Project no. 505428 (GOCE)

AquaTerra

Integrated Modelling of the river-sediment-soil-groundwater system; advanced tools for the management of catchment areas and river basins in the context of global change

Integrated Project

Thematic Priority: Sustainable development, global change and ecosystems

***Deliverable No. :*BASIN R3.11**
Title: **Compilation of data collected and fed into a hydrogeological database in the Walloon Meuse catchment region**

Due date of deliverable: May 2005
Actual submission date: May 2005

Start date of project: 01 June 2004 Duration: 60 months

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Revision: H. Rijnaarts / J. Barth

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SUMMARY

Based on a first inventory of available case studies, test sites have been selected in the Walloon part of the Meuse Basin in Belgium. These sites meet the requirements and objectives of the researches performed by different partners in AquaTerra. Available information and datasets have been collected for these sites and complementary investigations and experiments have been organized. Existing data and recently collected data have been compiled into a hydrogeological database developed by HGULg for the Walloon region and adapted to the specificities and needs of the AquaTerra project.

The deliverable provides a general description of the hydrogeological database developed by HGULg: the conceptual model, specific adaptations performed for the AquaTerra project and interfaces for encoding, querying and exporting hydrogeological information stored in the database. A synthesis of datasets available in the HGULg Hydrogeological Database for the selected test sites in the Meuse basin is also provided.

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R3.11. Compilation of data collected and fed into a hydrogeological database in the Walloon Meuse catchment region.

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1. Introduction

During the first 12 months of the AquaTerra project, the planned activities of HGULg within Workpackage BASIN R3 (MEUSE) have been to collect available data on possible test sites in the Walloon part of the alluvial plain of the river Meuse for further investigations. Because of the requirements and deadlines of other teams concerned by the experiments in the Walloon Meuse basin, the initial planning was slightly modified.

Based on a first inventory of available case studies, several test sites were selected that meet the different AquaTerra partners' requirements and objectives. In a second step, available information and datasets were collected by HGULg for these sites and complementary investigations and experiments have been organized. Existing data and recently collected data have been compiled into a hydrogeological database developed by HGULg for the Walloon region and adapted to the specificities and needs of the AquaTerra project.

The objectives of this deliverable are to provide a general description of a hydrogeological database developed by HGULg, including specific adaptations made to meet the AquaTerra project's needs and to provide a synthesis of available datasets for the selected test sites in the Meuse basin.

First, a general description of the Walloon Meuse basin and the selected AquaTerra test sites is provided. Then, the general concepts, the conceptual model and the developed interfaces of the HGULg hydrogeological database are presented. Finally, a summary of datasets available for the selected test sites is provided.

2. The Walloon Meuse basin and the AquaTerra sites

The Meuse is the main river in the Walloon part of Belgium. The river has its source in the northern part of France and flows through Belgium and the Netherlands to the North Sea.

The surface of the whole basin is about 36.000 Km^2, from which 38.75% is located in the Walloon region (approximately 17.000 Km^2), where it represents ¾ of the Walloon territory (Figure 1). This means that 45.7% of Belgium is drained by the Meuse catchment (Haddouchi, 1987).

Based on available data and on the AquaTerra partners' needs (HGULg, VITO, CHYN, EPFL, BRGM …), four test sites have been identified as suited to the project's objectives (Figure 2). In these test sites, existing geological, hydrogeological data have been collected intensively by HGULg. Complementary investigations and measurements have also started for obtaining complementary information relevant for the research objectives.

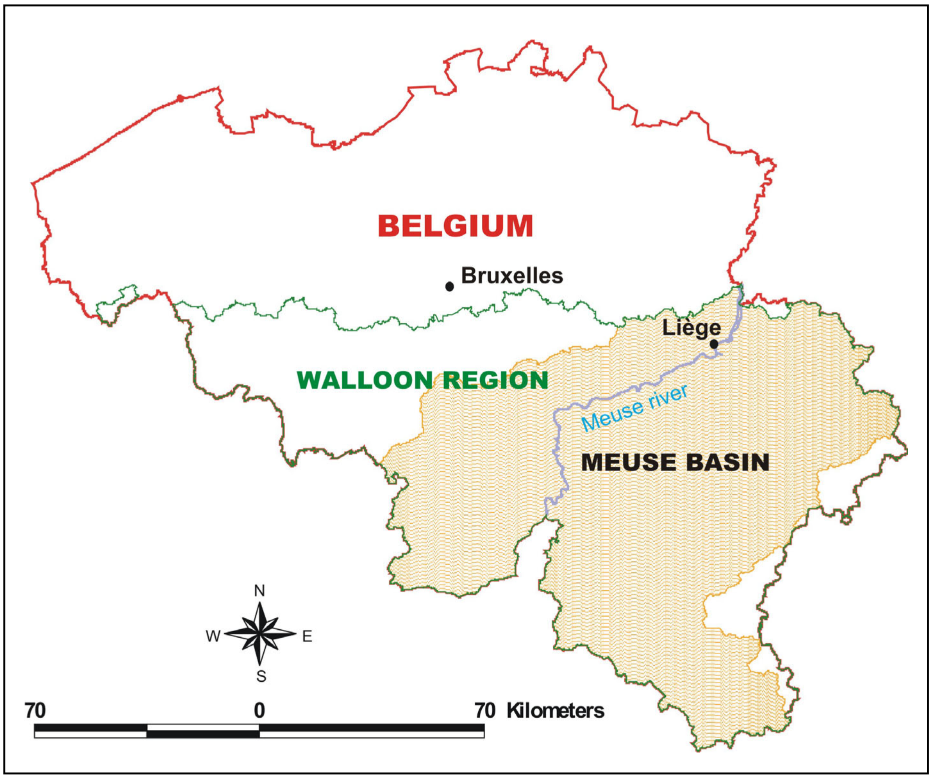

Figure 1: Location of the Meuse basin in the Walloon region

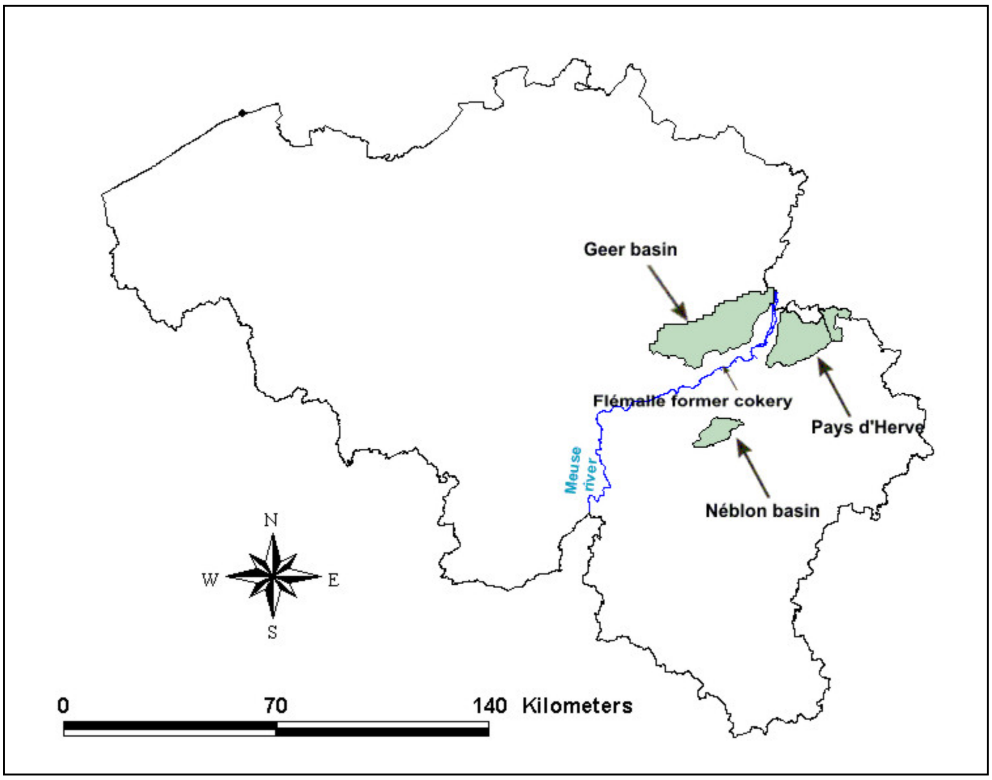

Figure 2: Selected AquaTerra test sites

2.1. The Flémalle former cokery site

The site of the former cokery is a brownfield of 7.3 ha, located in the left bank of the river Meuse, close to the river (10 – 15 m), upstream from Liège (Figure 3).

Various activities related with coking processes were carried out in the past, between 1922 and 1984 years. Nowadays there is no more activity and all industrial substructures have been removed. These activities have produced an important contamination of soil, subsoil and groundwater.

The Flémalle former cokery site has been selected because of several interesting characteristics for the AquaTerra project:

- It is close to the Meuse river, which is interesting for HGULg research activities on groundwater – surface water interactions in the scope of Workpackage R3 BASIN/MEUSE.
- First investigation campaigns have highlighted the existence of a large variety of contaminants, at relatively high concentrations, in both the unsaturated zone and the saturated alluvial deposits, such as BTEX, PAH, cyanides, heavy metals, mineral oils... This is interesting for HGULg as well as for different AquaTerra partners involved in WP BIOGEOCHEM: CHYN-UNINE, VITO, BRGM and UHT.
- Several former field investigations were performed (large number of boreholes available…) and a new campaign has started in February 2005 (financed by the SPAQuE: Société Publique d'Aide à la Qualité de l'Environment), giving the AquaTerra partners the opportunity to collect fresh soil and subsoil samples and to perform field measurements and investigations.

Each AquaTerra partner involved in the Flémalle former cokery site has in mind specific objectives adapted to their goals in the project:

- BRGM and UHT partners are concerned in the identification and quantification of biogeochemical processes involved in the mobility of the inorganic pollutants in the vadose zone. They carry out ex situ experiments in order to determine the impact of microbilogical and geochemical processes on the fate of metals (As, Pb, Zn, Cd and Hg).
- VITO perform batch tests to evaluate the impact of microbiology on the fate of metals in a saturated zone. This includes looking at the impact of different electron acceptors available for the micro-organisms on metal release or precipitation/sorption.
- UNINE-EPFL study *in situ* biodegradation of PAHs to explore the extent of contamination and predict its future development. To reach this goal, they use an approach based on stable isotope analysis (isotopic fractionation). Groundwater samples were taken from different recently drilled wells to determine carbon and hydrogen isotope ratios along the groundwater flow path.
- HGULg is concerned by general hydrogeological investigations, groundwater – surface water interactions in relation with contamination issues and transport

properties of gravel deposits. Field experiments such as geophysics, pumping and infiltration tests, tracer tests…aiming to understand and quantifying hydrodynamic and hydrodispersive properties of the gravel aquifer and groundwater and pollutants exchanges are planed for the ongoing field works. Groundwater modelling is also planned.

The final goal of all experiments carried out by each partners is to propose an optimal measure of decontamination of the site, taking into account all the aspects studied *in situ* and *ex situ* by the AquaTerra partners.

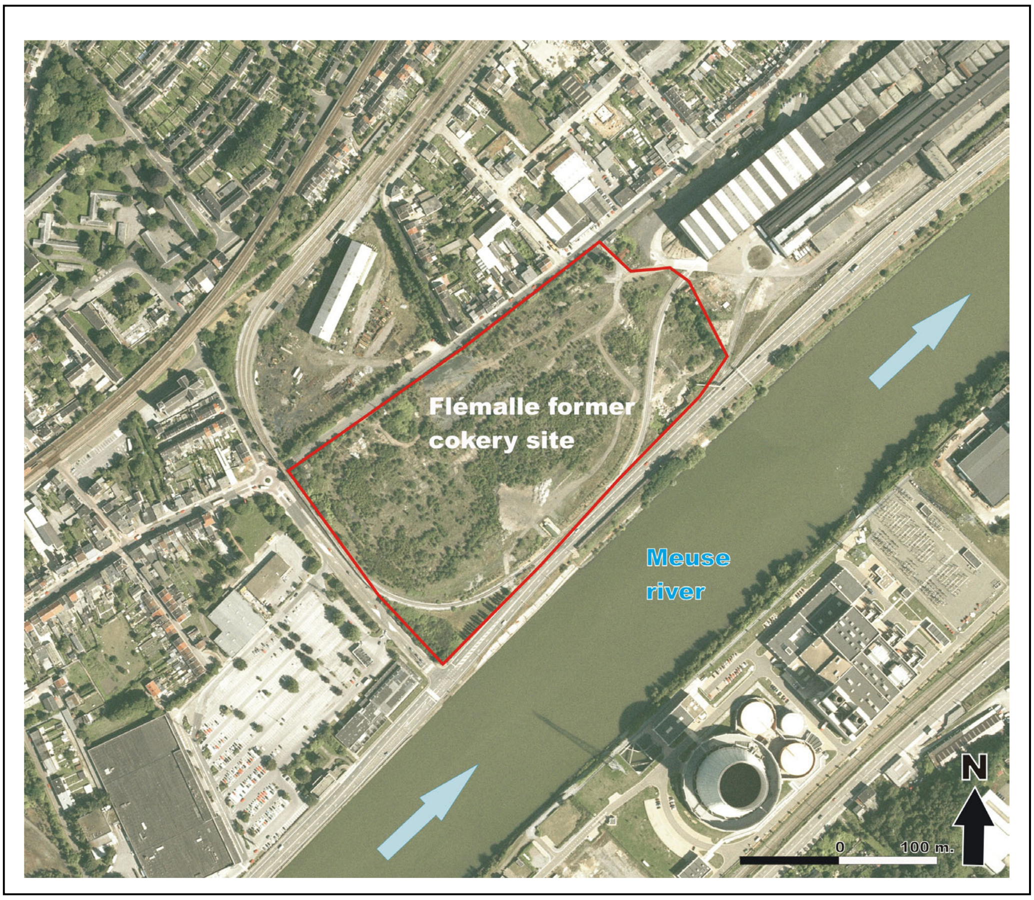

Figure 3. The Flémalle former cokery site (source: MET).

The geology of the site, from top to bottom, is made of:

- 0 – 2.5 m: backfill deposits (waste materials from former buildings, ashes, …);
- 2.5 – 5.0 m: silty clay deposits with sand;
- 5.0 – 7.0 m: sandy layer with gravels;
- 7.0 – 13.0 m: alluvial gravels;
- >13.0 m: carboniferous shale bedrock;

The main aquifer is located in the alluvial gravels, from 5 meters depth to the bedrock. In periods of high water levels, a shallow temporary perched “aquifer” is formed between 2 and 4 meters depth (Figure 4).

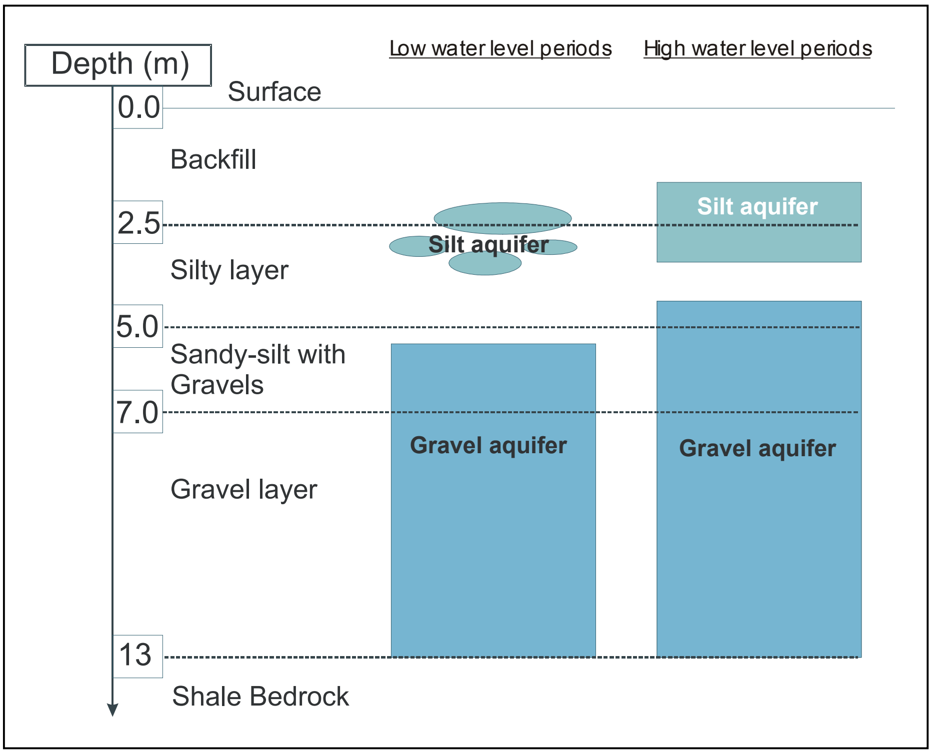

Figure 4. Schematic representation of both shallow and deeper aquifer in Flémalle cokery site (source: SPAQuE)

After all industrial activities were terminated in Flémalle, a series of characterization studies were carried out between 1992 and 2002, coordinated by the SPAQuE:

1. The first characterization campaign was performed in 1992 (report in July 1992). 64 piezometers were drilled, 10 groundwater samples from the shallow aquifer and 30 from the deep aquifer were analyzed and 248 soil samples were analyzed.

2. The second characterization campaign was performed in 2001 (report in April 2001). 10 new piezometers were drilled and 11 trenches for a volumetric estimation of contaminated soil. Groundwater samples taken in both the news and former piezometers were analyzed: 6 from the shallow aquifer, 17 from the deep aquifer. 9 soil samples and 5 gaseous phase were also analyzed.

3. During the third characterization campaign, carried out also in 2001 (report in September 2001) 26 new piezometers were drilled. 4 groundwater samples,14 soil samples and 5 samples from gaseous phase were analyzed.

4. During the fourth characterization campaign, performed at the beginning of 2002 (report in February 2002), 2 deep piezometers were drilled and groundwater samples taken from these wells were analyzed.

5. At the beginning of 2002, an estimation of the volumes of contaminated soil and groundwater was carried out.

The existence of such a large dataset also gives one the opportunity to test the adequacy of the new hydrogeological database developed for the alluvial plain in the Walloon Meuse catchment.

2.2. The Geer basin

The Geer basin, a tributary of the river Meuse, is located in the eastern part of Belgium (Figure 5), North-West from Liège. A very important groundwater resource is located in this basin: the Hesbaye aquifer. This aquifer supplies annually drinking water to about 600.000 people in Liège and its suburbs, which means approximately 30 millions cubic meters in volume, which are pumped out by galleries and pumping wells (Brouyère et al., 2004a,b).

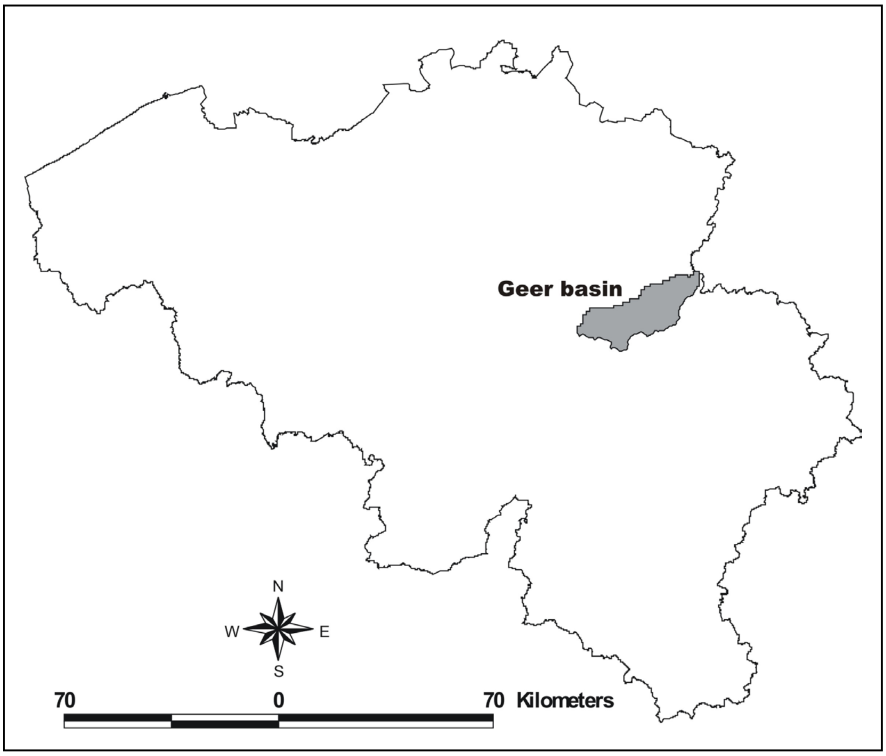

Figure 5. Location map of the Geer basin.

The plateau of Hesbaye extends over about 350 km^2, with altitudes ranging between 80 m in the North-East and 206 m in the South-West. The geology is made, from top to bottom, by (Figure 6):

- Quaternary loess of variable thickness, up to 20m;
- Locally, several meters of tertiary sand deposits;
- A maximum of 10 m of flint conglomerates, which is a heterogeneous material made of dissolved chalk residues (flints, sand, clay and locally phosphate residuals);
- Senonian chalks showing depths ranging from a few meters, up to 70 m, in which the aquifer is located;
- Several meters of smectite clay, of low hydraulic conductivity, forming the aquifer basis.

This aquifer is located in the fractured, dual-porosity chalk formations. The large porosity of the chalk (30 to 50%) provides it with an important water storage capacity and the intense fissure network drains groundwater stored in the chalk. Piezometric measurements indicate a North-oriented hydraulic gradient, draining most of the groundwater (Dassargues and Monjoie, 1993).

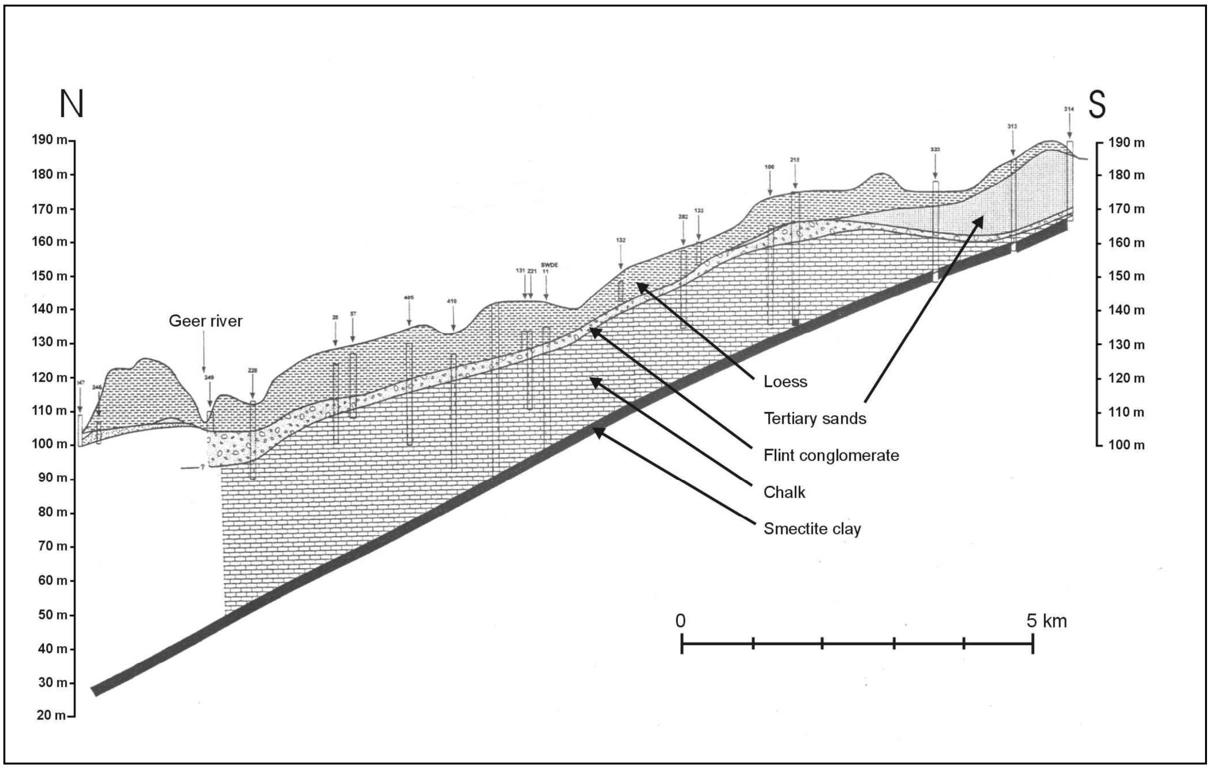

Figure 6. Geological cross-section in the Hesbaye aquifer (source: Brouyère et al., 2004b, modified from Hallet 1998).

Most of the aquifer is unconfined except in the North, where semi-unconfined conditions prevail close to the Geer river, and locally under tertiary clayey sediments, where confined conditions prevail.

The Geer basin has been selected because of several interesting characteristics for the AquaTerra project:

1. This basin has been the topic of several research projects and investigations by HGULg, including modelling (Brouyère et al. 2004a, Orban et al. 2005), and an important dataset is available. This makes it an interesting case study for research activities in relation with the workpackage COMPUTE. Interactions with the University of Trento are envisaged.

2. From a quantitative point of view, this groundwater resource is of major importance for the Walloon region. Any reduction in groundwater recharge in the future, e.g. in relation with climate change, could have major consequences for water distribution in the region (Brouyère et al. 2004a). Research activities related to estimating the impact of climate change on water/ groundwater resources in the Geer basin (HYDRO H1) are thus of major interest. Interactions with the University of Newcastle are planned.

3. Because of the existence of a thick layer of loess, the region is intensively cultivated. From 1960, nitrate concentrations have risen annually at a rate of 0.1 mg/l in the semi-confined to 1 mg/l in the unconfined part (Hallet 1998, Brouyère et al. 2004b). Presently, nitrate concentrations are close to the drinking limit (40 mg/l). From time to time, pesticides (mainly atrazine) have been detected in some observation and pumping wells. Estimation of present and future groundwater quality trends in this basin is of first importance for supporting any decisions in terms of land use (changes in agricultural practices etc). The Geer basin will thus be the focus of HGULg research activities in TREND T2 (groundwater quality trends), using both statistical trend analysis techniques and modelling tools. Cooperation is foreseen with BRGM and UHAGx.

2.3. Others test sites

For research activities in relation with workpackage TREND T2 (groundwater quality trends), three other sub basins have been selected: The groundwater body of 'Pays de Herve', located North-East from Liège, close to the border with Germany, the Neblon sub-basin (sandstone and limestone aquifer) and the alluvial plain of the river Meuse (Figure 2).

In these basins, statistical trend analysis will be performed using available datasets on nitrate concentrations in groundwater. Details about these basins can be found in the deliverable TREND T2.1.

3. The Hydrogeological database

3.1. General interest and concepts

3.1.1. Hydrogeological data

The spreading of hydrogeological sources of data is one of the most important problems encountered by researchers and operators related with hydrogeological sciences. Any data search process, which at first should be a very simple task, can be really complicated and complex when data are not archived in a well designed database.

Naturally, there are many different reasons for data spreading and search. First of all, one can see different interactions between multiple institutions such as universities, administration, water suppliers, research organisations and groups, requiring a close cooperation between them. Hydrogeological data exchanges are required where, for example, there is a water supply well with a group of piezometers controlled by different institutions. Secondly, it is also very interesting to have access to individual research projects, which results are not really disseminated nor integrated into large national structures.

Furthermore, hydrogeological data are usually related to many other data, such as geological data, chemical data or geophysical data. This complexity is very difficult to manage, if data are not stored in a well structured database.

Finally, the database helps in structuring and formatting the information for further export and use in other applications such as groundwater mapping, groundwater modelling, trend analysis etc.

3.1.2. Relational approach

A database is a collection of data and files, concerning one or many clearly defined topics. When the amount of data becomes important, one should create a relational database, based on a data model. A relational database stores different related data, structured in tables describing one and only one subject; one single table containing distinct information about wells, sources, protection zones. A table is made of rows and columns. One column defines different attributes of an object, while a row represents a specific instance of an object (a record) (Figure 7).

Fields with attributes (colons)

Records (lines)

ID point	Point name	Point type	X	Y
22	Pz4	Well / piezo	193899	106904
23	Pz5	Observation point	194367	106943
24	Pz6	Well / piezo	193359	106664
26	Pz7	Borehole	193943	106859
27	Pz8	spring	193594	106730

Figure 7. Simple table in a Relational Database

In a hydrogeological database, tables can contain, for instance, data about:

- geological logs, where one finds types of soils and rocks encountered in a drilling process and described by a geologist;
- borehole construction details and well equipment;
- groundwater chemical analysis with samples;
- geophysical logs containing data about natural radioactivity, electrical properties or a formation density;

- ...

In such a system, tables are related with each other and a Relational Database Management System (RDBMS) manage these relations, joining different information using a unique identification code base which is called the *primary key*. In the Figure 8, the primary key is represented by a ID_point column, where each record has its own unique number. A RDBMS is used to define, to manipulate and to control data.

As far as a relational database concept is concerned, one can establish three main types of relationships between different database tables. These are : “one-to-one”, “one-to-many” and “many-to-many”.

A “one-to-one” relationship defines that between two different tables, for a record from the first table, there is one and only one related record in the second table and vice-versa.

A “one-to-many” relationship states that for one record from the first table, there are many records in the related table, but for a record in the second table, there is only one record in the first table.

A “many-to-many” relationship permits that one record in the first table has many related records in the second table and the relationship is reciprocal.

As stated above, at first, a conceptual hydrogeological data model should be elaborated. One has to define all data which will be stored, create future tables and create relationships between them. A conceptual (logical) data model[1] can be based on a pure entity-relationship notation[2], or can present an Object Oriented Model approach, where each table (class) describes a specific type of objects and each object can be physically represented in a modelled environment, with its specific behaviour depending on its type. The second approach can be very precisely described by UML[3] – Unified Modelling Language class diagrams, which permits a very simple and clear graphical presentation of classes containing objects and different relationships between them.

3.1.3. Geodatabase concept

Data and information which are required in hydrogeological studies, are very numerous and complex. Furthermore, such data are geographically referenced in space (location) and time. To make a complete analysis of any hydrogeological process, one has to combine different pieces of information such as: geology, hydrogeology, soil, land use, topography, water table altitude and many other features. All these data need to be managed in one system and the most appropriate way, is to use geographic information systems (GIS) (Zeiler, 1999). It is worth to know that in recent years the use of GIS has grown very quickly in many branches of industry, economy and science. It is now also widely used in groundwater

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[1] The logical data model presents the user’s view of data and the database model implements the data model within the framework of relational database technology.

[2] In the past, the most popular method for drawing a conceptual (logical) model where to use an entity-relationship diagrams. Nowadays modellers use various design methodologies and diagram notations.

[3] UML is a standard notation for expressing object models, it is a diagrammatic notation, not a design methodology. It is widely used by object-oriented modellers.

management, water resources estimation, recharge process modelling, water resources exploitation and protection.

The hydrogeological data model introduced into GIS can use a general coverage data model conception, where spatial data (grouped in three main entities such as points, lines and polygons) are combined with attribute data. Spatial elements are stored in indexed binary files, which structure are optimised for display and access, while attribute data are stored in tables and are related by a common identifier.

The most advanced, but very complex solution is a geodatabase concept which uses an object-oriented data model, which permits to add natural behaviours to different objects and relate them using any sort of relationship which exists among these features. The geodatabase data model allows bringing a physical (implemented) data model closer to its logical data model. In addition the user can define different possible interactions among the database objects. Moreover, because of numerous benefits, features can have a richer context, a user works more intuitively with data objects and can draw better, more complex maps.

3.1.4. Interoperability

Another advantage of a data modelling and structuring is that a common data model and its implementation into a GIS environment enables an easier exchange of data. In this approach a logical and physical structure of data is described using common rules which simplify data access, manipulation and extraction by different operators. A well conceived hydrogeological data model must assure interactions between projects teams, researchers, governmental institutions and water suppliers.

Moreover, future data model conversion and modification can be easily applied and the hydrogeological data model can be implemented in other systems, or its data can be transferred using OpenGIS Consortium[4] and ISO/TC211[5] standards. This data exchange process can be performed by XML (eXtensible Markup Language) or GML (Geography Markup Language) files.

3.1.5. Metadata

To insure the interoperability between different systems and implemented databases, it is crucial to precisely describe the content of the hydrogeological database. The most common way is to add metadata. Metadata give information about the structure of data, unit precision, description of tables, relationships between classes and objects.

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[4] The Open Geospatial Consortium, Inc. (OGC) is a non-profit, international, voluntary consensus standards organisation that is leading the development of standards for geospatial and location based services. Through its member-driven consensus programs, OGC works with government, private industry, and academia to create open and extensible software application programming interfaces for geographic information systems (GIS) and other mainstream technologies, www.opengis.org

[5] ISO is a network of the national standards institutes of 150 countries, on the basis of one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system. ISO/TC211 : Standardization in the field of digital geographic information. This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth, www.isotc211.org

3.2. Conceptual model

The presented hydrogeological conceptual data model has been created to assure its good interaction and implementation in Geographic Information Systems. It uses a general coverage data model (relational model) coupled with some Object-Oriented Modelling conventions (abstract classes, object classes and relationship conventions). All objects of that conceptual approach have been subdivided into three main geographic groups: *points, arcs and polygons* (Figure 8). These groups represent spatial object classes. For example, a *point* class may represent a well, a source or a surface water point, a *line* class may represent a river, and a *polygon* class may represent a study zone or a protection zone for a water capture well.

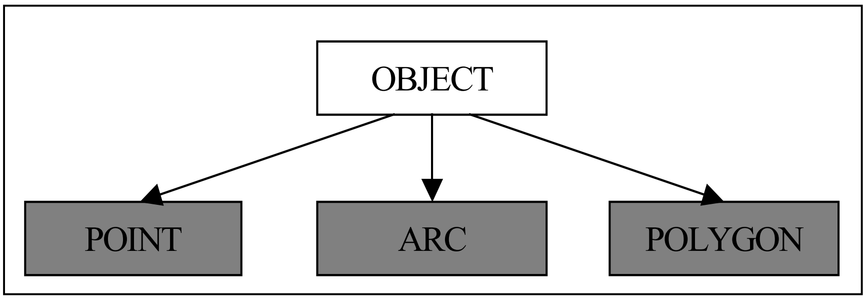

Figure 8. Basic elements of hydrogeological data model

The first main table called OBJECT can be considered as an abstract class in UML diagram notations. It is a specification for subclasses. In our case this class distributes identification numbers which are *primary keys* of the database objects. This prevents database objects confusion – each instance of a class has its own unique number, which is the main concept of entity-relational data modelling.

Between the OBJECT abstract class and *point, arc and polygon* classes there is an inheritance relationship which permits to transfer common elements – like *primary keys*, date of creation of the object and its type. A one-to-one relationship exists between these classes.

A *point* class has many subclasses such as wells, sources, boreholes or climatic stations. An *arc* class can produce different subclasses – rivers, galleries, cross sections, geophysical test. A *polygon* class can represent different surface features such as mathematical model zone, protection zone, study zone, water basins or a mined area.

In Figure 9, the three main classes are presented (dark grey) with their appropriate subclasses (light grey). Subclasses contain a specific set of attributes, which is exclusive for the objects they can create, for instance a Walloon Region code and a depth of a well set of attributes is contained in a *well* subclass in the *point* class.

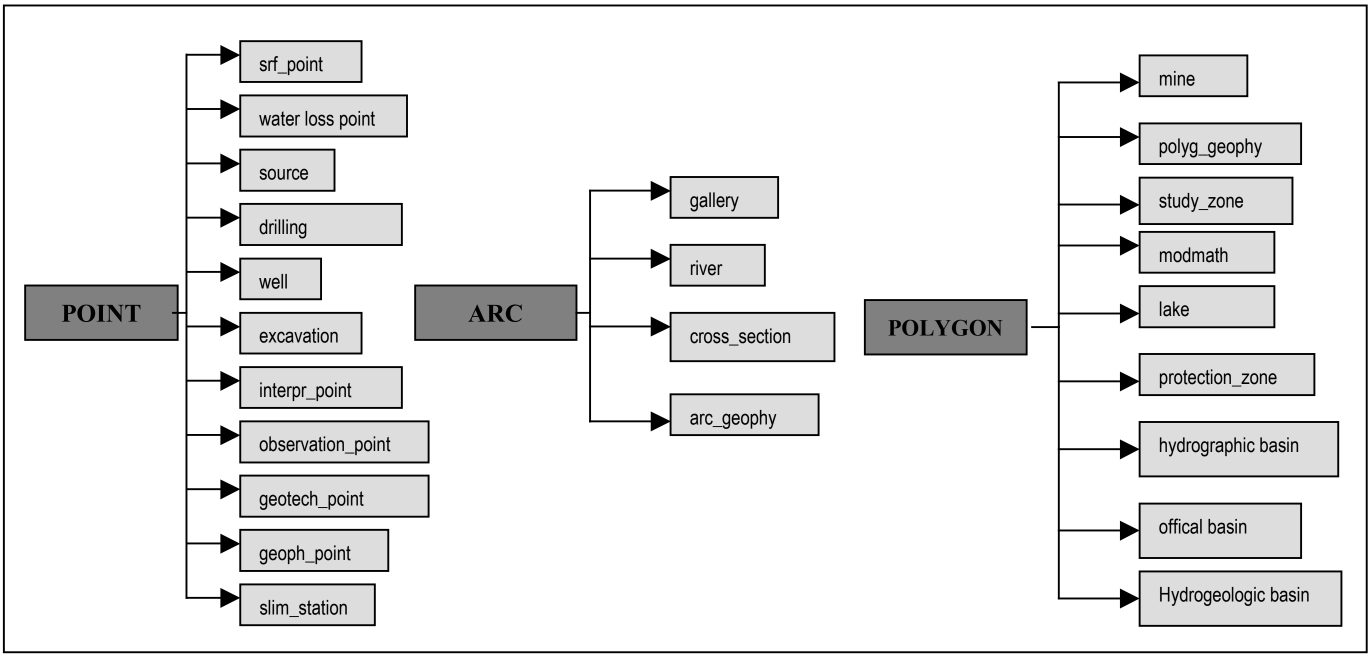

Figure 9. Three main spatial classes and their related subclasses.

3.2.1. Relationships

As described in the previous section, a relational data model uses three main types of relationships which are: “one-to-one”, “one-to-many” and “many-to-many”.

Relationships between the OBJECT abstract class and the *point, arc, polygon* classes are of the “one-to-one” type. It means that only one point, arc or polygon, can have the same primary key generated by the OBJECT table.

A “one-to-many” relationship exists between a well and many piezometric head measurements, or one sample and many parameter measurements on it.

A “many-to-many” relationship is established between many wells that are taken into consideration in a study zone and many study zones, which could implement one set of well measurements.

3.2.2. Specific model elements relevant for the AquaTerra project

An important part of hydrogeological data is focused on information about wells, piezometric heads, references for piezometric measurements, well equipment (Figure 10), geological description (lithology) and links to geological samples (Figure 11).

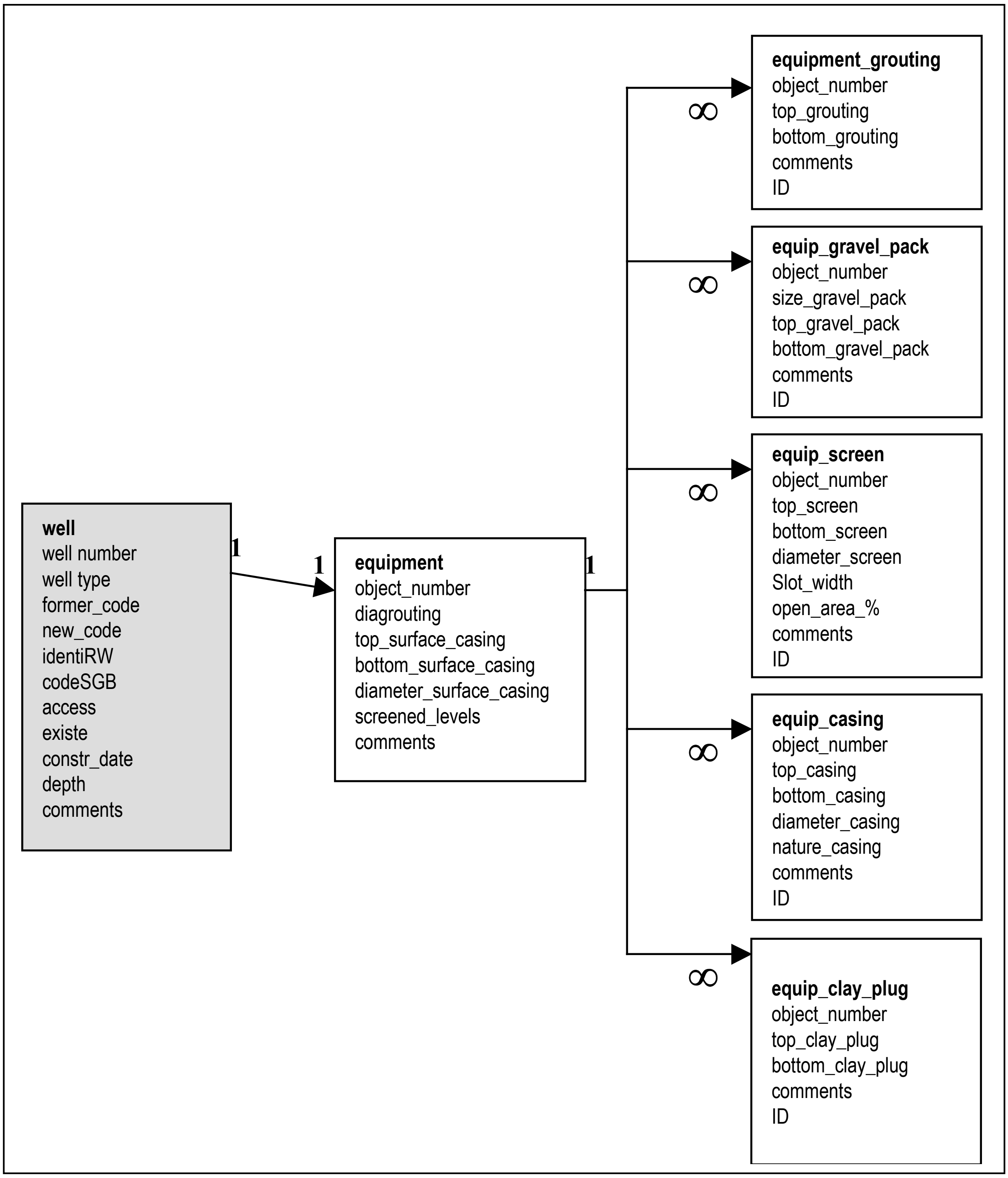

Figure 10. Relationships between well class and other tables

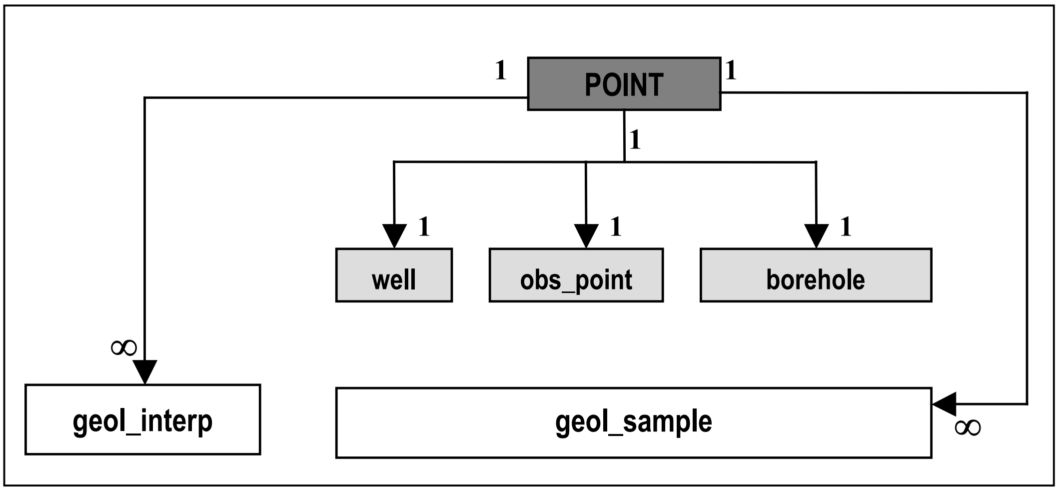

Figure 11. Relationships between point class and lithology types and geological samples

Apart from that basic information, a very important aspect that has been developed in the hydrogeological conceptual data model having in mind, among others, the specific needs of AquaTerra, treats about the groundwater chemistry. Different test sites (the Flémalle former cokery plant for instance) used in hydrogeological studies, provide numerous data describing chemical analyses of groundwater: The results of such analyses should be stored in the database in a well structured way. To achieve this, the HGULg database has adopted the parameter classification from SPAQuE, already used in former investigations (Figure 12). Figure 13 shows a detailed description of the chemistry sub-model, which illustrates the existing tables and their relationships.

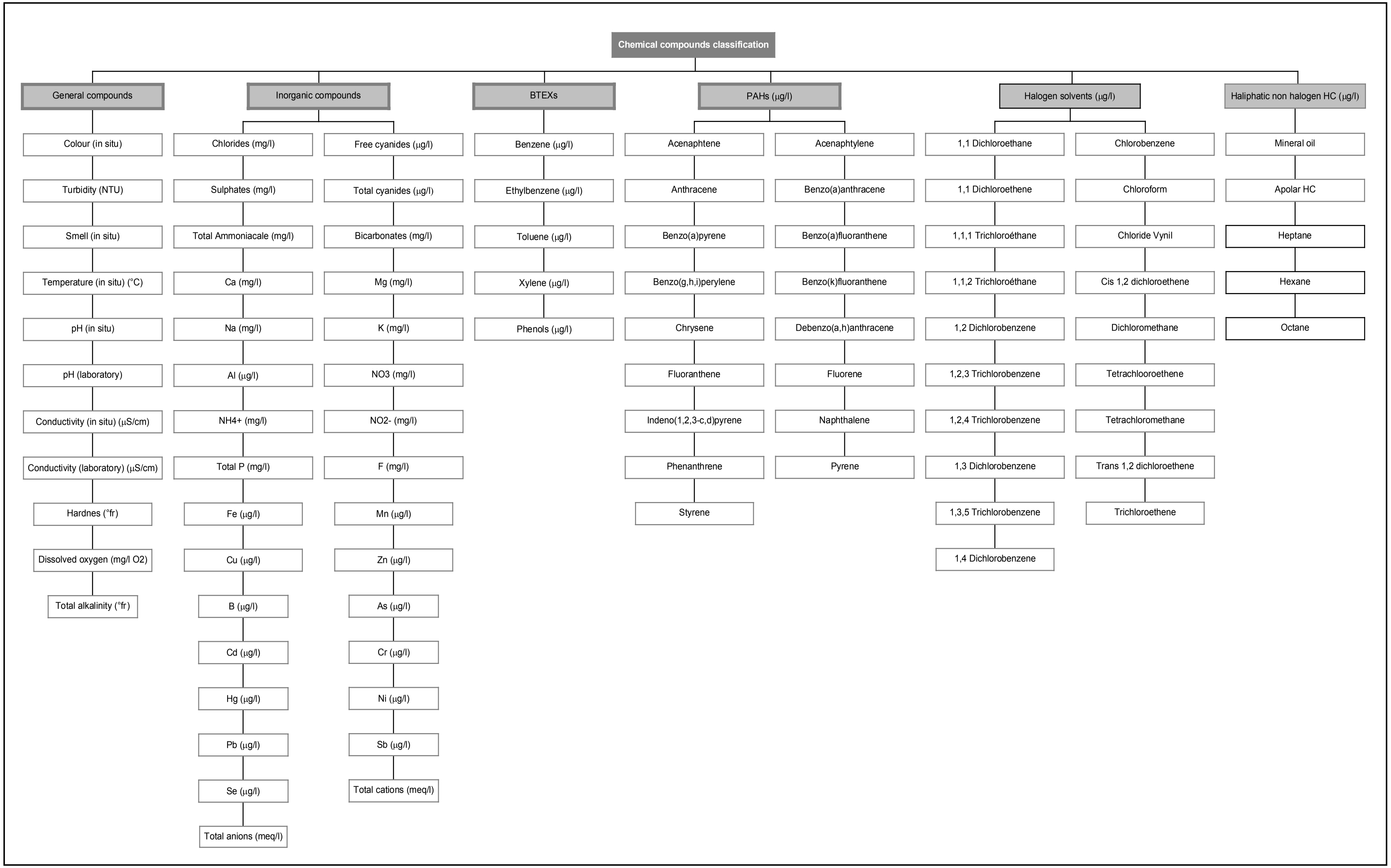

Figure 12. Classification of chemical parameters in the HGULg Hydrogeological Database.

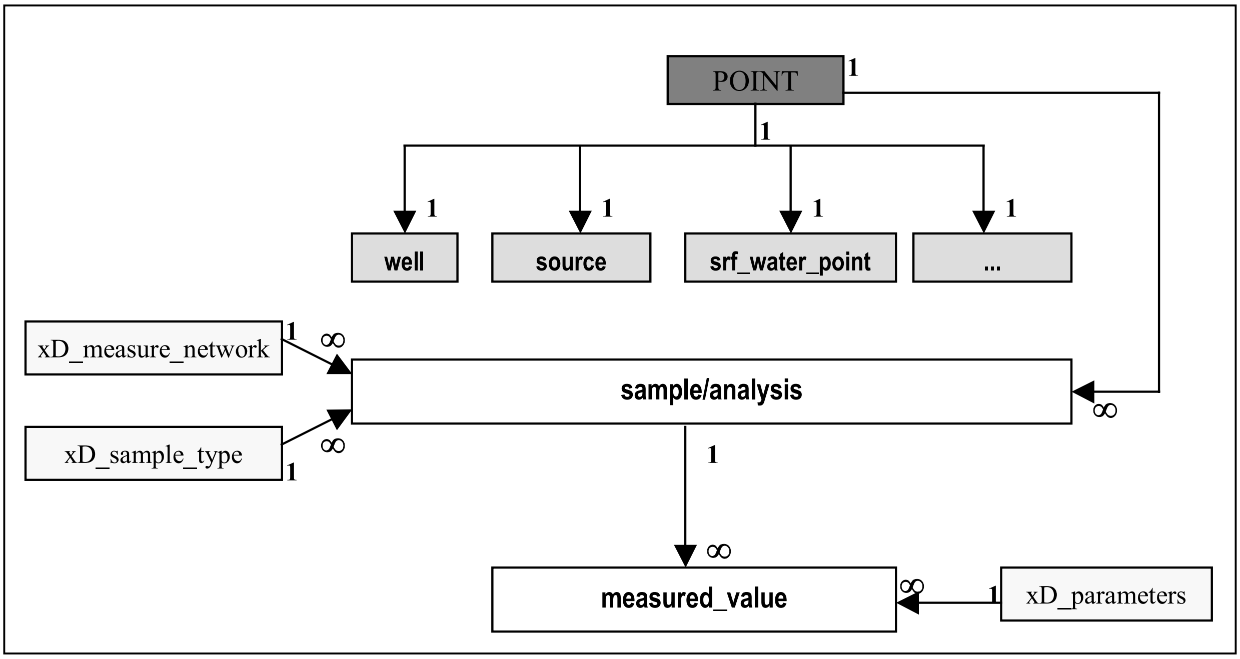

Figure 13. Chemical data sub-model in the Hydrogeogical Database.

As shown in Figure 13, several samples/analyses can be available for each *point* type object. Each analysis can also contain many measurements of parameters. For instance, 3 groundwater samples can be encoded for one piezometer and the results of the analyses made by a laboratory can be introduced.

The database also contains dictionary tables. This concept preserves a common naming convention for standard parameter's names and characteristics, types of samples or measurements networks which have been already encoded in the database.

Field experiments such as pumping tests and tracer tests also constitute very important information that might be quite complicated to handle and requiring specific fields for storing the associated information (experimental conditions and results). There are usually several wells involved, with an experimental configuration that might change from one test to another etc. To deal with the specificities of field tests, a logical scheme (test sub-model) has been developed, with all relationships between concerned tables, presented in Figure 14.

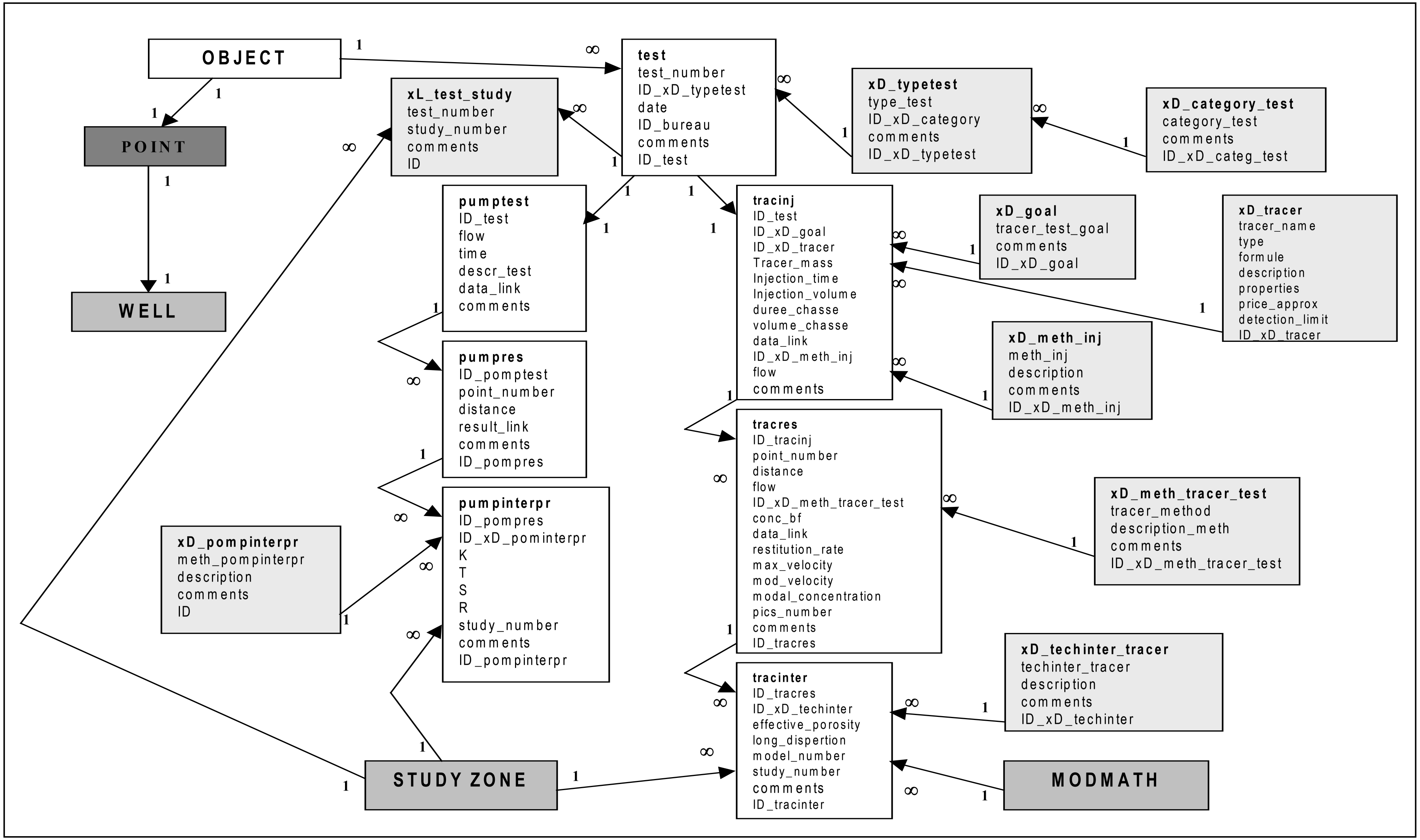

Figure 14. Data sub-model for pumping tests and tracer tests in the Hydrogeological Database.

In the test sub-model, the user can store data and information concerning different hydrogeological tests, which are divided into two categories – pump test and tracer test.

The first category describes general conditions of pump tests such as date, flow rate, pumping time etc which are strictly linked to the pumping well. Then several measurements points can be encoded with their distance from the pumping well and different observations. Finally different interpretations of pumping tests issued from each measurement point can be given, with parameters such as hydraulic conductivity, transmissivity, storage capacity.

The second category organizes information on tracer tests such as test objectives, information on used tracers, tracer injection which are associated to injection points (piezometers etc). Similarly, information associated to observation points are organized (sampling method, pumping rate etc). To both points, tracer test results can be associated (concentration evolution at the injection point, breakthrough curve at the pumping well etc). Finally, interpretations such as calibrated effective porosity or longitudinal dispersion, depending on the interpretation method and software, can also be stored.

The test sub-model is linked to the study-zone module, mathematical-model-zone module and different dictionary tables.

3.2.3. Implementation of the conceptual model in a Database Management System

A very important aspect in the conceptual data model implementation is the choice of a Relational Database Management System (RDBMS). An Access 97 RDBMS in a Windows Operating System environment has been adopted for the following reasons:

- it is a common known and accepted standard;
- it is possible to convert subsequently the data model to other more advanced and multi-user systems like SQL Server or Oracle;
- direct links are possible with almost every common Geographic Information System by ODBC (Open Database Connectivity) such as ArcGIS, GeoMedia Professional;
- it is possible to personalize it using SQL (Structured Query Language) and VBA (Visual Basic for Applications) tools;
- the data model representation is simple;
- there are good professional support – books, articles, internet specialised forums;
- it is a user-friendly environment.

However, an Access 97 application has also some drawbacks:

- the lack of multi-user environment,;
- the limits in data storage capacity (up to 1Gb in a single database file);
- the ambiguity in the data model representation: lack of good description rules and standards;
- the fact that database performance depends of its scale and growth.

For the Flémalle test site and the AquaTerra project, these drawbacks do not have any negative impact and a good performance of the database will be preserved.

3.3. User interface

Because of the very important amount of data and the elaborated structure of the database model, it is crucial to develop an interface, which manages data introduction (encoding process) and specific data extraction (data search and export).

This development enables an easy use of data and permits to define good security rules for different users. It also diminishes possible errors during data introduction, which is very important for the homogeneity and reliability of stored data.

The user interface should have a logical structure following an established scheme for data introduction or extraction. The user has to be guided through successive forms by pressing specific buttons. He/She has an access only to specified working modes (encoding or extraction of data) depending on his/her privileges.

The first form gives a choice between encoding or searching of data (Figure 15).

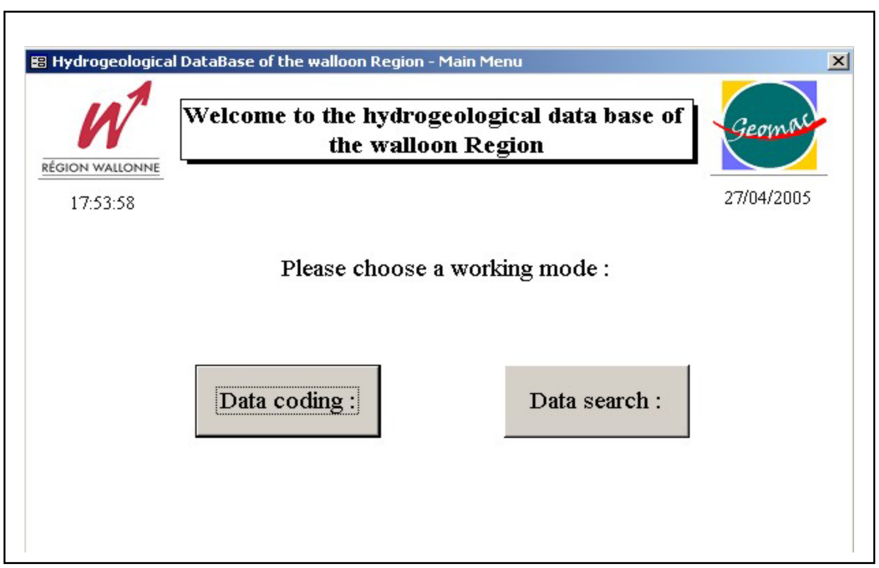

Figure 15. User interface main form, where data encoding or data search options are proposed

After the main form, the next form gives the choice to work in different modules:

- Well module;
- Test module;
- Contact module;
- Study zone module;
- Protection zone module;
- Others.

Each module contains specific data and functionalities relative to a specific problem. (Figure 16, 17, 18).

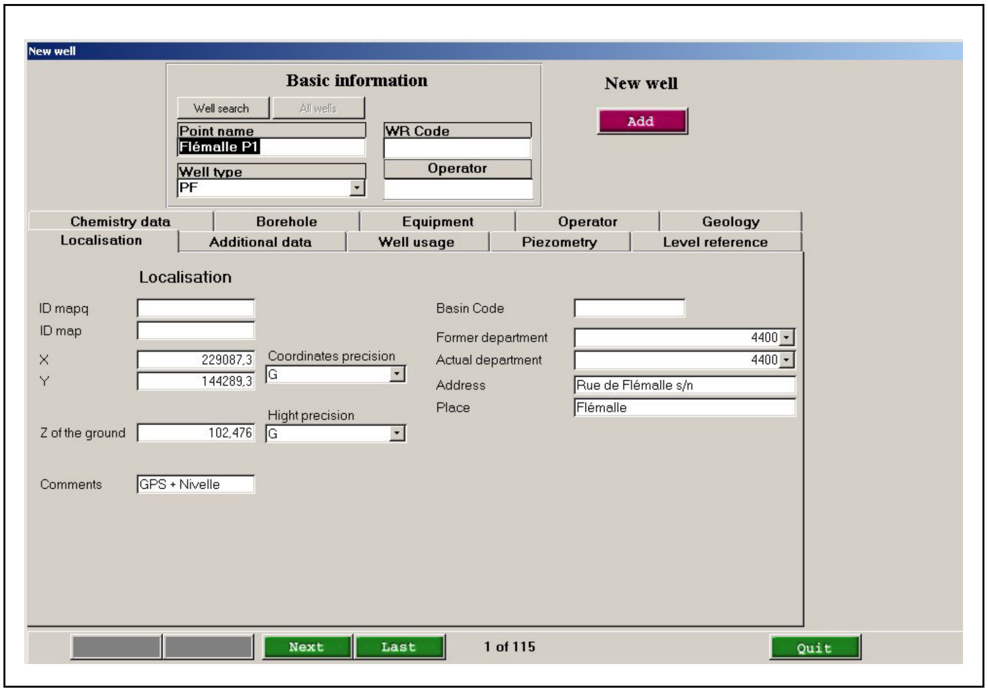

Figure 16. Localization form in the interface-encoding menu.

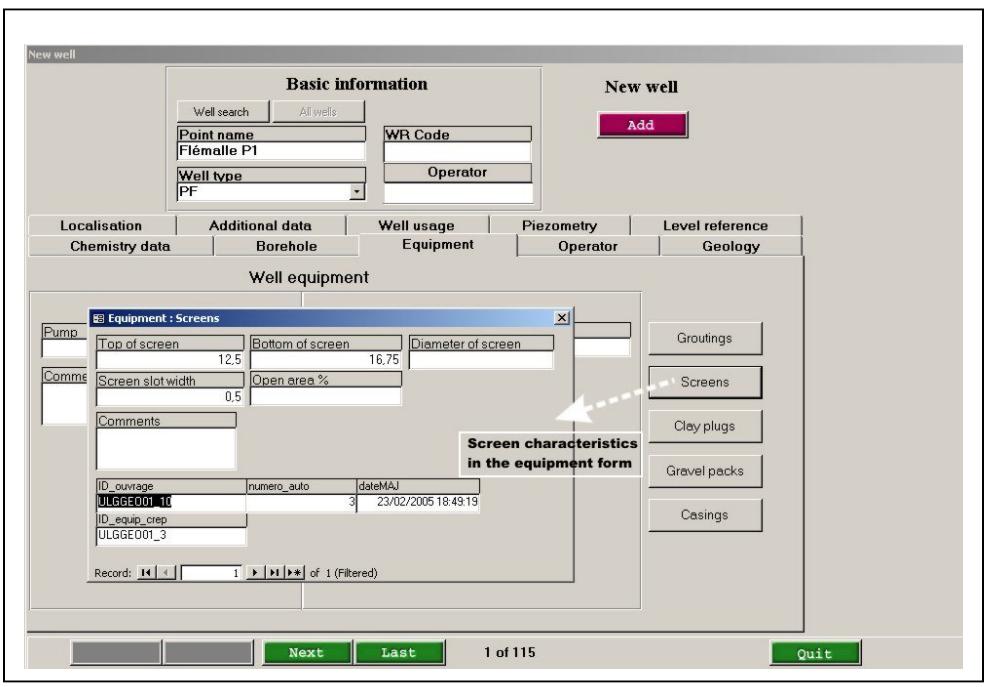

Figure 17. Example of equipment form with sub-window of screen data for a piezometer called Flémalle P1.

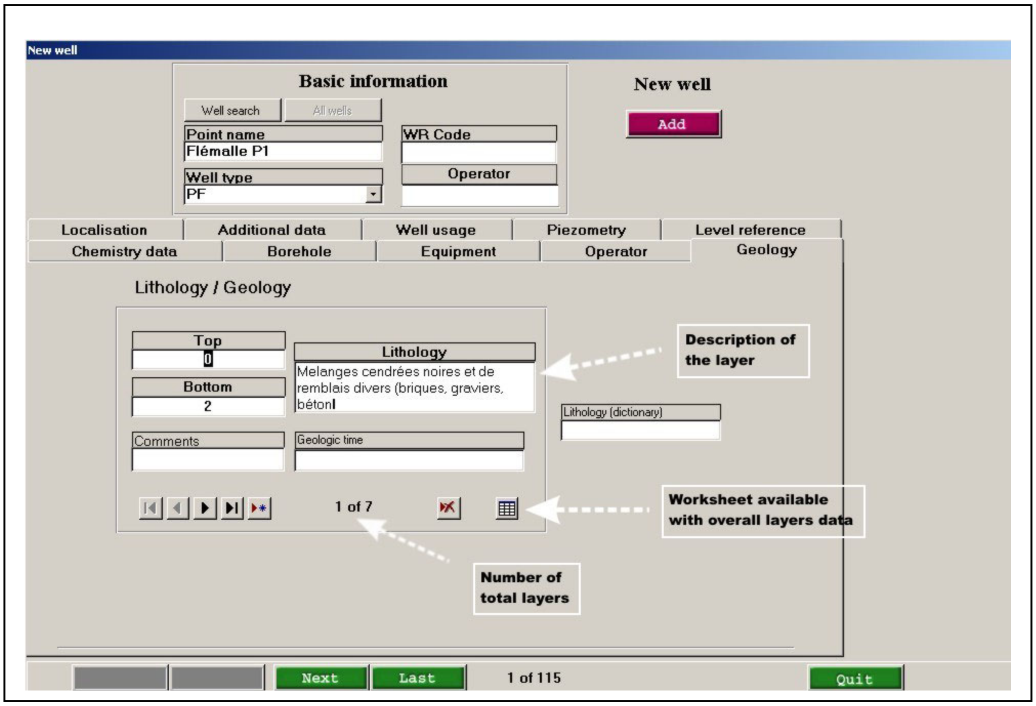

Figure 18. Lithology data encoding window.

After the data introduction process, the user has access to and possibility to search, to extract and to export stored data from the database, most often in a specified format for subsequent use and analysis (statistical analysis, groundwater modelling etc). For this purpose, several forms have been developed. One can search for a specific well, a specific contact person or research institution (drilling enterprise, chemistry laboratory, hydrogeological consultant), for pumping and tracer tests, etc, according to its location, date or type. These tools are still in development.

The search/extraction section has the same logical structure as the data introduction section, but the user has access to specific search forms (Figure 19, 20).

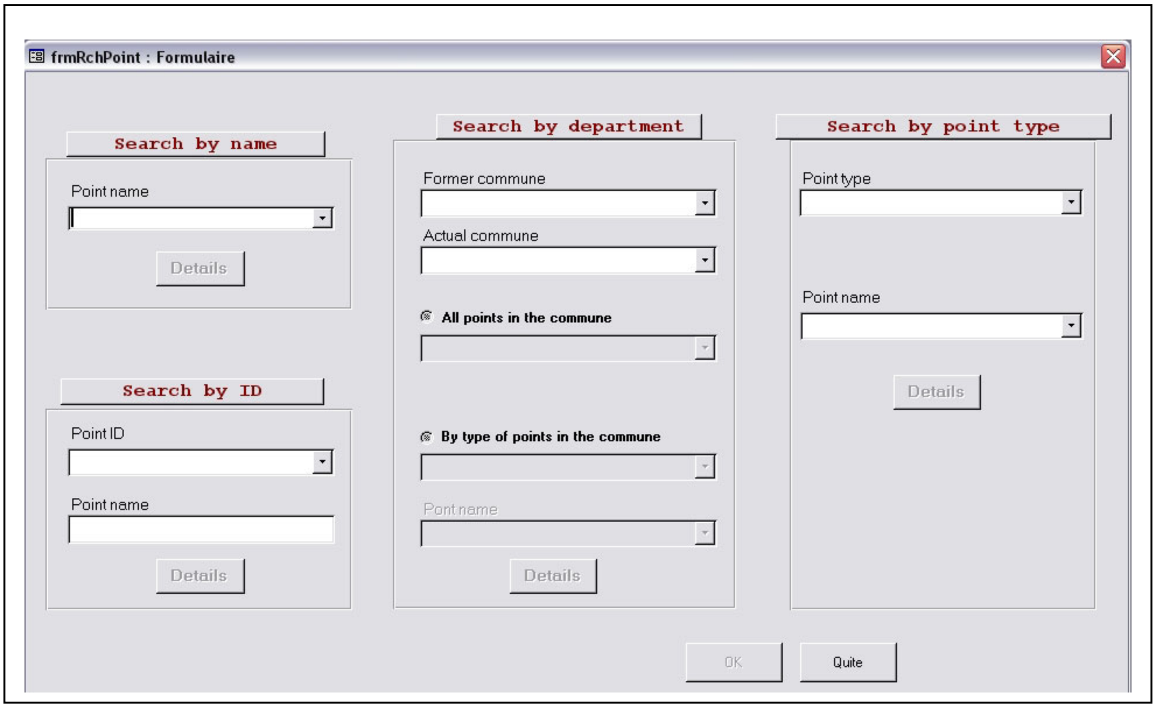

Figure 19. Point search, user interface

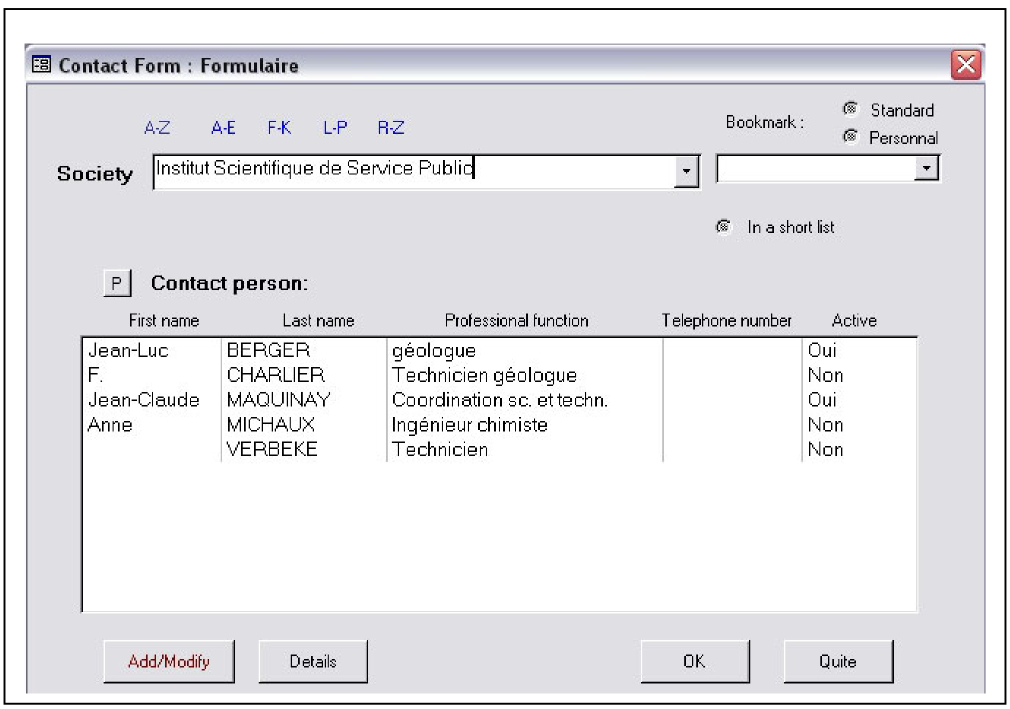

Figure 20. Contact and sub-contact person search

Different, additional logical and functional links between database elements can be introduced by a link module. The simplest example from the Flémalle test site is a link between this study zone and its different elements (Figure 21). This solution allows one to store topological information, which is independent of the GIS use and provide a powerful tool for the information search.

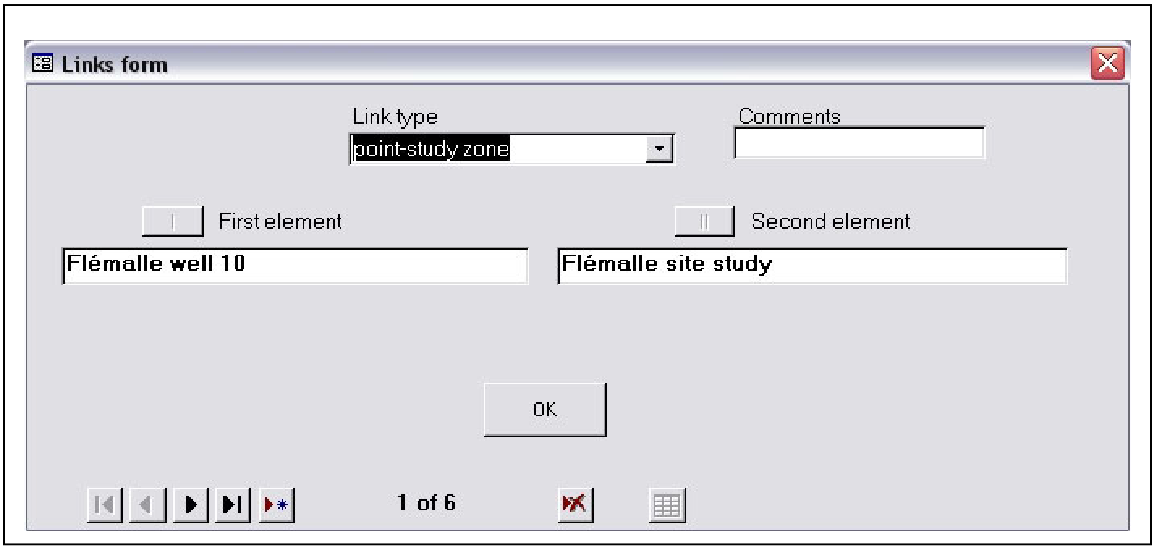

Figure 21. Example of a links form.

4. Summary of data collected in the Meuse basin and encoded in the Hydrogeological Database

4.1. Data collected and available for the whole Meuse basin

For the whole Meuse Basin in the Walloon region, information is presently available for about 4074 points of different types, more precisely:

- 913 drilled wells;
- 773 wells of unidentified type;
- 581 piezometers;
- 564 “traditional” wells;
- 316 water loss and emergence points (karstic features);
- 228 unidentified and other type points;
- 173 exploited springs;
- 158 access wells and galleries;
- 136 gauging points;
- 90 drains;
- 46 points of quality measurements;
- 40 other sources;
- 29 boreholes;
- 27 carries and mines extraction points.

At the following, more details are provided about data availability for the different study zones considered in the AquaTerra project.

4.2. The Flémalle former cokery site

As a result of former investigations and of the recent drilling campaign (carried out last march 2005), a substantial dataset is available for the Flémalle test site. This dataset will still increase thanks to ongoing field investigations related to the BASIN workpackage (pumping tests, tracer tests, geophysics…). Table 1 presents a summary of available piezometers/wells. In addition to these 110 piezometers, there are also 43 old piezometers not listed because they are not considered anymore as useful for different reasons: they are broken, clogged or dry.

An important dataset of chemical groundwater analyses is also available from groundwater samples taken from both the shallow and the deeper aquifer. These analyses include:

- General parameters measurements, such as pH, conductivity, temperature and dissolved oxygen;
- Inorganic compounds such as nitrates, cyanides…
- BTEXs and Phenols;
- PAHs;

- Halogenic solvents;
- Mineral oils, Heptane, Hexane and Octane;
- Heavy metals such as As, Ni, Cd, Zn, Pb…

Figures 22, 23 and 24 present a summarized overview of groundwater contamination from samples taken during a former field investigation (May 2001). Figure 21 shows that BTEX contaminants are present in specific locations, with a variable range of concentrations (up to 200000 μg/l). Figure 22 indicates a relatively high dispersion of inorganic contaminants and heavy metals, which some element, like Zn, reaching concentrations as high as 14000 μg/l. Figure 23 indicates a relatively large range in concentrations of mineral oils (frequently more than 20000 μg/l) as well as their high dispersion. Naphthalene is found in a high range of concentrations (between 13 and 8000 μg/l), but its presence seems to be limited to two main zones of the site.

Soil sample analyses are also available for several piezometers from two former field investigations (1992 and 2001). The distribution of contaminants is similar to what is observed in groundwater.

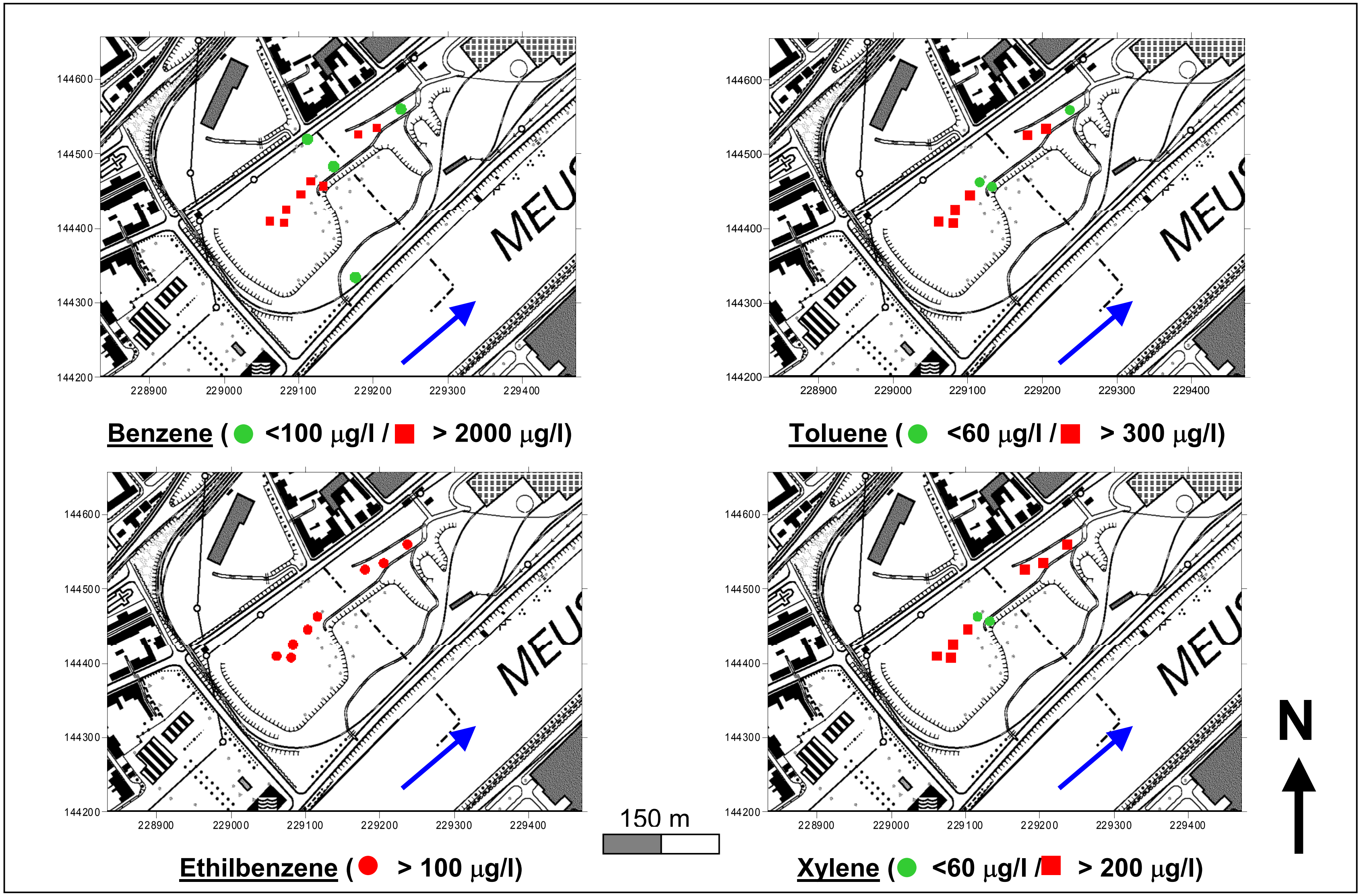

Figure 22. Summary of concentrations for different components of BTEXs in the Flémalle former cokery site.

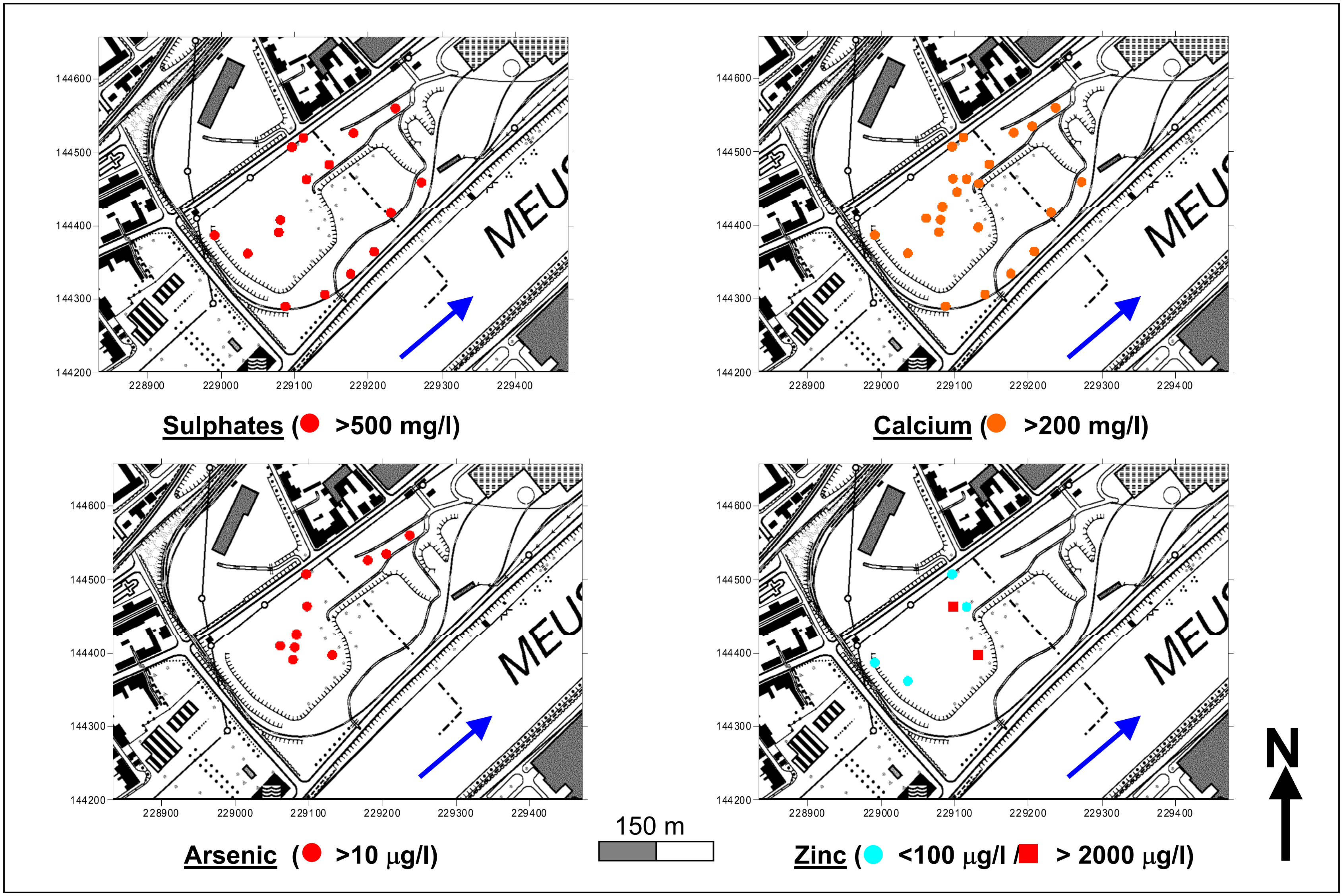

Figure 23. Sulphates, calcium, arsenic and zinc concentrations in the Flémalle former cokery site.

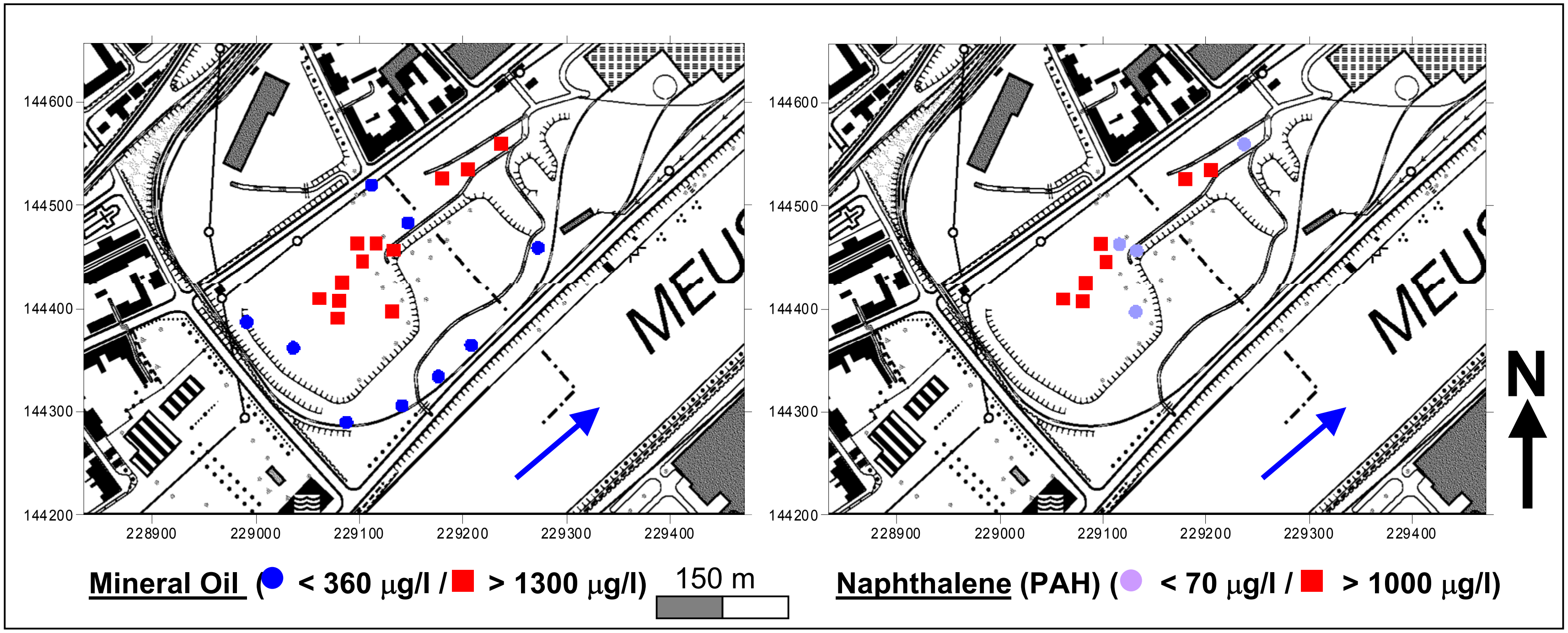

Figure 24. Groundwater concentrations of mineral oil and naphthalene (PAH) in the Flémalle former cokery site.

Table 1. Dataset summary of data available in Flémalle former cokery site.

ID	Latitude (N)	Longitude (E)	Z (m)	Depth (m)	Piez. Data (from march'05) [6]	GW Chem. analyses [7]			Soil Chem. analyses [8]		Log [9]
						1992	2001	2002	1992	2001	
1	20°36'17.59"	005°29'14.20"	67.515		✓				✓		
2	50°36'18.49"	005°29'16.21"	67.402	10.47	✓	✓			✓		
5	50°36'21.18"	005°29'22.21"	67.135	19.09	✓						
6	50°36'18.32"	005°29'13.38"	67.871	11.20	✓	✓			✓		
7	50°36'19.26"	005°29'15.42"	67.391	10.85	✓	✓			✓		
8	50°36'20.13"	005°29'17.38"	67.507	10.49	✓	✓			✓		
9	50°36'21.56"	005°29'18.70"	66.975	16.84	✓	✓					
10	50°36'22.55"	005°29'20.84"	66.789	16.23	✓						
11	50°36'19.50"	005°29'12.06"	64.560	15.50	✓	✓	✓		✓		
12	50°36'20.40"	005°29'14.03"	64.647	13.74	✓	✓					
13	50°36'21.35"	005°29'15.99"	65.140	15.93	✓	✓			✓		
14	50°36'19.41"	005°29'13.50"	67.530	18.80	✓	✓					
15	50°36'19.81"	005°29'16.25"	67.586	18.12	✓	✓					
101	50°36'21.55"	005°29'11.04"	64.920	9.85	✓		✓			✓	
102	50°36'20.35"	005°29'12.80"	64.688	8.67	✓		✓			✓	
103	50°36'21.15"	005°29'10.26"	64.753	6.88	✓		✓				
104	50°36'19.74"	005°29'10.28"	64.629	5.67	✓		✓				

[6] Piezometric data availability.
[7] Groundwater chemical analyses availability.
[8] Soil chemical analyses availability.
[9] Lithology log from drilling process.

ID	Latitude (N)	Longitude (E)	Z (m)	Depth (m)	Piez. Data (from march'05)	GW Chem. analyses			Soil Chem. analyses		Log
						1992	2001	2002	1992	2001	
201	50°36'18.31"	005°29'09.56"	64.846	7.92	✓			✓			
202	50°36'21.98"	005°29'15.53"	64.743	8.75	✓						
220	50°36'21.95"	005°29'15.69"	64.617	5.23	✓						
221	50°36'21.54"	005°29'15.92"	64.660	5.11	✓						
222	50°36'21.85"	005°29'16.33"	64.645	3.73	✓						
224	50°36'18.89"	005°29'09.23"	64.676	4.43	✓						
225			64.721	3.81	✓						
226	50°36'18.73"	005°29'10.13"	64.798	3.29	✓						
227	50°36'18.65"	005°29'10.83"	64.690	4.01	✓						
228	50°36'18.06"	005°29'09.89"	64.759	4.68	✓						
229	50°36'19.30"	005°29'09.48"	64.597	4.90	✓						
251	50°36'20.82"	005°29'06.53"	68.422		✓		✓				
252	50°36'22.16"	005°29'20.32"	66.922	10.94	✓		✓				
300	50°36'17.95"	005°29'09.56"	64.802	13.48	✓						✓
A2p	50°36'16.47"	005°29'11.68"	64.690	6.84	✓	✓			✓		✓
A2s	50°36'16.47"	005°29'11.68"	64.690	3.38	✓	✓			✓		✓
A3	50°36'16.04"	005°29'10.61"	64.420	9.20	✓	✓			✓		✓
A4p	50°36'15.60"	005°29'09.55"	64.540	6.61	✓	✓			✓		
A5	50°36'15.31"	005°29'08.20"	64.622	7.97	✓	✓			✓		✓
B1p	50°36'17.59"	005°29'11.98"	64.796	5.80	✓	✓	✓		✓		✓
B3p	50°36'16.75"	005°29'09.94"	64.665	7.05	✓	✓			✓		✓
B4p	50°36'16.28"	005°29'08.86"	64.620	7.50	✓	✓			✓		✓

ID	Latitude (N)	Longitude (E)	Z (m)	Depth (m)	Piez. Data (from march'05)	GW Chem. analyses			Soil Chem. analyses		Log
						1992	2001	2002	1992	2001	
B5p	50°36'15.81"	005°29'07.77"	64.639	6.80	✓	✓			✓		✓
B6p	50°36'15.63"	005°29'07.01"	64.682	6.90	✓				✓		✓
C2	50°36'17.82"	005°29'10.27"	64.760	3.90	✓				✓		✓
C3bis	50°36'17.46"	005°29'09.10"	64.755	12.40	✓	✓			✓		✓
C3p	50°36'17.41"	005°29'09.26"	64.723	8.30	✓	✓	✓		✓		✓
C3s	50°36'17.41"	005°29'09.26"	64.723	3.55	✓	✓			✓		✓
C4	50°36'16.89"	005°29'08.20"	64.751	8.30	✓	✓			✓		✓
C5p	50°36'16.49"	005°29'07.09"	64.926	6.67	✓	✓	✓		✓		✓
C6	50°36'16.11"	005°29'06.18"	64.807	7.75	✓	✓			✓		✓
C6bis	50°36'16.41"	005°29'06.41"	64.835	14.60	✓	✓			✓		✓
D1p	50°36'19.15"	005°29'10.55"	64.688	8.27	✓	✓	✓		✓		
D2bis	50°36'18.55"	005°29'09.48"	64.872	15.77	✓				✓		
D2p	50°36'18.51"	005°29'09.53"	64.842	3.44	✓	✓	✓		✓		✓
D2s	50°36'18.51"	005°29'09.53"	64.842	3.53	✓	✓			✓		✓
D3p	50°36'18.03"	005°29'09.40"	64.770	7.96	✓	✓	✓		✓		✓
D3s	50°36'18.03"	005°29'09.40"	64.770	2.92	✓	✓			✓		✓
D4p	50°36'17.32"	005°29'07.74"	64.828	7.08	✓				✓		✓
D4s	50°36'17.32"	005°29'07.74"	64.828	3.32	✓				✓		✓
D5p	50°36'16.81"	005°29'06.71"	64.835	6.81	✓				✓		✓
E3p	50°36'18.81"	005°29'07.16"	64.958	6.92	✓				✓		✓
E4p	50°36'18.25"	005°29'06.84"	64.963	6.96	✓	✓			✓		✓
E5p	50°36'17.89"	005°29'05.51"	64.808	6.89	✓				✓		✓

ID	Latitude (N)	Longitude (E)	Z (m)	Depth (m)	Piez. Data (from march'05)	GW Chem. analyses			Soil Chem. analyses		Log
						1992	2001	2002	1992	2001	
E6p	50°36'17.32"	005°29'04.82"	64.816	8.47	✓	✓	✓		✓		✓
E6s	50°36'17.32"	005°29'04.82"	64.816	6.86	✓	✓			✓		✓
F1p	50°36'20.33"	005°29'09.22"	64.522	8.20	✓	✓			✓		✓
F3p	50°36'19.68"	005°29'06.82"	64.836	8.43	✓	✓	✓		✓		
F4	50°36'19.24"	005°29'05.76"	64.950	7.38	✓	✓			✓		✓
F5p	50°36'18.52"	005°29'05.05"	64.985	8.41	✓	✓			✓		
P1	50°36'14.13"	005°29'09.63"	67.911	18.20	✓		✓				✓
P2	50°36'14.63"	005°29'12.38"	68.036	16.00	✓		✓				✓
P3	50°36'15.52"	005°29'14.18"	67.807	15.00	✓		✓				✓
P4	50°36'16.49"	005°29'15.82"	67.754	15.50	✓		✓				✓
P5	50°36'18.20"	005°29'17.03"	67.352	15.35	✓		✓				✓
P6	50°36'19.51"	005°29'19.17"	67.195	16.60	✓		✓				✓
S1p	50°36'21.73"	005°29'14.53"	64.668	8.75	✓	✓	✓		✓		✓
S1s	50°36'21.73"	005°29'14.53"	64.668	3.60	✓	✓			✓		✓
S2p	50°36'21.99"	005°29'15.81"	64.626	6.59	✓	✓			✓		✓
S2s	50°36'21.99"	005°29'15.81"	64.626	3.13	✓				✓		✓
S3	50°36'22.79"	005°29'17.45"	64.590	4.85	✓	✓	✓		✓		✓
S5p	50°36'17.95"	005°29'09.39"	64.808	7.24	✓	✓	✓		✓		
S5s	50°36'17.95"	005°29'09.39"	64.808	3.52	✓	✓			✓		
S7p	50°36'19.71"	005°29'11.22"	64.633	9.20	✓	✓	✓		✓		
U2	50°36'17.16"	005°29'05.89"	64.868	11.00	✓						✓
U3	50°36'18.31"	005°29'05.75"	65.011	10.00	✓						✓

ID	Latitude (N)	Longitude (E)	Z (m)	Depth (m)	Piez. Data (from march'05)	GW Chem. analyses			Soil Chem. analyses		Log
						1992	2001	2002	1992	2001	
U4	50°36'18.63"	005°29'11.49"	64.749	10.70	✓						✓
U4b	50°36'18.63"	005°29'11.49"	64.749	7.50	✓						✓
U5	50°36'17.60"	005°29'11.14"	64.734	11.50	✓						✓
U6	50°36'18.30"	005°29'12.22"	64.797	7.00	✓						✓
U7	50°36'17.27"	005°29'11.54"	64.932	8.00	✓						✓
U8	50°36'15.67"	005°29'10.51"	64.563	7.00	✓						✓
U9	50°36'15.67"	005°29'10.51"	64.563	11.00	✓						✓
U10	50°36'15.68"	005°29'12.80"	67.277	14.50	✓						✓
U11	50°36'17.57"	005°29'13.70"	67.462	9.00	✓						✓
U12	50°36'20.86"	005°29'11.46"	64.636		✓						✓
U13	50°36'18.66"	005°29'13.97"	67.411	14.20	✓						✓
U14	50°36'18.62"	005°29'15.05"	67.735	8.00	✓						✓
U15	50°36'18.35"	005°29'18.38"	67.088	14.20	✓						✓
U16	50°36'20.35"	005°29'19.05"	66.109	7.50	✓						✓
U17	50°36'19.85"	005°29'20.35"	67.096	14.80	✓						✓
U18	50°36'21.38"	005°29'21.28"	66.929	8.99	✓						✓
U19	50°36'21.38"	005°29'21.28"	68.553	14.30	✓						✓
U20	50°36'18.59"	005°29'18.33"	64.593	7.00	✓						✓
U21	50°36'22.72"	005°29'18.32"	64.637	11.80	✓						✓
U22	50°36'21.85"	005°2917.41"	64.778		✓						✓
U23	50°36'21.85"	005°29'17.41"	64.778		✓						✓
U24	50°36'22.91"	005°29'16.57"	64.609	10.80	✓						✓

ID	Latitude (N)	Longitude (E)	Z (m)	Depth (m)	Piez. Data (from march’05)	GW Chem. analyses			Soil Chem. analyses		Log
						1992	2001	2002	1992	2001	
U24b	50°36’22.91”	005°29’16.57”	64.609	7.50	✓						✓
U25	50°36’22.47”	005°29’13.90”	64.732		✓						✓
U26	50°36’20.97”	005°29’14.28”	64.593	8.00	✓						✓
U27	50°36’19.37”	005°29’14.26”	67.357	11.00	✓						✓
U28	50°36’16.90”	005°29’01.99”	65.889		✓						✓

4.3. The Geer basin

For the Geer basin, the Hydrogeological Database contains presently 461 information points (Figure 25) with hydrogeological data in many cases available, such as well characteristics, geological logs, monitoring of piezometric levels, groundwater sample analyses, nitrates survey network and results of hydrogeological tests (pumping tests and tracer tests).

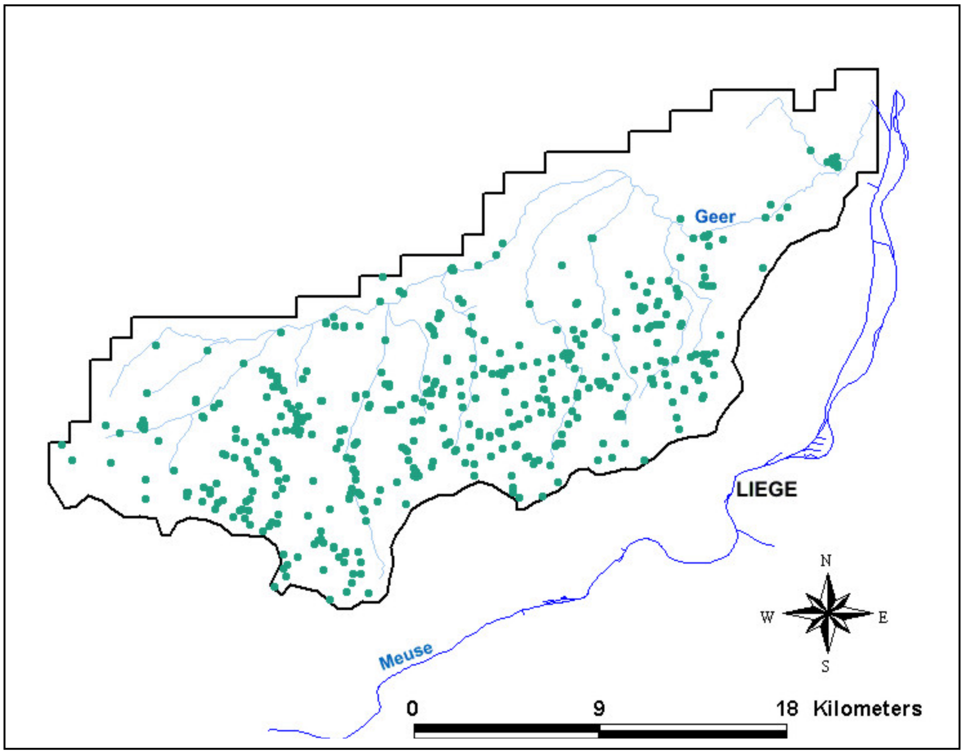

Figure 25. Groundwater points in the Geer basin.

Because of its importance, many hydrogeological tests has been carried out in the past in this groundwater body. Figure 26 indicates locations where piezometric data are available. Figure 27 shows locations where pumping tests (in blue), tracer tests (in green) and groundwater chemical data (in red) are available.

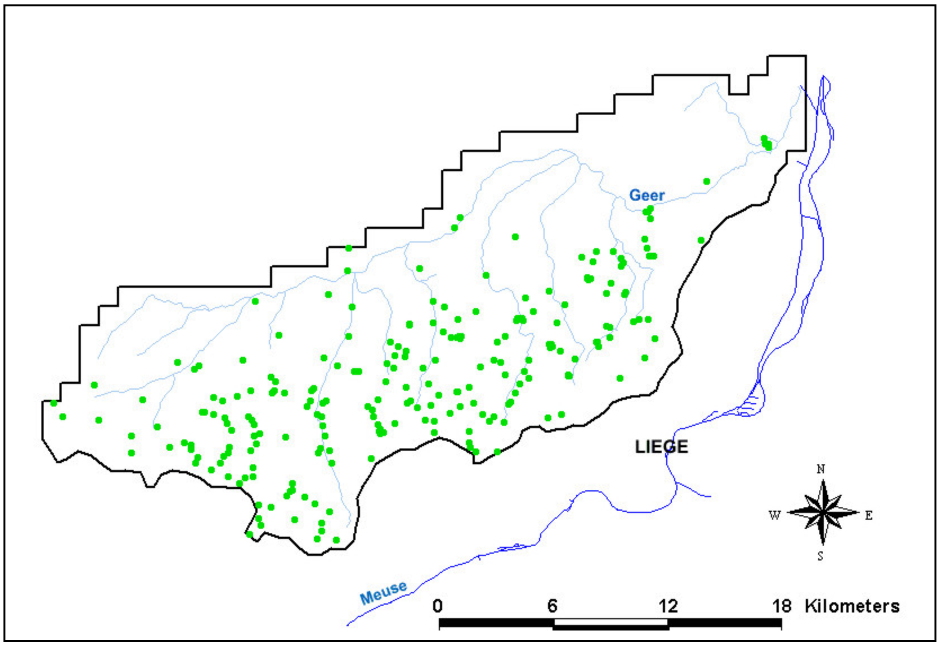

Figure 26. Groundwater points with piezometric data in the Geer basin.

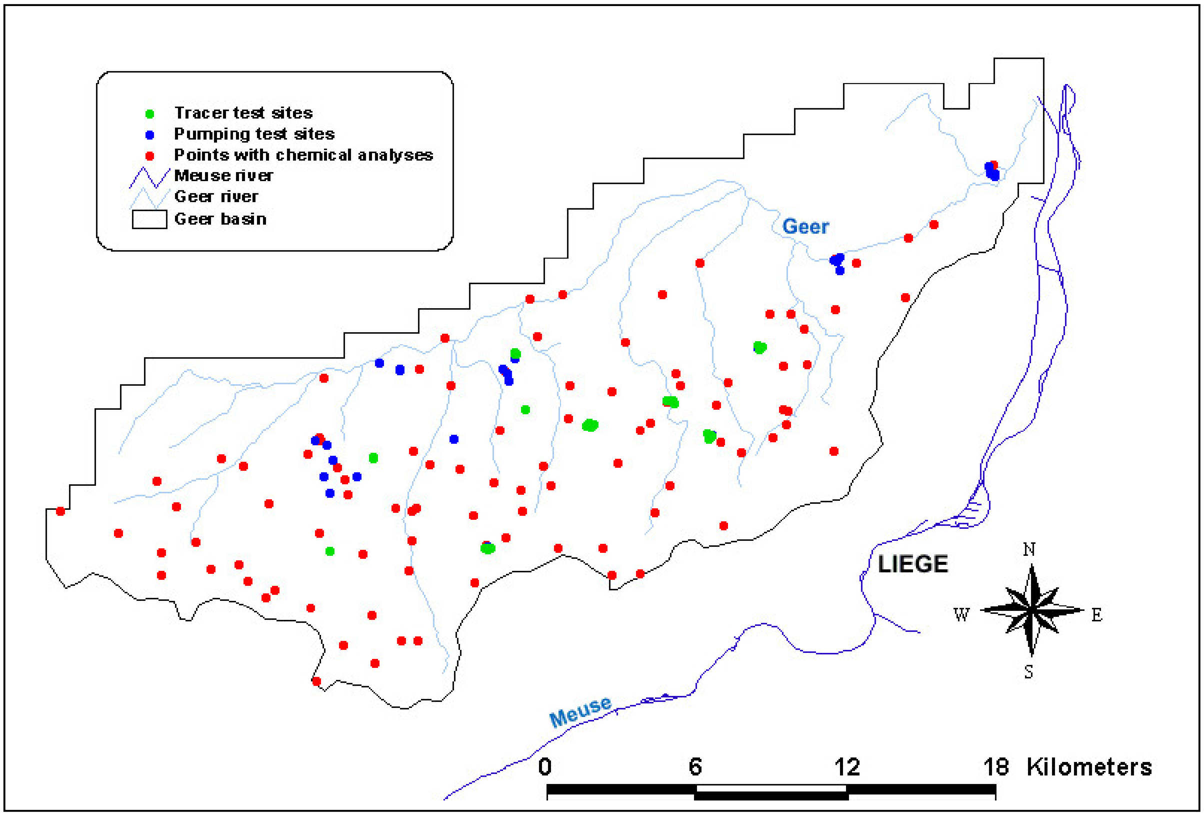

Figure 27. Groundwater points with pumping tests, tracer tests and groundwater chemical data available in the Geer basin.

5. Conclusions and perspectives

A general inventory of possible test sites has been performed in order to identify relevant case studies for the research activities of HGULg and other interested partners in the AquaTerra project. Based on this survey, two main test sites have been selected. The first is the Flémalle former cokery site, where joint research efforts between BASIN and BIOGEOCHEM activities will be carried out for studying surface water – groundwater interactions in relation with contamination problems and for assessing the fate of organics and heavy metals in both the saturated and the unsaturated zone. The second is the Geer basin (Hesbaye chalk aquifer), which will serve as a support for different research activities in common between BASIN, COMPUTE, HYDRO H1 and TREND T2.

In order to manage all information available for these test sites, the Hydrogeological Database developed by HGULg for the Walloon region has been adapted to the needs and specificities of the AquaTerra project (management of results of hydrogeological tests, chemical data etc). Using detailed datasets collected in Flémalle and in the Geer basin, the HGULg Hydrogeological Database has been tested to check its efficiency and adequacy to the AquaTerra project.

Subsequent data collected and field investigations, measurements and experiments will continue to feed the Database and all these data will be used in the future for the different activities foreseen by HGULg in the project (direct activities in BASIN and TREND, cooperation with HYDRO and COMPUTE).

6. References

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