The Application of GIS to Watershed Environmental Management

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Abstract

The transfomal relation of pollutants in different transport media (e.g. air , water , soil) should be considered into the effective strategy of controlling environmental contamination. Such that , Watershed Environmental Management(WEM)will be an appropriate approach to work out the strategy , and the aid of geographic information system(GIS)could be useful in managing the environmental contamination. In this study , the authors have proposed four suggestions or steps in the application of GIS to WEM , including:(1)investigation of watershed existent environmental contamination , (2)control of watershed environmental contamination , (3)prevention and examination of watershed environmental contamination , (4)draft of the strategy of WEM. Watershed Environmental Geographic Information System(WEGIS)is a project supported by Taiwan EPA in 1993. The main purpose of this project is trying to offer the great effort in establishing the system according to four steps mentioned above. There are four different analytical modules contained in this system , such as environmental quality display , major theme overlay , environmental simulation models , and different kinds of map management. It could provide more specific information pertaining to environmental protection tasks and monitor the change of environmental quality.
Keywords:Watershed , Geographic Information System , Environmental Management

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Introduction

In Taiwan, the quick economic growth and unbalanced population distribution have lead many area-divided activities such as land usage, urban areas development, agricultural and industrial development, and energy development to become environmental problems[1]. Water shortage and floods, soil remediation, land subsidence, ecological preservation are urgent problems that should be solved. Thus, under the instruction of the present environmental protection policies, policies of resource development, public nuisance prevention, and nature presevation are aimed to have environmental plan and management proceede and to have environmental quality monitoring, environmental information system and man-power assistant plan established[1]. Management system divided by environmental media (air, water, and soil). Also, the thing concerned most has been changed from simple pollution prevention to risk-prevention evaluation and urgent remedies are produced to establish the work of pollution prevention[2].

Information is an important element for the work of environmental plan and management and the establishement of environmental information system is a crucial step in Environmental Management System. Since space and location always need to be concerned in environmental problems, Geographic Information System is especially suitable for dealing with area environmental problems by digitizing applied data(e.g. soil, river, and well location) into different major theme maps and combining easy analytical functions to provide controllers different information. In this study Watershed Evironmental Management and the tendency of pollution prevention pollicy are disscussed first and later the appling methods of geographic information assistant management policy wich can be the future model for the watershed management strategy application will be explained.

Analysis of Watershed Environmental Management Strategy.

1. The necessity of watershed environmental management

The transformable relation of pollutants in different kinds of media(e.g. air, water, wastes, and poison) should be considered into the effective strategy of controlling environmental contamination. From the sensitivity of pollution acceptance, ecological is most vulnerable to pollution and the following are water, air and soil. Although the air and soil pollution system boundary cannot be confirmed easily by pollution prevented execution policy, ecological will be bettered after the improvement of all kinds of pollutions has completed. Because, the work of water pollution prevention needs to consider the water influence caused by pollutants, and its system boundary can be drawn by the transferability. Watershed, which is consisted of many catchment units, can show the indepedence and completeness of surface water. Undoubtedly, by this management, the pollution prevention strategy will be developed[3]. We need to know that it is impossible to end pollution if we only aim to keep from pollutants. The filed and saved watershed environmental geographic data such as basic background data, public nuisance data, and controlled area data, can provide the application of environmental impact assessment, continuious investigation, and auditing. The watershed environment can be planned and managed with new and supplementary data.

2. Watershed Environmental Pollution Control Plan

In 1993, according to "Air Pollution Prevented Law", "Water Prevention Law", "Waste Treatment Law", "Toxic Chemical Material Management", and other related rules, the Chung-kang River Watershed was taken as an example to establish pollutants control plan and to show the urgent job to do was to protect citizens' living surrounding and health, to keep the lasting usage of water resources and to control pollutants. At the same time, air, water, waste, and poisonous chemical substances should be controlled together to achieve maximum results with little effort [4]. The executive strategy include the following steps.

(1) Establishing basic data of air, water, waste, toxic material and other related pollutants in watershed
(2) Establishing the environmental quality monitoring network and geographical information system
(3) Reducing 50% of air, water, wastes, and toxic material pollution quantity
(4) Promoting resource reclamation system to reduce quantity of wastes treatment
(5) Beautifying both scenery routes along watershed and community environment
(6) Establishing chemical damage prevention and emergency system
(7) Establishing public nuisance dispute system

By practicing these steps, goals such as (1) decrease of total producing and emitting capacity of watershed pollution, (2) natural resouce preservation and environment-beautifying, and (3) promotion of watershed and artificial environmental quality. After the tendency of the environmental management strategy has been understood, the application of GIS to watershed is expected to be practiced.

The Establishment of Watershed Environmental Geographical Information System(WEGIS)

1. A brief introduction of the case area

The Chung-kang River which originates in the Lu-chung Mountain (at the elvation of 2616m), travels through O-may Village in Hsin-chu County; Nan-chung Village, San-won Village, Chu-nan Towan, Ho-long Town in Mao-li County and runs into the Taiwan Strait when it is close to Wen-chito area. The total length of this river is 54.14km and its total watershed area is 445.58km square(e.g. Figure 1) There were 200,000 people, 100,000 heads of pigs, 242 water pollution controlled factories, 56 factories with wasetewater more than 50 tons per day, 7 garbage disposal places which disposed 181 tons of garbage per day, 439 air pollution controlled factories, 76 factories which pollutes more seriously, 20 chloride factories that were controlled by making public, and an asbestos factory, in this area. The San-won Bridge, the Ping-an Bridge, the Tong-shin Bridge, the Chung-kang River Bridge, and the Tien-may River-blocking Weir which was built in 1993 are locations of water quality stations established by Taiwan Environmental Protection Department. According to the annual water quality investigation which was conducted by Taiwan Environmental Protection Department, it showed that part of the Chung-kang River between the Tong-shin Bridge and the river entrance had been contaminated seriously. Thus, the river not only failed to correspond with the water standard of river classifications but also can do harm to costal irrigation and river-breeding water and living environment quality of people [5]. The estimated result which was based upon data mentioned above shows that industrial waste pollution was about 51.1%, animal husbandary was 26.8%, and domestic wastewater was around 22.1%.

2. System Description

The establishment of WEGIS is aimed to provide basic data for environmental impact assessment and countinuous research. Also, pollutants and investigation background data needed for other environmental protection work can be used for management-tracing. The demands for this system were software of ARC/INFO 6.1 and hardware of HP9000 series. Establishing steps include planning for database framework, designing, data-filing, database-establishing, planning and designing for system function framework, system operation, and managemet explanation. (see Figure 2) After the WEGIS was established, it has been considered to do the same thing to other watersheds. The system functions include display overlay, magnification and contraction, space and attribute query, data statistics and sorting, data input and output, file-changing, color symbol set-up, and map display. And environmental quality display, major theme overlay, environmental simulation models, and map management are a set of function modules designed to deal with many kinds of environmental related work and database. The following explains the process of database and system establishment:

(1) The Establishment of Watershed Environmental Geographic Database

Data-filing should be proceeded at the stage of watershed environmental control and the most urgent job to be done before working on database establishment is the work of database frmework plan and design. It is important to be certain about expected demands first and later design database and methods of continuous filing to make the process of data-filing easily and and to be the basis for data establishment.

A. The design of database

Space data mentioned in the study are mainly vector data which include background, public nuisance, and controlled areas data ; and raster data such as satellite image, entity photos and other Digital Graphic Data and later have these data become map database. The Nine National Territory Database[10,11], and the database designed by EPA [9] can be referred in this study.

The big amount with small variablity of map data and big amount and variavbility of attribte data are elements that should be considered when database is in the process of being established. Thus, it is needed to design and to build map data and attribute database separately to have them applied by combining database. Based upon visiting results of EPA, non-digital map data such as attribute and written form data will be used to establish basic file and then be connected to map data file through GIS indentified code (Figure 3), the framework chart of watershed environmental geographic database based on the Chung-kang River watershed, is the model for other watersheds. It is the framework chart of watershed environmental geographic database based on the Chung-kang River watershed (Figure 4).

B. Data-filing

Since database framework for establishing spatial geographic data has been mentioned, we do not need to repeat here. The following jobs are to vectorize data through measureing and digitizing, to integrating GPS and RS with GIS, and to assist data-gathering. Filing data include 43 kinds of backgrounds data, control data, and public nuisance data (Table 1). Therefore, the data Integration which can reach goals like database establishment and continuous application, will be explained.

a. Vector Data

One of the most crucial things to do in the application of geographic information system to watershed environmental protection work is to vectorize spatial geographic data. Basic environmental data like topography, geology, soil, catchment areas, and watershed range, are possessed with traits of spatial distribution and geographic location. And location and area data of many protection, preservation, and control zones are important information for management planers or controllers.

b. Satellite Data

Satellite remote sensing image data has wide-range for covering, and can be chosen in different time. Data which have been through the analysis of satellite image can provide information about big area land usage. Thus, the saving of man power and time to file related environmental basic data for National Terriroty Database can be madeup.

c. GPS Data

The GPS satellite positioning measurement, conducted by receiving satellite message, can be a fast way to figure out the location coordinates of receiving antenna. This can be appied to space-positioning of environmental protection locations (e.g. factories, industrial areas. disasters zones, and water catchment)

C. Data Integration

Now, spatial geographic data such as vector coverage filed by GIS, file of factory locations and specific topography built by GPS, and digital image obtained by satellite remote-sensing, and image being disposed,

have been filed separately. After being processed, those data can be integrated and organized through ARC/INFO to become different major theme maps that are helpful in dealing with work of EPA.

(2)The Establishment of WEGIS

It is our first time in the respect of Watershed Environment Management (WEM) to build data for environmental improvement measures and to establish Watershed Environmental Geographic Information System (WEGIS) by taking ARC/INFO as a tool. This is an organized and integrated information system which was designed by EPA to deal with the work of watershed environmental improvement.

A. Goals of System

By using the project of the Chung-kang River, goals of this system is to establish an exemplary working-system for other watersheds and to consider the future possible application and expansion when system framework is designed. Because the environmental protection business in air, water, waste, toxic chemical material, and ecological possess high possibility to apply the geographic data mentioned above. The environmental quality improvement and pollution prevention can be achieved if information is under full control. Goals of the system are described as follows:

a. Displaying the influential range of weatershed pollutants
b. Having full control over pollutants and environmental quality condition with the view-point of whole area
c. Under the environmental improvement measures, providing all kinds of air, water, land, and ecological problems which are resulted in pollutants and their connections by visualization
d. Providing basic data for environmental impact assessment and continuous research, and the backgournd data for EPA investigaion control and management-tracing
e. Having the ability to handle the work of EPA and to supply information assistance that is needed in the early system establishment

B.Analysis of System Requirements

The system esatblishement of this project was designed from the consideration of its application and establishment. The first step is to have analysis of requirement inquiry proceeded to establish the need of data and information which can provide related information of system function design and system framework.

(1) Overviewing of EPA presenl business operation
(2) Interviewing of EPA requirement on system function
(3) Functional Analysis of system requirement and data requirement analysis
(4) Specification establishment of system function requirements

C. System Framework

WEGIS is aimed directly to meet application needs of EPA, to provide many bussiness divisions a more concrete example for appling, and to consider the flexibility for the future development. The bottom framework which includes environmental quality display sub-system, major theme overlay sub-system, environmental simulation models sub-system, map management sub-system, GIS common funtions, and etc.(eg. Figure 5) These systems can be used for data retrieving, displaying, overlaying, analyzing, computing, outputing, and managing in the established environmental geographic database.

The concerning of Watershed Environment Management (WEM) was adopted in this project for the first time to establish data that are needed for improving environment and to show the distribution and impact ranges

of watershed pollutants. The main job for the first stragegy of pollution prevention was to control pollutants and environmental quality by taking the whole-area idea and then to remedy the deficiency of work by assisting other related geographic information. Under the environmental improvement measures which are based on environmental improvement measures of investgation pollutants, the system can pointout the water, air, land and ecological problems resulted in pollutants. And the future possible application and expansion are considered in establishing system framework. This can be explained well by referring to Nine National Territory Database [10,11], Environmental Information System Framework [9], and the Framework Figure of Environmental Geographic Information System (showed in Figure 6).

D. System Design

In order to meet the requirement of system-users, the system model design is based on the entire function prototype which were established by " Document of System Requirement Analysis" and the early designing content of "System designing Document",and needs be modified continuously. The following brief discriptions are about modified system contents and development environment.

a. System contents

Four sub-systems are included in this system:

(a) Enviromental quality display sub-system

(b) Major theme overlay sub-system

(c) Map management sub-system

(d) Environmental simulation models sub-system

(e) GIS common functions

b. Development environment

(a) Hardware: HP9000/720 Map working station

(b) Software: ARC/INFO V6.1 (Except COGO)

(c) Operating system: HPUX+MOTIF

(d) Chinese code: BIG.5

c. System design consideration

Under the establishment plan of " the Chung-kang River watershed environmental geographic information system", this system is designed to deal with requirements of different business units and to simplify operation. Brief explanations of its designing ideas are following.

(a) Using GUI of ARC/INFO 6.1 to design operation interface to increase friendliness of operation

(b) Having all kinds of sub-functions and utilities be used in icon form to increase friendliness of interface operation

(c) Reducing operation steps, increasing operating efficiency, adopting all kinds of default display

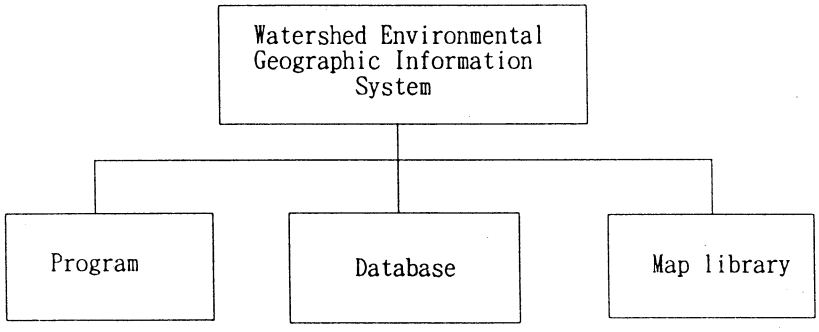
(d) With the consideration of future data expansion and maintenance, concept of ARC/INFO map library is addopted to manage maps.

E. System Integration

After database establishment and system design have been completed, system integration is the next-step. Module concept is adopted separately when system design is under the process. This means that coding of different function modules and application modules are to be executed after the recognition of function requirements. The final step is to have a complete system which is reached through different function modules

integration and organization. Prototype system development, which is used in our case study, has to proceed requirement recognition every week and to modify detail function repeatedly.(slight revision on frmework)

Our project was based on the instruction of working flow. The database establishement and system design were organized and integrated after they were finished separately. Since the design of logic database is completed under the working process of database framework, the entity database establishement should be accomplished during the integration of framework. Also, with the adoption of map library concept, storing data into map library is part of system integration. The WEGIS is devided into main, database and map library.



F.Results Display

The coding of system detail design was developved through modulization and the most difficult task was program integration. Figure 7 displays its results after modification. The icon buttons located on the left side of that frame are GIS common functions. In order to ease the operation of theme overlay through icon functionlizing, icons above the frame are purposefully designed to correspond with the meaning of each sub-system theme. Now, the finished WEGIS can be the basis to proceed watershed data establishment and to apply geographic data system to watershed environmental management policies .

The Promotion of Watershed Environmental Management Policies

1. The control of Watershed Environmental Pollution

The concern of watershed environmental management has changed from point and line to the entire area regulation and arrangement. After the collection of data such as pollutants, polluted areas investigation, environment sensitive areas, and management assistant data have been completed (e.g. Figure 8), database management system will be established to proceed graphy and attribute data management (e.g. Figure 9). It is possible to control the amount and characteristics of each pollutant's distribution after having pollutants and related spatial geographic data be computerized (e.g. Figure 10).

2. The Regulation and Auditing of Watershed Environmental Pollution

The understanding of air , water, soil, and ground water quality can be provided by information from database management system (e.g. Figure 11). Once change of qualities happens, possible pollution route and pollutants are predictable through environmental data to provide prevented measures (e.g. Figure 12). Also, organization of environmental quality monitoring network and the establishment of public nuisance dispute process model are included into this regulation to strengthen pollutants dentification and public nuisance handling ability. Serious pollutants, which have the priority to be audited first, can be screened from database. Besides this, database can also supply environmental information to draw up environmental quality

improvement program and prevention measures. With the cooperation of graphic user interface, this method can show what key problem of pollution is and then promote efficiency of pollution regulation and auditing.

3. Prevention and Examination of Watershed Mangement

The way to treat pollution thoroughly is to reduce chances for serious pollution to be happened. Although many building projects were passed under examination, ecological was destroyed and pollution became out our control after projects began. This leads to the decrease of environmental quality and increse of people's complaining. With the shortage of environmental related data, the planned pollution control measures in deveolping areas were hard to draw up a set of management rules. Now, with the application of geographic information system and remote sensing skill, data are compared and saved shortly to establish a standard working process which can shorten time of environmental impact assessment (e.g. Figure 13). This transparent working procedure is to provide citizens the willingness to protect our environment and to establish the authority of the government. Environmental impact assessment is a kind of prevention working procedure and watershed management can both control and prevent environmental quality well and take good advantage on watershed land usage.

4. The Establishment of Watershed Management Decision Support System

It is needed to establish watershed management and to addopt assistant system (e. g. Figure 14) to transparent decision working process, for the previous process caused many disputes and objections. Undoubtedly, in this decision support system, the related information system assistance is definately in need and plays a crucial role [13]. The gist of this decision support system is to take different policy-decision goals as the changeable element that can be decided by decision-makers. This system is the analytical tool with the most flexibility. Decision-makers can either set up sollutions by themselves and have model base system predict future conditions or choose among alternatives which come from policy-making methods and then have policies established through simulation. Thus, the scientific decision-making theory and process can pursuade people to trust our government and promote decision-making quality. Surely, these will not be achieved without the completeness of data.

Conclusion

The quick change of land usage, which is brought by economic growth, has led the traditional working-process to meet present working demands with a failure and brought about new technology to deal with spatial problems. The WEGIS is a special product designed to solve the watershed environmental problem. The change from watershed to the entire environmental information system can display present environmental quality influenced by air, water, and soil, and can supply data and information needed for the work of environmental planning and management. The following series of suggestions can be used as references for the future research development.

1. Discussion

(1) Environmental protection data in computerize form absolutly is helpful toward control, auditing, evalution, and prevention of environmental quality pollutants. Also, geographic information system, remote sensing, and global positioning system can be used to obtain and file spatial geographic data.

(2) Under the instructed policy of National Territory Information System(NTIS), the establishment of environmental database and information system has laid the foundation of environmental protection job and stepped out toward the long-range goal of NTIS. In the future, interaction between environmental database and National Territory Database will be practiced to produce applied information.

(3) Environmental Geographic Database is based upon the Chung-kang River watershed with consideration of other watersheds establishment. Not only frameworks of National Territory Database and Environmental Protection Geographic Database were referred but also mapped and attribute data were designed and managed separately.

(4) In this study, Environmental Geographic Information System framework and Environmental Geographic Database framework respond to each other. Because framework which is based upon watershed can be applied to other watershed data, it will be taken as an establishing principle.

2. Suggestions

(1)Computer system has its life cycle. Thus, in dealing with environmental problems that are open and semi-structural, the practility of system functional system should be concerned especially if promotion of environmental quality will be assisted by computerized working procedures. In order to avoid difficulty of this system that might lead people unwilling to use the system and to reinforce system functions by basing modified environmental law and responsing to working models and information requirement, system functional development is suggested to be renewed and strengthened as commercial the software development model .

(2)Basic analysis functions (major theme, contour line) cannot fully meet all kinds of demands of environmental management, so advanced model analysis function should be adopted. Limitations such as " application of models", "public acceptance", "acquisition of data", "operation time", " and "friendliness to users" should be taken into consideration to meet needs for development.

The work of collecting and filing data of each watershed should be proceeded continously and the establishement of modification, model base, and expert system must be responded to the application of watershed environmental management policy. As for the bussiness promotion of application information assistance, considering the practical working problem and the free provision of basic data is always helpful for the future development. Although decision data computelization is the goal that upper decision-makers have longed for, the environmental problems of decsion cannot be ilicited from uncertain procedures. Thus, visual information from different view-point, porvided by applicable data, is what we will strive for in the coming future.

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Table 1 Data Explanation List

Data Items		Data Type	Scales	Cover Areas	Data Resources
N-1	Weather	ANNUAL REPORT	COORDINATE	Taiwan	Central Weather Bureau
N-2	Surface Topography	DTM	40M DISTANCE	Chung-kang river	Space Remote Sensing Center of Central University
N-3	Geological	RAW GRAPHY	1/250000	North from Tai-chung	Central Geographic Regulation Laboratories
N-4	Soil	DWG	1/25000	Chung-kang river	Taiwan Province Water Protection Bureau
N-5	Geohydrological	REPORT	1/100000	Chung-kang river	Taiwan Province Water conservancy Bureau
N-6	Water catchment	RAW GRAPHY	1/250000	Taiwan	Agricultural Industry Committee Board
N-7	Watershed	DXF	1/5000	Chung-kang river	Data Centwe of Ministry of Interior
E-1	Water protection area	COVERAGE	1/25000	Chung-kang river	The third Control Department of Running Water
E-3	Nature preservation area	COVERAGE	1/25000	Chung-kang river	Niao-li County Goverment
E-5	Forest range	COVERAGE	1/25000	Northern District	Forest Industry Bureau
E-6	Artificial reef area	COVERAGE	COORDINATE	Taiwan	Fishing Industry Bureau
E-7	Reef protection area	COVERAGE	COORDINATE	Taiwan	Fishing Industry Bureau
E-8	Costal fishing resouce protection area	TEXT DATA			Fishing Industry Bureau
E-9	Dam water log area	COVERAGE	1/5000	Chung-kang river	Data Centwe of Ministry of Interior
A-1	Transportation system	DXF	1/5000	Chung-kang river	Data Centwe of Ministry of Interior
A-2	Goverment boundary	DXF	1/5000	Chung-kang river	Data Centwe of Ministry of Interior
A-3	Relics	TEXT DATA		Miao-li county	Niao-li County Goverment
A-4	Specific scenery area	.....		Miao-li county	Niao-li County Goverment
A-5	Land usage	.....	1/5000	Chung-kang river	Agricultural Aviation Laboratories
A-7	Land usage district of urban planning	COVERAGE	1/1000	Chung-kang river	Residence Bureau,Niao-li County Goverment
A-8	Water intake point	COVERAGE		Taiwan	EPA-Env.Monitoring and Data Department
A-9	Irrigation water supply system	RAW GRAPHY	1/50000	Chung-kang river	Farmland Water Conservancy Association
M-1	Air quality monitoring station	REPORT	COORDINATE	Taiwan	EPA-Env.Monitoring and Data Department
M-2	Water quality monitoring station	COVERAGE		Chung-kang river	Taiwan province Environment protection Department
M-8	Water classfication area	COVERAGE	1/25000	Chung-kang river	Taiwan province Environment protection Department
M-10	Water pollution control area	REPORT		Chung-kang river	Taiwan province Environment protection Department
M-12	Groundwater control area	REPORT		Taiwan	Taiwan province Environment protection Department
M-13	pollutions position	COVERAGE、REPORT	COORDINATE	Chung-kang river	EPA-Env.Monitoring and Data Department,Niao-li County Goverment,Hsinchu County Environment Protection Bureau
M-14	public nuisance dispute district	REPORT		Chung-kang river	Niao-li County Goverment、Hsinchu County Environment Protection Bureau
G-1	Image of satellite remote sensing	SPOT	20m×20m	Chung-kang river	Central Weather Bureau
G-2	Image of aviation potho	POTHOGRAPHY	1/5000	Chung-kang river	Agricultural Aviation Laboratories
G-3	Image of present condition pothos	PICTURE		Chung-kang river	Energy and Resource Research Laboratories of Industrial Technology Research Institute

*There is not data in some items, so not list in the Table 1, but they exist in framework of watershed environmental geographical database.

中 文 摘 要

環境整體污染防治策略之擬定，須考量各類污染物在不同媒介（空氣、水、土壤)中型態轉移之關聯特性。針對流域傳輸特性且污染源之分佈包括點源、線源及面源，不同的污染型態存在或轉移，對於污染防治策略的擬定，以流域整體環境管理角度切入較爲恰當，而對於實際執行面之進行，應用地理資訊系統輔助流域環境污染掌控、稽查、預防及管理，能符合人類直覺推理之作法。本文乃提出以下幾點策略建議，包括：（1）流域環境污染現況掌握；（2）流域環境污染稽查管制；（3）流域管理之污染預防及審查；（4）流域管理策略之擬定及決策支援建立等階段工作，作爲地理資訊系統應用於整體環境改善措施擬定及規劃之執行方向。流域環境地理資訊系統（Watershed Environmental Geographic Information System, WEGIS）爲環保署82年施政計畫，即依據上述四階段作法，進行系統建置，除資料庫與人機介面外，內容尙包括環境品質展示模組、主題套繪分析模組、模擬分析模組與圖籍管理模組，提供環境保護相關業務輔助資訊，協助對環境進行監視，適用於推廣至各流域資料之展示活用。

關鍵詞：流域、地理資訊系統、環境管理

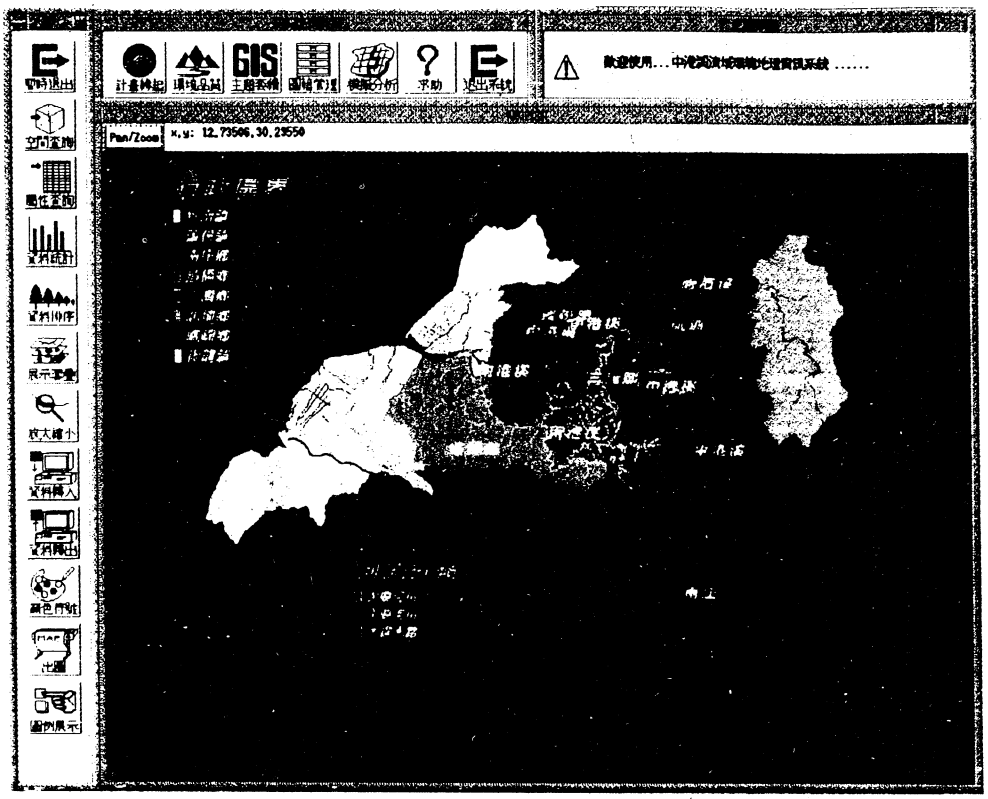


Figure 1. Map of the Chung-kang River Watershed Environmental Area

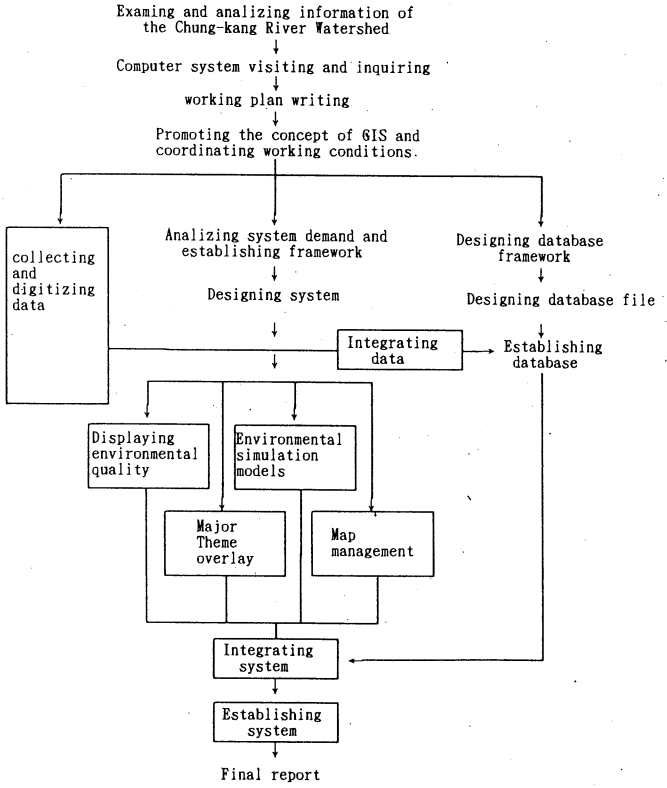


Figure 2. Working-Flow Chart of System Execution

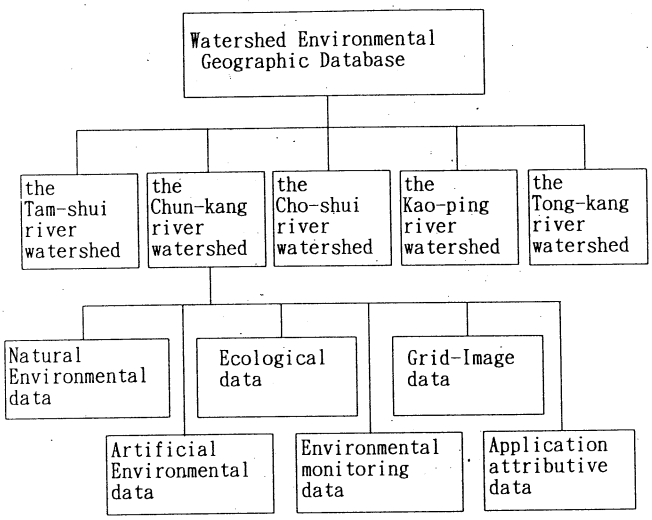


Figure 3. Framework Chart of Watershed Environmental Geographic Database

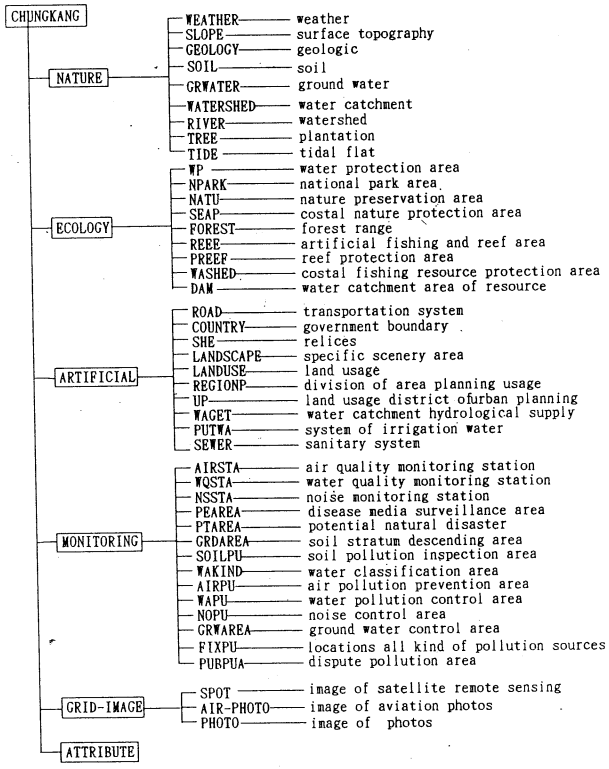


Figure 4. Framework Chart of the Chung-kang River Watershed Environmental Database

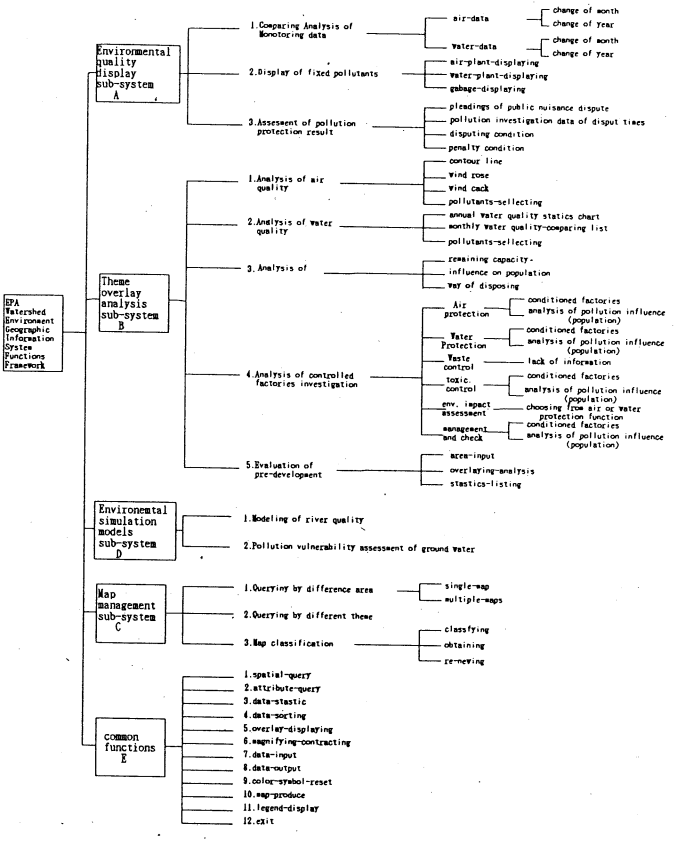


Figure 5. Framework of Watershed Environmental Geographic Information System Function

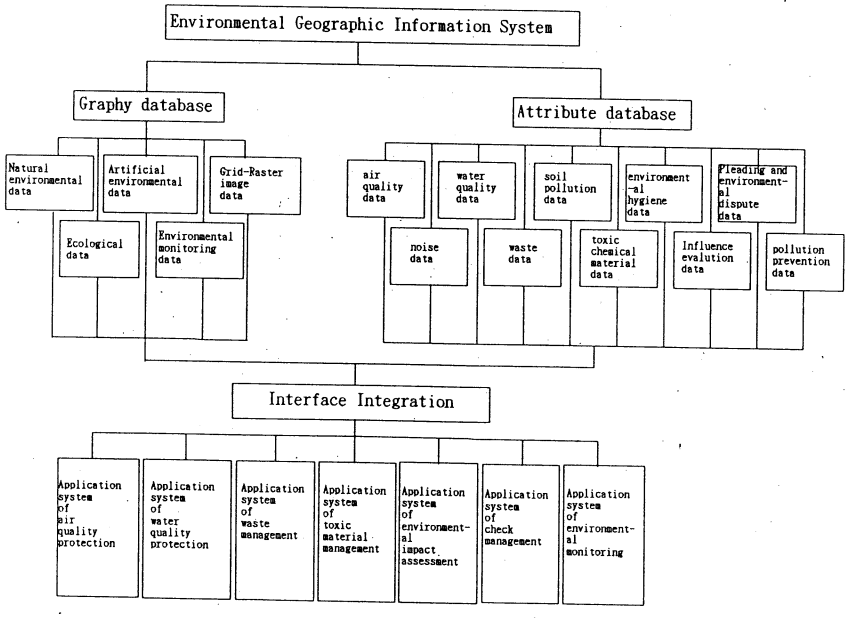


Figure 6. Suggestions for Environmental Geographic Information System Framework

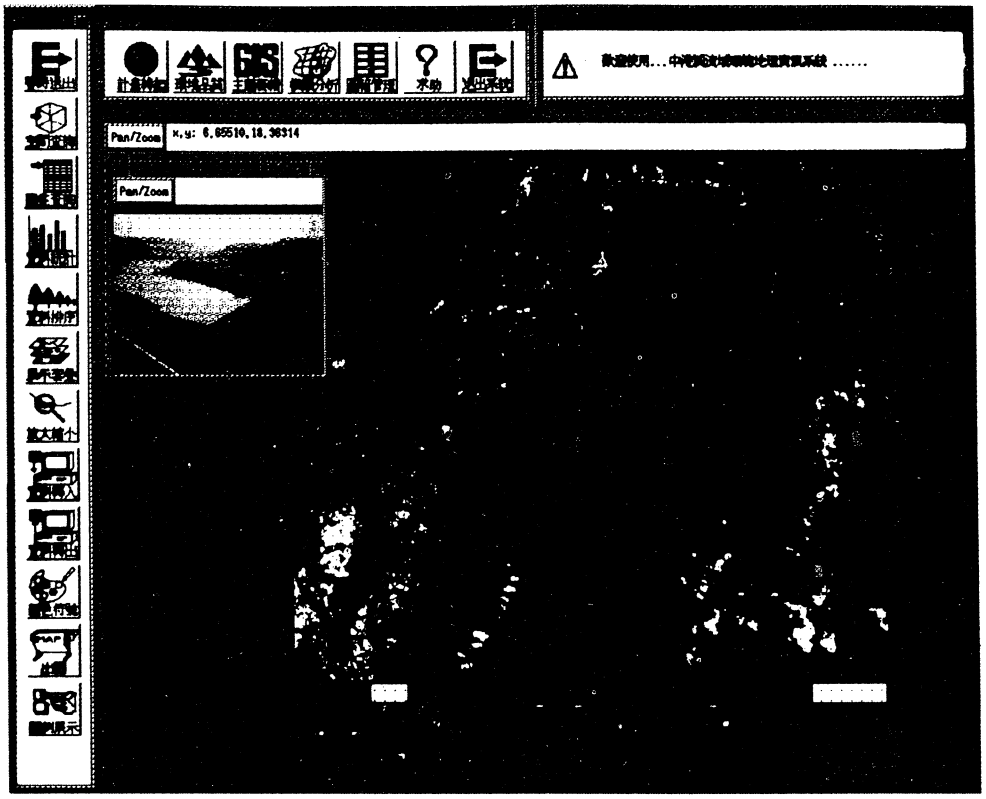


Figure 7. Outlay of the Chung-kang River Watershed of Reservoir Image, Watershed Map and Classified Image in 1993

Figure 8. Outlay of the Chung-kang River Watershed of Aviation Photo Display, Transportation System and Land Division of Urban Planning

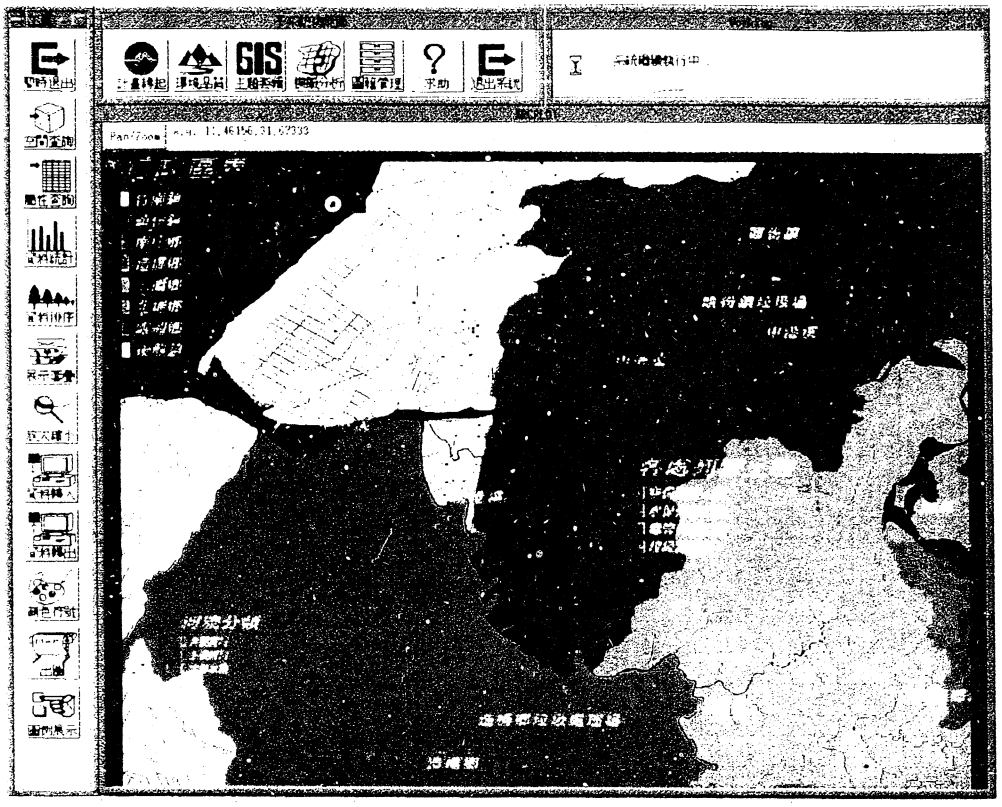
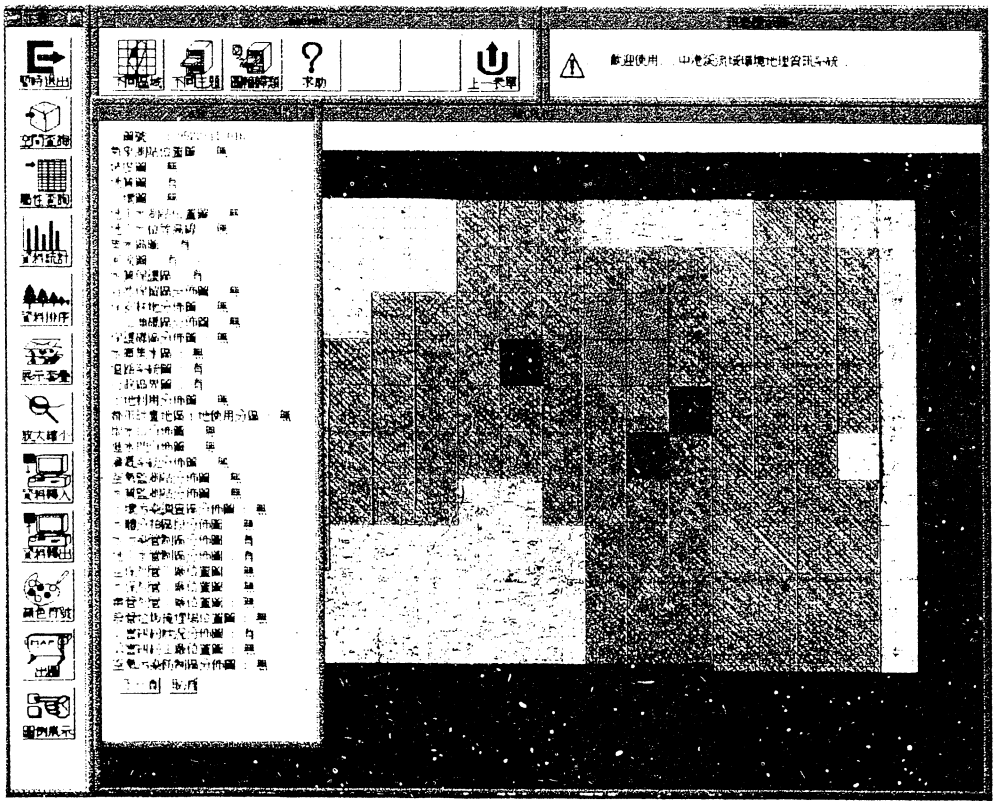


Figure 9. The Distribution of the Chung-kang River Water Pollutant sources



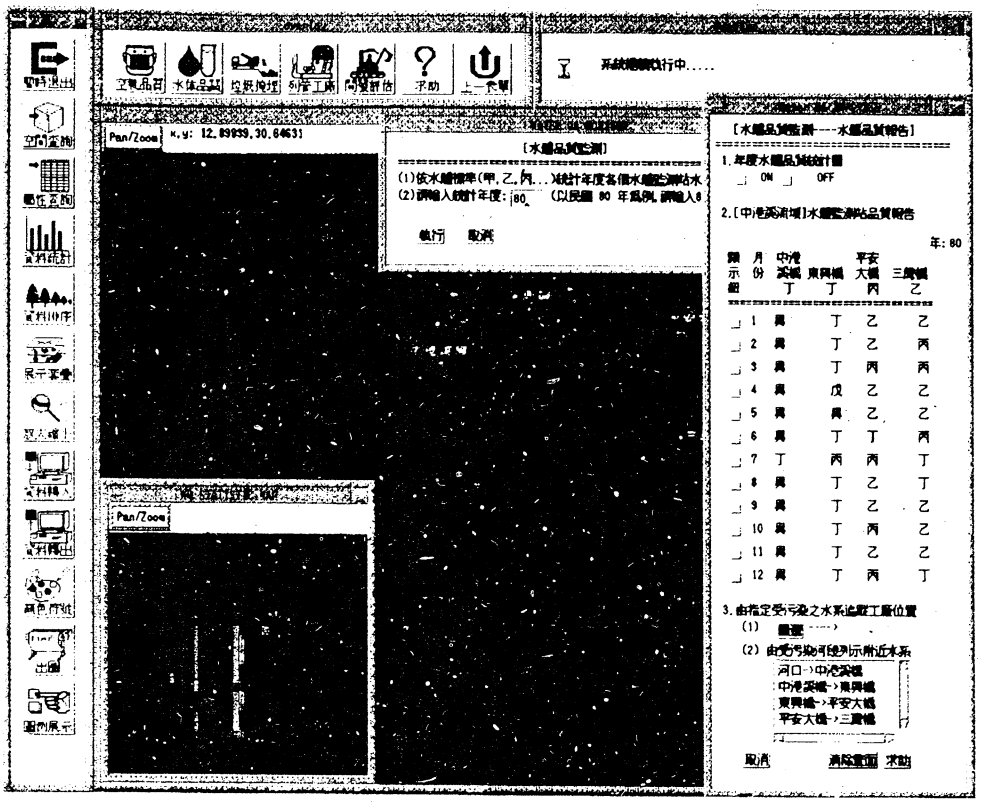


Figure 11. Disply of Water Quality of the Chung-kang River Conforming to Water Classification

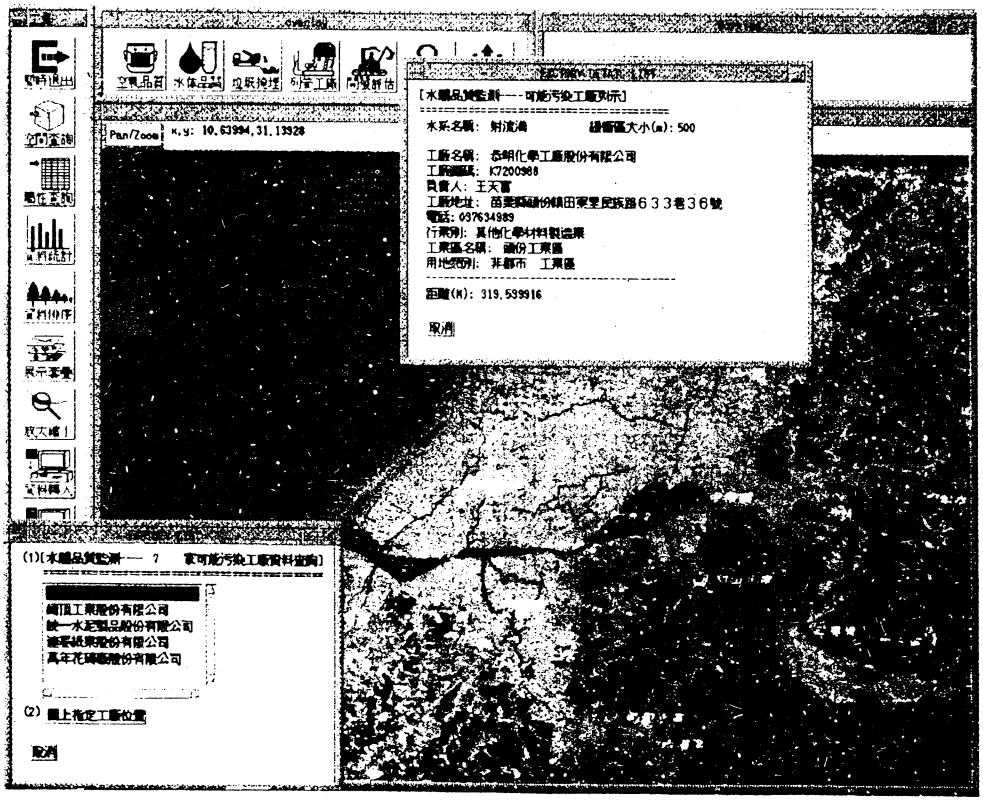


Figure 12. Inquiring of Water Pollution Factories in drainage channal of the Chung-kang River

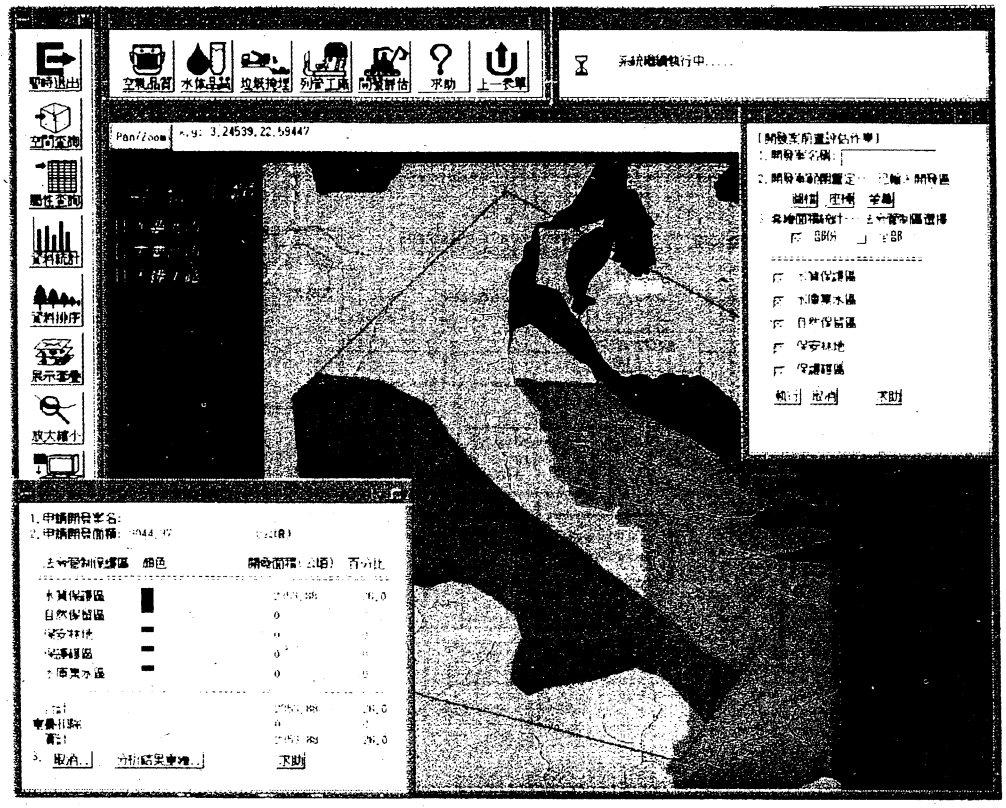


Figure 13. Analytical Result of Pre-development Evaluation

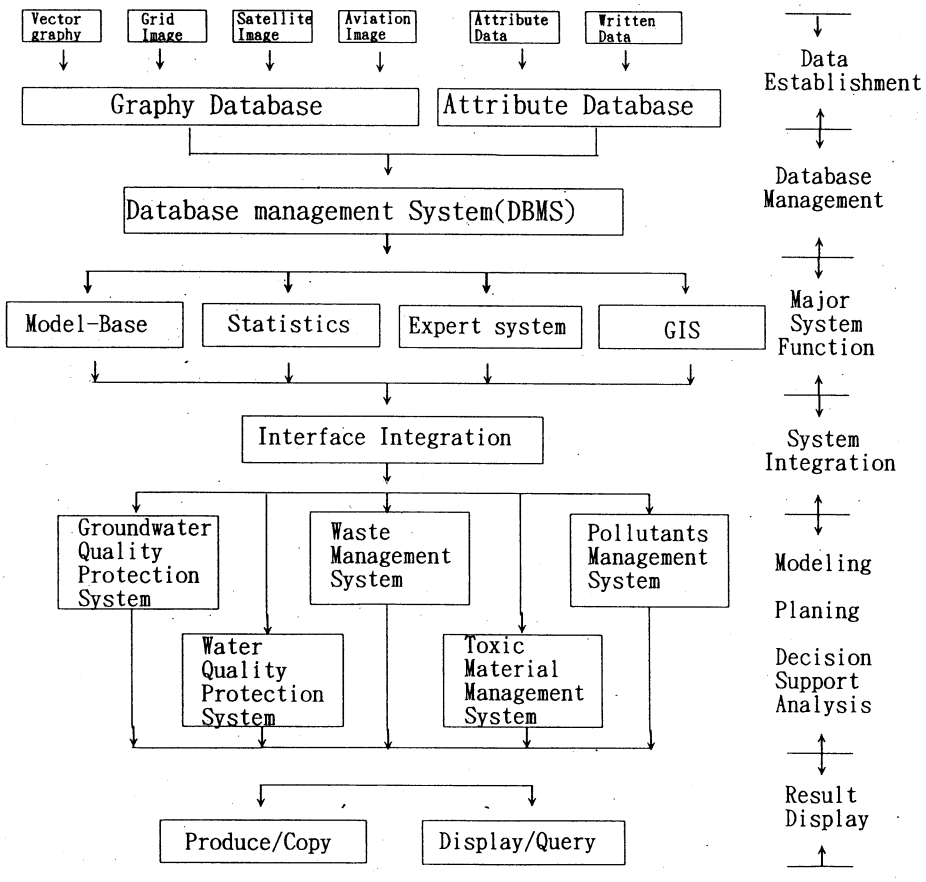


Figure 14. Frmework Chart of Watershed Management Decision Support System