

# A PROTOTYPE ENVIRONMENTAL DATA MANAGEMENT GIS FOR SHELL PETROLEUM DEVELOPMENT COMPANY OF NIGERIA LIMITED

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## ABSTRACT

The Shell Petroleum Development Company (SPDC), Nigeria has been, for nearly a decade, the major player utilizing Geographic Information Systems and Remote Sensing technologies in its operations. The Environmental Special Studies Unit (HSE-ENV) recently implemented a GIS for environmental data management to overcome data management constraints associated with traditional data acquisition, storage, retrieval and analytical methods in the company. This paper details the phases and technical considerations in developing the prototype Environmental Data Management GIS (EDM-GIS).

The EDM-GIS resolves three problem areas: (1) difficulties in tracking and using existing environmental data; (2) most data exist as hardcopy reports, making timely information storage and retrieval problematic; and (3) limited data sharing and linkage due to the inflexibility of the storage/retrieval systems. The GIS development phases include: screening/review of available reports and maps; extraction of relevant field and laboratory data and transfer to digital data templates; development of a physical database structure with defined entity-relations; database population; GIS customization for database analytical operations.

The physical database is in Microsoft Access and ARCVIEW GIS 3.2a formats, taking advantage of their relational database management functionalities and security features. Avenue Scripting Language was used for user-interface development while access to the Microsoft Access database is through ODBC – Open Database Connectivity technology. Specific customization features include report browsing; hotlinks of digital photos, movies and reports to specific locations; database linkage with other existing enterprise-wide systems, maintenance and systems administration functionalities. Enterprise-wide sharing of the EDM-GIS using a Web-based platform is planned for a later date. The EDM-GIS is a pioneering initiative by any oil company in Nigeria.

Keywords: Environmental Data Management, GIS, Relational Database Management Systems

## 1 Background

Effective and efficient environmental management practice requires careful collection and monitoring of a large amount of data. One way to meet this data management challenge is to tie together data sources in the form of text, tables, photographs and maps through a computerized geographic information system (GIS). A GIS is an information system capable of capturing, storing, updating, manipulating, analyzing and displaying data identified according to their spatial locations (Tomlin, 1990; Star and Estes, 1990; Tomlinson, 1998). Recent years have witnessed increasing use of GIS in environmental management and monitoring such as managing site characterization data, developing natural resource data repositories, non-point pollution modeling and other environmental management applications (Janssen, 1992; Goodchild, 1993; Eastman et al, 1995; Sprague and Watson, 1996; Keyworth and Healey, 1996).

The popularity of GIS in environmental applications lies in its ability to answer queries such as, "display all wetlands within a 10-mile radius of Idoho flowstation," or "show all spill response storage facilities within SPDC oil management leases". Because of its flexibility, GIS also captures data in different formats and can output the information using various display plotting, printing and transfer functions. GIS is used increasingly in specific environmental management tasks. However, GIS can bring tremendous benefits to the entire field of environmental management and has indeed gained wide recognition for this purpose in various parts of the world.

Use of GIS was initiated in Shell Petroleum Development Company of Nigeria Limited (SPDC) in the early 90's, with the introduction of the Genamap system at the Survey and Mapping Units of the Geomatics Department (DTE).

Although the system had since been applied, with clearly defined gains, in various arms of SPDC including geophysical, reservoir engineering and pipeline functions, its application to environmental management processes at this initial stage was minimal. This variance was traced to limited awareness, lack of a clearly defined plan and implementation strategy and the non-flexibility of the Genamap system.

While the search for a more suitable information management system continued, the environmental data management problems progressed into undeniable challenges. The initial case for action was poor accessibility and use of some valuable historical information existing as numerous hard copy reports, and unavailability of these data for inter-functional sharing and prompt decision making at various levels of the organization.

A number of information management systems were explored and a few piloted but with limited potential for meeting expectations of target users. The ARCGIS pack came into clearer view in 1998, with the visit of a contingent to ESRI headquarters in Redlands California. The visit threw more light on environmental applications of GIS and the overwhelming advantages of the ARCGIS products relative to the Genamap system. With the Shell Group adoption of ESRI ARCGIS, and its approval for use in SPDC (in DTE) late 2000, renewed interests in GIS capabilities were resuscitated. There was thus an increasing need to:

- maximize the benefits of existing information sources (hard copy environmental reports and other reference sources) in SPDC, through optimal use of available GIS/Remote Sensing resources
- create an appropriate and more focused GIS framework for data management, while increasing level of awareness/interest among environmental personnel in SPDC
- improve the quality, duration and cost of environmental management processes, thereby facilitating better decision-making, company growth and profitability

This paper details the phases and technical considerations in developing a prototype Environmental Data Management GIS (EDM-GIS) to resolve these requirements. The EDM-GIS implementation project is targeted at achieving the following objectives:

- review current environmental data management situation in SPDC and identify user needs/existing gaps
- track, collate and inventorise over 300 available environmental hard copy reports; extract and re-format all available environmental data (residing in hard copy and electronic reports)
- integrate extracted data into an Environmental Data Management GIS system as historical reference sources, using customized data templates and modules
- develop user-friendly interface and information linkage to existing environmental databases, with ArcView/Arc Info capabilities
- assess compatibility of the set-up with existing data management systems (WMS, ENDAMS, Spill Database, etc); conduct hands-on training for all anticipated users and
- procure relevant implementation tools (e.g. potable GPS units), and other accessories for field checks and quality control by identified pilot users

## **2 Steps In Developing the SPDC EDM-GIS**

### **2.1 Functional Requirement Study (FRS)**

As is typical in most GIS implementation, a Functional Requirement Study (FRS) commonly referred to as a user needs assessment was conducted at project start-up. The FRS served many purposes. Principally, it provided a framework for the interdisciplinary team to focus the overall project objectives from both a managerial (users) and technical (systems development) perspectives. The interactive sessions ensured that users expectations are clearly outlined and defined unambiguously. Moreover, it facilitated exchange of ideas between relevant stakeholders within the SPDC group and the project development team on issues such as enterprise-wide data sharing, data ownership, linkage of existing systems and so on. . From the FRS process, it emerged that the EDM-GIS should be capable of executing the following tasks:

- environmental data capture and data integration from multifarious sources
- environmental data storage, management, analysis and other typical functions for decision support purposes
- seamless integration into existing enterprise-wide database for shared and repetitive use of data

Finally, from the FRS stage, we identified the available data types to populate the EDM-GIS when developed and candidate data products to be generated by the system.

## **2.2 Data Review and Screening**

Over 300 environmental hard copy and electronic reports detailing studies carried out by SPDC Environmental Consultants over the past two decades, in and around the Niger Delta area were collated. These reports contain data pertaining to all known environmental processes in both onshore, near shore and off shore related SPDC operations. The first step in reviewing the data, was the development of a universal checklist of environmental data sets typical in oil and gas operations. All the environmental reports were then categorized under 10 major study types in the final checklist as listed below:

- Baseline environmental Studies (BS)
- Environmental Impact Assessment Reports (EIA)
- Environmental Audit (EA)
- Post Impact Assessment (PIA)
- Compliance Monitoring (Gaseous, Aqueous, Drilling & Dredging)
- Oil Spill
- Remediation Studies
- Collision Incidents
- Environmental Special Studies (Toxicology, Wildlife)
- Environmental Sensitivity Index (ESI) Mapping reports

A checklist of broad data types and typical data elements was also developed for each of the study types. Each report was meticulously reviewed by thematic experts consisting of biologist, geologist, vegetation, wildlife, socio-economics and GIS specialist to identify quality data for populating an environmental database using the checklist as a guide. Moreover, the review and screening process revealed data gaps that may have to be filled in subsequent environmental studies.

## **2.3 Data Extraction**

Data extraction was at two levels. At the first level, measured parameters and other useful information identified during the review process were extracted from the reports. Standard digital templates were thereafter developed for typical parameters identified in each study types for this purpose. Extracted data are a mix of quantitative, qualitative, spatial and image data formats.

The attribute data extraction templates were developed as Microsoft Excel files (.xls format). Each template was designed to capture measured elements relating to a data category. For instance, an EIA report typically contains broad data categories such as physico-chemical properties of sediment and water, geology and climate, socioeconomics and vegetation information. Measured elements of these categories include ph, conductivity, oil and grease, particle size, rainfall, temperature, population characteristics, infrastructure distribution, landuse, flora and fauna and so on.

At the second level, each environmental report was scanned on an "as-it-is" basis and converted to Portable Document Format (.pdf). The pdf format ensures that captured information cannot be modified as in the case with Word Processing formats. The need to preserve the original contents of the reports largely informed this decision, since approvals for some of the reports had been secured over the years from local environmental regulatory authorities.

Extracted data at the first level were quality controlled to check for omissions, multiple entries and accuracy. The process involved comparing data as recorded in the hard-copies with data entered in the templates. The QC/QC process at the second level involved checking for missing pages and pages that are not captured correctly due to human errors or machine failures (Burrrough et al, 1996; Carver et al, 1996). Data review and extraction were carried out over a period of 9 months.

## **2.4 Physical Database Development**

### **2.4.1 Conceptual Database Design**

In this particular GIS implementation, it was obvious at the end of the FRS that the database to be developed must meet the specific needs of an operating oil and gas company pursuing a corporate strategy of maintaining environmentally friendly operations. Two broad factors are therefore considered in conceptualizing the database design strategies:

- the environmental department of SPDC strategically services Line and other departments within the company. This is a direct result of SPDC's global corporate environmental policy. For this reason, some data necessary for populating the database and existing database systems with environmental contents are external to HSE-ENV
- Other considerations in the database conceptual design include entity-relation modeling of extracted data, GIS user interface consideration and expected functionalities.

The database design is conceptually simple and is illustrated in Figure 1.

Data sets are at the base and owners are indicated at the top. The user interface provides access to data sets using Object Database Connectivity - ODBC. ODBC is a standard that provides applications with a common interface to data held in relational databases. Any application that can act as an ODBC client can access data held in any relational database that has a suitable ODBC driver.

Interface functionalities include basic GIS functions - queries, data display, analysis and product generation. Additional functionality permits the development of specific applications. Power users are indicated at the top. Multiple users can log on to the database in a multi-tasking, networked environment.

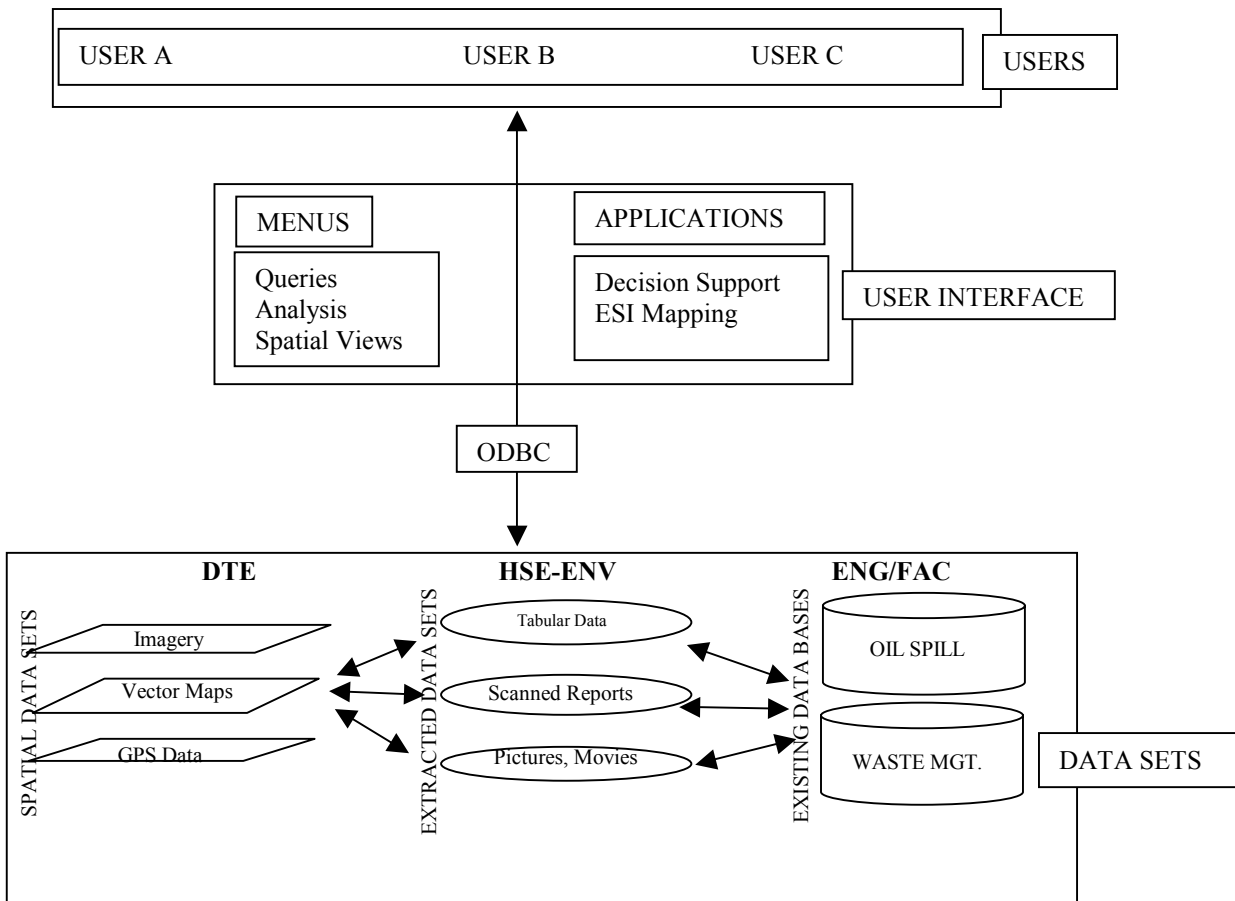


Figure 1: Database Design Concept

## **2.4.2 The Physical Database**

The physical database has three components - table and map feature structures, linkages between tables and map features on one hand and linkages to existing databases on the other hand.

### Table and Map Feature Structures

The physical database was developed in Microsoft Access RDBMS software. Twenty-two tables in dbf format were created from the Excel templates and stored as a Microsoft Access mdb file. As a minimum requirement, each table contains five key fields referencing both report tracking and location information. These fields are:

- Report serial number - a unique number for each of the reports
- Study code - a unique code for each study type (EIA, PIA, BS etc)
- Facility type - each report is associated with an oil facility type such as oil field, flowstation, pipeline, terminal
- Study area - the general area of the study, such as name of facility or name of community/village or town
- Sample number - a unique number assigned to each data element collected at distinct location

The table model is essentially relational. Tables can be related to each other using any of these fields. A primary table contains a global list of distinct sample numbers as well as x and y coordinate data for referenced sample numbers. As more data become available, the mdb file would be incremented with the additional data.

Most of the reports, which were primarily produced through local and international consultancy, contain one map feature or the other. However, the review and screening process established that their quality and accuracy is suspect. The decision was subsequently made to use the Geomatics department (DTE) as the main spatial data source for the database. The DTE is the repository of all spatial data sets within SPDC. Data sets acquired over the years and processed to world class standard by the unit include: imageries - LANDSAT TM, SPOT, IFSAR, IKONOS; a variety of vector format and CADD data including Arc/Info coverage, ARCVIEW shapefile, AutoCAD dwg, Microstation dgn and GPS data. A key structure of the GIS therefore is that spatial data is external to the system but available as at when required for any analysis.

### Tables and Maps Linkages

A loose linkage exists between the tables and available maps. This is deliberate, as in general, all the tables have spatial information in the form of study area, facility type and sample number. When linked to the primary table, this information is sufficient for most applications of the database provided a suitable vector map or imagery forms a background against which data can be plotted and viewed. This helps to keep the database simple and easy to be manipulated by even novice users with limited knowledge of GIS. However, advanced users can also define table - map feature relationships when required using an entity-relation model diagram accompanying the project.

### Linkages to Existing Databases

One example of linkage to external data source (spatial data) has been discussed above. Apart from this, the database is also linked to two existing databases. These are the Oil Spill Database and Waste Management System. The study area field is the primary key used for this purpose.

## **3 The EDM-GIS User Interface**

### **3.1 User Interface Architecture**

The EDMS-GIS requires ARCVIEW 3.2 or higher versions to run. Adobe Acrobat 4.0 or higher is required as a document file viewer and Microsoft Access 2000 is needed for relational database management. Recommended computer resources are: a minimum of Pentium III 500mgz, 128 MB RAM, 20GB Hard-disk drive, CD-Rom drive and 21" color monitor. Operating system could be Win 95, 98, 2000, NT.

A Microsoft Access Open Database Connectivity (ODBC) driver links the user interface with the Microsoft Access RDBMS. ODBC accepts Structured Query Language (SQL) data requests from the client application and translates these into a form acceptable to the target database engine. This is sometimes hidden from the user because the client application has its own "query-by example" interface. The flow of data is two-way. SQL is both a data retrieval language and a data definition language. Using SQL, data tables can be created, indexed and inter-table relationships defined. Moreover, database users can define 'views' of the data - insert, delete and update data rows.

User interaction with the database is through menus, buttons, tools and dialog boxes. The user interface is organized as a series of ARCVIEW project files (.apr) all running from a base project file named GIS Database.apr (Figure 2). Avenue object oriented scripting language was used for customize the user-interface development.

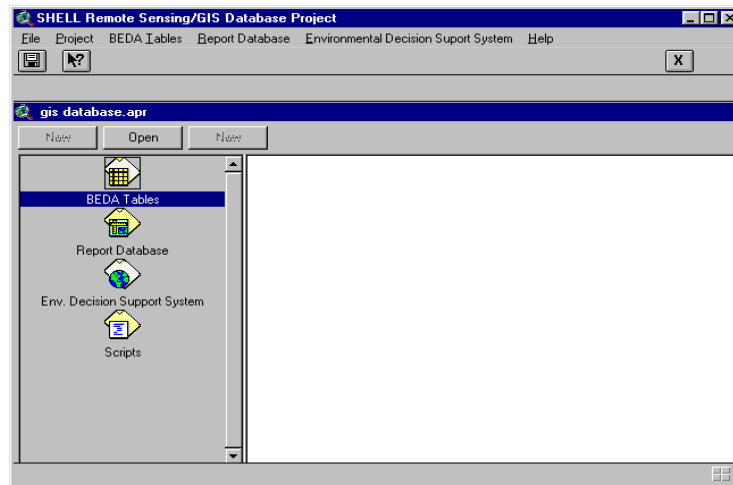


Figure 2: The EDM-GIS User Interface

### 3.1.1 The GIS Database.apr Project

The GIS Database.apr project is actually the base project on which three other specific ARCVIEW GIS projects are built. The projects are customized to view and manipulate the Microsoft Access Relational Database Management System. Depending on the functionality desired, users have the option of accessing and manipulating the Microsoft Access database from any of the three projects named:

- BEDA Database Project
- Report Database Project
- Environmental Decision Support System Database Project

Users can access the functionalities provided in each of the three projects using standard methods provided by the Microsoft Windows operating system. Figure 3 provides a schematic representation of available projects and menus and menu items of the user interface.

### 3.1.2 The BEDA Database Project

This interface is customized to access specific data of interest relating to baseline environmental data types only. Four major menus are available for this purpose: BEDA Tables, Compliance Monitoring, Waste Management, and Drilling and Dredging menus.

The interface emphasizes only viewing access to the Microsoft Access Database. This implies that the Microsoft Access Environmental Studies Database.mdb file cannot be modified from the BEDA module. However, the tables created in this interface are mirror images of the original in the Microsoft Access Environmental Database. These tables can be modified, the data analyzed and manipulated using standard ARCVIEW Table functionalities.

### 3.1.3 Report Database

Scanned copies of the hardcopy environmental reports are accessed using the report database module. The module is intended to provide access to digital copies of all submitted reports. Moreover, it provides a simple interface for generating textual information. Existing documents can be browsed using this module. It also allows new documents to be created "on-the-fly". A global list of all currently processed reports is accessible from this module.

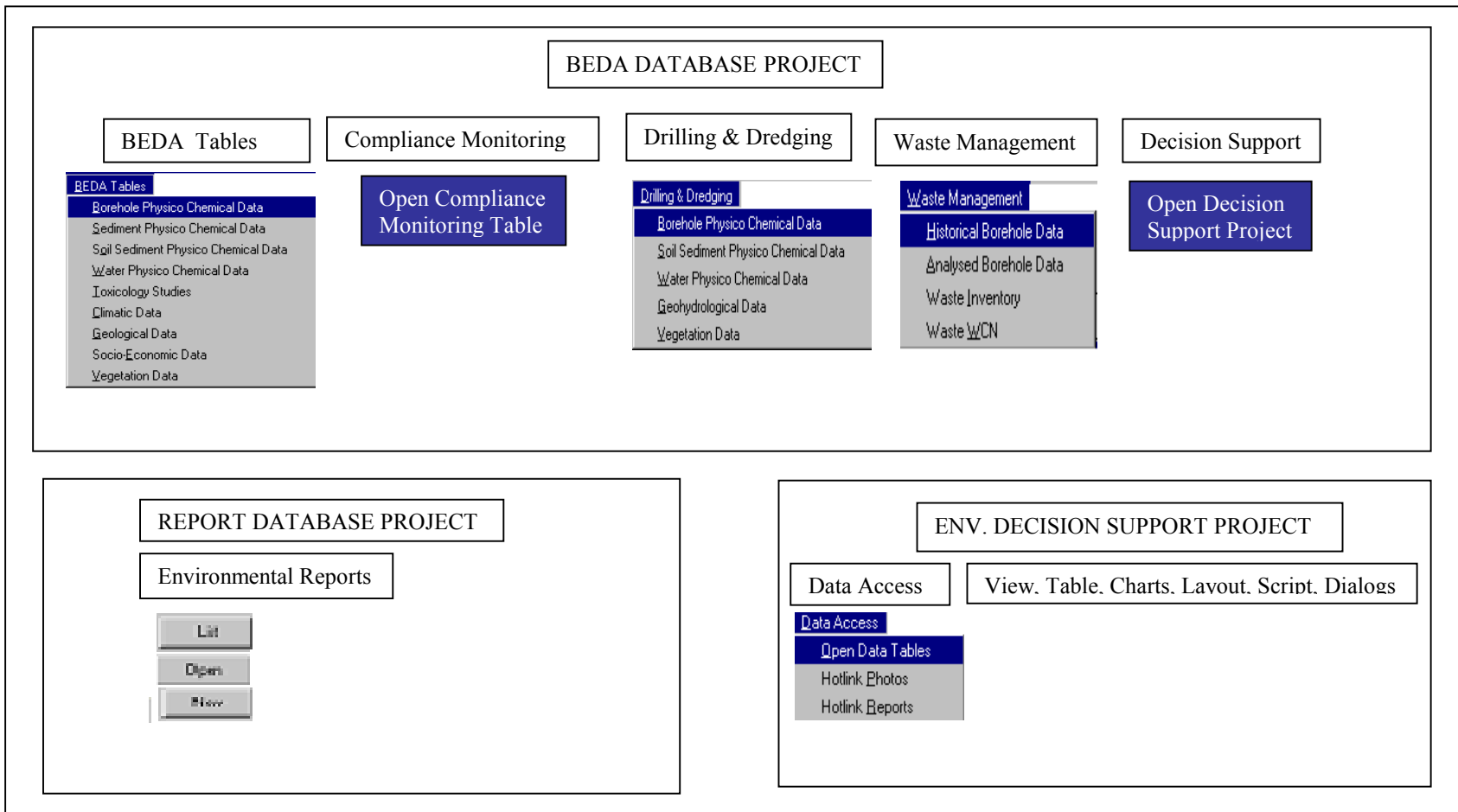


Figure 3: A Schematic Representation of EDM-GIS User Interface Objects

### **3.1.4 Environmental Decision Support System**

The Environmental Decision Support System (EDSS) module is organized in such a way as to utilize all the available functionalities and tools of the ARCVIEW GIS software as well as associated extensions. Unlike the other modules, all ARCVIEW GIS Document Graphic User Interface (DocGUI) are available in the EDSS module. These are Views, Tables, Charts, Layouts, Scripts and Dialogs.

#### Views

The View DocGUI provides the platform for creating, accessing and analyzing spatial data available as Arc/INFO coverages, AUTOCAD dwg/dxf files, Microstation dgn files, Radar, SPOT, LANDSAT etc images and of course the native ARCVIEW GIS shape file format. Available spatial analysis functionalities of the View DocGUI include buffering, overlays, neighborhood analysis, image interpretation, distance operations and the like.

#### Tables

The Table DocGUI provides tools for creating, accessing and analyzing tabular data in a simple relational database systems framework.

#### Charts

The Chart DocGUI provides a means of creating and editing charts. Data for charting are accessed from the opened tables in the Table DocGUI.

#### Layouts

The Layout DocGUI provides the interface for composing maps, imageries, pictures, tables, charts and other objects for printing.

#### Scripts

The Script DocGUI makes available to the veteran programmer a simple object oriented language for customizing the ARCVIEW GIS interface and tools for extending the basic capabilities of ARCVIEW GIS and associated extensions.

#### Dialogs

The Dialog DocGUI provides tools for creating dialog boxes including pull-down lists, combo boxes, message boxes and other dialog types.

Expectedly, the Environmental Decision Support System module would be the main module for developing decision support applications especially in environmental monitoring and management. The Data Access menu enables users to access tabular, spatial and hotlink data that would, in conjunction with the functionalities and tools of the above DocGUIs provide users the means to build decision support applications. There are three menu items under the Data Access menu: Open Data Tables, Hotlink Photos and Hotlink Reports.

Open Data Tables item enables users to gain access to all the data tables in the Microsoft Access Database. These tables can be manipulated using standard tools and functionalities in ARCVIEW GIS.

Hotlink Photos item provides access to important photos scanned from the reports and existing videos as hotlinks to spatial views. By clicking the point/line/ and/or area entity (in the View DocGUI) that these photos and videos are attached to, the photo is launched in an Acrobat Reader window while videos are replayed using the Windows Media player. This gives users of the database a quick snapshot of environmental related information on the area of interest for decision-making purposes.

Hotlink Reports item provides a spatial view of all the scanned reports. Each report is associated with a study area defined as a pair of x and y coordinates. Each report is therefore hotlink to a point theme in the ARCVIEW View DocGUI. By clicking on any point entity in the View DocGUI that these reports are



attached to, the report is opened in an Acrobat Reader window. This gives users of the database a quick way of viewing environmental related information on the area of interest from the EDSS module.

### **3.2 Database Maintenance and Security**

Standard functionalities are inbuilt for database maintenance and security to preserve data integrity. Initial access to the EDM-GIS is through passwords assigned by the systems administrator. Database design is such that multiple users can log on to the database, however, these users are prevented from making changes to the Microsoft Access mdb file from their terminals. Only a database administrator can update the Access database or assign users for the update task.

### **3.3 Data Products**

#### **3.3.1 Data Mining and Mapping**

The EDM-GIS has the capability to graphically display all data sets associated with environmental study types with respect to base map features. Typical base map layers include states, oil management leases (OML), roads, well fields, and other coverages. Users can use any of these spatial features to select attribute data using any of the typical GIS selection tools - radius select or polygon select functions. The maps allow users to zoom and pan to desired scale and position. Base maps can be imported for use as layers in displaying RDBMS data from .dwg (AutoCad), dxf, ESRI Shape, ArcInfo, Tiger, .tif and other image files, and many other formats (ERML, 2001).

#### **3.3.2 Environmental Decision Support**

The flexible design structure of the EDM-GIS gives users an unlimited number of ways to evaluate environmental data spatially and to develop decision support applications. Evaluations can be in terms of using existing data attributes or aggregates to create new data. Alternatively, table data can be used to generate spatial evaluations and existing spatial data sets can be combined with table data to generate new relationships.

## **4 Conclusion**

The prototype EDM-GIS described in this paper is an attempt by Shell Nigeria (SPDC) to standardize environmental data collection and management practices in order to maintain a corporate commitment to environmentally friendly operations. This is a pioneering attempt by any oil and gas corporation operating in Nigeria. The prototype EDM-GIS has been fully implemented within the HSE-ENV department. However, there are ongoing plans to migrate the prototype into ArcGIS format using ArcObjects development environment when the enterprise-wide software migration to ARCGIS products, presently ongoing at the Geomatics department of SPDC is completed. It is hoped that the success of this initiative will stimulate the interest of environmental regulators and operating companies alike in the implementation of GIS for environmental data management.

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## **References**

Burrough PA, McDonnell R (1998) Principles of Geographical Information Systems. Oxford University Press.

Burrough PA., Van Rijn R and Rikken M (1996) Spatial Data Quality and Error Analysis Issues: GIS Functions and Environmental Modeling. In: Goodchild MF, Steyaert LT, Parks BO, Johnston C, Maidment D, Crane M and Glendonning S (eds) GIS and Environmental Modeling: Progress and Research Issues. GIS World Books, Boulder pp 29-34

Carver S, Heywood I, Cornelius S and Sear D (1996) Evaluating Field-Based GIS for Environmental Characterization, Modeling, and Decision Support. In Goodchild MF, Steyaert LT, Parks BO, Johnston C,

Maidment D, Crane M and Glendinning S (eds) GIS and Environmental Modeling: Progress and Research Issues. GIS World Books, Boulder pp 43-48

Eastman J, Kyem P, Toledano J, Jin W (1995) GIS and Decision Making. UNITAR Explorations in GIS Technology, Volume 4

ERML (2001) EDM-GIS Version 1.0: Installation and User Manual. Lagos.

Goodchild MF (1993) Environmental Modeling with GIS, The State of GIS for Environmental Problem-Solving. Oxford University Press, Oxford

Janssen R (1992) Multiobjective Decision Support for Environmental Management. Kluwer Academic Publishers

Keyworth C and Healey M (1996) Using Geographic Information Systems for Environmental Management of Multiple Facilities. Pollution Engineering, 1:

Sprague Jr RH and Watson H J (1996) Decision Support for Management, Upper Saddle River. Prentice Hall Inc, N.J.

Star J and Estes J (1990) Geographic Information Systems: An Introduction. Prentice Hall Inc, N.J.

Tomlin CD (1990) Geographic Information Systems and Cartographic Modeling. Prentice Hall Inc, N.J.

Tomlinson R (1998). The Canada Geographic Information System. In: Foresman TW (ed) The History of Geographic Information Systems: Perspectives from the Pioneers. Prentice Hall Inc, N.J. pp 21-32