MOBILE GEOGRAPHIC INFORMATION SYSTEMS FOR WATER RESOURCE PROTECTION

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KEY WORDS: Water resource protection, GIS, GPS, remote sensing.

ABSTRACT:

Implementations of Geographic information systems, remote sensing, and GPS for water resource protection at Taipei Watershed Management Bureau (WRATB) have been pursued for more than a decade. The objective of water resource protection management at WRATB is to provide sustainable drinking water for about four millions people in Taipei. The quality of drinking water in Taipei is one of the best in Taiwan. This is a nice proof of well-done job at WRATB. Water resource protection at WRATB is not simple a job of traditional water management. WRATB is more like a county government agency rather than a typical water resource management authority. WRATB has to take care of soil and water conservation, sewage management, house management, garbage collection, illegal land use enforcement, tree plantation, and water resource management simultaneously. Jobs have to be done in office and in the open field efficiently. Integration of remote sensing, GIS, and GPS in the past several years for water resource protection at WRATB has provided options other than traditional approaches. The objective of this paper is to discuss how mobile GIS was developed and implemented at WRATB. A personal digital assistant (PDA) device is one sort of palm-size computers for open field implementations. ArcPad 6.0 software was chosen for PDA to integrate GPS, GIS, and remote sensing in the open field. Microsoft embedded visual Basic was the programming language for attribute manipulation and data base operations for PDA. Customized and personalized field solutions for water resource protection were then can be done in an easy way. Parcel information is the key component for field operations such as illegal land use enforcement, illegal housing enforcement, water pollution control, and sewage management. With a little bit of visual Basic programming, the owner and address for a given piece of land parcel can be extracted on a PDA which was attaching to a hand-held GPS device in the open field. Display, query, and map navigation were done by ArcPad. Customized data base manipulations were accomplished with embedded visual Basic programs. The rest of field operations and paper works were taken cared by Basic programs as well. PDA has its drawbacks to overcome such as 32 MB RAM or 64 MB RAM and a 320X240 display resolution. The most important part of the whole process is to accomplish all types of customization in the personal computers and then deployed to PDA. One of nice functions provided by ArcPad is hyperlinks between map components and their relevant attributes of the data bases. Additional information such as zoning codes, house site maps, sewage facility maps, and land slide sites were then

added as additional map layers. In short, mobile GIS for water resource protection at WRATB have paved a way for jobs can be done easily both in office and in open field. More applications of PDA and mobile geographic information systems for water resource protection at WRATB were scheduled for further studies.

1. INTRODUCTION

Taipei Watershed Management Bureau (WRATB) is one of the eleven watershed management authorities in Taiwan. It is in charge of water resource protection in order to provide sustainable drinking water for about four millions population in Taipei. There are five townships, two major watersheds, one large reservoir, and 717 square kilometres under its jurisdiction. Management prescriptions of water resource protection at WRATB are not confined to traditional approaches. Remote sensing, geographic information systems (GIS), and global positioning systems (GPS) are the three key components for water resource protection. Water resource protection at WRATB is not simple a job of traditional water management only.

The quality of drinking water in Taipei is one of the best in Taiwan. This is a nice proof of well-job done at WRATB. WRATB is more like a county government rather than a typical water resource management authority. At WRATB, both daily operations and long-term management have to looking into those businesses that seem not quite relevant with traditional water resource management such as housing management, house construction supervision, illegal land use enforcement, tree plantation, garbage collection and management. Remote sensing, GIS, and GPS have been implemented to solve problems encountered on water resource protection for many years. This is not a description of working history at WRATB. A series of development have been performed for more than a decade (Wu, et al. 2002). Integration of remote sensing, GIS, and GPS may be the first stage of development for water resource management at WRATB. Web-based GIS may be the second stage of development. Mobile GIS is the current stage of development at WRATB.

Adequate spatial information can be extracted on the right spot with finger touch in real time is a must for management of water resource protection at WRATB. Both daily operations and long-term management of water resource protection at WRATB have to look into a single watershed, a given township, a single spot, and the whole area simultaneously. How to make the management of water resource protection simple and efficient is the major goal of implementations of GIS.

The objective of this paper is to discuss how mobile geographic information systems were developed and implemented at Taipei Watershed Management Bureau.

2. DEVELOPMENT OF MOBILE GEOGRAPHIC INFORMATION SYSTEMS

Development of geographic information systems at WRATB was a time consuming and expensive process. Data bases have to be set up in the first place. Integration of remote sensing, GIS, and GPS needs more technical effort than budget. Web-based GIS with all Chinese-menu driven is almost a must such that every technician would like to implement for day to day operations at WRATB. Task-oriented application modules that can be customized and personalized for solving certain problems encountered on water resource protection are the key components where mobile GIS can be successful and operational.

2.1 Data Bases Manipulation

Mobile GIS usually implemented a PDA (personal digital assistant) device as its major computer. Although a PDA device is cheap and convenient in the open field, its drawbacks consist of limited data capacity, 32 or 64 mega-bytes, and low display resolution, 320 by 240. Data bases that can be implemented in the open field have to be downsized and categorized in the personal computers and then download into a PDA device.

One single sheet of digital map has to be simplified as many layers as possible in one place but may be needed to organize several similar layers into on single layer for field implementations. Data bases for a given township, a given watershed, a given village, and a given sheet of map have to be manipulated and set up, and they are ready for implementations both in the office and in the open field.

Land parcel information, both maps and attributes, is the basic information for water resource protection management. More than 320,000 pieces of land parcel attributes and maps have been set up in the data bases. Hyperlinks of attributes and its land parcel maps can be done automatically. Cadastral maps usually

come with many types of scale and coordinate systems. They have been rectified and transformed into topographic coordinate system such that overlay with other maps can be done correctly and smoothly. The x and y coordinates for a given location that generated by a GPS device can be shown on a PDA device right away and the associated cadastral information can be inquired accordingly. Further management prescriptions can be adopted as well.

2.2 Software Integration

The Microsoft Windows CE 3.0 Chinese version was implemented for PDA devices. Colour display is a must for a PDA device. ArcPad is the main software for mobile GIS but is not the only one. Microsoft eMbedded Visual Basic was the main program language for data base manipulation and paper works in a PDA device. The data base management program for a PDA device is Pocket Access. It is easy to convert an Access file with MDB extension into Pocket Access file with CDB extension.

The data base file format implemented by ArcPad is DBF. Data base file format has to convert into DBF that can be accepted by ArcPad. The main data bases were stored in Microsoft Access MDB format and SQL Server. It is not difficult to convert into DBF. However, Hyperlinks between DBF and ArcView Shape files need some programming effort. Then, ArcView shape files can be converted into new files for ArcPad in a PDA device. Image file format acceptable by ArcPad is JPG for low resolution and SID for high resolution. For those high resolution image files with very large size say, 500 mega-bytes, ECW file format by Ermapper can be implemented in ArcView without any charge. ArcPad implements XML (extensible mark-up language) as its map documents. It will be convenient if one can modify ArcPad map documents to show some personal flavour. In this case, a little bit of XML knowledge is required.

One of several nice properties of ArcPad is that a point information with x and y coordinates given by a hand-held GPS device can make integration of remote sensing, GIS, and GPS easily.

2.3 Task-Oriented Application Modules

Customization and personaliz ation are two big reasons for implementation of ArcPad. Usually, application modules were developed only to meet some requirements at a department-level at WRATB. There are five departments at WRATB. Each department has their own jobs to be done in order to protect water resource at WRATB. Task-oriented application modules were developed on a build-to-order basis to solve problems encountered at every department. But it is more desirable that application modules can be developed to meet requirement at a personal level. With some manipulations of the data bases, it is not difficult for development of application modules using ArcPad and a PDA device together.

3. IMPLEMENTATION OF MOBILE GIS

There are five departments at WRATB. Each department have several types of management to be done in order to pursue water resource protection. Whenever one type of jobs that requires maps and x, y coordinates, mobile GIS can be implemented. Although mobile GIS is mainly for implementations in the open field, it is very convenient for indoor implementations as well. It is a simple a process that personal computers were used instead of PDA devices. On the other hand, the whole process is more powerful that drawbacks of a PDA device can be got away.

3.1 Water Quality and Quantity Monitoring

There are two major watersheds at WRATB. Water quality and quantity monitoring is one of the several essential processes for water resource protection. Both water quality and water quantity are required for protection at WRATB. Twelve monitoring stations and four gauge stations were set up at three major rivers. Locations of these stations have been verified by GPS devices and shown on the map ready for field inspection. A PDA device was mainly used for field data collection and comparison with the data stored in the data bases. Water pollution monitoring and control have been managed based on analysis of data collection on those stations. Fortunately, water quality is always good enough for drinking water.

3.2 Land Use Monitoring and Enforcement

Land use classification of the two watersheds has been done recently. Land use maps at a scale of 1:5,000 have been converted from MapInfo file format into ArcView shape file format. The landslide layer was extracted as a single map and serves as the basic map information for landslide management. Vector maps such land uses can be converted into high resolution image files that they can serve as background information. Since the x and y coordinates were retained in the image files, land uses information can be implemented in the open field as a single layer. However, a single land use image file for a given sheet of map at a scale of 1:5,000 has a file size of more than 150 mega-bytes. With the help of image compression software, the large image file size is not a problem at all. On the contrary, it can be implemented in a more user-friendly way.

Remote sensing is good for land use monitoring. SPOT satellite images with a pixel resolution of 12.5 meters are the typical images for large area monitoring. Several SPOT images taken at different dates were built into the data bases. All SPOT images are ready for overlay with the vector maps in the data bases. Land use enforcement requires cadastral information for a given piece of land. Zoning information and sewage facility information are the two other types of information may be essential for management prescriptions.

3.3 Cadastral Information

Cadastral information for a given piece of land is the most important information required for water resource protection management at WRATB. Cadastral maps at a scale of 1:5,000 and their associate attributes were built into the data bases. Hyperlinks between land parcel and its attributes were accomplished such that cadastral information can be extracted in several ways. Cadastral information can be extracted and inquired in ArcView, ArcPad, ArcExplorer, and Microsoft Internet Explorer. In the open field, a PDA device and a hand-held GPS device would indicate cadastral information for a given piece of land such as land parcel number, land owner, address with the help of ArcPad. This is one type of inquiry between maps and its attributes. Attribute inquiry can be done by Pocket Access in PDA and by Visual Basic in personal computers.

3.4 Landslide Management

There are many landslide sites to be monitored closely at WRATB. Landslide site maps have been extracted from the land use maps at a scale of 1:5,000. One SPOT satellite image was overlay as the background information. Although the landslide maps were extracted from more than 70 sheets of maps at a scale of 1:5,000, its file size is small enough for PDA and ArcPad implementation. Soil and water conservation engineering needs location of every single site of landslide at WRATB. What kind of management prescriptions for a given landslide site can be taken accordingly. Long-term monitoring of landslides are possible and efficiently.

3.5 Sewage Management

There are two large sewage treatment systems to manage the two major watersheds at WRATB. The whole sewage system consists of three large sewage treatment plants and nine small plants. More than 80% of households have their sewage collected to one of the three plants. Sewage management is one of the major forces to develop mobile GIS at WRATB. Sewage data bases consist of large scale layout and construction maps. Sewage application modules have been developed to depict the collection systems rather than geographic locations. Those sewage-to-be-collected houses locate in remote areas and away from business quarters are the major priority for further sewage management. Day to day operation of sewage management

has to look into sewage facility house by house. Maintenance of sewage systems is also a very delicate process. With the help of mobile GIS, sewage management is more efficient than before.

4. CONCLUSIONS

Taipei Watershed Management Bureau (WRATB) is responsible for water resource protection of two watersheds covering an area of 717 square kilometres. Its management prescriptions can not confine to traditional approaches because of four million populations in Taipei. The demand of sustainable supply of high quality drinking water is the major driving force. Watershed management is the typical top priority of water resource protection when traditional approaches were implemented. Mobile geographic information systems development and implementation for water resource protection at WRATB was one step beyond integration of remote sensing, geographic information systems, and global positioning systems.

Mobile GIS for water resource protection at WRATB have paved a smooth way for jobs can be done easily both in the office and in open field. More application modules, not discussed in this paper, for management of water resource protection at WRATB can be developed to serve more types of jobs that have to be done daily and in the long term in the near future.

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