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Design of GIS-Based Nile River Information System

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Abstract: The Nile River is an essential resource to maintain environmental balance in Egypt, it supplies drinking water, low cost transportation, irrigation, hydropower, and provide livelihoods. The conjunction between river human interventions and morphological changes impacts show real challenges to the government and researchers. The design of information system to observe these impacts is necessary and required for Nile River sustainable development, management, and planning. This paper introduces the potential of GIS in developing a comprehensive Nile River information system (NRIS). This system is the key factor to facilitate and attain efficient decision making to the responsible of water management organizations. Scripts using python language is developed enabling the decision maker to access, edit, search, analyze and manipulate the available database. In addition, proposes that the designed GIS based information system can substitute the traditiona1 methods for extracting accurate information from database and can be updated in easily. Using the developed GIS-based information system in Nile river management is one of the most valuab1e tools that keep step with the development of Decision support systems.

Keywords: Geographical Information Systems GIS, Python, Decision Support System (DSS), Nile River, Geo-database

I. INTRODUCTION

Nile River characterized by length of about 6700 kilometers. According to its length, it is suffered from many changes and obstacles [1]. It should be studied and analyzed. GIS is a group of computer programs capable of analysis processes as storing, manipulating, and displaying spatial referenced information [2]. Responsible and successful Nile river management and planning is necessary for protecting our natural water resources.

GIS technology is used to support and deliver information to water management organizations and decision makers. GIS processes the analysis operations of various layers and data features of location-based data. GIS water management solutions especially in Nile River enable decision makers to ensure accurate reporting with improved data collection, improve decision making, provide better data analysis, and presentation options, and model dynamic phenomena.

Significant studies have been carried out to investigate the changes process in Nile River using GIS. GIS spatial analyst application was presented for morphological analysis and proposed an algorithm to use it for morphological changes studies [3]. A developed application combine between GIS with other Software Engineering to collected maps, data, functions and information were used in an easy useful way using programming language to build up an automated web application of navigation system [4]. A developed GIS application to evaluate and analyze navigation efficiency for the Nile River supported with construction of geo-database which is used as part of information systems to make intelligent and correct decisions [5]. In this paper designed GIS-based Nile River Information System is introduced to organize the utilization of all the facilities on the Nile River by determining their different 1ocations and forms. Also, facilitate the planning and developing of resources (mechanisms, maintenance, dredging, etc...) which decrease the time and expenses required.

II. OBJECTIVE

The main objective of the research is designing GIS based information system using python supported by advanced Geo-database with integration of a large amount of high-quality collected data to handle Nile River spatial analysis. This designed system facilitate the planning of Nile River in Egypt (Development, dredging, projects locations, mechanisms, Structures maintenance, etc...) and decrease the required time and expenses. Then, this system provides the base and the foundation for Nile River GIS development and management.

III. Methodology

This research proceeded through different study phases. These phases are displayed under the following headlines as shown in Fig. 1:

1. Data collection
2. Establish Nile River Base Map in Egypt
3. Develop and design Geo-database
4. Conceptual, logical and Physical design of Nile River Information System
5. Develop ArcGIS NRI toolbar with new analysis tools using Python language
6. Implement Nile River Information System

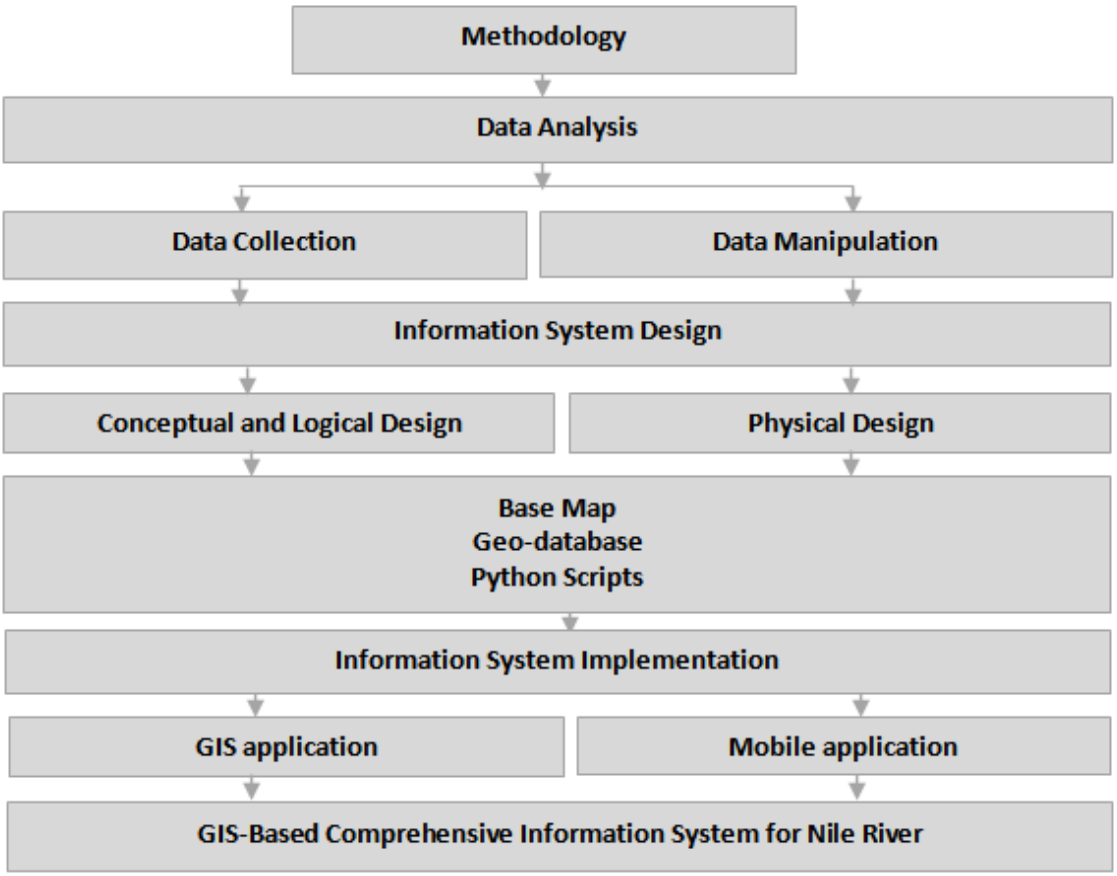


Figure 1: Schematic set-up of methodology for developed system

IV. STUDY AREA DESCRIPTION

This paper focuses on Nile River in Egypt. Its total length is 953.5 km from downstream Aswan High Dam AHD to Delta Barrage, and two branches Damietta and Rositta as shown in fig.2. It is divided into four reaches via four barrages. It is characterized by many natural phenomena represented in multiple qualities of the island's characteristics, and many bends [1]. It is usually exposed to many of human interventions that increase the impacts of different low and high flows on morphological characteristics, and affect river stability.

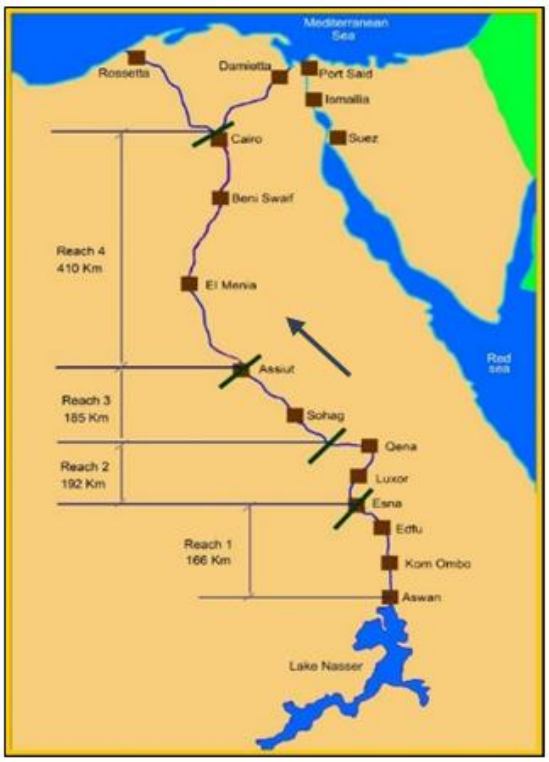


Figure 2: Nile River Reaches

V. DATA COLLECTION AND ANALYSIS

5.1 COLLECTION OF DATA LAYERS

In this part, the data collection is needed to form Nile River base map include the major Nile River features (major river and lake Nasser), Islands, Nile Km, Egypt boundaries, Administrations boundaries, roads supported with Satellite images. Detailed Nile River and other data layers were collected from Nile Research Institute (NRI) Hydro-Topographic maps, and recent technical reports.

5.2 DATA LAYER MANIPULATION

Some Feature data sets used in this paper were not rearranged insufficient format; consequently, they were refined and projected to be in convenient level of detail, so they were processed and manipulated.

VI. Conceptual and Logical Design of Nile River Information System

Conceptual and logical design, considered as the basis of the success of the designed system. It extract and move main objects of research from true world to information world. Fig.3 shows the Schematic set-up of conceptua1 and logical design of information system.

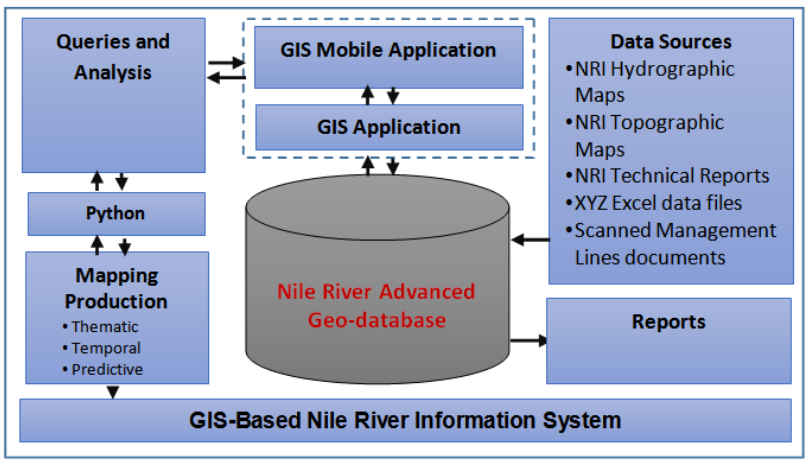


Figure 3: Schematic set-up of conceptual and logical design of information system

In the conceptual and logical design of this system, the need to synthesized and analyzed the data is necessary for Nile river responsible organizations and decision makers. Designed Nile River Information system draws from many disciplines to create meaningful, intelligent digital maps used by these organizations and Decision Makers. Fig.4 shows the flow chart of designed system.

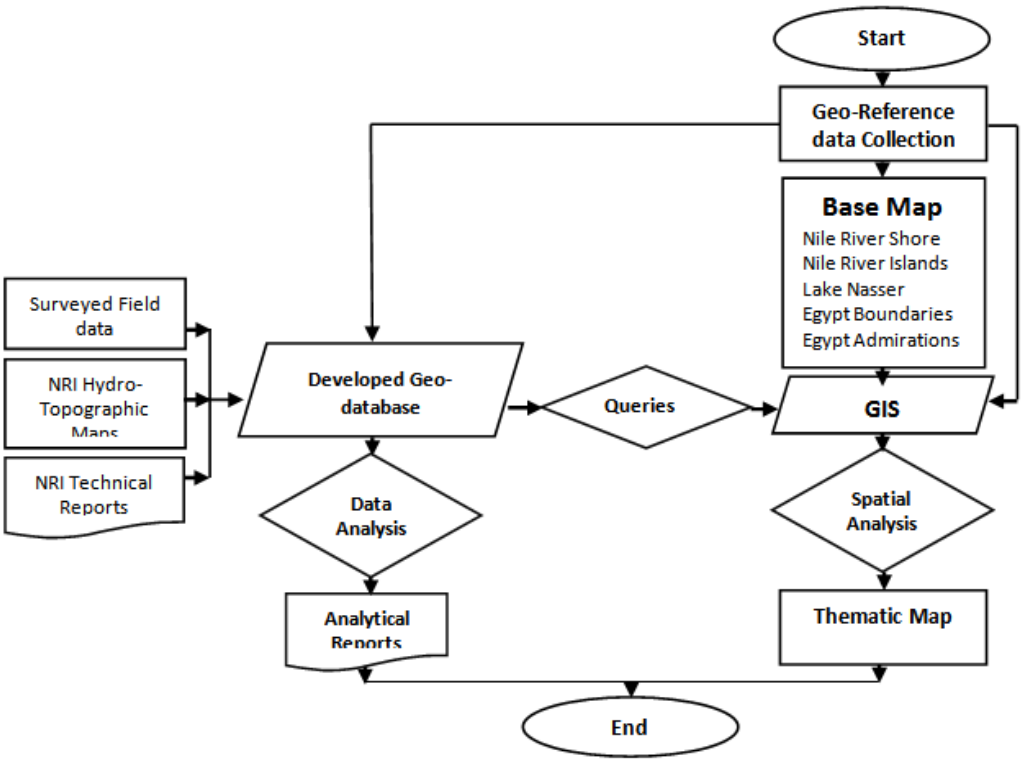


Figure 4: Flow chart of GIS-based Nile River Information System

VII. PHYSICAL DESIGN OF NILE RIVER INFORMATION SYSTEM

The physical design describes the actual processes of entering, verifying, and storing data; the sorting procedures; the accurate format of reports. In this part, the data management and spatial analysis are applied.

6.1 ESTABLISHMENT OF BASE MAP

A base map provides adding process by overlaying other information on top of it, it is the foundation. Base map contains reference information that may provide different geospatial information. In designed Nile River Information System (NRIS), the base map contains Egypt and administrations boundaries, city names, Nile River km, Major Nile River, and Lake Nasser which it is supported with satellite images as shown in fig.5.

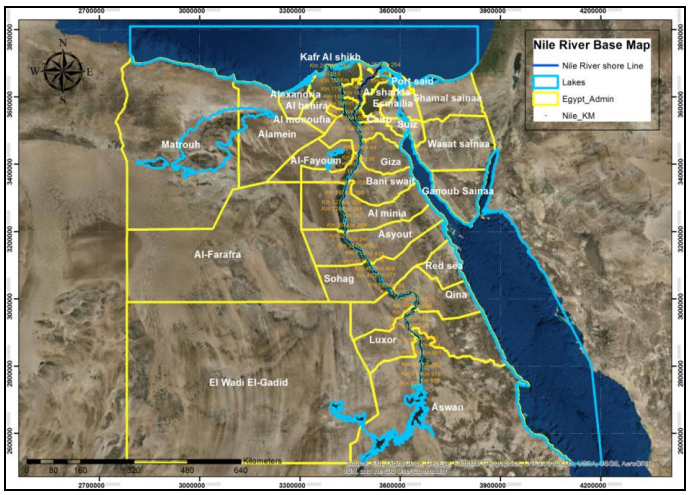


Figure 5: Nile River Base Map

6.2 DESIGN NILE RIVER GEO-DATABASE

The designing and implementation of Nile river database can be considered as the base of this system construction. It supports all forms of data, as attribute data, features, raster, vector data, and field measurements. It can be used in the processing and analysis of data. The major advantage of designed geo-database that it improves database management. In addition, It has another advantages Such as a) the ability to integrate into the spatial system and all different data can be saved by one database; b) data entry and editing are precise and errors can be prevented, defined during edition d) easily maintaining e) data stores easily linked with other data f) the use of massive amount of data allows the development of high degree of excellence digital maps g) data collection can continuously be done [6-8].

Arc Catalog 10.5 is used to develop Nile river geo-database as shown in fig.6. It includes the construction of new files in various data types and formats, as shape files, tables, geo-databases, and layers. Data shape files which obtained from Nile Research Institute topographic maps (2003-2010) and technical reports (1995-2019). Designed geo-databases provide the foundation for Nile River GIS development and management information system. With advanced geo-database having accurate and complete data, there can be reporting and modeling to support the various Nile River decisions required.

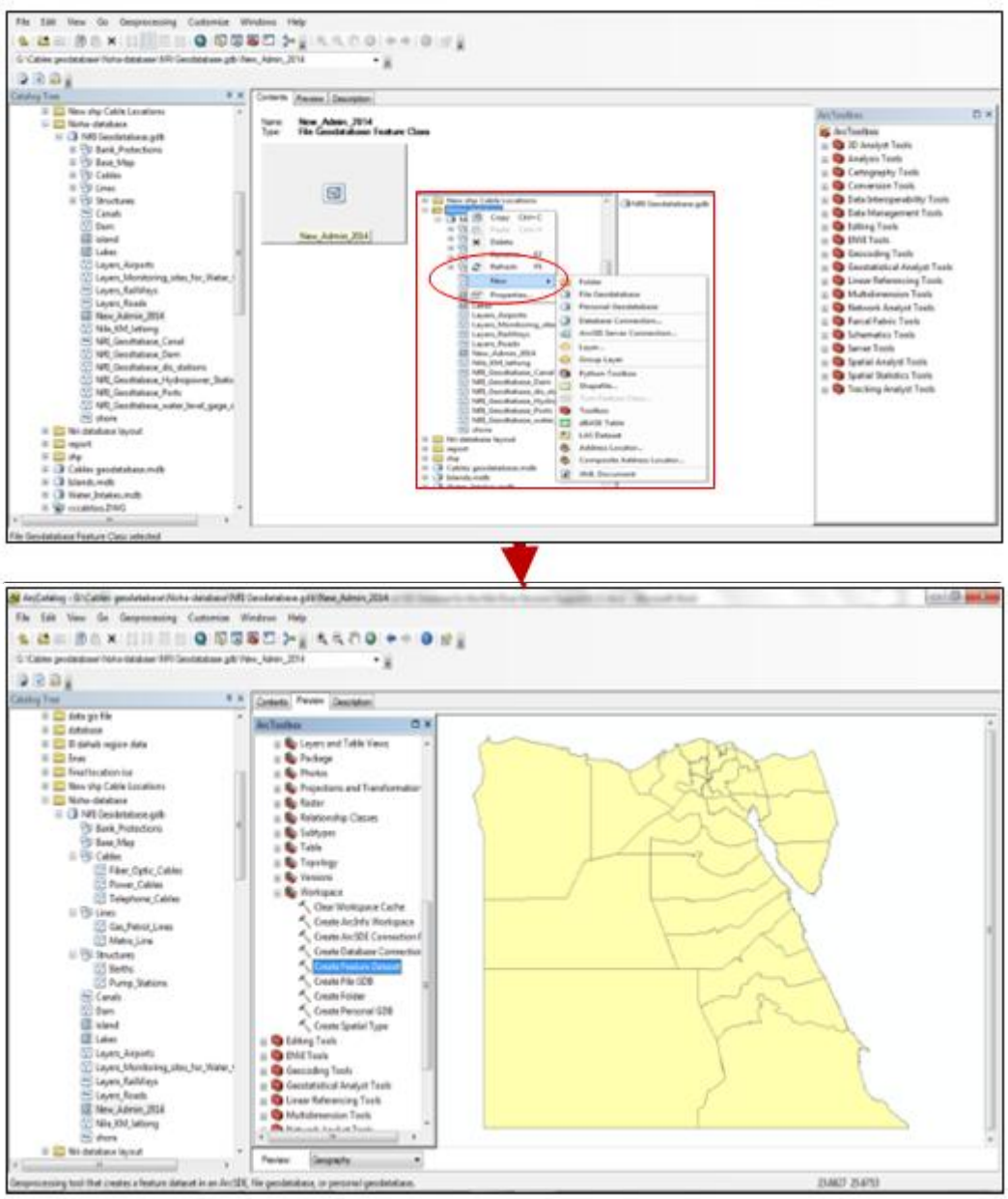


Figure 6: Arc-Catalog to create geo-database

6.2.1 GEO-DATABASE STRUCTURE

The data are contained entirely in tables. There are Common fields related these tables. Data entry in some data tables was used Microsoft Excel file, and they were saved in the dBase file format (*.dbf). Data were entered in the attribute table of the data shape file, which is automatically saved into a dBase file by Arc Map. In this part, the data types and the design of data contained in each table was shown as:

1- Water pump stations
2- Water Level and Discharges Gauge Stations
3- Hydropower stations
4- Bank Protections
5- Berths
6- Management Lines
7- Ports
8- Hydro-Topographic Maps
9- Cables (Telephones, Fiber-optic, power)
10- Water Quality Monitoring Sites
11- Lines (Gas, Petroleum, Metro)

The structure of developed geo-database can be seen in the fig.7. The datasets are divided into feature datasets. These features represent the precarious items, such as water pump stations, hydropower stations, Berths, Ports..etc. Also, tabulated attribute data has been designed for each feature. It is clear that the developed geo-database allows all Nile River feature data related to be collected in one database, forming different types of data at any time. It also permits the decision maker to query, extract reports, analyze, and create intelligent maps.

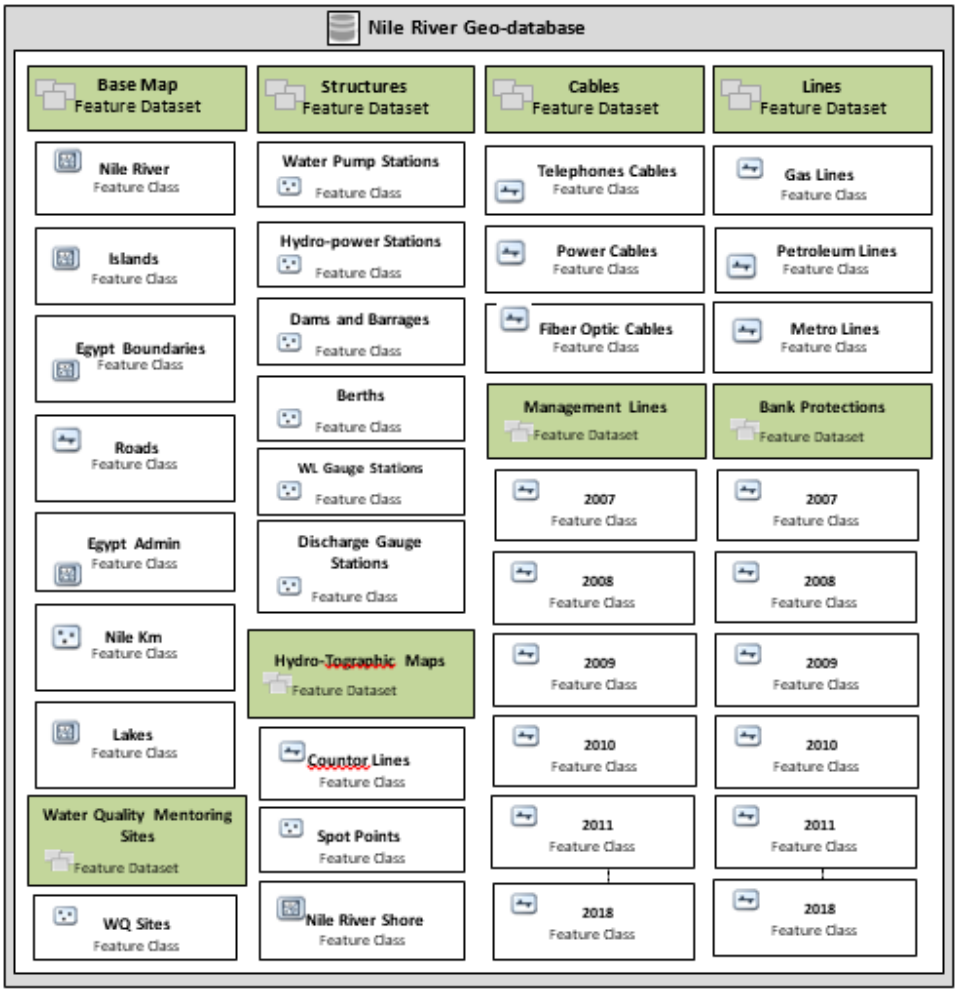


Figure 7: The structure of developed geo-database

6.3 DEVELOPED PYTHON SCRIPTS FOR QUERIES AND ANALYSIS

Python is a scripting language that is used to automate computing tasks through programs. In the developed system python is used to execute spatial data management and spatial analysis using automated geo-processing functions.

6.3.1 DEVELOPED NEW TOOLBAR (NRI TOOLBAR) BY PYTHON

New toolbar is called NRI toolbar is developed by python. It contains all necessary analysis and management new tools. In developed system, these new tools are used for management data as select, search, edit, delete and for analysis as create Digital Terrain Model DTM, create Digital Elevation Model DEM, Define Projection, and Extract by mask as shown in fig.8.

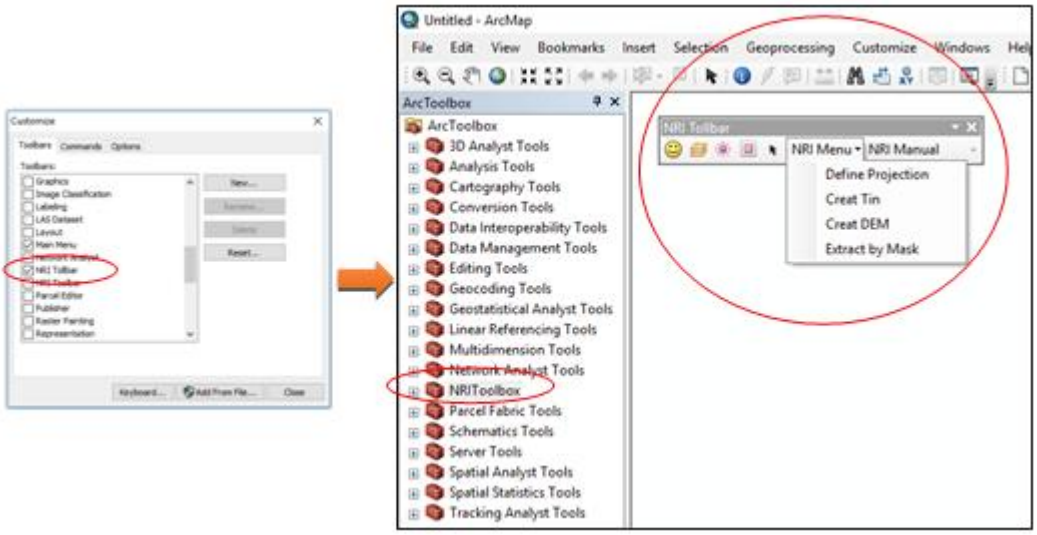


Figure 8: The developed NRI Toolbar with new tools

6.3.1.1 DEVELOPMENT DATA MANAGEMENT TOOLS

In developed system, queries are used to select a subset of features and table records and build dynamic inelegant maps. They are formed by Structured Query Language SQL operators and functions. Data management tools are used for select, edit, search, and delete. These tools can run by using the buttons in new NRI toolbar. Such as select water pump feature by using query builder you can generate map for selected water pump stations at certain km as shown in Fig.9. By accessing multiple geographic datasets, Nile River management processes can be performed easily.

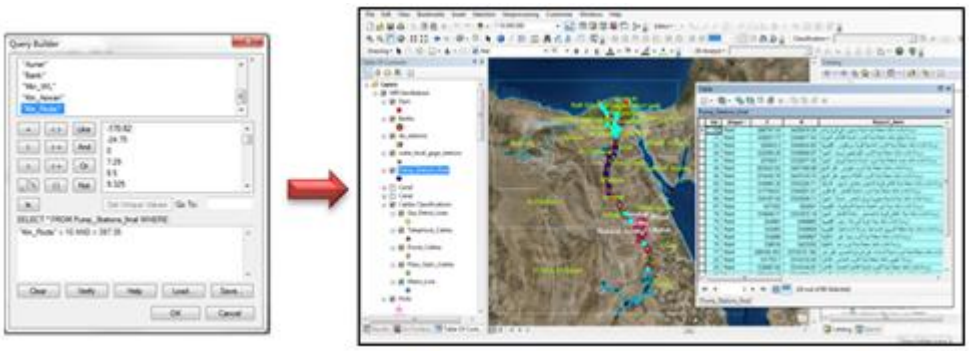


Figure 9: Query Builder (select tool)

6.3.1.2 DEVELOPMENT GEOSPATIAL ANALYSIS TOOLS

GIS for Nile River geospatial analysis is used to generate intelligent maps for exploring the spatial relationships, patterns, morphological changes, geographic and physical processes. There are two methods of spatial analysis; the first one is quantitative mapping which presents how much of something is in a selected study area. It is a spatial representation of numeric values such as Nile river bed levels, water quality

parameters, temperatures, and so forth. The second is thematic mapping which introduces a specific data feature such as water pump stations, ports, and cables crossing Nile River.

The data-mining technology of geo-database can be employed by spatial analysis. In the developed NRI toolbar the need to use of spatial analytic tools is necessary to mine datasets across a wide range of different data types. Spatial analysis offers insight about Nile River analysis options. NRI toolbar contains the analysis tools as Create DTM, Create DEM, Define Projection, and Extract by mask. Fieldwork in every location in Nile River study to survey the bed levels, magnitude, or concentration of water quality parameters or any phenomenon is usually expensive and difficult. By using developed Spatial Analyst tools, it is able to choose the best interpretation method for the surveyed data, by creating continuous surface from certain locations and make predictions from these measurements to create continuous surface representation. Surface interpolation developed tools have the ability to create a Digital Terrain Model DTM and Digital Elevation Model DEM. The feature data set hydro-topographic maps in the developed geo-database are used for creating DTM as shown in fig.10.

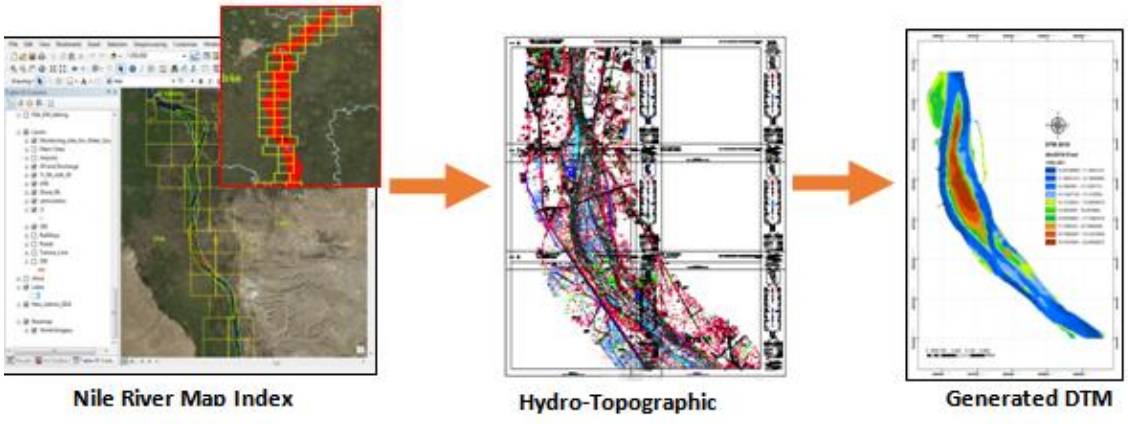


Figure 10: Surface Interpolation

The Nile River developed toolbar is used for analyzing the Spatial Relationships for all structures along Nile River. The developed system is integrated with the developed base map, which it has the ability to analyze geographic location and the information linked to those locations. In a dynamic process; maps can be created, information can be linked to a map, and data can be visualized and analyzed in new ways. The cardinality which represents the record relationships between tables describes how individual record values relate to each other. Such as Nile River km, water pump stations, and Hydro-power stations a one-to-many cardinality, which means that individual records from km may be repeated for many related records in water pump stations and Hydro-power stations. For Nile River, monitoring and evaluating morphological changes during time period by using Hydrographic maps produced and designed by Nile Research Institute NRI which stored in developed geo-database indicates trends and patterns.

VIII. NILE RIVER INFORMATION SYSTEM IMPLEMENTATION

The implementation of Nile River Information system can be divided into two process; the first is loading of data and the second is programs developing and debugging. For simplify the data entry, output and management processes, designed Nile River Information system was developed by ArcGIS and Visual Basic. The flexible interface of designed system is showed in Fig.11.

Figure 11: the Interface of NRIS

Nile River management processes can be performed easily, by gaining access to multiple geographic datasets. The designed system incorporates a mixture of data types, this large amount of data supports the management and decision of Nile River as shown in fig.12 and fig.13. In addition, the regular inventory and documentation of data through developing geo-database allow for analysis, evaluation, and continuous improvement in the overall Nile River Management Plan.

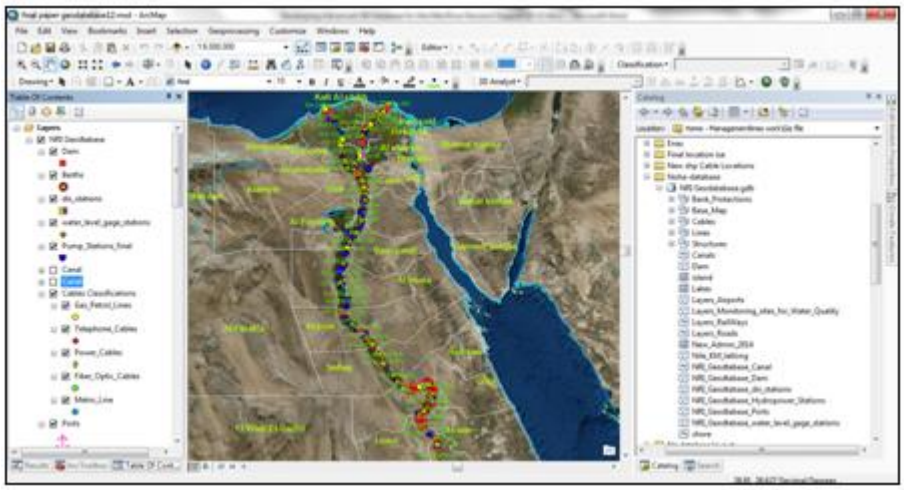
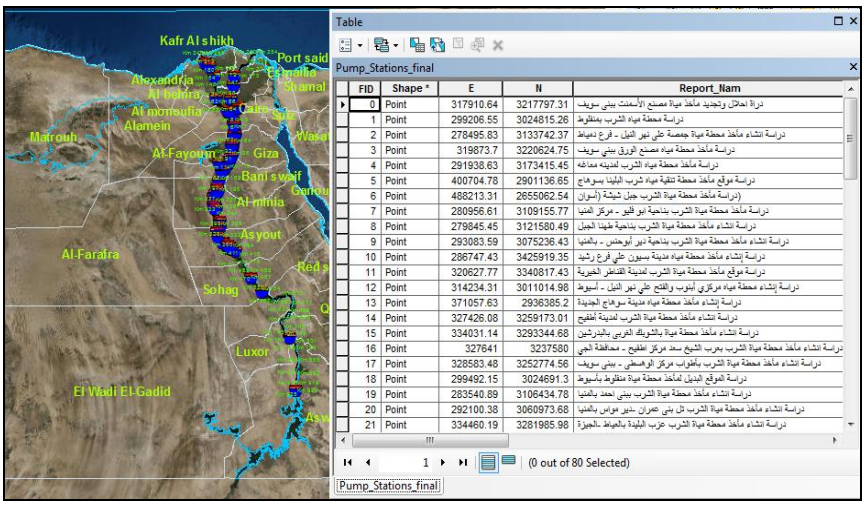
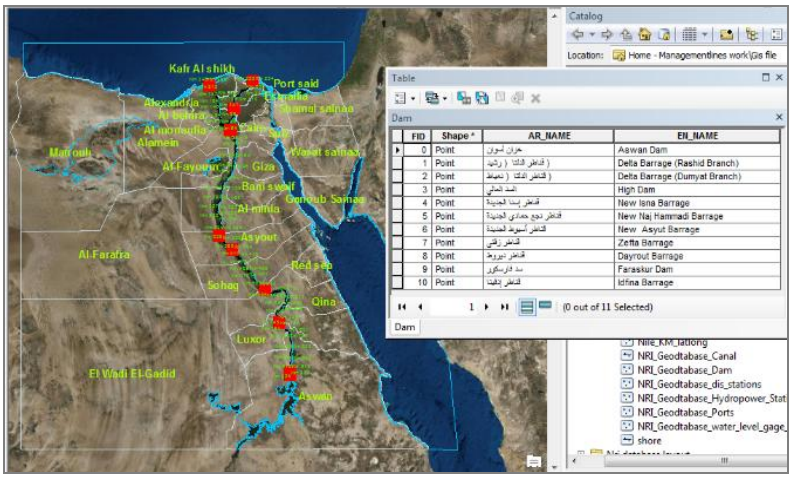


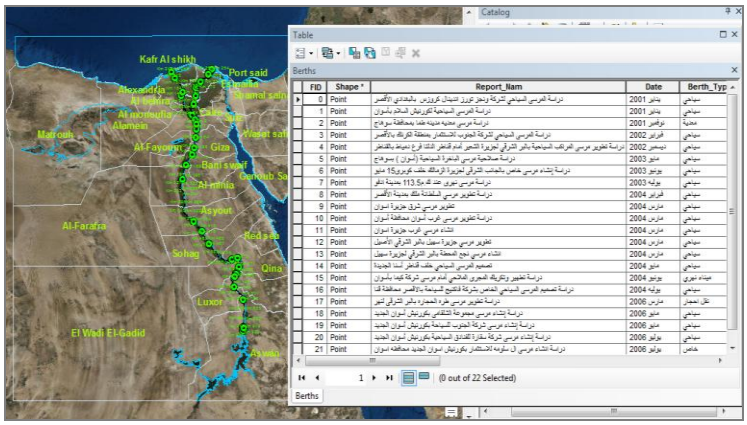
Figure 12: GIS-Based NRIS



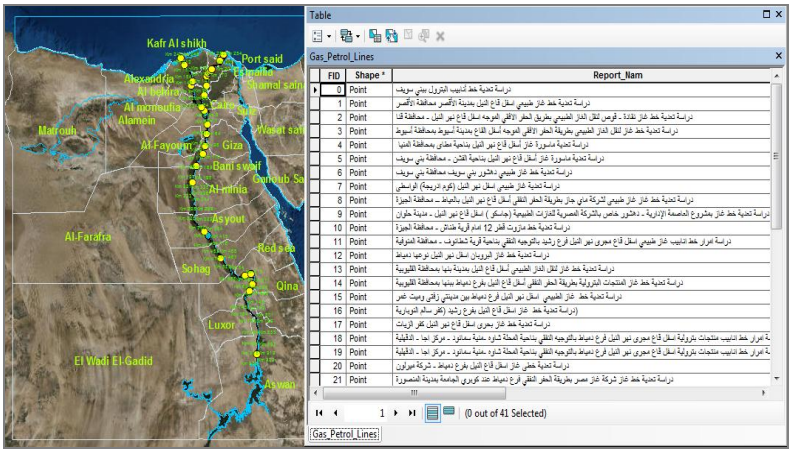
a. Water Pump Stations Feature Datasets



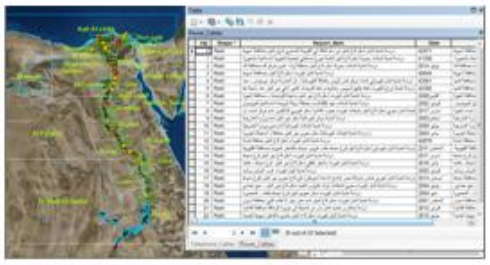
b. Dam and Barrages Feature Datasets



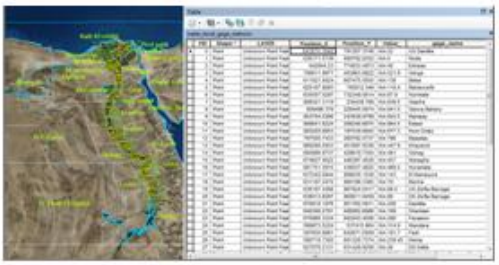
c. Berths Feature Datasets



d. Gas and Petroleum, Metro lines Feature Datasets



e. Telephone, Fiber optic, and Power cables Feature Datasets



f. Water Level Gauge Stations Feature Datasets

g. Discharge Gauge Stations Feature Datasets

h. Ports Feature Datasets

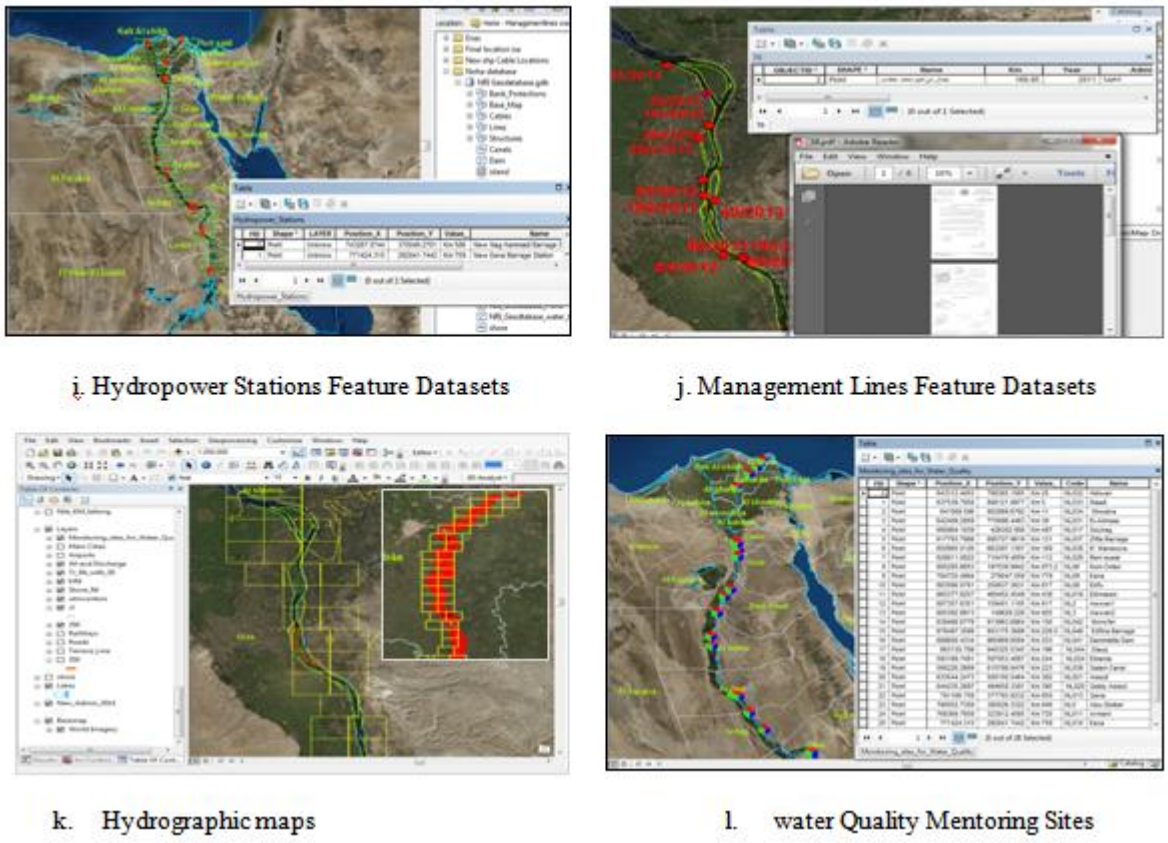


Figure 13: Developed geo-database with different feature datasets and attribute tables

IX. GIS MOBILE APPLICATION

Supplying and integrating GIS with mobile technologies, enhance the accessing of geospatial data, and services through mobile devices via wireless networks as shown in fig.14. GIS Mobile application is an integration of both software and hardware framework. GIS mobile application is used for data acquisition via advanced geo-database in the field which supports the instant right decision. The GIS mobile application connected to developed geo-database, it can be noted that this integration support in the field work, which maintain the database setting, accuracy, and link the spatial analysis in the field.

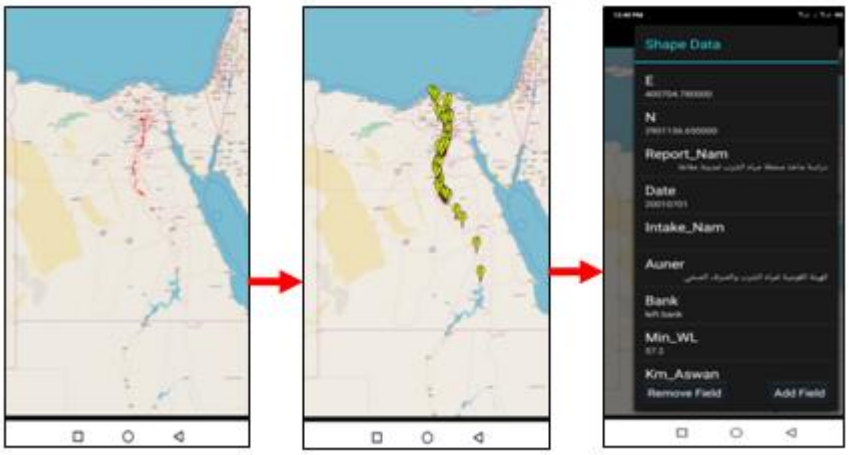


Figure 14: GIS Mobile Application (Pump Station data layer)

X. CONCLUSION AND RECOMMENDATIONS

Nile River information system based on GIS is designed and developed to meet the demands from the responsible of Nile River data management and analysis. The developed information system can utilize a wide range of data formats to merge datasets, explain new data, and perform complex analysis operations, such as

terrain analysis, surface modeling, and statistical analysis. In addition, it introduces the common data access and Nile River management framework. It controls representation, accessing, storing, and managing. It is clear that the developed NRIS introduce many advantages such as

- Evaluated and presented the quality assurance of data.
- The ability to control of new data.
- Data can be processed and modeled to support the responsible of Nile River data management to have control.
- Multiple users able to carry out synchronous updates to developed geo-database by allowing Data versioning.
- Easily Maintenance

It can be concluded that the developed GIS application supported with advanced geo-database provides the foundation for Nile River GIS development and management which support decision maker and Nile River organizations in Egypt. It is recommended to provide this system with all the available data of the Nile River from the competent authorities so that a comprehensive information system with an effective value can be built and used in building sustainable plans for the development of the Nile River.

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