Journal of the Korean Nuclear Society
Volume 36, Number 3, pp.263～275, June, 2004

〈Technical Note〉

Database Modeling and Environmental Information for a Radioactive Waste Repository Site

S. M. Park, C. G. Rhee, J. B. Park, H. J. Lee, and Chang Lak Kim
Korea Hydro & Nuclear Power Co., Ltd.
150 Deokjin-dong, Yuseong-gu, Daejeon 305-353, Korea
smpark365@khnp.co.kr

(Received September 29, 2003)

Abstract

For the safe management of nuclear facilities, including a radioactive waste repository, data about the facility site and the surrounding environment must be collected and managed systematically. This is particularly true for a radwaste repository, which has to be institutionally controlled for a long period after closure. The objectives of this study are (1) to establish a systematical management plan for information about a radwaste repository site and its environment, and (2) to design a database management program for this information, based on the Relative Database Management System (RDBMS). The spatial data are designed by the geodatabase, which is a new object, based on the RDBMS, to manage spatial information related to the database. To meet this requirement, a new program called "Site Information and Total Environmental data management System (SITES)" is being developed. The scope that produced from the first step of the present study for development of the SITES is introduced. The database is designed to combine spatial and attribute data, and is designed for the establishment of the Geographic Information System (GIS). The hardware and software systems are designed with consideration given to the total data management of the items within the radioactive environment.

Key Words : SITES, geodatabase, GIS, radwaste repository

1. Introduction

In general, for the safe management of a radioactive waste repository, information about the site and its surrounding environment have to be collected and managed systematically starting from the initial site survey. This is particularly true for a radwaste repository, which has to be institutionally controlled for a long period after closure; for safety, data on the repository site will be continuously collected and maintained by means of a monitoring program. As the data collected from the environmental assessment, the site investigation, and the monitoring of the site increases, the complexity of the data will also increase, leading to difficulties with efficient data management. Therefore, a powerful data management system is required to manage the data for a radwaste repository site.

The proposed data management system is

Table 1. Relevant Regulators and Guides Used in SITES

RER	STMR 94- 4	Site characterization of LILRW disposal
	STMR 96- 9	Site criteria of LILRW repository
	STMR 96-12	Site characterization of spent fuel interim storage
	STMR 96-11	Function of LILRW disposal facility
	STMR 91-11	Design criteria of LILRW facility
SCR	STMR 01-25	Environmental survey on radioactivity around nuclear facility and radiation environmental report
	STMR 01-24	Environmental report on nuclear facility
	STMR 96- 4	Site characterization of LILRW disposal
	STMR 96-12	Site characterization of spent fuel interim storage
	Reg. guides on nuclear	Technical standards on Radiation safety management
ER	Law of environmental assessment	
	Law of Environment policy	
	Law of Nuclear	Chapter 11-2
	STMR 92- 8	Environmental assessment Reporting on Spent fuel interim storage
	STMR 92- 9	Environmental assessment Reporting on LILRW disposal facility
	STMR 90-11	Regulatory on radiation dose
	STMR 85- 5	Guides on environmental survey around nuclear power plant
	EMR 91-30	Regulatory on environmental assessment reporting
	Law of Water environment	Detailed rules
	Law of Atmosphere environment	Detailed rules
	Law of prevention from Noise and oscillation	Detailed rules

expected to improve public acceptance of nuclear waste management, because it can demonstrate the safe and clear management of nuclear waste to the public. In addition, a system incorporating the Geographic Information System (GIS) will allow a more efficient analysis of the data from the nuclear waste site and facilities. In this study, we introduce a scheme for using the GIS in the database of the radioactive waste disposal.

A new system under development that combines the GIS and the nuclear site database has been named the " Site Information and Total Environmental database management System," or "SITES".

In this paper, we introduce the study of the database and the design of the SITES for the integrated management of a radwaste repository. The relevant regulations, laws, standards, and guiding factors for a proper safety assessment of a radwaste repository were considered during the design of the SITES (see Table 1). The limitations of a commercial GIS database system, in terms of efficient management of attribute data, are described. A great deal of effort was spent on integrating the Relative Database Management System (RDBMS) and Geodatabase for SITES. The design of the radioactive environment database model was intended to accomplish the following: 1) to model the user' s view of radioactive environmental data, 2) to define objects and relationships, 3) to identify the representation of entities, 4) to design separate spatial and attribute databases, and 5) to match the File Identity (FID) between the spatial and attribute tables.

2. GIS Data Model

Previous research on GIS data models for radwaste disposal management has been performed in many countries; however, a system using GIS that integrates site information and environmental data has not been developed. Hanford, located in the US, is using the Hanford Geographic Information System (HGIS) for site data management and the Hanford Environment Information System (HEIS) for an environmental sampling database and on-line search. These two systems will soon be integrated under the name "Integrated Environment Safety and Health Management System (ISMS)"[4].

The purpose of using the GIS in this study is to provide a spatial framework to support decisions for the intelligent use of the environmental data and to manage the man-made environment. In this study, the database is designed to part the spatial and the attribute data, and stores the data in a relational database. By this method, the GIS can achieve a higher performance.

There is, however, a critical shortcoming to storing spatial data directly in a relational database. Features in the GIS are aggregated into homogeneous collections of points, lines, and polygons with generic behavior. The behavior of a line representing a road is identical to the behavior of a line representing a stream. The generic behavior enforces the topological integrity of a dataset. Therefore, it is also desirable to support the special behaviors of streams.

To overcome this kind of limitation, a new object-oriented data model called the 'geodatabase data model' was selected as the spatial data model for our study. The geodatabase data model was introduced by the Environmental Systems Research Institute, Inc. (ESRI), which developed the ArcSDE as commercial GIS software for the multi-user geodatabase.

2.1. ArcSDE: Geodatabase Model

The native data format for ArcGIS is called the geodatabase. The geodatabase is a relational database that includes spatial data types--in addition to standard data types like numbers, characters, and dates--and a rich set of tools for modeling relationships between GIS data and for maintaining its integrity during editing. It is possible to extend the functionality of several industry-standard RDBMS and store the spatial data by using ArcSDE. The ArcSDE software consists of two major components.

The ArcSDE server works cooperatively with the RDBMS server to store and retrieve spatial data. RDBMS provides physical storage in the form of relational tables, while ArcSDE interprets the contents of the tables for use in GIS. By default, RDBMS and its command interface, the structured query language (SQL), are not equipped to process spatial data, although they do allow users to store raw data in virtually any format. ArcSDE enhances RDBMS and SQL by interpreting geometric data, which is stored in an unformatted, binary column on the RDBMS tables.

Client applications use the server to either load or fetch spatial data. Typically, the client application resides on a separate host computer from the ArcSDE and RDBMS servers. Clients communicate with the ArcSDE server over a TCP/IP network. By sharing the processing workload with its clients, the ArcSDE server is free for service requests from many client applications simultaneously. The functionality built into the ArcGIS client applications also allows these applications to connect directly with the database without using the ArcSDE server.

2.2. ArcSDE: Data Storage Model

Spatial data is stored in tables of RDBMS, divided into business, feature, and spatial index tables. As shown in Figure 1, the business table contains the attributes of the feature class. Each row in the business table represents one spatial feature (single- or multi-part), with a unique shape identifier. The unique shape identifier is stored in the spatial column of the business table. The name of the business table is the name of feature class. Each record is related to a corresponding row in the feature table or "F table" by means of the unique feature identifier.

The F table physically stores the geometry in a binary column. There is a relationship between the business table and the F table. The final tables stored in the database for the feature class are the spatial index table or "S table." The S table stores grid tiles and feature envelopes for the feature class. Only grid tiles referred a feature envelope have an entry in the table. The feature identifiers are also stored within the S table to provide 'one to many' relationships from either the business table or the F table to the S table. The rows in the business, F and S tables are connected through a unique feature identifier. ArcSDE will maintain the integrity of the feature class tables whenever features are added, deleted, or modified. Optionally, related attribute tables can be stored in the database. These tables would be linked to the business table by a key. ArcSDE provides a unique ID to each feature class loaded into the database. This ID is used to name the supporting F and S tables and to relate them to the business table.

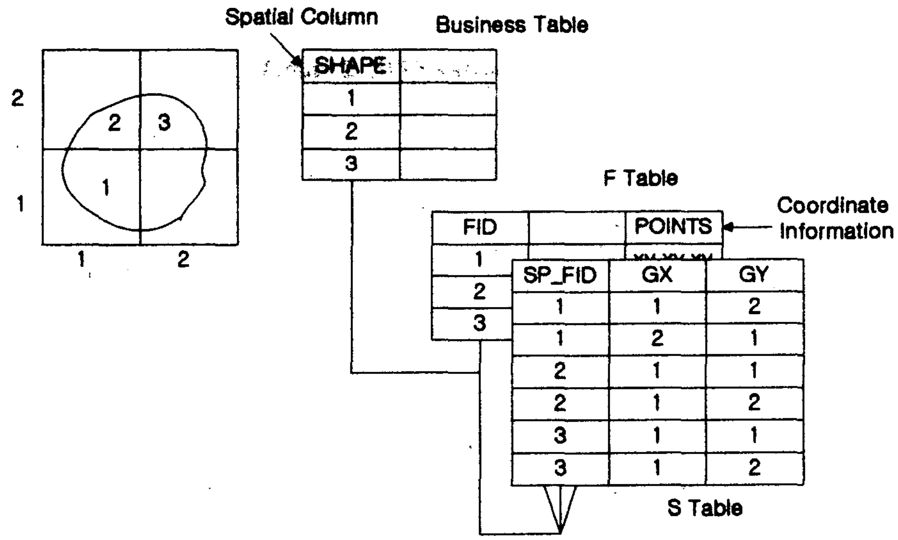

Fig. 1. ArcSDE Data Storage Architecture

3. Design of the SITES

3.1. Classification of the SITES Data

The purpose of the Site Information and Total Environmental data management System (SITES) is to make it possible to systematically manage the relevant information from a radwaste disposal site and its environment. Various items such as geology, atmosphere, ecology, and others are taken into consideration for the SITES design. The relevant regulations and guides are also reviewed for this study (See Table 1).

The SITES program comprises two modules: the Database Management System (DBMS) and the Monitoring and Assessment (M&A). The DBMS module is composed of two sub-modules (See Figure 2). One is the Site Information Management System (SIMS) that manages data produced from the site characterization, such as topography, geology, hydrogeology, and engineering geology. The other is the Environmental Information Management System (ENVIS) that manages data produced from the environmental assessment. To enhance the effectiveness of SIMS and ENVIS, the objects are

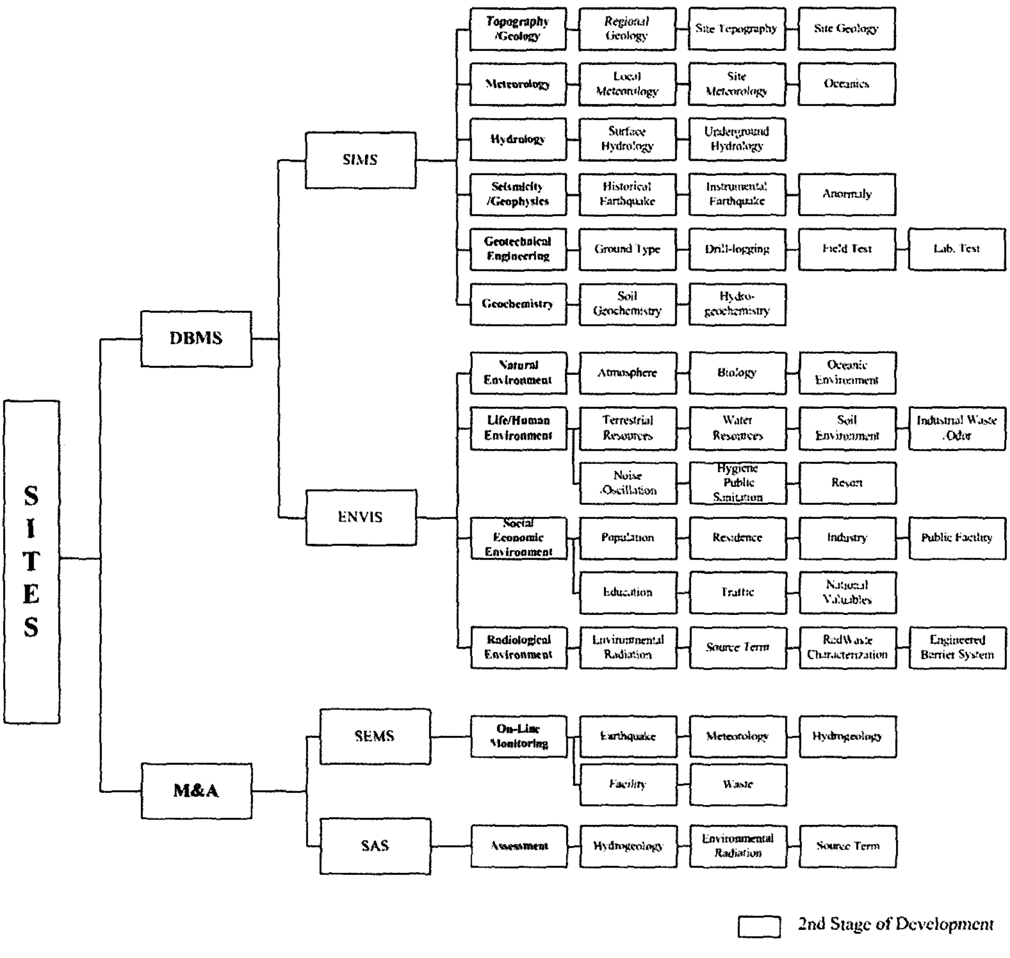

Fig. 2. SITES Structure of Database Items

itemized by analyzing the end-user's demands, reflected by domestic regulatory guidelines. The mutual relationships of each item in SIMS and ENVIS are analyzed, and the results are used for the database design.

The next step in the development of the present project is to construct the sub-modules of M&A: the Site Environmental Monitoring System (SEMS) and the Safety Assessment System (SAS). The SEMS will manage the driving stories and inspection records of the individual measuring instruments and facilities, the on-lined site, and environmental monitoring data. The SAS will analyze and predict the monitoring results. When completed, the SITES will be run via the World Wide Web. It will make a valuable improvement in long-term management effectiveness and will function in the environmental monitoring of disposal facilities. This future development of SITES will be discussed in a coming paper.

3.2. Hardware Configuration

The scope and function of the SITES program will be explained, beginning with the first step of the SITES development. The design concept of the SITES will follow. The SITES is developed with a database and a three-tiered server/client system that is composed of a server, a middle-ware, and a PC client. The server is for RDBMS and GIS management, and the PC client offers a variable Graphic User Interface (GUI) in respect of end-users. The middle-ware is for the system management such as transactions. For this system, ArcSDE of the ESRI is used for unifying the spatial and attribute data to the RDBMS. The hardware composed of a client, a server, and a middle-ware, as shown in Figures 3 and 4, were designed in this study.

In the server/client system, a data management program runs on the server, providing access to

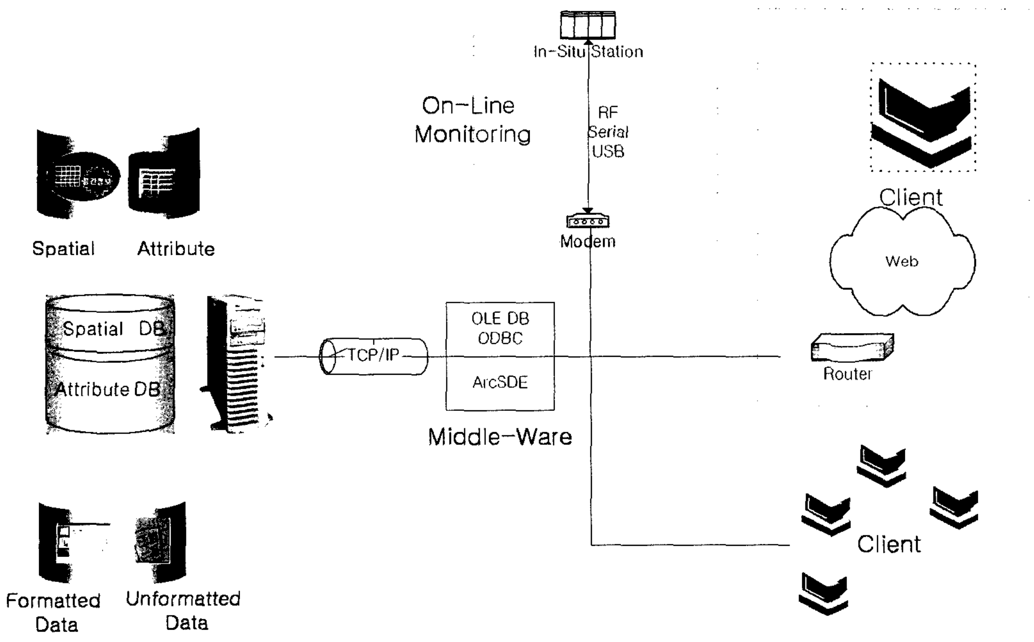

Fig. 3. SITES Hardware Configuration

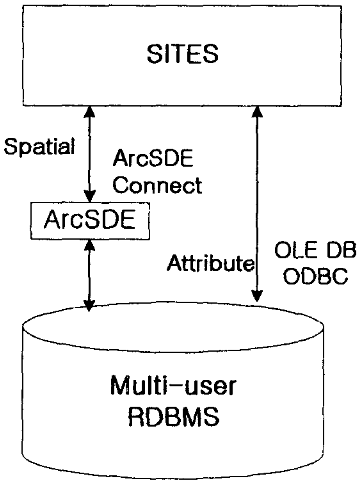

Fig. 4. SITES Database Interface Model

the data through a system process. One computer is designated the server, and it stores the data management software and the data itself. This system may also be used as the workstation for an individual user, but not recommended for the situation of high volume. More commonly, the server computer is placed on a network with the user computers, or "clients." The software on the server works with that of the client computers to provide access to the data.

Figure 5 shows a flow diagram of the internal client-server operation in the SITES. It contains the client component at the top and the SQL server part at the bottom. The client has been customized to make it easy for the SITES users to manage the data in ways that are useful for them. The SQL server user interface is used without modification for data administration tasks. Between these user-interfaces are a number of pieces that work together to provide the data management capabilities of the system.

Figure 5 illustrates that the server is more simply designed and the client is more complicatedly designed than those of the commercial products

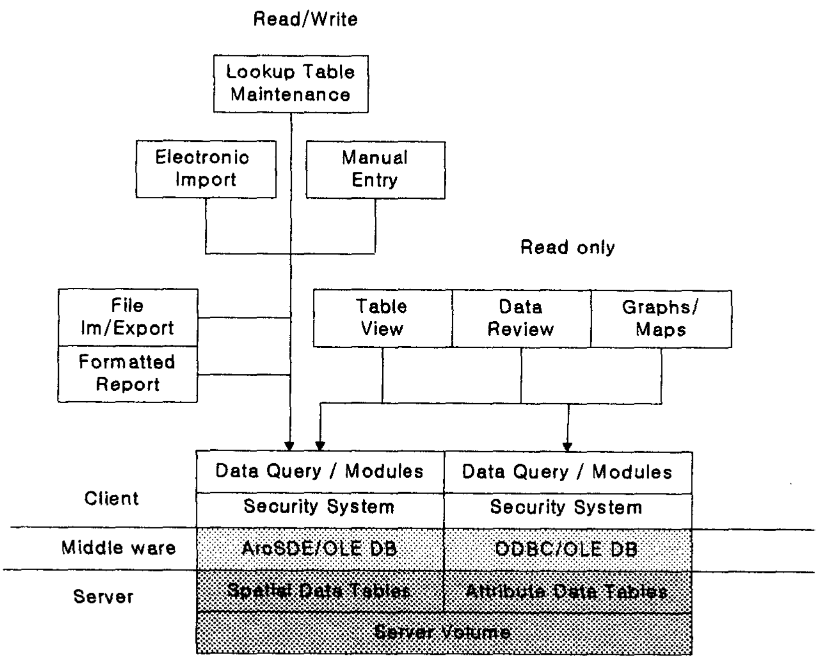

Fig. 5. Data Flow Diagram in Client-Server of SITES

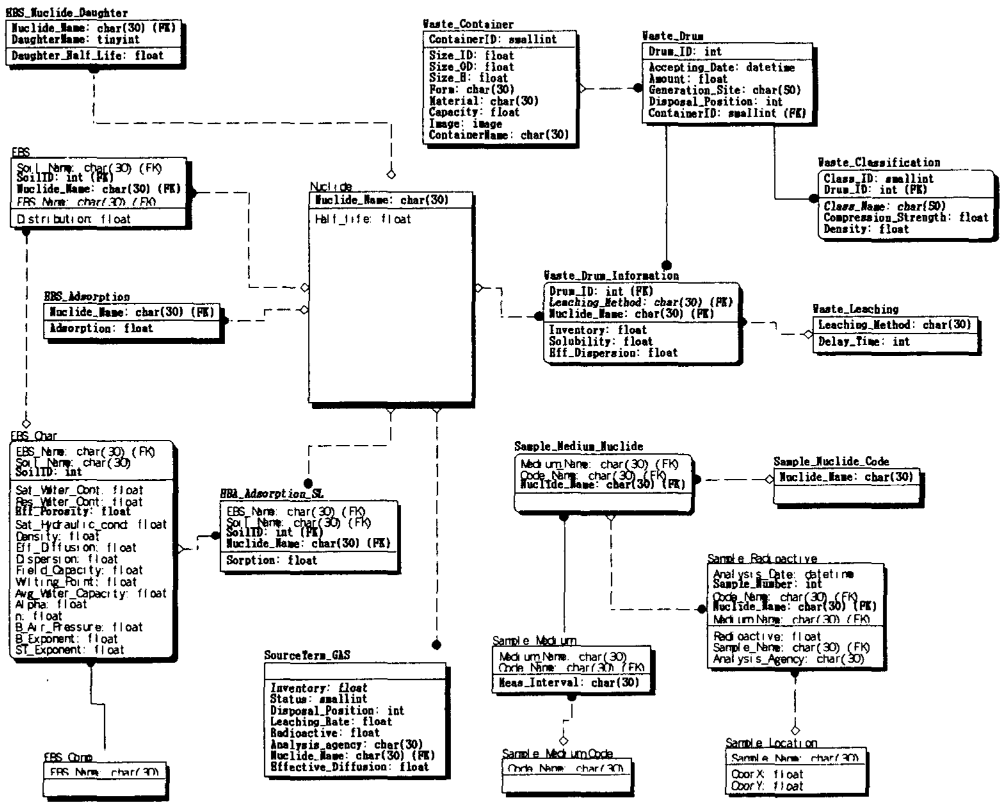

Fig. 6. Entity-Relationship Diagram of Attribute Data

are. This is because the more complicated client makes the user manage and change the program easy and prompt. The shade at the bottom represents the SQL server, and the rest represents the client. This sequence provides the most orderly view of the system.

The basic foundation of the server side is the SQL server database, which is actually a file on the server hard disk that contains the data. This table space is maintained by DBMS, and can be changed by the database administrator (DBA), if necessary. Unlikely many computer files, it will not get larger automatically as data are added. Therefore, the table space needs to be monitored periodically for database management and performance tuning. The software works this way because the location and the structure of the file on the hard disk are managed by the SQL server to provide maximum performance (speed of query execution).

The database tables are stored on the SQL Server. These tables are similar to those of RDBMS, in function and appearance. They usually contain data in a normalized database form. The data in tables are manipulated by means of the SQL queries passed to the SQL server, via Open Database Connectivity (ODBC) and ArcSDE, for spatial data from clients. Users can see the tables in the SQL server through the database window in the client system. However, a user' s ability to manipulate data is dictated by the authorization of a security system. A system administrator should back up the data in the SQL server tables on a regular basis.

The interface between the SITES and the SQL server is protected by a security system that is partly implemented in the SQL server and partly implemented in the client system. It is recommended that most users have read-only permission for working with the data; that is, they should be able to view the data but not change it. A small group of users, the data administrators, should be able to modify the data, which would include importing, entering, changing, and deleting the data.

3.3. SITES Data Model

The data model for a data management system is the structure of tables and fields that contain data. The logical data model (Entity Relation Diagram: ERD) describes, at a conceptual level, the data content for the system, as shown in Figure 6. The lines between boxes represent relationships in the model. The physical data model describes in detail exactly how the data will be stored with names, data types, and sizes for all of the fields in each table, along with the relationships (key fields which join tables) between the tables.

The overall scope of the logical data model was defined in the early stages of the SITES design process. The relational database design of the SITES should reflect the physical realities of the data being stored. For environmental data, samples should be taken at specific locations, at certain times, depths, and/or heights, and should then be analyzed for certain physico-chemical parameters. The tables and relations are used to model this pattern of usage.

Tables - the data model for storing site environmental data consists of three types of tables: primary, lookup, and utility tables. The primary tables contain the data of interest. The lookup tables contain codes and their expanded values used in the primary tables to save space and to encourage consistency. Sometimes the lookup tables contain other useful information for the data elements that is represented by the coded values. The utility tables provide a place to store various data, often related to the operation and maintenance of the system. Often these tables are related directly to the primary tables.

For the most part, the primary data being stored in the SITES has a series of one-to-many relationships. It is fortunate that these relationships are one-to-many rather than many-to-many (many-to-many relationships can be managed in the relational data model). They require an additional table, sometimes called a "join table," to track the links between the two tables. The primary tables in this system are named *Sites, Stations, Samples, and Analyses.* The detailed content of these tables is described below. The *Site* table contains information about each facility being managed in the system. The *Station* table stores data for each location from where samples are taken, such as monitoring wells and soil borings. The *Sample* table represents each physical sample or monitoring events at specific stations. The Analyses table contains specifically observed values or analytical results from the samples.

Relationships - The relationships between the tables are obvious. Each site can have one or more stations. Each station has one or more samples, and each sample is analyzed for one or more constituents. However, each measurement corresponds to one specific sampling event, from one specific location, at one specific site. The lookup relationships are one-to-many, with the "one" side being the lookup table and the "many" side being the primary tables.

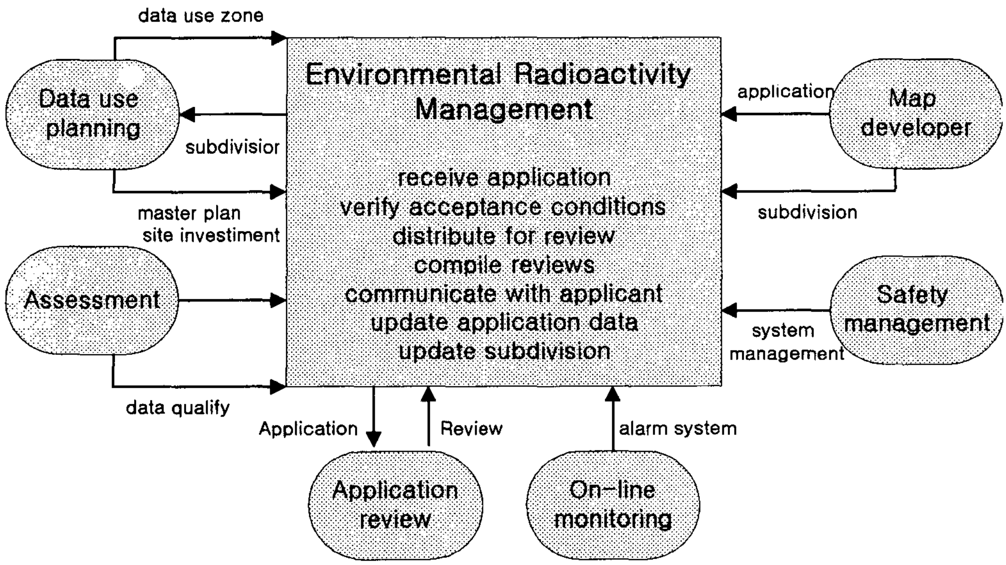

Fig. 7. Data Hlow Diagram of the Environmental Radioactivity

Items	Spatial data	Attribute data
Common data	Thematic Maps	nuclide data
Environmental Radioactivity	Sampling location	date/sample/ media/nuclide/ frequency/sampler/ radioactivity ···
EBS	Distribution map	soil information charaterization composition
Waste Charaterization	Facilities management	drum information drum grouping classification leaching data
⋮	⋮	⋮

Logical Design

Real Object	Geodatabase	RDBMS	Behavior
Road	Line	Name Type	Direction Width
Soil	Polygon	Satureated Water Content Residual Water Content Effective Porosity Density Capacity ⋮	Domain
Environmental Radioactivity	Point	Data number Name Sampling data Nuclide Media Frequence Sample number Radioacitivity	Not duplicated
⋮	⋮	⋮	⋮

Fig. 8. Definition of the Objects

4. SITES, Unified Database Modeling

In this study, it is carried out to part spatial and attribute data and to unify these data using with ArcSDE. The environmental radioactivity information is designed by this method.

The first step in the design of a database for the environmental radioactivity data is to model the user' s view of the data. The database design will be influenced by the structure of our organization, NETEC. Distinct departments may have responsibility for different segments of the environmental radioactivity data. At the basic level, the key data flows are modeled in Figure 7. This is the starting point for determining a logical grouping of the data.

Based on the data flowchart, the objects and relationships are defined. In this step, objects are

ID	DatabaseName	Owner	Name	Subtype Field
5			Env_Radio_Sampling	SamplingType
7			Plants	PlantType
9			Loads	LoadType

GDB Objects Classes

ObjectID	Shape	SamplingType
1	Binary data	6
2	Binary data	6
3	Binary data	6

Env_Radio_Sampling Table

IndexedObject	MinGX	MinGY	MaxGX	MaxGY
1	101	95	101	95
2	102	201	102	201
3	205	105	205	105

Env_Radio_Sampling Shape Index Table

Fig. 9. System Tables of Spatial Database

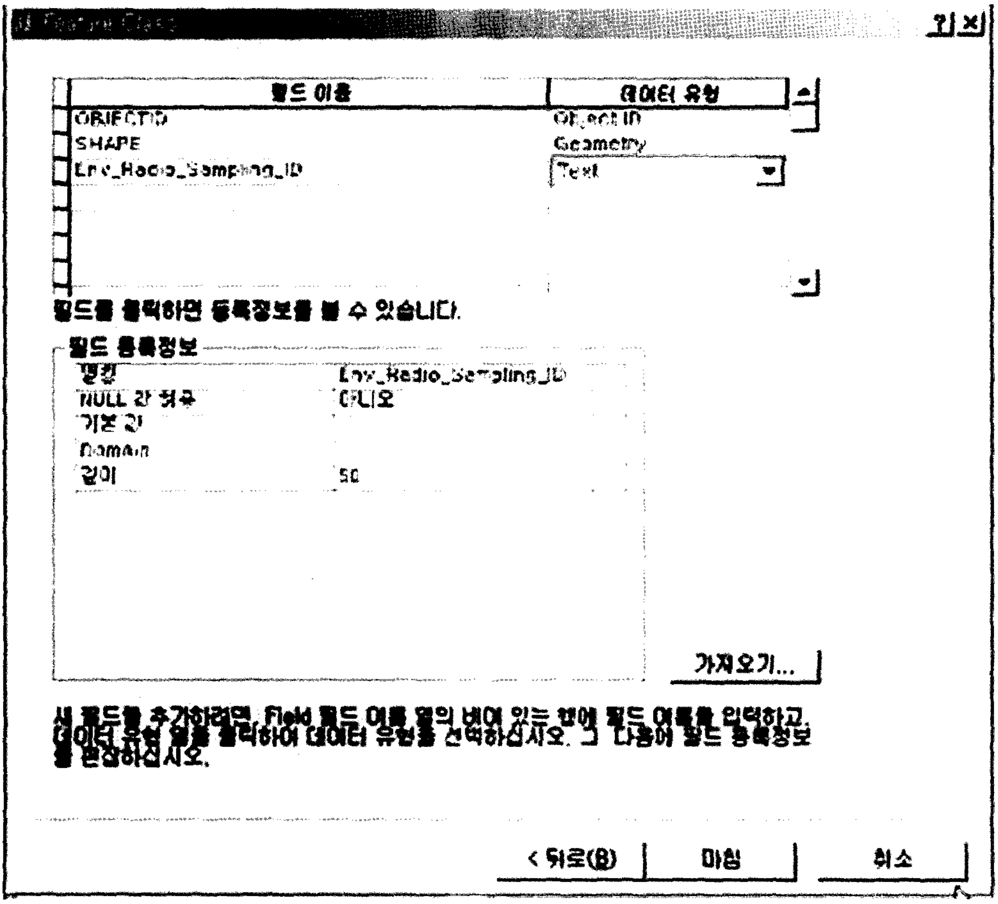

Fig. 10. Feature Class Model of Spatial Data

identified and described, and the relationships between objects are specified. Figure 8 shows the definitions of the objects for the environmental radioactivity data and their thematic map.

The spatial data design is composed of matching to database elements such as polygons, lines and points, and designing the attribute data and determining the behavior as shown in Figures 8, 9, and 10.

In this study, to develop a spatial database, the registration of feature classes and the determination of behavior was carried out. On the other hand, the related attribute data are not designed in the geodatabase. In other words, the attribute data related to spatial information that has limitation in management and normalization are modeled in RDBMS. The spatial database is linked with these external attribute data by an FID key.

Figure 6 shows the entity relationship diagram (ERD) for the sampling location of environmental radioactivity. The information of environmental radioactivity is divided into two groups. One group is stored in the spatial database and the other in the attribute database. The business table in the spatial database has a name of sampling location as a primary key, and the other tables are stored in the attribute database.

To join the spatial and the attribute databases using the primary key, the feature class is registered, as shown in Figure 10. ArcGIS is used to model and to display the spatial data in this study. To unify the spatial and attribute data, the tables should be joined by the primary key. This procedure of modeling the information of environmental radioactivity is shown in Figure 11.

5. Conclusion and Future Work

The site and environmental data for a radioactive

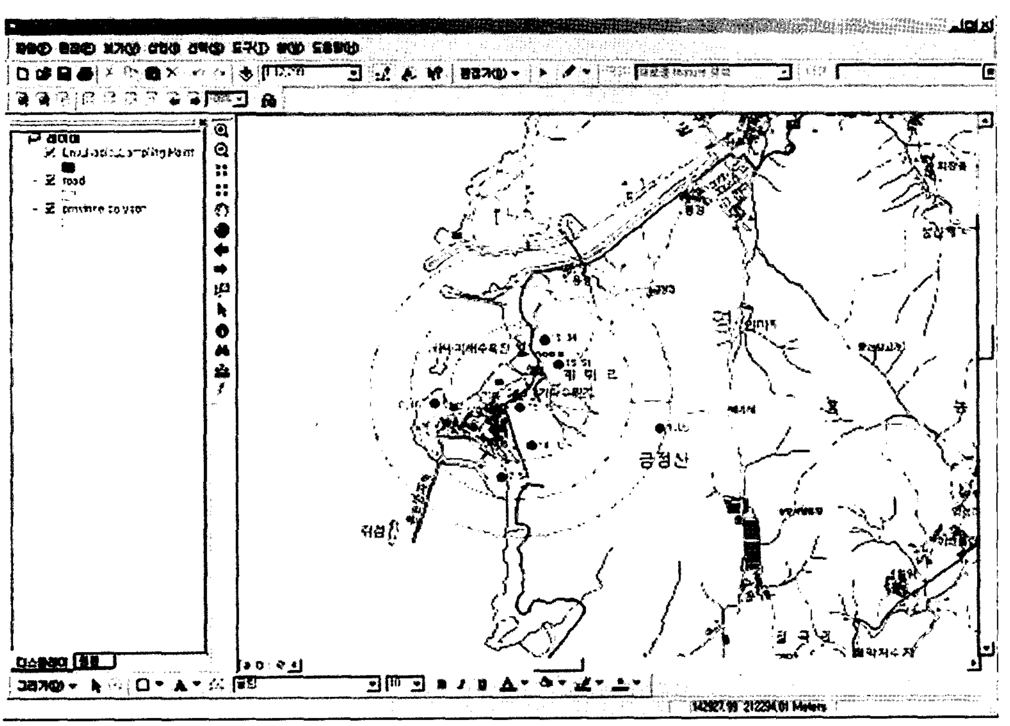

Fig. 11. GIS Display of the Environmental Radioactivity

waste repository require systematic management. A spatial information management system that reflects a continuous, or periodical, monitoring of a radwaste repository has not yet to be developed. The "Site Information and Total Environmental Data Management System (SITES) is being developed to provide such an information management system. A system of hardware and software that includes geographic information is developed to provide convenient data access to user of the SITES. The spatial and attribute databases in the SITES are designed based on the RDBMS for the GIS and for data integration. Both the spatial and attribute databases can be managed separately from each other when expend the GIS application for the next scope of work.

In addition to demonstrating the ability of SITES to manage spatial and attribute information efficiently, a procedure for a practical database design and an integration plan for database management are introduced in this paper. The database structure and content can be changed during the design and development of the whole system, because the database is in early development.

Despite the site and environmental data for establishment of management system are limited for the design concept of the SITES, the necessity of safe radwaste disposal management is obvious, with respect to both efficient safety assessments and public acceptance. The SITES and database will be developed in near future, based on the initial work on database design, as described in this paper. A more advanced version of the SITES for radwaste disposal management will be introduced in a forthcoming paper.

Acknowledgements

This work was carried out as a part of National Research Laboratory (NRL) program and financially supported by the Ministry of Science and Technology (MOST), Republic of Korea.

References

1. Michael Zeiler, "Modeling our world," ESRI, New York (1999).
2. C. L. Kim, C. G. Rhee, S. M. Park, and M. J. Song, "Development of SITES for Radioactive Waste Repository," ANS 2003 Annual Meeting, American Nuclear Society, San Diego, June 2003.
3. C. G. Rhee, S. M. Park, Y. S. Lim, H. J. Lee, J. W. Park and C. L. Kim "Systematic Management of Environmental Monitoring Data for Radioactive Waste Repository," EGS-AGU-EUG Joint Assembly 2003, Geophysical Research Abstracts, Vol. 5, 08147, 2003.
4. Hanford' s Environment Restoration Project "Project Management and Support", www.bhi-erc.com/projects/p_m/eis.htm.
5. David W. Rich, "Relational management and Display of SITE Environmental Data," Lewis Publishers, New York (2002).
6. Hewlett-Packard Company, "Enterprise Data Warehouse-Planning, Building, and Implementation Volume 1," Prentice Hall PTR, New York (1999).
7. ESRI, "Creating and Managing Geodatabases using ArcInfo and ArcEditor," Cadland (2001).
8. J. W. Park, C. L. Kim, J. B. Park and E. Y. Lee, "Development of a Quality Assurance Safety Assessment Database for Near Surface Radioactive Waste Disposal", J. Korean Nuclear Society, Vol. 35, No. 6, pp. 556~565, Dec. 2003.