Utilization of Geographic Information Systems (GIS) for Improved Local-level Integrated Water Resources Management – "Egyptian Case Study in Bani Suef"

Yasser Sherif Elmanadili[1] and Charles Batchelor[2]

[1] Associate Professor of Surveying & LIS, Faculty of Engineering, (DRTPC) Cairo University.
E-mail : yassersherif@yahoo.com

[2.] International Water and Sanitation Research Center (IRC). Delft, The Netherlands

ABSTRACT

Geographic Information Systems (GIS) are being used increasingly in programes of integrated water resource management as a means of analyzing and displaying societal and technical information. The increasing participation of stakeholders and their representatives in water resource management has created a demand for GIS and other methodologies that, if used appropriately, are capable of improving information management and stakeholder dialogue. This paper summarizes progress that has been made by the EMPOWERS Project on the development and evaluation of GIS methodologies that can be used to support local-level water management at the governorate, district and village levels. Particular attention has been given by EMPOWERS to the ways in which GIS can best be used to support an approach to local-level water management that is based on a project management cycle.

Progress to date has focused on information & needs assessments at the governorate and village levels and the establishment of GIS information bases and applications for Bani Suef governorate, Ehnasia District, and for two pilot villages, namely Monshaat Kasab and Al-Masharqa. Cost, data access, institutional responsibility, and sustainabilty issues have been addressed. Ongoing work includes using the information bases and GIS methodologies: 1) To build consensus amongst stakeholders on the causes and scale of water-related challenges in the pilot villages and 2) To support participatory decision-making linked to identification of appropriate strategies for tackling priority water-related challenges. Many lessons have been learnt and these are listed in the paper along with provisional recommendations on future use of GIS in local-level water management.

1. Introduction

Good quality societal and technical information is a pre-requiste for successful integrated water management (GWP, 2000). Consensus amongst stakeholders on information related to the causes, scale, severity and location of water related challenges is crucially important if participatory decision-making is lead to outcomes that are an improvement on those that might result from more traditional top-down approaches to water management. The institutional arrangements and protocols for a managing and sharing information are also critically important (GWP, 2000). Clearly, information needs to be updated routinely and made available when and

[1] Dr Yasser Sherif El-Manadili, Associate Professor of Surveying and GIS, Faculty of Engineering, Cairo University & Team member of the DRTPC, partner of EMPOWERS project. He has twenty years of experience in the fields of Surveying, Mapping, LIS, and GIS.
E-mail : yassersherif@yahoo.com, Telephone: + (02) 5735497, Office: DRTPC, Cairo, Egypt

where it is needed in formats that can be understood easily by the users. When information is incorrect and/or there is little consensus amongst stakeholders, it is almost inevitable that blame culture will develop (i.e. stakeholder groups blame each other for problems and the failure of interventions to solve these problems). Hence, village-level participation in the groundtruthing and validation of information is essential to establish a good information base in which local-level stakeholders have confidence and some level of ownership (Roy, 2000).

Many studies have shown that GIS can play a very important role in water management in aspects that include analysis and presentation of societal and technical information, identifying the root causes of problems and planning activities and interventions aimed at solving these problems (e.g. Rama Mohan Rao et al, 2002). Other studies have shown that GIS, if used appropriately, has an important role to play in facilitation (SLIM, 2005). The SLIM Project concluded that GIS provide "visual representations that interpret from the point of view of a particular stakeholder the relationships that are perceived to exist among bio-physical and other aspects of a landscape, human actions and a range of environmental, social and economic outcomes". As important, these relationships can be represented at different scales and over different time periods.

The work reported here has been carried out as part of the Euro-Med Participatory Water Resources Scenarios (EMPOWERS) Project. This is a regional project with an overall objective of improving long-term access to water by vulnerable populations through more effective local-level integrated water resources management. The project purpose is to strengthen the horizontal and vertical flow of information and influence between stakeholders in integrated water resources management in MEDA zone. EMPOWERS intends to improve the flow of information, build up models which show the effect of certain barriers to development, and build capacity among different stakeholders and end-users groups. Therefore, there is a need to organise the collection of data (both quantitative and qualitative), desiminate information, and improve governorate and district/ directorate level staff capacity to work with communities / end users.

The project is working in three countries, nameley Egypt, Jordan and the West Bank & Gaza. The project area in Egypt is located in Beni Suef Governorate covering Ehnasia district, Ehnasia city, as well as Monshaat Kasab and Al- Masharqa villages.

GIS is just one of the methodologies being piloted by EMPOWERS. Other methodogies are described in the working papers that can found on the project web site (http://www.empowers.info/page/1057)

2. Adopting GIS as a Pilot Project for the Egyptian Governmental Staff

Utilizing participatory approaches, seven meetings and workshops have been held in Beni Suef. These involved village-level representatives and staff from relevant line ministries (e.g. local government, irrigation sector, information center, the potable water and sanitation authority, environmental authority, and agricultural sector). Less formal discussions involving stakeholders and EMPOWERS staff have also taken place on a regular basis during the last two years.

The vision of the Egyptian governmental staff in Beni Suef governorate concerns with increasing the efficiency of the management and planning processes by adopting GIS

as a major tool for data archiving, data transfer horizontally and vertically, planning, management, decision support, operation, and maintenance. Governmental staff also concerns with increasing awareness, reducing water consumption, strengthen cooperation among different governmental authorities, providing the city and villages with sufficient good-quality potable water and safe sewage collection and treatment systems, improving utilities infrastructure maintenance procedure, providing cultivated lands with suitable adequate irrigation water according to water needs, as well as implementing solid waste management and collection projects. After comprehensive analysis; accurate, complete, up-to-date data within an efficient GIS system is found to be within the most important factors affecting the vision and uncertain to happened and hence it has been selected to be the pilot project by the governmental staff.

Important conclusions from the meetings are that:

- It is agreed that there is much scope for improving the quality of information used by line-ministry staff , the sharing of information between line ministries and the use of information in decision-making processes;
- Until recently, water-related decisions have been made without the participation of village-level stakeholders. However, it is being recognized increasingly that the participation of stakeholders at all leads to improved outcomes;
- Government line department staff was very keen on the proposal that a common water-related information base be set up at the governorate level. There is also recognition that GIS software/applications can be used to improve the analysis and presentation of both societal and technical information.

By the end of this task, it was agreed that an information base and GIS applications would be established for Ehnasia District and, with a higher level, for the villages of Monshaat Kasab and Al- Masharqa. It was agreed also that protocols would be developed for managing the information base and for sharing information both vertically (e.g. between line departments and village-level stakeholders) and horizontally (e.g. between different line departments).

3. General Design Principles

The design of the EMPOWERS approach to using GIS was based on a number of principles that include:

- The approach should fit within the various steps of the EMPOWERS planning cycle and complement and supplement other methodologies that are being piloted by EMPOWERS (e.g. problem tree analysis, water resource assessments, scenario development);
- A distinction should be drawn between the use of the GIS application and the establishment of an EMPOWERS information base which will be used to store both spatial and non-spatial information.
- GIS software/application is a tool for analyzing and displaying spatial information. As such, the way in which it is used determines whether or not it is supporting stakeholder involvement in local level water management.
- Maximum use should be made of good-quality secondary data.
- Maximum use should be made of the stakeholders' views and knowledge regarding the status of water supplies and the causes of any problems.

4. Gis Use And The Empowers Planning Cycle

Project cycle management (PCM) approaches are being used increasingly in the implementation of programs of IWRM (Moriarty et al, 2005). PCM incorporates two important ideas. Firstly, it refers to the concept of a project or program proceeding through various evolutionary stages from visioning to planning to implementation and evaluation, forming an identifiable and rational cycle of development. Secondly, it recognizes the need for management of such a cycle through all its various stages. Central to PCM is the idea of managing a process, rather than managing a one-off event (e.g. construction of a water supply system). The EMPOWERS IWRM cycle (Figure (1)), in common with most such cycles emphasizes the need to put decision making regarding water based actions within a clearly defined set of steps that ensure that the decision reached are based on good quality information and a clear and logical flow of thought.

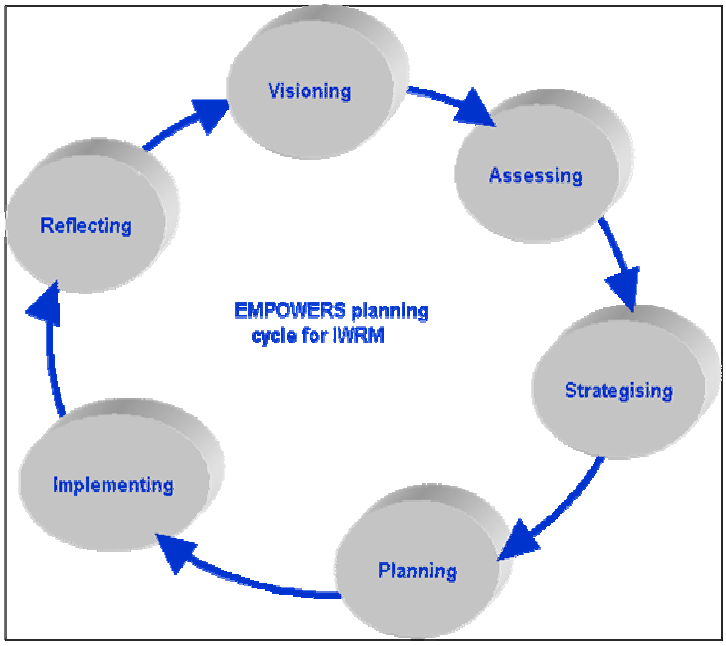

Figure (1) EMPOWERS IWRM Planning Cycle

The EMPOWERS approach to using GIS to improve local water management involves use of spatial information, and hence GIS, at every step. Examples of potential uses during each step are listed below:

- **Visioning:** Maps are produced to help stakeholders identify the location and scale of water-related challenges and to identify the locations of interventions that form part of an overall vision;
- **Assessing:** Data collected using PRA techniques along with more specialist analysis at the governorate-level are used to locate urban and rural areas with the most severe water problems. Information verification and ground truthing are important activities during this step. This step will result in hard and soft

copy layouts showing the "consensus" status of water infrastructure and water supply to different stakeholders;

- **Strategizing.** Maps are produced that show the location of interventions that might result from different strategies and the potential impact that these will have on water supplies for different uses and users at a range of different scales;
- **Planning.** Maps are produced to support plans for different activities and interventions. Maps also show the boundaries of villages or areas in which different user groups might be active;
- **Implementation.** Maps are used to show areas in which implementation is going to schedule and/or where there might be problems;
- **Reflection.** M&E information can be displayed on maps. Ideally the emphasis is on using simple color-coded maps that highlight locations with specific problems. Although large amounts technical and/or specialist information is often available, the urge to present this on maps for general use is to be resisted.

Each of the steps listed above requires measures to build awareness and confidence in the use of spatial information. It is necessary also to build the confidence of the village level stakeholders and the government staff in both an information base and the use of GIS software/application. This will only be achieved if information in the base is accurate and in a form that is helpful to stakeholder dialogue.

5. Analysis Phase

Execution plan has been performed in the beginning of December, 2004, including specifying major work phases and activities and identifying partners' responsibilities, Table (1). Then, various tasks have been carried out; including user needs assessment, capacity assessment & requirements analysis, and data assessment.

Activity / Phase	Responsibility	End time
Analysis Phase		15/1/2005
User Needs Assessment	Gov. staff /All	
Capacity Assessment	DRTPC/EMPOWERS Team	
Data Assessment	DRTPC/All	
Design Phase		30/2/2005
HW & SW specifications	DRTPC/EMPOWERS Team	
Database Conceptual Design	DRTPC/EMPOWERS Team	
Data Model Development	DRTPC	
Applications Functionality	EMPOWERS Team /All	
Implementation Phase		30/12/2005
Data Collection	Gov. staff /All	30/9/2005

Data Validation	All	30/10/2005
Database Development	DRTPC/EMPOWERS Team	30/11/2005
Applications Development	DRTPC	30/11/2005
Applications Testing	Gov. staff /All	30/12/2005
Training	DRTPC	30/12/2005
HW- SW Installation & Operation	EMPOWERS Team /All	30/11/2005
Technical Support	DRTPC /NGO	30/3/2007

Table (1) Execution Plan for GIS Development in Bani Suef

5.1 User Needs Assessment

EMPOWERS team members conducted meetings and workshops with representatives of major stakeholders to identify and assess their information needs. Data types and level of details as well as GIS software application functionalities and tools were identified and listed in a user-needs assessment report. During these discussions, line ministry staff agreed to share available secondary data related to Ehnasia District and the two pilot villages and village-level representatives agreed to help EMPOWERS staff in collecting social and demographic data as well as data regarding potable water and sanitation systems.

5.2. Capacity Assessment & Requirements Analysis

The capacity of the governmental staff in the line departments with an interest in water management to operate and manage the proposed systems has been investigated. The responsible staff should have fair GIS theoretical background as well as good practical experience in using GIS software and the developed applications. Two EMPOWERS partners in Beni Suef already have good GIS experience which are the governorate information center and the potable water and sanitation authority. Other partners need to build their capacity from scratch. Consequently, a training and capacity building program has been initiated.

Young dedicated engineers and/or university graduates with good knowledge of using Windows operating system, and Microsoft Office are going to attend the proposed training program to be qualified for systems operation and management. Training should include three major components: GIS concepts, GIS software practical training, and on the job training on using and managing of the developed applications.

5.3. Data Assessment

Numerous data sets have been identified in association with different major data sources. However, the majority of these data are available in hardcopy format. Hardcopy base maps (scale 1: 50000) covering the geographic extent of Bani Suef governorate and Ehnasia district have been purchased from the Egyptian Survey Authority (ESA), with a price of $ 6 per map. Hardcopy base maps (scale 1: 2500) covering Monshaat Kasab and Al- Masharqa villages have been purchased from ESA, with a price of $ 5 per map.

Two digital raster aerial photos covering the core of the populated regions of the two villages have been acquired from the sanitation authority in Bani Suef. Descriptive data regarding irrigation and drainage network, agriculture lands and crops, potable water network and facilities, sanitary systems, and environment are collected from all stakeholders in paper format.

After analyzing the data, details of some scattered populated data are missing and the base maps are old. Hence, it is recommended to adopt another methodology for building the GIS database major layers (roads – irrigation & drainage network – buildings), through using recent high-resolution satellite images with 0.6 – 1 meter resolution in association with 1:2500 old base maps that provide the necessary controls as well as the agricultural data and some attribute data. The price of such image for the pilot two villages will not exceed $ 1000 (50 square kilometer times $ 20 / km2).

6. Design Phase

In this phase, the specifications of the required hardware and software have been identified. Then, the databases are designed and the data models have been developed. Two applications have been designed, one for the district and the governorate and the other for the villages and communities. The following sections summarize the work that has been carried out in these tasks.

6.1. Hardware & Software Specifications

Typical PC can be used to operate the developed systems, with specifications not less than P4 3. GH, 80 GB HD, 512 MB RAM, 15" monitor, and a CD R/W for data backup and transfer between various stakeholders. ARC GIS/ ARC View 9.x is the adopted GIS software. Cost for the PC is about $ 1000 and for the software is $ 2200.

6.2. Database Design & Data Model Development

At the governorate and district levels, database layers include: district boundaries, River Nile, lakes, canals (with various categories) , drains (with various categories), irrigation structures (regulators, culverts, bridges, water inlets, water outlets), bridges, roads, railways, urban areas, major potable water pipe lines, potable water treatment stations, major sanitary pipe lines, sewage stations, and dump areas as well as raster base maps. Some data sets are have been also collected, including environmental issues and problems, health issues and problems, fertilizers quantities and distribution over various seasons, crop pattern and distribution over various seasons, solid waste management system and components, industrial infrastructure and types, brick factories, and fish farms. At the village's level, various layers include: village boundaries, River Nile, canals, drains, Mesqas, Hods, parcels, roads, populated areas, buildings, potable water layers (pipes, valves, stations, tanks), and sanitary system layers (sewage pipelines, treatment stations, dump areas). Linked tables have been added lately for storing water-issues problems, proposed solutions, expected cost, actions taken, actual budget, and history. These data will be used to generate thematic (color) maps for monitoring and management purposes.

6.3. GIS Applications Design

GIS applications have been designed to perform required functions and tools specified by the stakeholders including: data retrieval, data exchange, data editing, display control, spatial measuring, database query, spatial query, statistical analysis, proximity analysis, overlay analysis, reports generation, maps production & plotting, charts generation, water balance assessment, and thematic maps production.

7. Implementation Phase

Three main activities have been carried out during this phase, including data conversion and GIS database development, applications development, as well as building capacity and human resources development.

7.1. Data Conversion & GIS Database Development

Hardcopy maps with scales (1:50000 & 1:2500) have been transformed to the appropriate GIS format. The process includes scanning of hardcopy maps, geo-referencing using tic marks, on-screen digitizing, revision and editing, edge matching, GIS data preparation, data entry, and QC/QA. Raster digital aerial photos have been geo-referenced using common features obtained from the developed GIS vector layers of the base maps. Then the GIS database is updated from the digital aerial photos.

Descriptive data obtained from the stakeholders in paper format are entered to the database and integrated with the system. Other data will be collected by the citizens from the field and will be stored in the database after validation. Figures (2) to (4) show the developed GIS database of the district and the two villages.

7.2 Applications Development

GIS applications have been developed for the district and the governorate as well as the villages and communities using ARC GIS ARC VIEW 9.x software package. Visual Basic (VB) and Visual Basic for Application (VBA) programming language have been used for building various functions and tools (Understanding GIS). Data Transfer Protocol (DTP) is developed to ensure that every stakeholder will be responsible about updating his layers and transfer the information with other stakeholders for database sustainability. Development and implementation time is about 70 days and the applications can be used for various districts and villages in Bani Suef. Figure (5) shows the interface of the developed district GIS application.

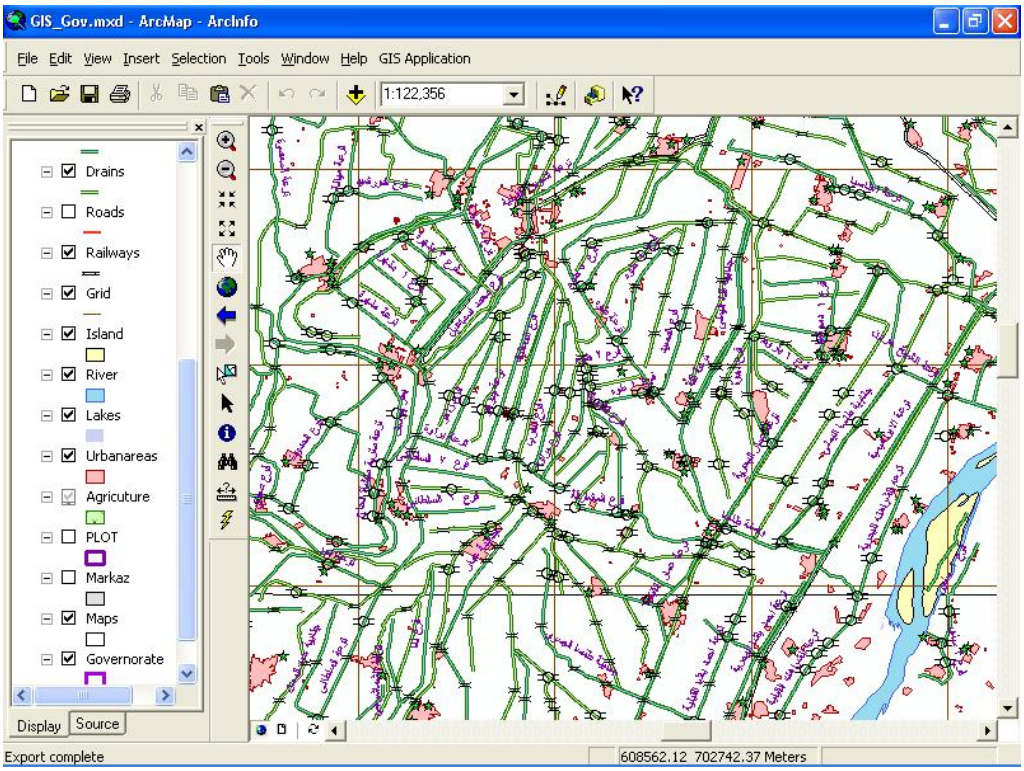

Figure (2) Developed GIS District Database

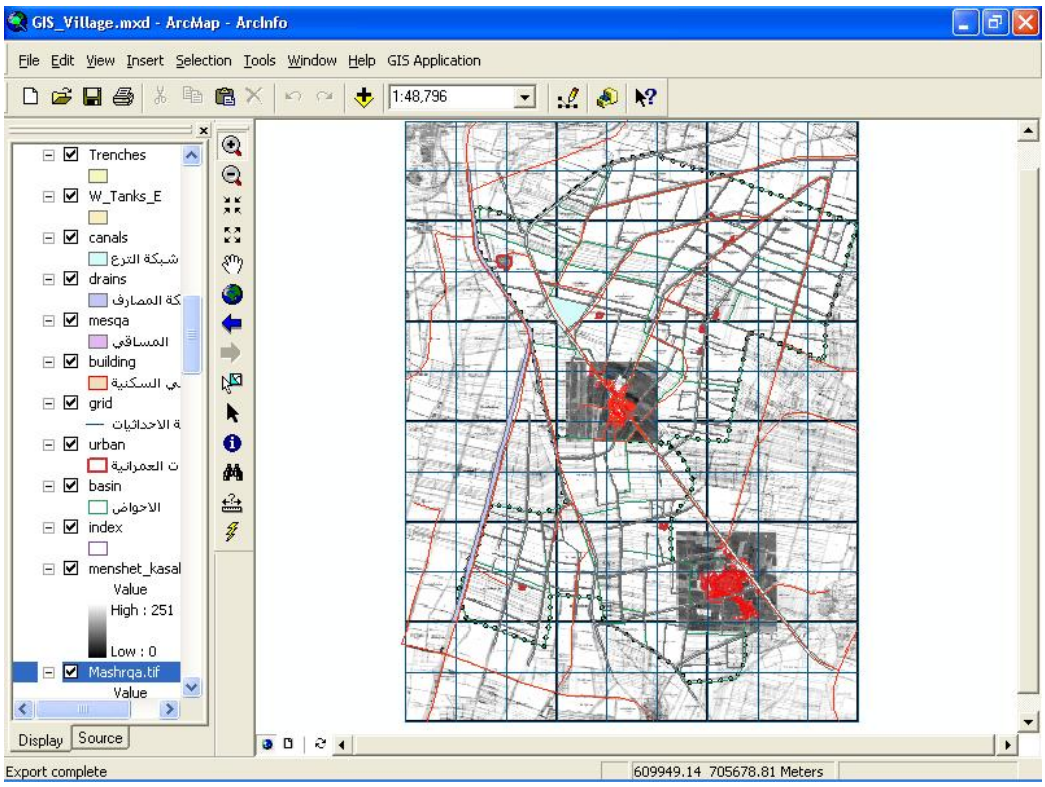

Figure (3) Developed GIS Villages Database

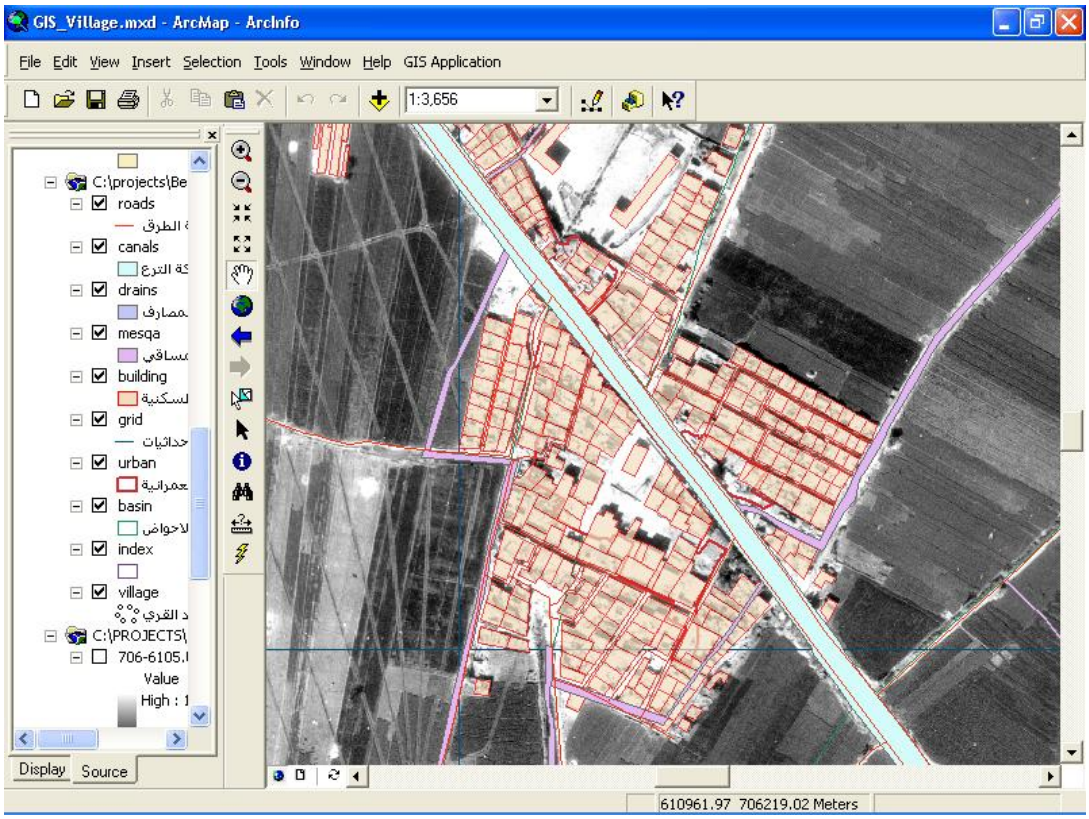

Figure (4) Updating of GIS Database from Digital Aerial Photos

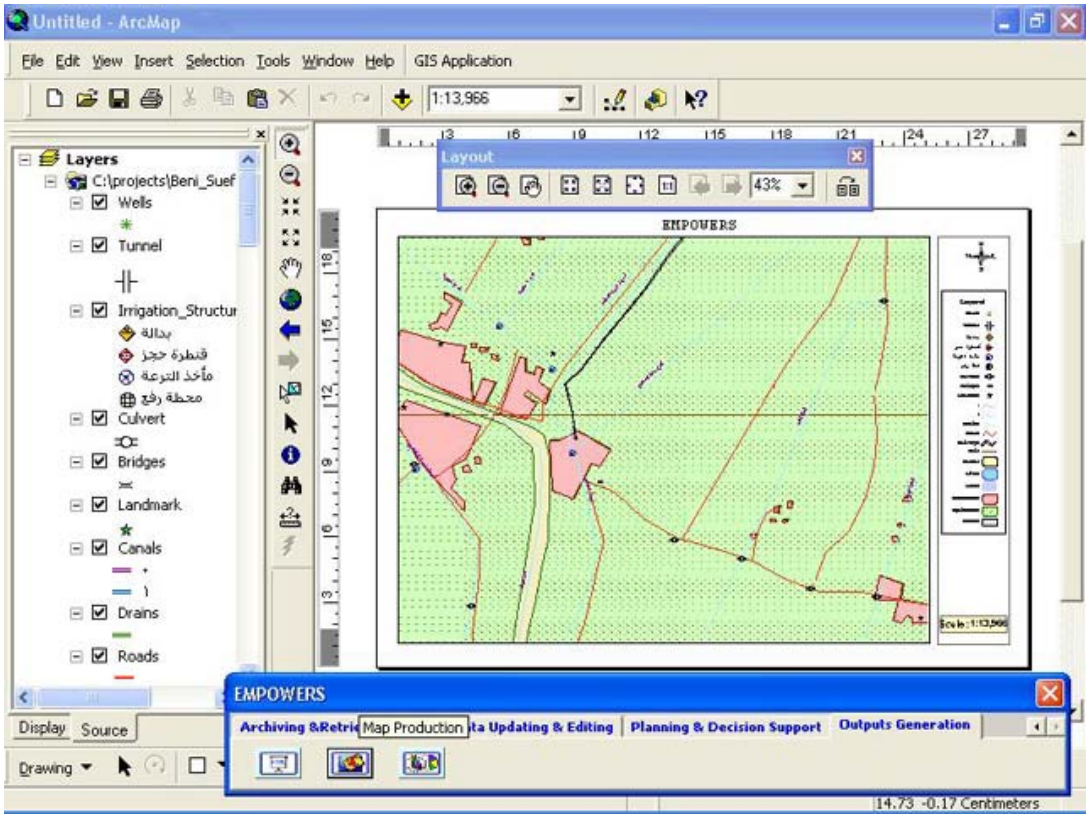

Figure (5) Developed GIS Application

8. Institutional Responsibility & Sustainability

It has been agreed that Governmental and NGO staff will be responsible for operating, managing, sustaining and extending the information base and the GIS applications after the completion of the capacity building. Technical support is an important issue that will affect the operation and sustainability of the information base. Initially, DRTPC staff will take overall responsibility through weekly visits, telephone calls, and e-mails but there will be a progressive handover of responsibilities as the confidence and capacity of relevant staff grows. Hence, the role of DRTPC will move progressively to one of providing technical support and guidance on the management of the information base and effective use of GIS applications.

It is planned that information management responsibilities will be spread across the relevant line ministries with each line ministry taking responsibility for their own information (e.g. irrigation sector is responsible of irrigation and drainage network as well as irrigation structures). Weekly information updating and sharing of information will be facilitated and carried out by the governmental information center in Beni Suef. Better planning and management could be then achieved for various governmental sectors. One example is that potable water authority will have complete information about the citizens, buildings, and existing potable water network with associated maps and can plan for expansion and providing un-served buildings with potable water efficiently. Another example is that irrigation sector can plan for the water year depending on actual agricultural information showing served fields and crops for different canals and Mesqas (small canals) and design criteria for irrigation network.

Consideration is being given to involving a district-level NGO in activities aimed at ensuring that village-level stakeholders have reliable access to information held in the information base. The NGO will be responsible of collecting problems regarding water issues and storing them in the system, sending these problems to the information center, as well as monitoring of actions and solutions in association with the information center which will result in strengthen the horizontal and vertical flow of information and influence between stakeholders in integrated water resources management in Egypt. Thematic (color) maps will be periodically printed from the systems for follow up. Planning of future projects and management of water resources will be done based on actual collected field information regarding water problems and based on the participatory approach which will improve long- term access to water by vulnerable populations through more effective local integrated water resources management mechanism.

9. Conclusions

Well-managed information bases and GIS applications have the potential to improve access to the information that is needed to support and improve local-level water management. However, establishing and sustaining information bases, ensuring reliable access to information by village-level stakeholders and creating capacity for GIS software/applications use are not trivial matters.

EMPOWERS has been addressing these challenges and, with the participation of governorate and village-level stakeholders, has developed an information base and GIS applications for two pilot villages in Ehnasia District. Digital aerial photos (or high resolution satellite images) in association with high scale old base maps (1:2500) are the best sources for establishing the main base layers.

Decisions have been made on establishing an institutional home for this information base. It is planned that systems for managing the information base and for sharing information will be developed. Progress has also been made on approaches to using GIS applications that will lead to spatial information being more readily available at different steps during the EMPOWERS IWRM planning cycle. These approaches are being piloted in Egypt as part of decision-making processes that are leading to funding being allocated to a second phase of village-level interventions in the pilot villages.

It is anticipated that process documentation will show whether or not stakeholders identify real benefits from having improved access to information as GIS outputs and in other formats.

References

ESRI, 2004, "Understanding GIS- the ARC/INFO method", U.S.A.

GWP, 2000, "Integrated Water Resources Management", Global Water Partnership TAC Background Paper No. 4.

http://www.gwpforum.org/gwp/library/IWRM%20at%20a%20glance.pdf

Moriarty, P., Batchelor, C.H. and Laban, P. 2005, "The EMPOWERS Participatory Planning Cycle for Integrated Water Resource Management", EMPOWERS working paper No. 3.

http://www.empowers.info/page/1057

Rama Mohan Rao, M.S., Batchelor, C.H., James, A.J., Nagaraja, R., Seeley, J. and Butterworth, J.A., 2003, "APRLP Water Audit"

http://www.nri.org/WSS-IWRM/reports_aprlpwra.htm

Roy, U.N. 2002, "Participatory RS and GIS for micro-level watershed planning and management"

http://www.isprs.org/publications/related/ISRSE/html/papers/821.pdf