EFFICIENT DAM MANAGEMENT USING SQL AND GIS

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Abstract: *This paper discusses use of SQL and GIS tools in nowadays dam management. Dam management requires the use of a highly-sophisticated measuring, monitoring and general management tools, since it is not only economical aspect of importance of these projects, but also about the security risks that require the highest possible caution and a precisely-developed control systems. Therefore, SQL and GIS are tools to be considered and implemented. GIS is widely used in spatial planning and connected management processes - because it allows easy way of storage, processing, analysis, modelling and display of spatial data. It has a wide range of features and is used in many areas. Structured Query Language (SQL) is a programming language for databases, written to be easy to understand and to use. SQL provides integration and presentation of data, optimization, easy reporting and analysis. In hand of trained professional analysts, SQL can make database search efficient and flexible, which is the key feature in demanding management processes as dam management.).*
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1. INTRODUCTION

Dam management is a very demanding task that can be adequately performed only with the help of modern tools for creating and managing databases. The importance of efficient dam management has been recognised and several authors have considered developing their solution. Rodrigues et al. (2002) proposed a system DamAid which is divided into two components, the Emergency Manager component and Geographic Information component. Rodrigues et al. (2002) induce that the main advantage using Geographic Information component are low cost and simple implementation, but the disadvantages are lack of GIS analyses tools and large amount of RAM memory. Jeon et al. (2009) developed KDSMS which is enterprise management system covering the detailed activities, notifications, reports and work flow of all groups from field engineers where all the data is stored in databases. Qi and Altinakar (2012) studied the possibilities of GIS-based dam-break decision support environment systems and they concluded that such system is user-friendly and reliable tool. In this paper examples of mentioned systems will be provided, and different method based on GIS and SQL will be explored. As a database, GIS is widely used nowadays tool. It is difficult to handle the management of spatial planning related processes in general without GIS. GIS allows storage, processing, analysis, modelling and display of spatial data. Because of its wide range of features, this system has great use in many areas. Structured Query Language (SQL)is a programming language intended for working with databases. It is used to create, modify and search specific data that are usually organized in the form of a table. Each table contains its own data and the purpose of SQL is to find and change the information in the way we want it.

2. SQL and GIS

SQL stands for Structured Query Language which is a language for databases querying from language group called RDBMS (Relational Database Management System). In other words, SQL is a database management system like Oracle, IBM DB2, Ingres, Microsoft SQL Server, Microsoft Access and others. It is originally developed in IBM in the 70's and then became the main language for working with databases. SQL is written to be easy to understand and use. Also, it is a declarative type of language, which means it is stated what to get, but without specific instructions on how to get it (as in case often procedural type of language). SQL provides integration and presentation of data, optimization of work, and reporting and analysis. With the knowledge of SQL languages, analysts can compile their SQL queries to search the database making it more efficient and more flexible (Mujadžević 2016).

The spatial database is a database system (DBMS) with additional functionality of spatial data management in a way that spatial data are present in the model and queries (geometry and relationships among them), and that spatial data is integral part of the system in such a way that there are spatial indicators and effective spatial relations algorithms. Spatial database provide the user with dual data benefit: storage mechanism and tools for analysis data, and the goal is not just to enable visualization of spatial data but also to give an answer to complex attribute and geometric queries (Tkalčec & Šimec 2014).

Specifically, databases do this by using geometric data. It is a data type that is equal to all other data types in the database and can be used to store data in tables. In order to manipulate such data type, spatial operators (functions) are defined. So, by using curves that can be converted into lines, SQL can measure the length, distance, and surface. It therefore supports geodetic and planar measurements (planar measurement is simpler in terms of calculation and applies to planar systems) (Tkalčec & Šimec 2014).

Today it is almost impossible to imagine the acquisition of new knowledge and geography research and the successful and efficient management of spatial resources without GIS. GIS (Geographical Information System) is the spatial data management system for integrating, saving, editing, analysing and displaying geographic information. “GIS can be implemented as a comprehensive, multipurpose system (e.g. GRASS, ArcGIS), as a specialized, application-oriented tool (e.g. GeoServer), or as a subsystem of a larger software package supporting handling of geospatial data needed in its applications (e.g. hydrologic modelling system, geostatistical analysis software, or a real estate services Web site). The multipurpose systems are often built from smaller components or modules which can be used independently in application-oriented systems.” (Neteler & Mitasova 2013).

GIS enables different users to have access to different information, allowing users to input and modify data while others are allowed to view and analyse them. Through the online user interface, access to the widest circle of users is enabled. GIS can be described as “a smart map” since it enables creating interactive questionnaires (user-generated research), spatial information analyses and data editing. Considering its features, GIS can be used for scientific research, resource management, asset management, development planning, cartography and road mapping.

Since many areas of modern management are based on multidimensionality and interdisciplinarity, especially in analytics and research work, GIS is an inevitable tool, especially in spatial management areas such as spatial planning, nature and environment protection, cultural heritage protection land policy, rural development, tourism development and energy etc. This tool can be used to evaluate landscape, create spatial models and strategic plans, landscape impact assessment including visual analysis and simulation, landscape character assessment, and landscape plans. Therefore, GIS application is needed and it is adequate in various sectoral instruments at all levels of decision-making processes within environmental and spatial planning (Tomić Reljić et al. 2017).

3. DEBATE ON DAM MANAGEMENT EFFICIENCY USING SQL AND GIS

Dam is a building constructed over a river valley or basin to exploit the water mass. Dam enables to create a lake, which is used to regulate the water regime for more efficient flood protection and water use for water supply, soaking, electricity production, navigation and recreation. Dam management is primarily concerned with monitoring and management of river and lake water levels, but there are also all associated management processes, besides, the exploitation of the energy that the dam produces, such as spatial planning or-environmental impact. For example, in order to monitor and take actions to prevent damage or demolition of the dam, all events related to the dam and its environment are constantly monitored (shifts and stresses of the dam and foundation soil, meteorological and hydrological conditions, seismic activity, deformation measurement…) (Martać et al. 2016).

Dams are “of vital importance for society, because they are used to produce electricity and water supply” (Martać et al. 2016), so it is highly important to prevent demolition or damage of the dams. The most important issue in this process “is necessary to establish communication between metering systems and computer models” (Martać et al. 2016).

It is superfluous, but important, to point out that the current dam (safety) management is based, besides the physically, mostly on software-supported technical systems. This established system of dam safety management is used for (Martać et al. 2016):

- tracking and monitoring the behaviour, which consists of continuous monitoring, measurement and determination of compliance measured values and their expected values,
- checking of the dam safety, which may be initial, periodic and extraordinary, and refers to determining the condition of the facilities and determining the degree of the facilities safety.

Workflow of mentioned system is shown on **Figure 1.**

Monitoring and tracking relies on adequate statistical models. In order to ensure the possible sudden and unpredictable occurrences of the objects, during the demolition of the dams, constant measurement of deformation or scuffle of high structures and hydroelectric power plants and the protection of the environment and downstream area from damage and disaster is carried out. Collecting the necessary data is based on geodetic technical monitoring carried out with the most accurate geodetic measurements, for rational maintenance of facilities during use.

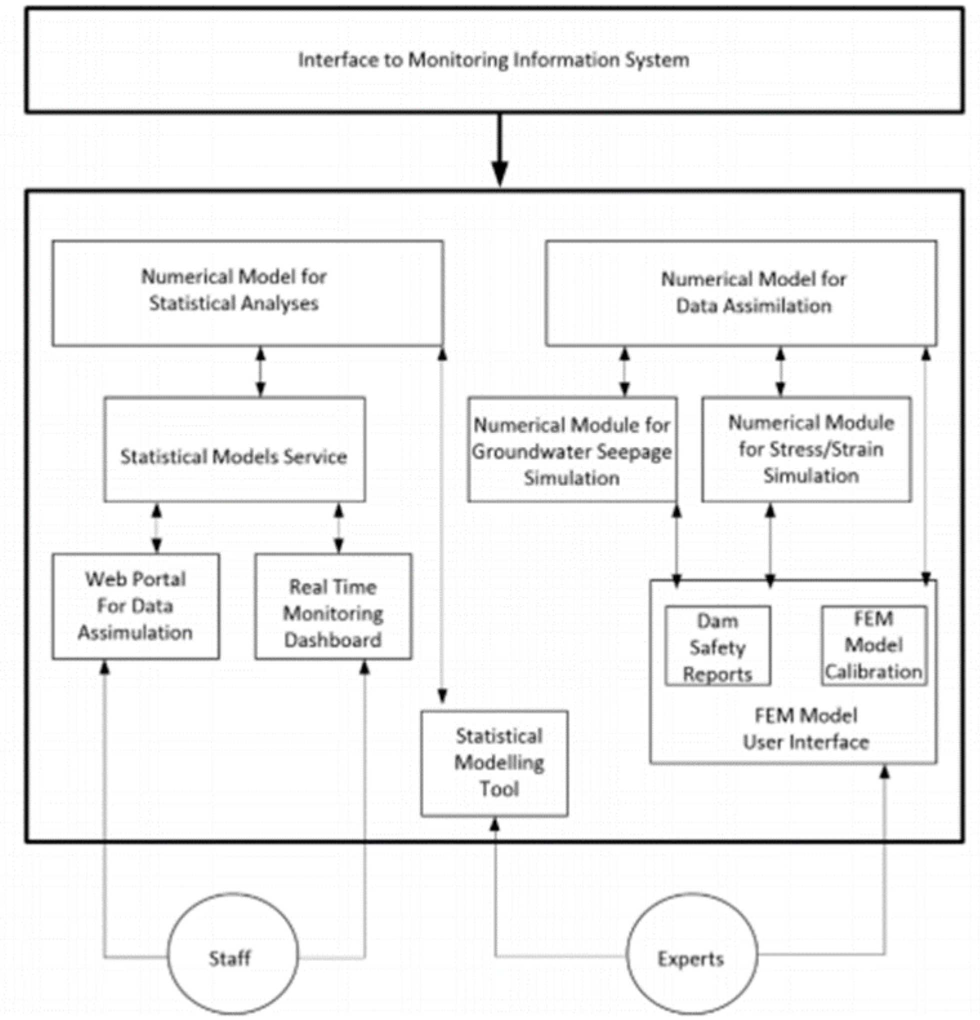

Figure 1. *Workflow of dam management software system (Martać et al. 2016)*

One of the key processes in dam controlling is geodetic measurements of the displacement. These measurements include all measurements in order to determine the shape or soil shape change under the influence of external or internal forces. The object is idealized with a certain number of points whose position is determined relative to the reference or base geodetic basis outside the range of possible shifts. Geodetic methods determine the position changes of individual points on the object, and deformation can be determined based on the displacement measurement results. The real behaviour of an object can only be determined by well-designed and well-made observations, as well as expert data processing. Example of deformation monitoring is shown on **Figure 2.**

Figure 2. *Deformation monitoring (Jeon et al. 2009)*

The most important thing is to timely record all events and conditions that could affect the security of objects, so the database must be multidimensional, multidisciplinary and interactive (Ožanić 2002).

In selection of software system to support dam safety management, it is highly important that the system we choose implements the use of data in real-time, and also "the expandability and interconnection with other information system" (Martać et al. 2016). One of the most used tools to create this sort of systems are spatial databases based on SQL, since it allows users to see "current measurements (measurements in real time) as well as the estimation of the state of the dam at the time" (Martać et al. 2016).

Considering demands of dam management, GIS is the perfect tool, since it enables application of spatial analysis methods that can help explain the fundamental issues of geographic research, understanding of spatial distribution patterns, relationships and processes and modelling their future development (Toskić 2015). "Due to strong spatial component, hydrotechnical systems are ideal for analysing using GIS. All the structures and systems, whether it is a water supply or wastewater drainage system or an irrigation one, are spatially located and have their own numerous characteristics. Their display and a systematic analysis greatly facilitate the application of GIS. Major role in such systems have hydrological data. The spatial distribution of such data, especially rainfall, is extremely important, so monitoring of such data by GIS is very practical." (Dadić et al. 2014).

Using GIS to build a system for the security surveillance, it is possible not only "to manage the data and information of tailings scientifically and effectively, but also give full play to the advantage of computer's storage of massive data" (Martać et al. 2016). GIS offers the interactive operation of spatial query and analysis which provides accurate and convenient search management, alteration and statistics of data.

Figures 3, 4 and **5** presents workflows of dam management systems developed by authors mentioned in Introduction. It is important to see that each solution has GIS component and database component. It is possible to input different types of data in database. Information such as the fluctuation of the water level are possible to obtain with the observation of the height of the seepage line of dam body, the index of dry coast, the water level in the tank, deformation and deviation of the dam body. This is important for forecasting stability of the dam body, achieving safe management of tailing pods and early prediction of danger.

As it is obvious, dams have a wide range of different instruments, such as rain gauges, water level gauges, flow meter, precipitation meter, etc., so in order to improve the observation and supervising, all these instruments should be brought into a single network and it is most important to enable those instruments to communicate with each other. This problem is mainly solved by using SensorML and Wireless Sensor Networks (WSNs).

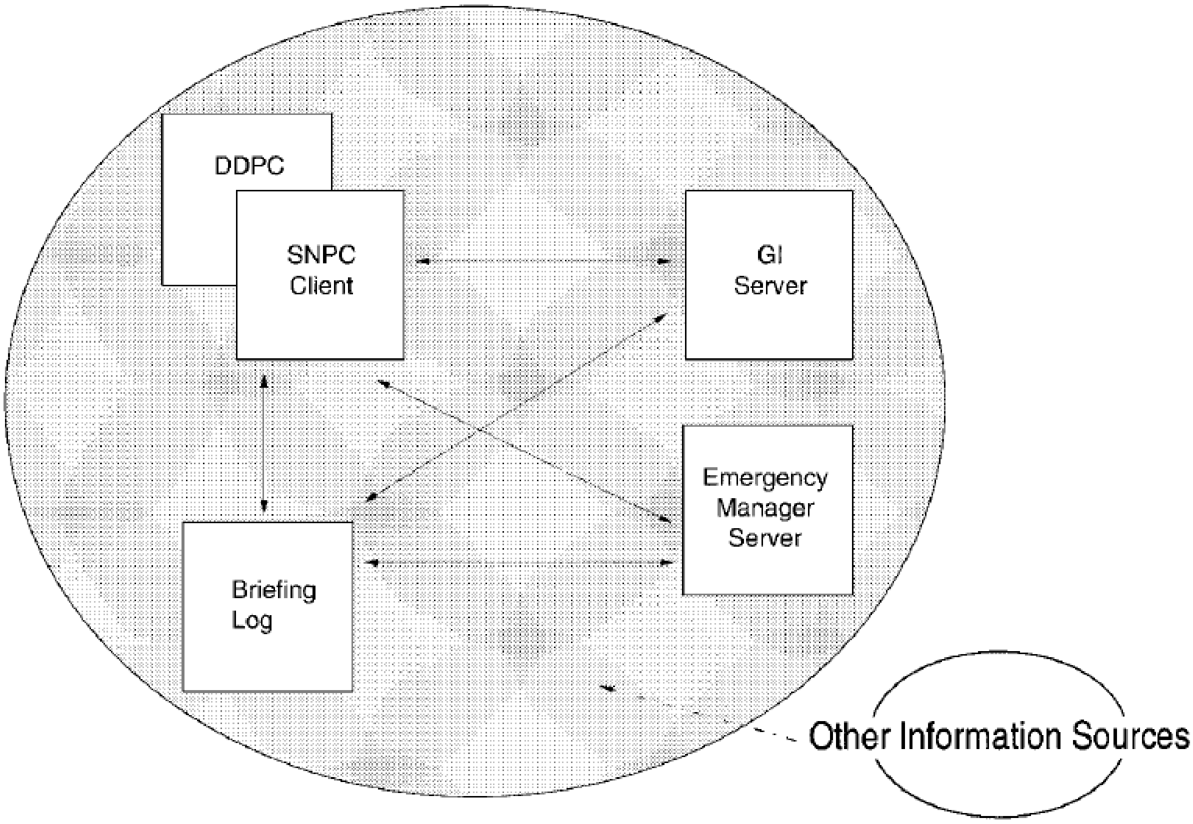

Figure 3. *DamAid Architecture (Rodrigues et al. 2002)*

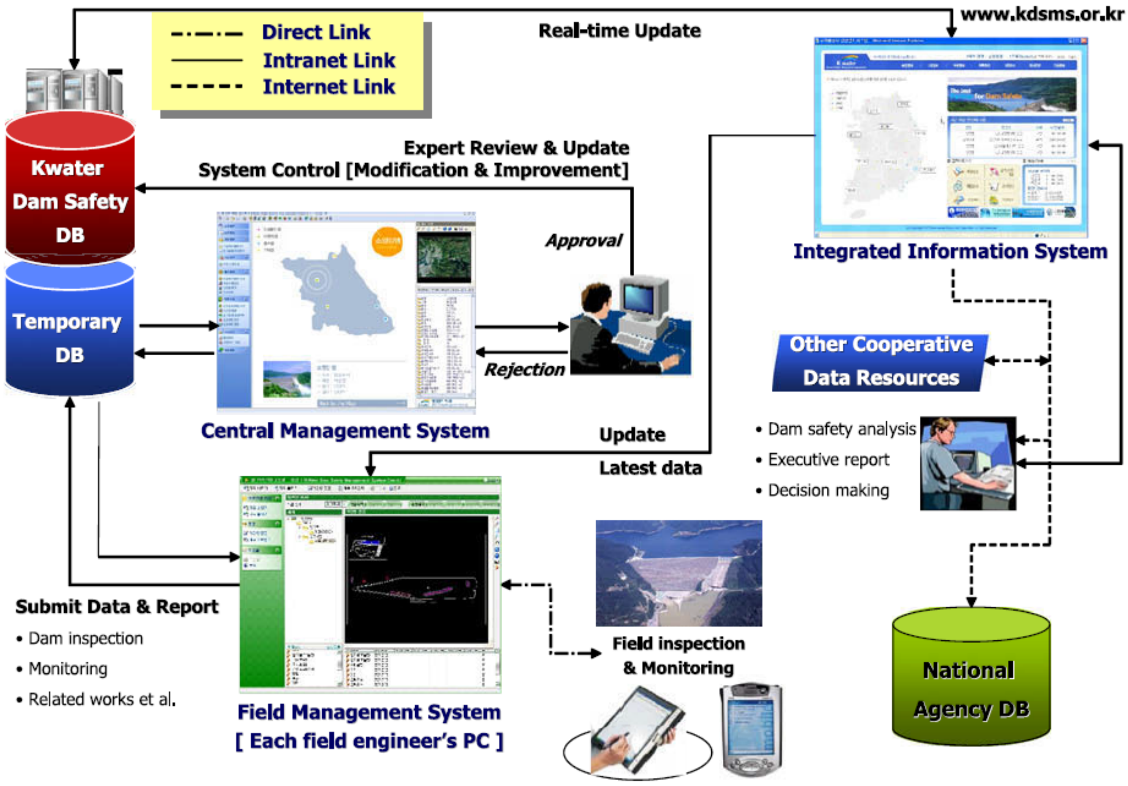

Figure 4. *Work process and data management architecture (Jeon et al. 2009)*

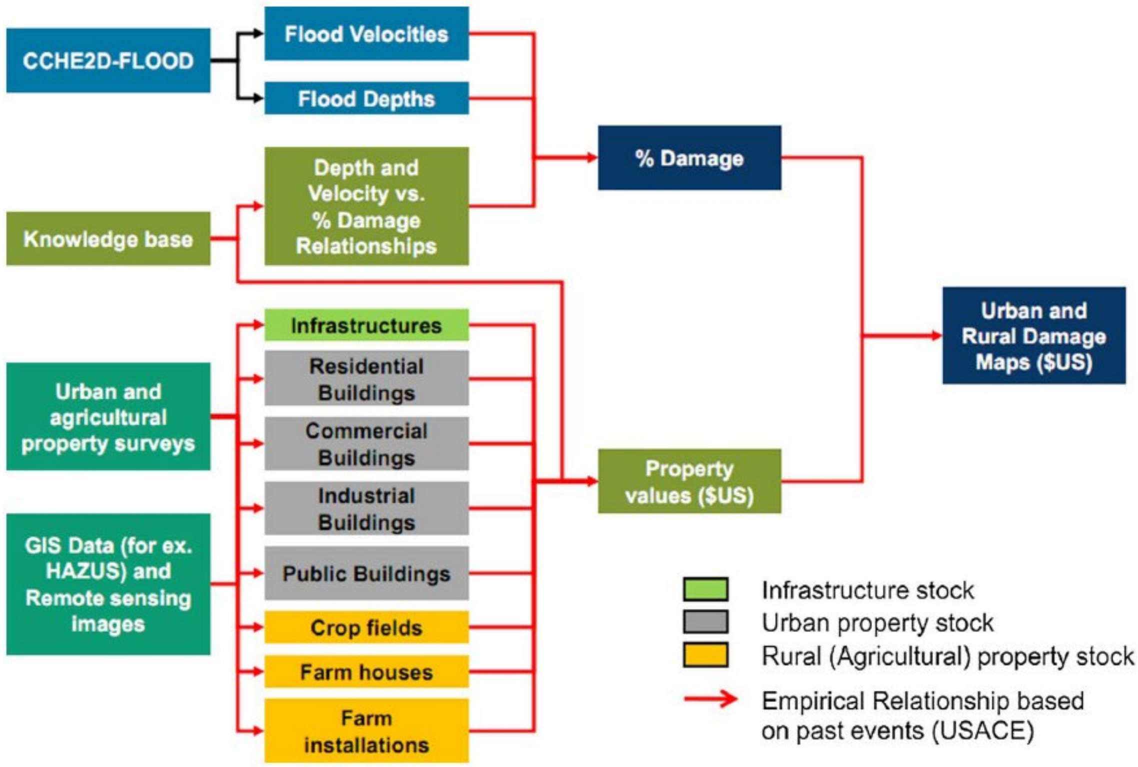

Figure 5. *GIS-Based Decision Support System (Qi & Altinakar 2012)*

Data collected can easily be implemented in GIS, and based on data, GIS software is able to make map service, develop the web page which can easily communicate with map service and carry on web site management, so that clients can use either vector or raster map and fulfil graphical operation, query, display, statistical and spatial analysis. As seen from **Figures 1, 3, 4** and **5** different authors proposed different solutions on dam management. For example, The ArcIMS, as one of the WebGIS software, composed of a few independent function units such as Author, Designer, Administrator and Manager etc., "can distribute or share various data on the internet, and it adopts distributed component and three-layer architecture, so the operation efficiency of system is high, and the function of upgrade is strong" (Martać et al. 2016). This kind of software is selected to organize and manage data, and to analyse information as well as to distribute results, etc., and offers next functions: map releasing, basic function, query function, statistic function. The attribute data are managed by SQL Server database, so the attribute database contains many tables, like table with basic information or table with hydrology data, the dam body character table, the sluice building character of dams and the benefit character of dams etc. Each table is connected by only dam code and spatial data is linked with attribute data by dam code, so the system is visual, intuitionistic and vivid, with query function as one of the main functions. Conditional query is also known as SQL. By selecting name, province basin, water system or dam height, users can acquire dam data. Each of mentioned dam management systems have some issues in processing possibilities or data structuring for database input. GIS became irreplaceable tool for managing spatial and other data but authors chose different database tools for managing and querying datasets. Authors of this paper consider SQL as the best solution for querying datasets. It is simple, user-friendly, easy to learn language but it has its limitations on large datasets.

4. CONCLUSION

GIS enables capturing, storing, checking, and displaying data related to positions on the map and thanks to its multidimensional character, GIS can show many different kinds of data on one map. This feature enables users to define, analyse and understand patterns and relationships in more easy and precisely way, and that is very important in complex and highly demanding management processes such as a dam management. Furthermore, considering the fact that data contained in GIS have their mutual topological and logical connections, GIS can perform various spatial and logical analyses. Results can be interpreted in different ways, depending on user needs. As a platform, GIS enables different kinds of information to be accessed simultaneously by a variety of types of users, ensuring timely data updating and constant, real-time access to the same. Efficient dam management couldn't be considered without support of GIS. However, GIS can have complex structure and it could be difficult to use. In combination with GIS dam management relies on different database solutions. In this paper it is considered the use of SQL which has advantages in ease of use but limitations on large datasets.

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