JENRM, Vol. I, No. 2, 69-74, 2014
ISSN: 2026-6189—Research Article

Development of an Open Access Water and Environment Data Repository in Ghana

Kodwo Beedu Keelson[1]*

Abstract
Access to water and environment data in Ghana either in hardcopy or digital formats is very frustrating and time consuming due to the fact that water resources and environmental management related information and datasets are scattered in various files and documents at different ministries, departments and agencies in Accra. It is now common practice for many students, researchers, local and international consultants to use the lack of data as a convenient excuse when conducting desk studies in this sector. The Ghana Hydro-Database Project has therefore been conceived to overcome this limitation. The initial developmental phase involved the use of open source software applications for database management functions and the processing of raw data. A web interface for the dissemination of information and datasets from the repository to the general public has recently been launched. This paper presents a description of the technical approach used to develop this repository and discusses its potential applications for the water and environment sector in the country.

Keywords
environmental information systems — Ghana Hydro-Database — GIS — HEC-DSS — water modelling

[1] *Department of Civil Engineering, Kaaf University College, Ghana*
*__Corresponding author__: kodwobeedu@yahoo.com

Contents

Introduction

Access to water and environment data in Ghana either in hardcopy or digital formats is very frustrating and time consuming due to the fact that water resources and environmental management related information and datasets are scattered in various files and documents at different ministries, departments and agencies in Accra. There has been very little effort over the years to harmonize data from the various government institutions and make it readily accessible to the general public. There is also the issue of poor storage of records that has led to the destruction of historical records dating back to the pre-independence period [1]. It is now common practice for many students, researchers, local and international consultants to use the lack of data as a convenient excuse when conducting desk studies for projects in the water resources sector.

The Ghana Hydro-Database has therefore been conceived to overcome this limitation. This privately funded project is being executed in three phases. The first phase involved the development of electronic data archives and a digital library for water and environmental modelling [2]. The second phase sought to test the applicability of two prototype data catalogues developed in the earlier phase by conducting a number of case study applications [3, 4]. The final phase will attempt to develop internet-based water and environment information systems for all metropolitan areas, municipalities and districts in the country

It is envisioned that this open access electronic data repository when fully operational will provide the general public with up-to-date information on the state of the water and environmental sector. It would also be of immense benefit to water modellers by providing readily accessible and usable baseline datasets which will assist in the characterization of natural and engineered water systems. Most significantly, it will facilitate the training of the next generation of highly skilled hydrologists, civil engineers, water resources planners and environmental scientists who would be able to take advantage of the technological advancements in remote sensing, aerial photography and Geographic Information Systems (GIS). This

paper presents a description of the technical approach used to develop the electronic data repository and discusses its potential applications for the water and environmental sector in the country.

1. Materials and Methods

1.1 Database System

The HEC Data Storage System (HEC-DSS) developed by the U.S. Army Corps of Engineers Hydrologic Engineering Centre is the database system that is being used for the Ghana Hydro-Database Project. HEC-DSS is designed to efficiently store and retrieve scientific data that is typically sequential [5]. HEC-DSS incorporates a modified hashing algorithm and hierarchical design for database accesses that is designed specifically for the storage and retrieval of large sets of data. This includes computed or observed daily flow values, hourly precipitation amounts, rating tables, and radar rainfall measurements. HEC-DSS is not optimized for dealing with small data sets or single data values, nor is it effective at conditional data searches common to relational database systems.

Data in HEC-DSS is stored in blocks, or records, and each record is identified by a unique name called a "pathname". A pathname consists of six parts that describe the data, including its region, location, parameter, beginning time and version. This convention makes the data set self-documenting. HEC-DSS can be installed on a variety of operating systems including Microsoft Windows, Apple Macintosh and Unix platforms. A wide range of industry standard water modelling software packages can be interfaced with HEC-DSS. Additionally, an assortment of utility programs have been developed to load and import data from a range of formats; export data; graph, tabulate and edit data; mathematically manipulate data; and perform various database utility and maintenance functions.

1.2 Graphical User Interface Program

HEC-DSSVue is a graphical user interface for the HEC Data Storage System. This Java-based visual utilities program allows users to plot, tabulate, edit and manipulate data in HEC-DSS database files [5]. HEC-DSSVue will display data in an HEC-DSS file in a tabular or graphical form. The graphics are highly customizable and can be saved in various formats, including jpeg and png, as well as printed or copied to the system clipboard. Data may also be edited in a table or a graph or in Microsoft Excel. HEC-DSSVue also has several utility functions for entering data, renaming record pathnames, copying data to other HEC-DSS files, as well as a variety of other functions. Routine sequences of steps can be programmed in HEC-DSSVue with the Jython scripting language, and executed from user-defined buttons or from batch processes. HEC-DSSVue provides a sorted, filtered list of pathnames for the user to select data sets of their choice. Pathnames from the file are displayed as either an alphabetized list of individual pathnames, a list of pathnames broken into their six parts, or a pathname part list where time-series data start and end dates are shown. Pathnames can be filtered in the list by selecting parts from pull-down boxes, giving the user the capability of quickly selecting the category of data he or she is interested in. The HEC-DSSVue software can be obtained from the HEC web site http://www.hec.usace.army.mil. Fig. 1, Fig. 2 and Fig. 3 show the display of data in pathnames, graphical form and tabular form respectively using the HEC-DSSVue program [5].

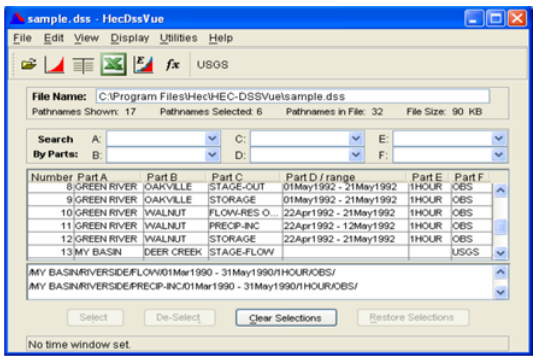


Figure 1. Display of pathnames

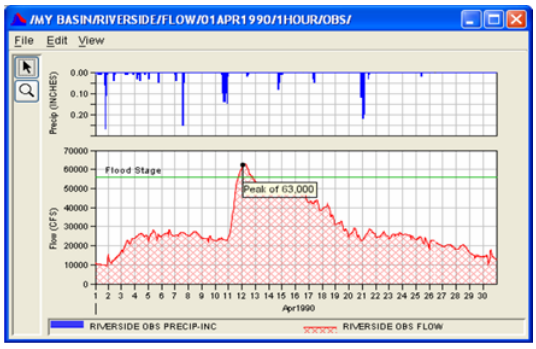


Figure 2. Display of data in graphical form

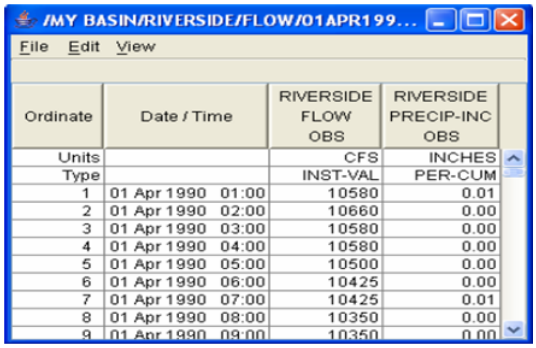


Figure 3. Display of data in tabular form

1.3 Archival Classification System

The archival classification system for the repository is based on three types of electronic data catalogues. These include the Urban Drainage Modelling Project (UDMP), River Basin

Modelling Project (RBMP) and Water and Environmental Sanitation Project (WESP) catalogues. UDMP catalogues are intended for relevant data on urban drainage systems in all the major cities in Ghana. RBMP catalogues are intended for relevant data on all surface water bodies in Ghana. WESP catalogues are intended for aggregated and disaggregated drinking water, environmental sanitation and hygiene statistics on all regions in Ghana.

1.4 Data Quality Assurance

In order to ensure that the data sets that would be compiled into the respective UDMP, RBMP and WESP catalogues are of a high quality, a range of quality assurance measures have been instituted. These procedures which are reviewed periodically relate to the sources of data, data processing methods and the types of GIS and water modelling software tools used in data processing tasks. Hydro-meteorological time series and base GIS map layers are obtained from credible sources such as local and international academic institutions, government departments and agencies, professional bodies and international development agencies. Value added data processing methods for hydrologic time series and GIS map layers are based on guidelines outlined in publications authored by internationally recognized institutions and researchers in the field of environmental hydrology and hydraulics [6, 7, 8]. All computer tools used for time series analysis and GIS processing are the latest versions of open source software packages developed by reputable organizations.

1.5 Data Storage and Dissemination

Data is currently being stored on CD-ROMs, USB 2.0/3.0 flash disks and external hard disks. Data dissemination will be done using both online and offline methods [8, 9, 10]. Data would be provided to interested subscribers based on e-mail or mobile phone text requests.

2. Results

2.1 Electronic Data Catalogues

A total of 30 prototype electronic data catalogues have been developed since January 2011. Five UDMPs have been developed for the Accra, Kumasi, Tema, Sekondi-Takoradi and Tamale metropolitan areas. Fifteen RBMPs have been developed for the Aka-Belikpa, Ankobra, Ayensu, Bia, Densu, Kakum, Ochi Amissa, Ochi Nakwa, Pra, Tano, Tordzie, Oti, Black Volta, White Volta and Lower Volta river basins. Ten WESPs have also been developed for each of the regions in Ghana. Fig. 4 and Fig. 5 show screenshots of the display of data files in the Accra UDMP and Densu RBMP respectively [2].

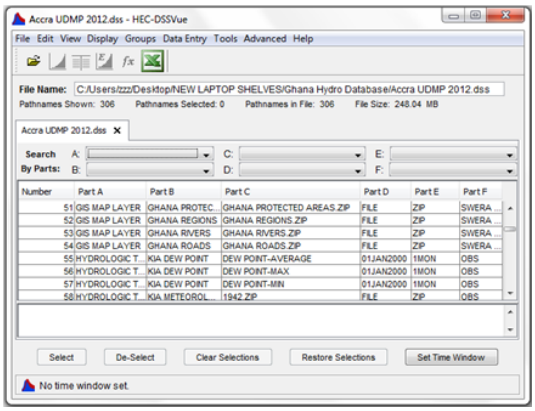


Figure 4. Display of data files in Accra UDMP

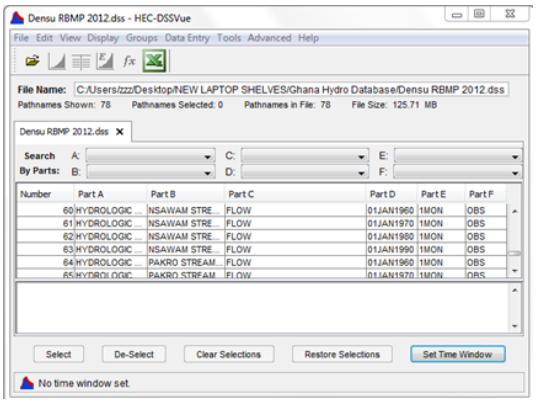
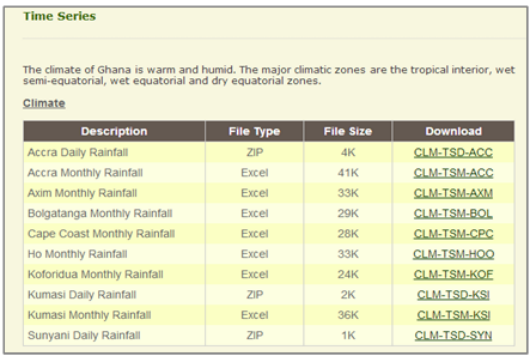


Figure 5. Display of data files in Densu RBMP

2.2 Web Interface

An open access web interface for the Ghana Hydro-Database repository was launched in the first quarter of this year. This internet portal `http://www.ghanahydrodata.com` provides open access to the general public. It covers water and environment themes such as: climate; dams and reservoirs; irrigation schemes; river basins; sanitation systems; urban drainage and flooding; water supply systems; water pollution and wetlands. These datasets are available in different electronic data formats such as time series, thematic maps, fact sheets and GIS vector layers. The web portal currently contains 32 Time Series, 79 Thematic Maps, 167 Fact Sheets and 99 GIS vector layers. Fig. 6 and Fig. 7 show screenshots of the download pages for time series and GIS data respectively.



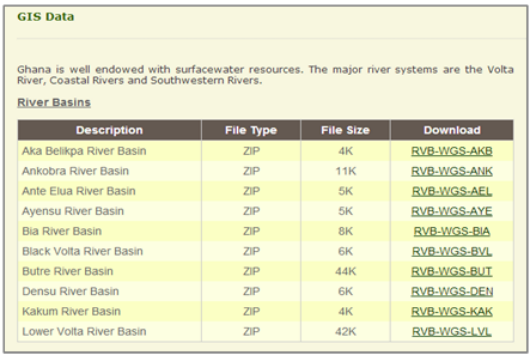
Time Series

The climate of Ghana is warm and humid. The major climatic zones are the tropical interior, wet semi-equatorial, wet equatorial and dry equatorial zones.

Climate

Description	File Type	File Size	Download
Accra Daily Rainfall	ZIP	4K	CLM-TSD-ACC
Accra Monthly Rainfall	Excel	41K	CLM-TSM-ACC
Axim Monthly Rainfall	Excel	33K	CLM-TSM-AXM
Bolgatanga Monthly Rainfall	Excel	29K	CLM-TSM-BOL
Cape Coast Monthly Rainfall	Excel	28K	CLM-TSM-CPC
Ho Monthly Rainfall	Excel	33K	CLM-TSM-HOO
Koforidua Monthly Rainfall	Excel	24K	CLM-TSM-KOF
Kumasi Daily Rainfall	ZIP	2K	CLM-TSD-KSI
Kumasi Monthly Rainfall	Excel	36K	CLM-TSM-KSI
Sunyani Daily Rainfall	ZIP	1K	CLM-TSD-SYN

Figure 6. Download page for time series



GIS Data

Ghana is well endowed with surfacewater resources. The major river systems are the Volta River, Coastal Rivers and Southwestern Rivers.

River Basins

Description	File Type	File Size	Download
Aka Belikpa River Basin	ZIP	4K	RVB-WGS-AKB
Ankobra River Basin	ZIP	11K	RVB-WGS-ANK
Ante Elua River Basin	ZIP	5K	RVB-WGS-AEL
Ayensu River Basin	ZIP	5K	RVB-WGS-AYE
Bia River Basin	ZIP	8K	RVB-WGS-BIA
Black Volta River Basin	ZIP	6K	RVB-WGS-BVL
Butre River Basin	ZIP	44K	RVB-WGS-BUT
Densu River Basin	ZIP	6K	RVB-WGS-DEN
Kakum River Basin	ZIP	4K	RVB-WGS-KAK
Lower Volta River Basin	ZIP	42K	RVB-WGS-LVL

Figure 7. Download page for GIS data

3. Discussion

The Ghana Hydro-Database is possibly the first of its kind in the Anglophone West African sub region. Similar internet-based water and environment data repositories which have been developed in Europe, South East Asia, Oceania and North America have proved useful in those jurisdictions. The Ghana Hydro-Database when fully operational could have numerous potential applications in the water and environment sector in the country. Three options are discussed in this section.

3.1 Dissemination of Environment Information

The Ghana Hydro-Database website is a one-stop platform for the general public to obtain regularly updated information on contemporary local and international environmental issues, such as climate change and illegal small scale mining, and their consequential adverse impacts such as drought, urban flooding and surface water pollution. This information is provided in printer friendly Fact Sheets and Thematic Maps which can easily be downloaded. A review of technical reports on the state of the environment in Ghana prepared by local and international organizations shows that these compilations typically provide information under various thematic categorizations. The Ghana Environmental Protection Agency [11] covers nine themes namely: land; freshwater; forestry; coastal and marine environment; biodiversity; energy and human settlements. A country environmental profile report prepared by the Euronet Consortium [12] covered eight themes including: land; water; air; climate; geology, seismicity and mineral resources; forest, vegetation, ecosystems and biodiversity; human settlements; urbanization, infrastructure and industry; energy production and waste management.

A content analysis comparison of these aforementioned reports with the UDMP, RBMP and WESP data catalogues shows that the Ghana Hydro-Database repository also covers a broad spectrum of environmental themes. However the repository currently does not have any or adequate information or downloadable datasets on air quality, toxicological effects of pesticide use, land degradation, marine pollution, deforestation and nature conservation.

3.2 Environmental Information Systems

Environmental Information Systems (EIS) provide a framework by which environmental information can be combined, structured, managed and made available to planners and decision makers [13, 14]. The term “EIS” broadly encompasses all types of information systems that are related to various environmental themes such as air, soil, water and waste. Typical examples include the German Environmental Information Web Portal and the French Water information system WIS-F [15].

There are a number of environmental information systems in Africa such as the Africa Environment Outlook – Environment Information System (AEO-EIS). The GEO Africa Data Portal (http://gridnairobi.unep.org/Portal/) is the web interface of the AEO-EIS [16]. It covers thematic areas such as: freshwater; land; socio-economic; forests and woodlands; atmosphere; energy; coastal and marine; health and environment; human settlements; biodiversity and wetlands. The web portal can generate output in the form of graphs, maps and tables and one can also download data in varied formats. However, a major limitation to these international data repositories is that the national environmental agencies in most African countries which are supposed to be the primary source of data for these repositories do not have adequate financial resources and logistics to collect data periodically. Data collection activities in most cases have to be financed by international donor agencies such as the European Union and the World Bank.

The successful development of the prototype Ghana Hydro-Database electronic data catalogues and the open access web interface provides the opportunity for the replication of similar systems at the metropolitan, municipal and district assembly (MMDA) level in Ghana. Figure 8 presents a conceptual framework for the design and implementation of the proposed MMDA-EIS. This framework has a modular structure and is therefore easily extensible.

An MMDA-EIS would represent a bottom up approach to the development of environmental information systems at the national level in African countries. This would allow for wider cross-sector collaboration and the spreading of costs among key stakeholders at the local government level. The national environmental agencies would then coordinate these data collection activities as well as collate and interpret results.

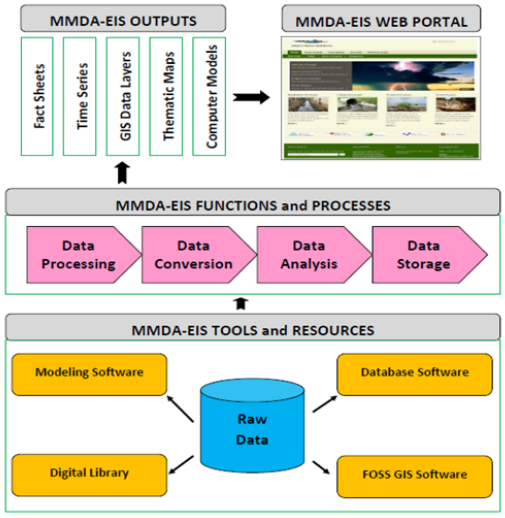


Figure 8. Framework for MMDA-EIS

3.3 Electronic Data for Water Modelling

Hydroinformatics is a growing discipline which aims to harness the benefits of all forms of information and communication technology in water resources engineering and management [17]. Increasing internet connectivity in Ghana means that many non-proprietary desktop software applications can now be easily downloaded unto personal computers at very minimal costs. However, the unavailability of high quality data sets in the requisite electronic formats has severely limited the potential for Ghanaian researchers, practitioners and educators to fully exploit the capabilities of contemporary information system tools.

The Ghana Hydro-Database archives contain daily and monthly hydro-meteorological time series as well as GIS vector and raster layers. These electronic datasets should enable users, such as applied sciences students or consulting engineers, perform a wide range of water modelling tasks including flood forecasting, bridge and culvert hydraulics, landfill water balance analysis, water quality analysis and river basin planning using various industry standard software applications that are freely available on the internet. Table 1 presents a list of some of the recommended open source modelling software and their typical applications [18, 19, 20, 21]. However, it is imperative to note that it may still be necessary to collect additional field data in order to calibrate these simulation models.

Table 1. Open source software tools

Software Tool	Modelling Tasks
WASP	Predict water quality response to natural phenomenon and man-made pollution in streams, rivers and lakes.
EPA SWMM	Simulate the hydraulic performance of various types of wastewater,storm water and combined collection systems.
STOAT	Simulate and predict the performance of various configurations of primary, secondary and tertiary wastewater treatment processes.
HEC-RAS	Perform 1-D steady and unsteady flow simulations for natural streams and engineered drainage channels.
HEC-HMS	Simulate rainfall-runoff processes for urban and rural watersheds.
HEC-ResSim	Simulate hydropower reservoir operations.
WEAP	Simulate alternative water development and management strategies.
MapWindow GIS	Visualization and analysis of vector and raster data including terrain analysis, watershed delineation, georeferencing, data import and export.

4. Conclusion

This paper has presented a description of the technical approach used to develop the Ghana Hydro-Database electronic data repository and discussed its potential applications for the water and environment sector in the country. By the successful completion of the 5 UDMP, 15 RBMP and 10 WESP prototype catalogues, a standardized procedure for developing low-budget electronic data archives through the exclusive use of open source software applications has been pioneered. Most significantly, the data formats that can be downloaded from the web interface will facilitate the use of several industry standard water modelling and GIS software packages by Ghanaian researchers, practitioners, educators and students.

Further work which will commence in the first quarter of Year 2015 will involve the development of two prototype Environmental Information Systems i.e. Accra Metropolitan Area Environmental Information System (AMA-EIS) and the Densu River Basin Information System (Densu-RBIS).

Acknowledgments

The author would like to express his gratitude to the Kspyx Ltd for providing funding for this research project.

References

[1] E.O. BEKOE, (2005). Application of a hydrological model in a data-poor tropical West African catchment: a case study of the Densu Basin of Ghana, PhD *Thesis, Cranfield University at Silsoe, United Kingdom*.

[2] K. B. KEELSON (2012). CThe Ghana Hydro-Database Project - IT applications in water resources engineering and management, 1st GIMPA School of Technology Workshop on Information Technology and Systems, Accra, Ghana.

[3] B. OSABU, B. ARMAH, and M. KUGBETA. (2012). Prediction of post-closure landfill percolation and evapotranspiration rates for waste disposal sites in the Greater Accra Metropolitan Area, *BSc. Degree Thesis, Kaaf University College, Ghana*.

[4] P. TUSAH, and E. GYASI-YEBOAH(2014). Rainfall-runoff modelling of the Odaw–Korle basin, *BSc. Degree Thesis, Kaaf University College, Ghana.*

[5] HEC (2009). HEC Data Storage System Visual Utility Engine user's manual, Report No. CPD-79. *US Army Corps of Engineers Institute of Water Resources Hydrologic Engineering Centre, Davis, California*.

[6] [6] USGS (1982). Guidelines for determining flood flow frequency, Bulletin 17B of the Hydrology Subcommittee. *United States Geological Survey, Office of Water Data Coordination, Reston, Virginia*

[7] J. R. STEDINGER, R. M. VOGEL, and E. FOUFOULA-GEORGIOU (1993). Frequency analysis of extreme events, In D.R. Maidment (Ed.), *Handbook of Hydrology, McGraw-Hill*

[8] WMO (2008). Guide to hydrological practices: Hydrology from measurement to hydrological information, WMO-No. 168, *World Meteorological Organization, Geneva, Switzerland.*

[9] UNESCO (1992). Information related to water and environment: databases available on-line and on CD-ROM, *International Hydrological Programme, IHP-IV Projects M-2-1 and M-2-2, UNESCO, Paris.*

[10] WHO (2003). Hydrological data management: present state and trends, WMO Operational Report No. 48, *World Meteorological Organization, Geneva, Switzerland.*

[11] EPA (2005). Ghana state of environment report 2004. *Environmental Protection Agency, Accra, Ghana.*

[12] EC. (2012). Country environmental profile Republic of Ghana, Final Report. *European Commission.*

[13] M. HAKLAY (1999). From environmental information systems to environmental informatics - Evolution and meaning, CASA Working Paper 7. *Centre for Advanced Spatial Analysis, University College London, United Kingdom.*

[14] C. PARADZAYI and H. RUTHER (2002). Evolution of environmental information systems in Africa. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV, Part 6/W6.* 73-77.

[15] EC Shared environmental information system, European Commission, `http://ec.europa.eu/environment/seis/real_life_de.htm`[Accessed 5th May, 2014]

[16] UNEP (2005). African Environment Outlook Environment Information System, United Nations Environment Programme, `http://gridnairobi.unep.org/aeo_eis/` [Accessed 5th May, 2014]

[17] D. BUTLER, and J.W. DAVIES, J.W. (2000). Urban Drainage, E & FN Spon, New York, 2000.

[18] D. CHEN, C. CARMONA-MORENO, A. LEONE and S. SHAMS(2008). Assessment of open source GIS for water resources management in developing countries *European Commission, Joint Research Centre, Institute of Environment and Sustainability*.

[19] WRC (2014). STOAT Installation and user guide, WRc Plc, *Swindon, United Kingdom,*

[20] J. P. HEANEY, D. SAMPLE, and L. WRIGHT(2000). Geographical information systems, decision support systems, and urban stormwater management. *University of Colorado, Boulder, Colorado.*

[21] D. C. MCKINNEY (2004). International survey of decision support systems for integrated water resources management, Technical Report. *US Agency for International Development, WATMAN Project, Bucharest, Romania.*