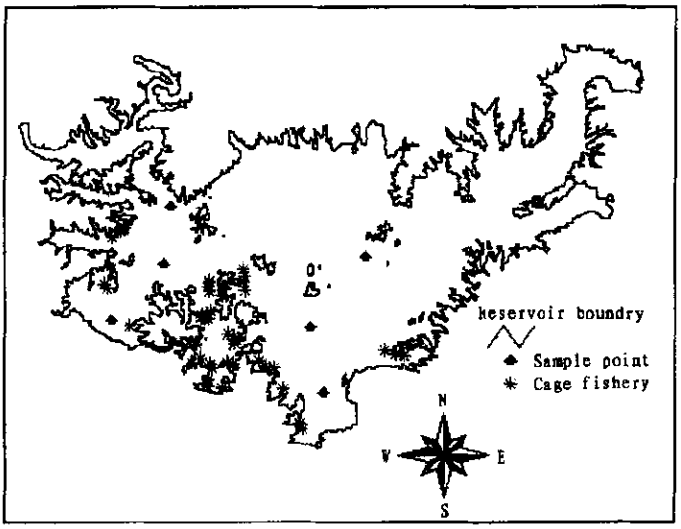

Fig. 6 The location of sample station and cage fishery in the Miyun Reservior

3.3 Integration with WASP5 model

3.3.1 Modeling reservoir water quality by WASP5

In Miyun Reservoir, with the point and non-point pollution sources of poultry wastes, farmland fertilizers and top-layer soil erosion from the watershed, the oxygen, nitrogen and phosphorus levels become the focus of the water quality modeling. In this project, WASP5/

EUTRO5 was used to model reservoir water quality.

The water quality analysis program (WASP) was developed in 1981 (Amborose, 1991). WASP5, the updated version of WASP, is a dynamic compartment model designed to analyze a variety of water quality problems in ponds, streams, lakes, reservoirs, rivers, estuaries and coastal waters. Because of its unique flexibility, the model has been widely used to predict water quality responses to natural and man-made pollution.

The WASP5 modeling system consists of two stand-alone computer programs, DYNHYD5 and WASP5. The WASP5 program is supplied with two kinetic sub-models to simulate two of the major classes of water quality problems: EUTRO5 for conventional pollution and TOXI5 for toxic pollution. The details of the WASP5 were omitted here.

3.3.2 Integrating WASP5/EUTRO5 with ARC/INFO

3.3.2.1 Generating data required by WASP5 through GIS operations

(1) Topographical features: The topographical features of the reservoir are digitized into ARC/INFO. According to the digitized contour, the topography of the reservoir bottom is generated by the CREATETIN function, which is a triangulated irregular network(TIN) model. It may be displayed by the VIEW function as a three dimensional model(Fig.7).

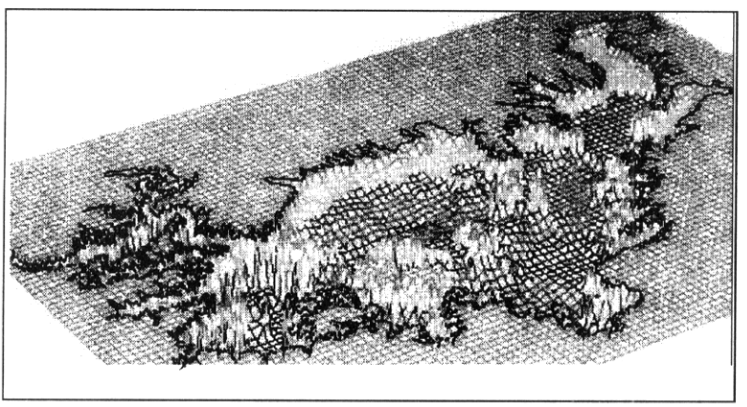

Fig.7 Miyun Reservoir bottom elevation model

(2) Segmentation of Miyun Reservoir: According to the use of the WASP5 model, the primary segmentation scheme of the Miyun Reservoir was made. All segment boundaries were defined in ARCEDIT environment. Background display of water quality information from sample stations, water flows, waste loading and reservoir bottom geometry data are options available for the user's selection, as references in the segmentation process.

(3) Spatial measurements: Using the ARC/INFO system, several spatial measurements can be calculated. These include: surface distances, surface and bottom areas, vertical profile areas, average bottom slope, volume, average depth and so on.

(4) Interpolation of samples data: Due to various reasons, the number of sample stations in this study is much less than the number of segments in the simulation model. For the segments which do not have a sample station, nutrient concentration and other variables required by the model input must be interpolated from the known values of the sample data in nearby stations. Using ARC/INFO, values for each specified point in the coverage can be generated. The operation is flexible in terms of interpolation calculation methods, segmentation schemes and sample variables.

3.3.2.2 Input-output cross-match between WASP5/EUTRO5 and ARC/INFO

The input data cross-match from ARC/INFO to WASP5/EUTRO5 is a complicated process. It includes the following steps(Fig. 8).

(1) Export from ARC/INFO. Data for each segment, each interface boundary, or each sample point are first exported from ARC/INFO files to ASCII text files.

(2) Merge with non-geographic data. There are other data needed by WASP5, which are not spatialy related, such as some function parameters or simulation control options. These data need to be merged with the ARC/INFO exported data file.

(3) Re-format of the ASCII files. The ASCII data files have to be re-formatted to match the input format requirement of WASP5.

The output cross-match from WASP5 to ARC/INFO is relatively simple. The basic processes are the same as the input cross-match. The processed files are converted to INFO files in the GIS database. AML interface programs select data of certain time and certain variables, defined by the user from the database, and relate them to the specified coverage for display, calibration or animation.

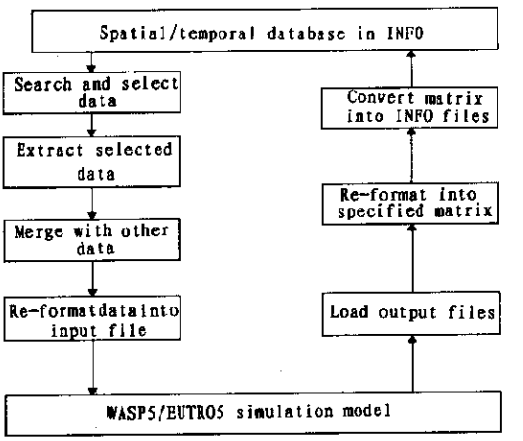

Fig. 8 Data flow between ARC/INFO and WASP5/EUTRO5

4 Conclusion

The applications of GIS techniques in environmental science are rare now in China, but it is believed that it has a good future. In this paper, the development of the GIS database for Miyun Reservoir water quality protection was described. This fundamental GIS database will support future projects on the water quality protection in Miyun Resrvoir greatly. Some applications of the GIS database were also presented. These applications described here include: integration with GPS, view and management of data and integration with WASP5 model.

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