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## eWater

# Inventory of hydrogeological maps and models available in partner countries

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***e*Content*plus***

This project is funded under the *e*Content*plus* programme[1],
a multiannual Community programme to make digital content in Europe more accessible, usable and exploitable.

[1] OJ L 79, 24.3.2005, p. 1.

# 1 Table of contents

# 2 Executive Summary

European countries are facing a challenge in defining Water (River Basin) Management Plans where groundwater is an important component. Groundwater is the only available source for water supply in many areas of the world, particularly in periods of severe drought, and this includes the southern European countries. Groundwater largely conditions economic development and is extensively used in agriculture. As something more recently valued, it does condition the health of the environment by providing the base flow of many rivers and wetland areas, and it plays a key role in maintaining these areas and the associated ecosystems during dry periods. European countries are also facing significant pollution of soil and groundwater resources caused by human activities in the past. Owing to the slow flow of groundwater compared to that of surface water, remediation is in many instances a long-term problem and its solution needs to be optimised in order not to deem cleaning extremely expensive and unaffordable.

The Water Framework Directive (WFD or Directive 2000/60/EC) establishes a framework for Community action in the field of water policy, and aims to protect and improve the status of the aquatic environment and promote sustainable water use, with an explicit mention to groundwater. The WFD is being implemented by involving a large number of working groups, experts and stakeholders who need to share some common basis of information. The importance of incorporating not only users of water resources in the decision-making process is also highlighting how essential it is to make wide use of the knowledge available on groundwater.

The national Geological Surveys have been responsible for preparing hydrogeological cartography for decades, and now have an important role to play in managing the information on the geographical definition of the groundwater bodies, their hydrodynamic properties and their flow models. In many instances, the national Geological Surveys are responsible for the associated monitoring programmes. The implementation of a system, such as eWater, which provides multilingual access to the groundwater databases managed in these institutions, will undoubtedly help to meet the WFD requirements and promote this culture of participation. Sharing the information that eWater may manage will facilitate the definition of the water bodies and their environmental impacts, the application of different remediation technologies, and the use and incorporation of proper monitoring techniques into the system.

In recent years, the Geological Surveys of European Union member countries have had to take into account and adapt to INSPIRE (Infrastructure for Spatial Information in the Community). This initiative aims to provide implementing measures in order to facilitate the use of spatial data from different sources across the Member States. These measures should be designed to make the spatial data sets interoperable. All Member States must meet the “interoperability” conditions required by INSPIRE in the medium term. The trend envisaged for the near future is to advance towards cross-border information systems.

One of the main objectives of eWater is to enhance “interoperability” among European Geological Surveys in general, and those of the participating countries in particular, allowing the hydrogeological cartography of any country hosted in the corresponding Geological Survey web server to be displayed, in such a way that the user is not hampered by language or national interpretations. The trend envisaged in the near future is to advance towards cross-border information systems. The present Project has already prompted the participating Geological Surveys to move in this direction. It is providing potential users of spatial hydrogeological data

with a significant amount of structured information and knowledge on how these data have been represented in hydrogeological maps in the past and how they are currently represented and managed.

Recognising that the display of large-scale (1:50,000) harmonised hydrogeological cartography of Europe is an ambitious objective on the one hand, and recognising the importance that initiatives such as the WHYMAP have for small scale maps (1:1,500,000) on the other, eWater tries to contribute to the exchange of information on groundwater and help the user to access the raw information produced originally in each country by facilitating understanding of the main concepts and symbols used in the cartographic products in the original languages.

This report presents an inventory of the hydrogeological maps available at the Geological Surveys of Austria, Denmark, Emilia Romagna (Italy), France, Hungary, the Netherlands, the Czech Republic, Lithuania, Slovakia, Slovenia, Spain, and Sweden, and an analysis of this information. Readers will be able to discover what the main achievements of the participating Geological Surveys were in this field in the past, and what products are currently being designed. They will also obtain an idea of the efforts that are proposed in order to enhance interoperability at national and European level for this geographical information in the future.

The inventory of hydrogeological maps has been built as a Database, which not only allows the information already compiled in the eWater project to be updated, but also for other EU countries to participate in this initiative in the future.

# 3 Objectives

## *3.1 Project objectives*

The main objective of the project is to increase the cross-border availability, accessibility and re-usability of spatial data on quality, location and use of subsurface waters. Geodata market research has shown that groundwater (hydrogeological) data is of great market demand, in second place in the rating list, immediately after the data on rock composition (lithology).

These data are currently stored in national databases and are available exclusively for the national user in the local language. Therefore, the hydrogeological data across the national borders form separated, uncorrelated, uninteroperable datasets. As a result, much of the hydrogeological spatial information is difficult to exploit in both the international and national water management contexts.

In order to achieve the main objective, the project will develop an internet system that will provide cross-border **multilingual** access to groundwater spatial datasets stored in the participating countries' national databases. The eWater Web portal will serve as a common gateway and meeting point for all those who have stakes in cross-border management issues, including the EC. The portal will primarily concern groundwater-monitoring measurements, such as water level and chemical composition, as well as digital hydrogeological and geological maps. A plan for portal augmentation and continued maintenance will be developed in order to provide sustainability to the system after the project has finished.

The project will contribute to the implementation of the European Water Framework Directive (WFD) for river basins and groundwater bodies as well as INSPIRE guidance regarding improvement of accessibility of geoenvironmental data to the public. Moreover, it may become a major tool towards achieving EU's Water Information System for Europe (WISE).

The exact datasets to be distributed via the eWater portal will be defined during the first stage of the project. The preliminary datasets that will have priority in the project include:

A) Hydrogeological point measurements (from monitoring wells)
- The geographical location of measurement wells
- Measurement metadata, including reference levels
- Water measurement data, namely hydrochemistry / quality and levels relative to the earth's surface level

B) Digital water management-related maps
- The description of spatial data available; these metadata are not harmonised internationally at the moment.
- Digital hydrogeological / geological maps, available in the participating organisations; hydrogeological maps are normally obtained as the result of the interpolation of point (well) measurement data and interpretation of the geological maps.

### 3.2 Objectives on interoperability of hydrogeological maps: Work Package 6

The project is separated into 12 technical work packages, distributed in time in three stages:

1. Inventory and definition stage (months 1-10)
2. Implementation and testing (months 11-18)
3. Dissemination and demonstration (months 19-24)

In work package 6 (WP6) interoperability of digital maps started at the beginning of the project will continue beyond stage 1 until month 12. WP6 will consider the main problems concerning the aggregation of digital thematic maps. The main objectives of WP6 are:

- To conduct a survey on current hydrogeological maps and models in the project partner countries.

- To make the objects available in the digital maps and models accessible via the Portal and present them in such a way that the user is not hampered by language or national interpretations.

- To provide insight so that these maps and models can be understood by potential users in other countries. Without appropriate information translated in one of the widely used languages, the user from outside the country is facing unbridgeable problems caused by different projections, legends, procedures, nomenclatures, definitions, standards, etc.

- To harmonise some cross-border maps for areas selected by the partners.

- To substantially increase the possibility of information sharing by enabling the user to locate the information, and explaining the information and making it available online in harmonised delivery formats.

This report presents the results of a survey conducted on current hydrogeological maps and models in the project partner countries, and analyses the answers provided by all 12 Geological Surveys participating in the project. This analysis, done during the first six months of the project, is considered the first necessary step for obtaining an overview of the maps and models, specifying their most important characteristics, such as type, format (paper, digital: raster or vector), scale, coverage, legend, projection system, and availability.

# 4 The participating Institutions

The eWater consortium consists of the following organisations:

1. The Dutch Geological Survey (TNO)
2. The Geological Survey of France (BRGM)
3. The Geological Survey of Denmark and Greenland (GEUS)
4. The Geological Institute of Hungary (MAFI)
5. Geofond – Czech Geological Survey
6. The Geological Survey of Slovak Republic (GSSR)
7. The Geological, Seismic and Soil Survey of Emilia-Romagna Region; the Emilia-Romagna Regional geological office (SGSS) is a part of the Italian Geological Survey.
8. The Geological Survey of Austria (GBA)
9. Lithuanian Geological Survey (LGT)
10. Informacines technologijos (Information Technologies (IT), Lithuania)
11. Geodan Mobile Solutions (the Netherlands)
12. G.I.M. Geographic Information Management NV (Belgium)
13. The Geological Survey of Slovenia (GeoZS)
14. The Geological Survey of Spain (IGME)
15. The Geological Survey of Sweden (SGU)

The eWater consortium consists of 12 Geological Surveys, these are data holders, providers and very often users, since they provide the governments with hydrogeological expertise for decision-making. The project also includes 3 commercial added-value data service companies. Their involvement will ensure that the eWater system will focus on external commercial end-users.

The institutions participating in the survey on the inventory of hydrogeological maps, all members of the eWater consortium, consist of the following 12 Geological Surveys, 11 national and 1 regional:

1. The Geological Survey of Austria (GBA)
2. Geofond – Czech Geological Survey
3. The Geological Survey of Denmark and Greenland (GEUS)
4. The Geological Survey of France (BRGM)
5. The Geological Institute of Hungary (MAFI)
6. The Geological, Seismic and Soil Survey of Emilia-Romagna Region; the Emilia-Romagna Regional geological office (SGSS) is a part of the Italian Geological Survey.
7. Lithuanian Geological Survey (LGT)
8. The Dutch Geological Survey (TNO)
9. The Geological Survey of Slovak Republic (GSSR)
10. The Geological Survey of Slovenia (GeoZS)
11. The Geological Survey of Spain (IGME)
12. The Geological Survey of Sweden (SGU)

European Geological Surveys have played and are playing a key role in the preparation of national geological maps and the resulting thematic maps, which cover aspects such as hydrogeology, groundwater resources, mineral resources, vulnerability of aquifers, geomorphology, geological hazards, soils, and geochemical characterisation. These European Geological Surveys are responsible for managing all the information compiled under these mapping activities, which is the starting point for many different projects of high strategic and economic impact in the areas of health, natural resources, public works, sustainable development and environmental protection.

# 5 Methodology: A survey to build an inventory of hydrogeological maps

## 5.1 Survey objectives

The inventory of hydrogeological maps to be built in this project was conceived to provide a picture of all the hydrogeological maps that all the partners currently have, or may have in the near future (in the next two years during the eWater project). The starting point was a rather complex and large amount of information that we were trying to structure and synthesise with the help of a Questionnaire designed for this purpose.

The objective of the Questionnaire was thus to obtain precise enough information to build an inventory of hydrogeological maps that could answer questions such as:

- What type of hydrogeological mapping activities and products do we have in Europe (primarily in the twelve participating countries)?
- What is the content of these maps?
- What format do these maps have?
- How can access be gained to this information?

The Questionnaire did not aim to do an exhaustive cataloguing of every single hydrogeological map produced by the participating Geological Surveys at any time in the past. Neither did it aim to select map series in vector format with a complete national or regional (in the case of Emilia-Romagna) coverage. It was rather conceived with a wide and open scope and allowed the participating Geological Surveys to decide whether to include any cartographic product that they deemed valuable in this inventory. As a consequence, maps of different types with different purposes, different coverages (national, regional or local), or different formats (paper format included) have been inventoried and are available for queries from any potential user.

As the inventory is an end-product, it is also the starting point to compare hydrogeological classifications and make recommendations on interoperability. More specifically, with this inventory it is possible to select the hydrogeological cartography from each country, which will be made interoperable via the eWater portal.

The Questionnaire was not only designed to help to produce a report on the inventory of hydrogeological maps, but also to cope with related tasks included in WP6. Accordingly, questions were organised in several Groups. One group dealt specifically with the hydrogeological classifications included in the maps, and a comparison of these classifications is the first step towards map harmonisation. Another group dealt with the issue of interoperability and recommendations will be made for this.

## 5.2 Definitions

Map series (Systematic Series): group of homogeneous maps, regarding contents, scale and dimensions, which cover the whole country without any overlapping among them. Map series deal with basic (or general) geoscientific aspects important for the economic and social development of one country. This justifies its necessary extension to the whole country.

Singular map: Map covering a specific area, administrative division, hydrographical basin, natural zone, etc. whose preparation without any connection to a Map series or other cartographic development is due to its specific interest in one or more issues related to the Environment. A singular map consists of one or more sheets.

Digital map: Group of digital files that allow the reconstruction of a legible graphical representation of the specific information contained on the map with the right applications or tools. A digital map may be a scanned image or a group of spatial files in vector or raster format with a series of properties associated with each spatial element. A digital map consists of one or more layers.

Digital layer: Group of digital files containing spatial and thematic information on one specific feature of the environment and, in general, with the same geometry (points, lines or polygons), e.g. hydrogeological formations or water points.

Normally, digital layers are produced after the digitisation of already published maps or maps in progress. On occasions, the digital layer is produced from raw data taken in a specific project that does not have a map as an end-product, e.g. a layer of points after an inventory drafted in paper format.

Memoir or map report: Explanatory document associated with a map which is published and distributed with it.

## *5.3 Question Structure and Groups*

A Questionnaire on "Interoperability of digital maps" was designed as an empty Database in ACCESS format to later analyse and present the information gathered (Fig. 5.3.1). A Guide to the Questionnaire for WP 6 was provided to all participants to assist them with its completion.

Questions were organised in the following nine Groups. Two specific groups were designed to emphasise the importance of interoperability and accessibility issues.

*GROUP 1. Institution*
*Sales Agency*
General information relative to the institution or institutions responsible for the preparation and commercialisation of hydrogeological cartography in each country is compiled in this group.

*GROUP 2. Person in charge of the questionnaire*
The person identified in this Group is the reference and contact person for any explanation of the information gathered in the questionnaire.

*GROUP 3. Physical and Logical Systems*
General Information relative to the physical and logical systems that give support and service to the information systems and digital hydrogeological cartography in the organisation is included in this Group. The incorporation or acquisition of this information was deemed important and of interest to be able to provide later recommendations on interoperability.

*GROUP 4. Catalogue of Hydrogeological Maps*

*4.1 Complementary information Paper Map*

*4.2.Topographic Base*

Groups 4 and 5 constitute the core of the Questionnaire and were designed in a way that allows the user to search for information on digital layers and map series and singular maps (in digital or paper format) of interest for the eWater project at any scale. Setting a limit for the scale of the maps to the inventory was not deemed necessary in this initial stage because European countries are very different in size.

Considering the aim of the project and, more specifically, the objectives of WP6, the "modern" unit of work to be used, as the core of the inventory, is the digital layer. However, since it is important to have as complete a picture as possible of the current situation, and not leave out important past and recent developments in hydrogeological mapping, two "levels" (map in Group 4 and layer in Group 5) were considered, the first level allowed maps in paper format under Group 4.2. to be clearly identified.

Group 4 applies to all types of hydrogeological maps. There is one full table for each series of maps or singular maps irrespective of whether they are digital or paper format. In order to limit the scope of the answers, however, we recommended focusing on map series, and preferably on those available in digital format, and limiting the information to be provided on singular maps or singular layers. More detailed answers were deemed necessary when defining digital maps; this is taken into account in Groups 5 and 6.

This part of the Questionnaire mainly reflects the concepts and structure of the metadata but it is important not to confuse these terms. This inventory does not intend to be a catalogue of metadata.

*GROUP 5. Content Layer*

*5.1 Attribute Layer*

This group is directly related to Group 4 but is to be completed only for digital maps (consisting of one or more layers). Dealing with digital maps means dealing with layers (Group 5) and their attributes (Group 5.1). It is only from the level of the layer that the user can obtain an idea of what geospatial information the Geological Surveys actually have.

It was possible to include in Group 5 some "isolated" but important layers of information that all Geological Surveys may have produced but had not yet put on a map, e.g. groundwater bodies identified for the Water Framework Directive. Therefore, Group 5 should include layers of information which are unique, continuous and consistent for the whole national territory in each of the participating countries, which could constitute a map if published in the web associated with a topographic base, and which are currently available or will be available in the near future during eWater.

*GROUP 6. Legend*

This group, directly related to group 5, allows the parameters used for representing, symbolising and classifying the hydrogeological information for each layer to be established. A study combining the information from Group 5 and 6 will give the basis for approximating a possible harmonisation of hydrogeological legends in the following stages of eWater.

*GROUP 7. Data model*
This group compiles information on the data models established for every type of map: series of maps or singular maps. This information is important to provide recommendations on interoperability.

*GROUP 8. Accessibility*
This group compiles information on the level of accessibility of the hydrogeological information for each of the inventoried maps and layers. Users will be informed about the services available to gain access to the maps, the sales agencies' addresses, and the estimated costs when maps are not free of charge.

*GROUP 9. Interoperability*
This group addresses direct questions on the degree of fulfilment of the interoperability standards of the catalogued layers.

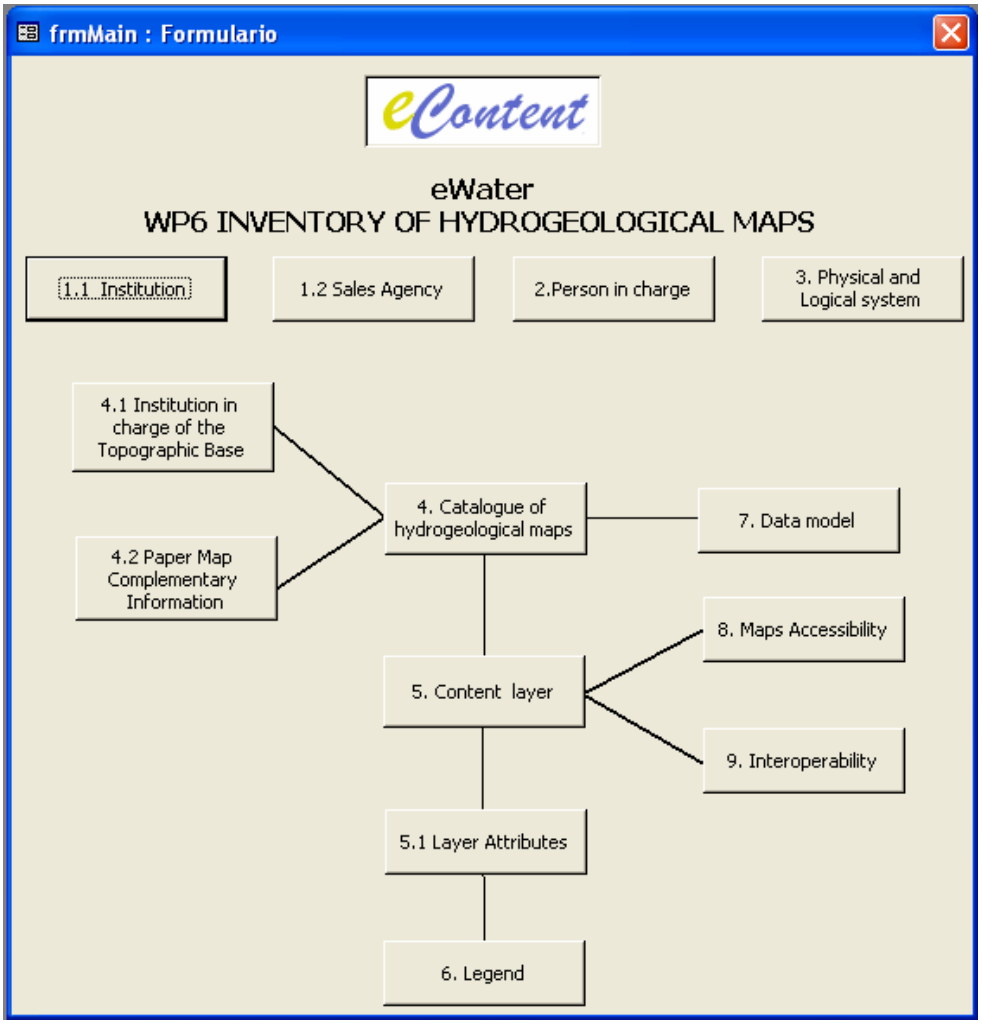



**Figure 5.3.1** Overview of Database

# 6 Status of hydrogeological mapping in the participating countries

The origin of the Geological Surveys in most of the European countries participating in this project lies in the national geological cartography initiated in the second half of the XIX century or the beginning of the XX century. Therefore, these Geological Surveys have been providing society with knowledge on the Earth Science infrastructure for an average of more than 100 years.

Alongside the technological progress in groundwater abstraction, namely with the design of submerged electrical pumps, groundwater resources began to play an important role not only in water supply but also in irrigation plans. The European Geological Surveys were forced to react and update their resources technically and strategically to adapt to the shifts in needs and demands regarding the use and protection of groundwater resources. One of the consequences was that many hydrogeology and groundwater studies were increasingly launched and conducted from 1960 to 1980 in European countries as part of ambitious multiannual Survey Plans on groundwater. The first hydrogeological maps in paper format were produced during or right after these times, when the need to synthesise the spatial knowledge acquired was felt to warrant better use of groundwater resources.

The participating countries produced their hydrogeological maps in the 1970s and 1980s at different scales to match their specific needs and target users in initiatives that continue to date. These hydrogeological maps made it possible to identify spatial information on the location of aquifer formations and their nature (karstic, porous, fractured), and to estimate their potential use for supplying groundwater resources, and also identify the principles of their hydrogeological functioning, recharges and discharges.

Hydrogeological maps were a “picture” of the knowledge generated up to a fixed date. The need to continuously update this knowledge required the preparation of new maps in costly and extremely demanding work in terms of human and economic resources.

The progress in Information Systems and the wide access to compatible personal computers in the 1990s made the European Geological Surveys react again and embark on huge Digitisation plans of the general cartographic information that they managed and the specific hydrogeological cartography that they had produced in vector or raster format. All the participating Geological Surveys have ended up making digital cartography products available to society, which facilitate the updating and re-edition of hydrogeological maps. Furthermore, in many instances, the Geological Surveys provide a much faster and permanent service to society on the location and interpretation of spatial hydrogeological information via their Web portals.

The boom of computer-assisted techniques (GIS = Geographic Information Systems and computer-aided design = CAD) and the wide use of individual platforms with graphic environments have given the European Geological Surveys a fresh outlook. GIS makes it possible to link a wide variety of attributes to the graphical entities represented on the maps and “to generate information from information.”

Most participating Geological Surveys began using GIS at the same time as they initiated the digitisation of their cartographic products. However, it was only at the beginning of the last decade when Information Systems developed with some stability and continuity, and cartography began to be distinctly associated with these systems. Nowadays it must be assumed that

cartography does not only mean what can be shown on a paper map, but also what can be accessed and managed via an information system with a wide range of associated possibilities.

Since the European Geological Surveys have participated in this technological progress, they are well equipped to face the demand of the European Commission Water Framework Directive. This demand is directed at protecting water resources and, more specifically, defining water masses and impacts. The spatial information required in this instance is definitely a digital hydrogeological cartographic product, which includes the associated information precise enough to identify risks and trends in the quality status of the water masses in European countries.

In recent years, the Geological Surveys of European Union member countries have had to take into account and adapt a more recent initiative INSPIRE (Infrastructure for Spatial Information in the Community). This initiative is directed at harmonising the existing cartography in the EU in a way that allows metadata to be analysed and display and download map services to be provided. All member countries must meet the “interoperability” conditions required by INSPIRE in the medium term.

The main objective is to enhance “interoperability” among European Geological Surveys in general, and that of the participating countries in particular, so that the hydrogeological cartography of any country hosted in the corresponding Geological Survey web server can be viewed. The trend envisaged for the near future is to advance towards cross-border information systems.

The present Project has already prompted the participating Geological Surveys to move in this direction. It is providing potential users of the spatial hydrogeological data with a significant amount of structured information and knowledge on how these data have been represented in hydrogeological maps in the past and how they are currently represented and managed.

The development and progress of hydrogeological cartography (purpose, types, formats and scales) in each of the participating countries over several decades is presented in this Chapter in brief summaries that will help the user to understand and value the information on the cartographic products in the database annexed to this report.

## 6.1 Austria

### Hydrogeological Mapping at the Geological Survey of Austria (GBA)

Since the foundation of the Geological Survey of Austria in 1849, its most important missions have been the geoscientific investigation of Austria and the production of geological maps.

In spite of geological mapping in Austria, the production of hydrogeological maps has a young history. The first hydrogeological map of the Geological Survey of Austria was done in 1968 by GATTINGER & PRAZEN. The scale of this printed map called “Hydrogeologische Karte der Republik Österreich” was 1: 1,000,000. The map showed the main geological formations and a regional estimation of groundwater discharge. Since the sixties GBA has also been involved in preparing the International Hydrogeological Map of Europe at the scale of 1: 1,500,000 (issued by Bundesanstalt für Rohstoffforschung, Hannover and UNESCO). In 1970 sheet C 5 Bern was printed, which covers the western part of Austria. In the late seventies GBA started a hydrogeological mapping programme at the scale of 1: 50,000 in the south-eastern part of Austria (KOLLMANN, 1982). Only a few maps were finished and were printed. In 2003 GBA published the Hydrogeological Map of Austria 1: 500,000 (SCHUBERT et al.). The content of this printed map corresponds widely to the international standard legend (STRUCKMEIER & MARGAT 1995). Fig. 6.1.1 to 6.1.3 show an overview and some details. A GIS-Version of this map is available on www.geologie.ac.at (GBA ONLINE, HYDROGEOLOGISCHE KARTE 1 : 500,000).

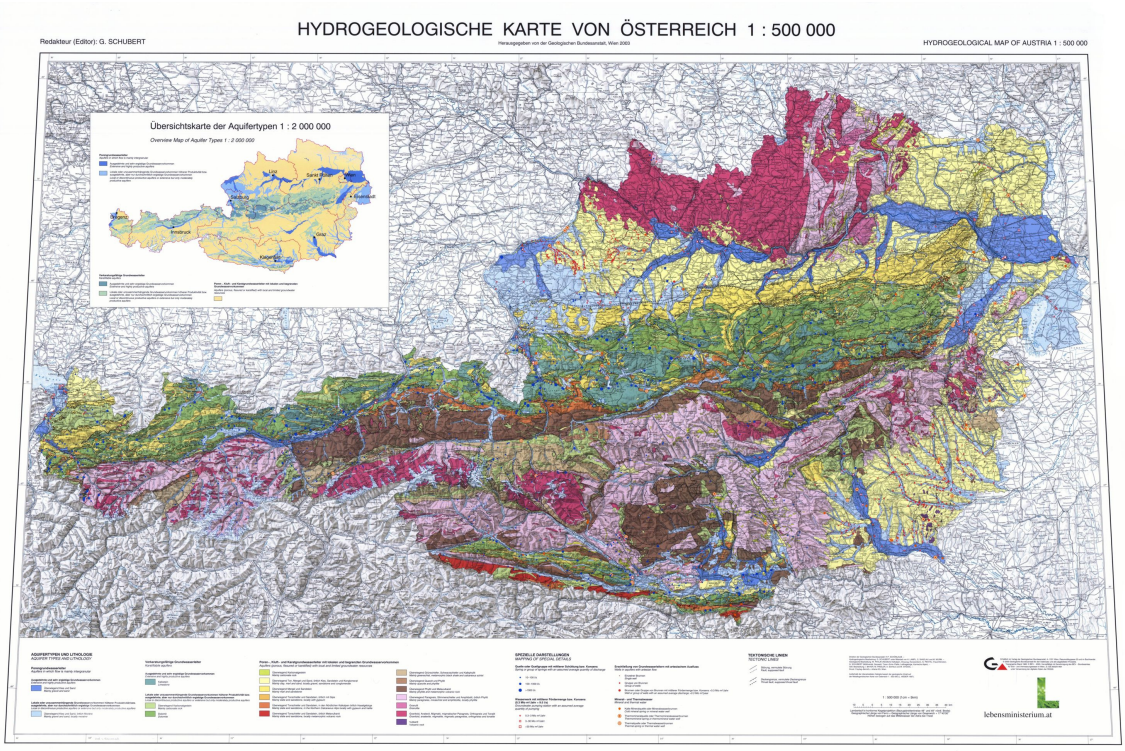



**Figure 6.1.1** Overview of the Hydrogeological Map of Austria 1: 500,000 (SCHUBERT et al.)

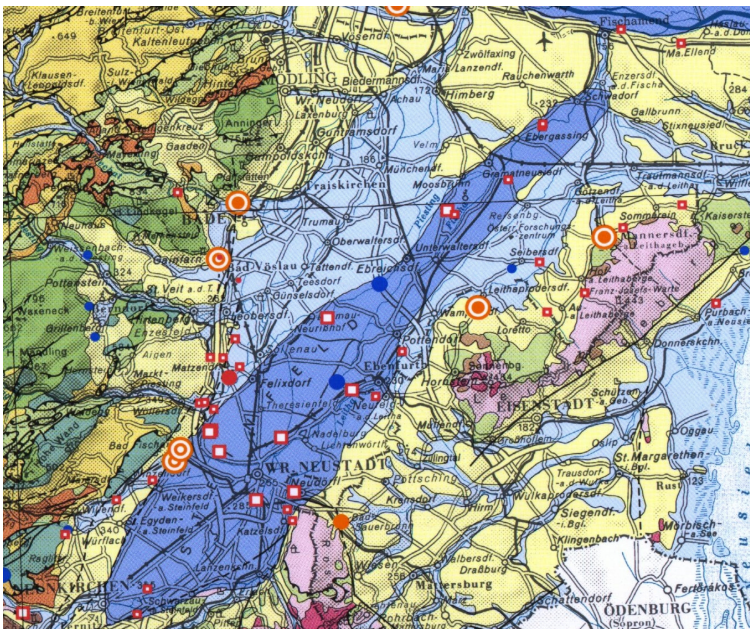



**Figure 6.1.2** Cutout of the Hydrogeological Map of Austria 1: 500,000 in the south of Vienna. The important porous aquifer of the Mitterndorf depression in the Vienna Basin is shown in dark blue. It contains productive pumping stations (large red squares) and large springs (large blue circles) which discharge the depression. Also the upwelling of thermal water at the border of the southern Vienna Basin is shown (different orange circles).

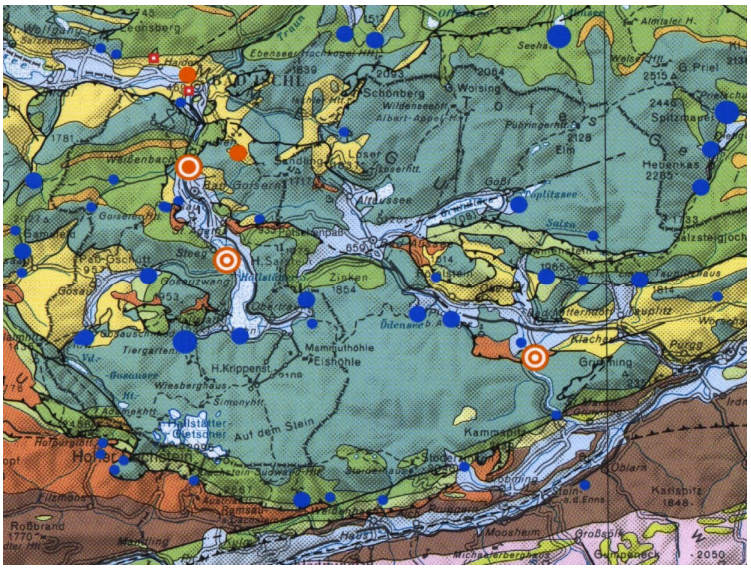



**Figure 6.1.3** Cutout of the Hydrogeological Map of Austria 1: 500,000 in the Salzkammergut region (Northern Calcareous Alps). The productive karst and fissured Aquifers are shown in greenish colours. They are discharged by the large springs in the valleys (large blue circles).

## *6.2 The Czech Republic*

### Development and progress of hydrogeological mapping at the Geological Survey of the Czech Republic

The start of hydrogeological mapping activities was connected with groundwater resource management applied in the 1960s. The first Hydrogeological Map encompassing the whole territory of Czechoslovakia was created in 1964. The map was completed with geological symbols, tectonic lines, isopleths of the Cretaceous Basin, groundwater data (e.g. permeability coefficients and spring type and spring discharge), surface-water data (e.g. water divide and stream catchments), artificial hydrogeological objects (e.g. boreholes based on type and yield). Map colours and hatches were adopted in accordance with the legend proposal for the Hydrogeological Map of Europe (scale 1:1,500,00) enforced by the IAH members at the International Geological Congress in 1965. Therefore, the 1965 hydrogeological zoning of Czechoslovakia and its application for water management balance can be considered as the first worldwide attempt.

The Hydrogeological Map of Czechoslovakia 1:1,000,00 for the public at large (Fig. 6.2.1), published in 1965, expresses schematic groundwater data and geological characteristics of rocks (basic stratigraphy, lithology and hydrogeological data – as an artesian basin boundary of main divide, main springs, mineral springs, mineral water wells, basic hydrochemistry data, faults, thrust line, isohypses of the base of the Cretaceous Basin in the Bohemian Massif and schematic permeability).

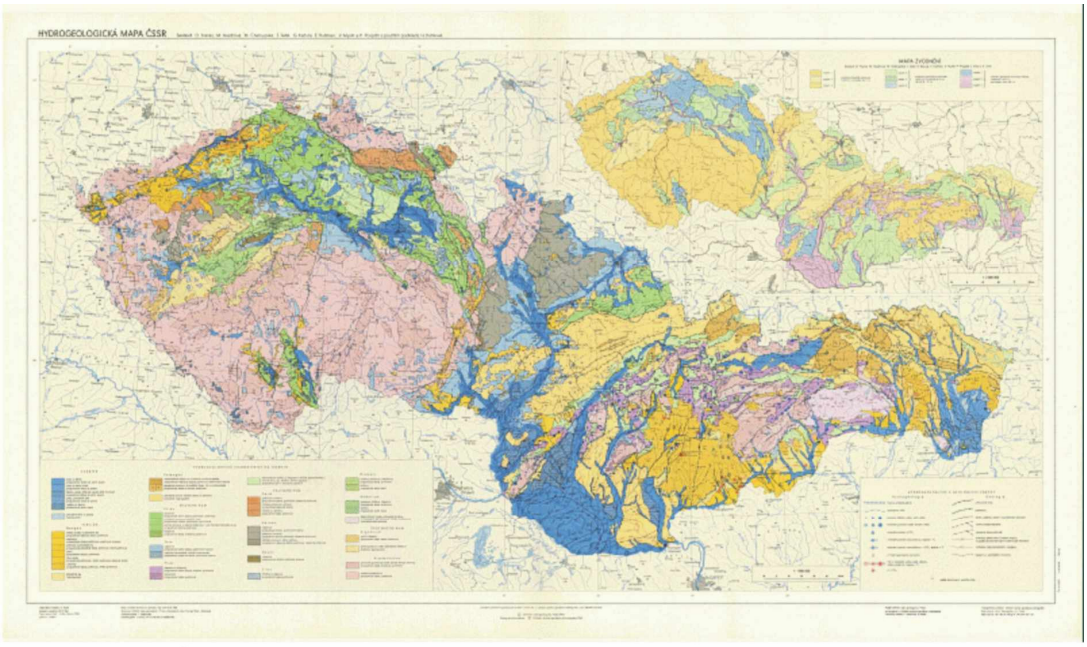
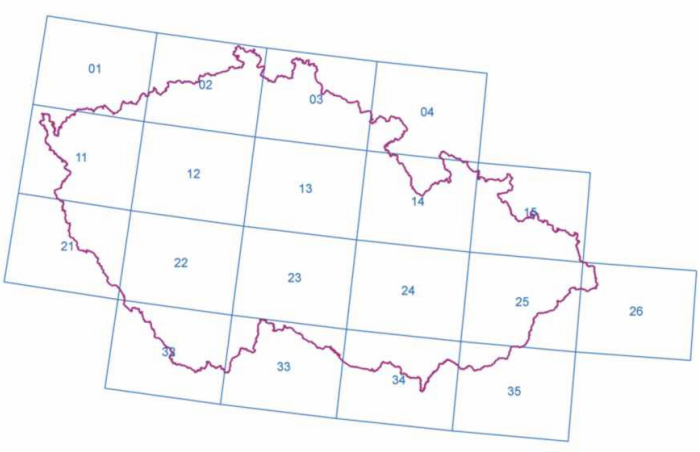



**Figure 6.2.1** Overview of the Hydrogeological Map of Czechoslovakia 1:1,000,000

**Figure 6.2.2** Sheet distribution at the scale 1:200,000




Between 1970 and 1987 the CGS conducted a systematic study of the Czechoslovak territory termed the National Plan of Groundwater Investigation, focusing on specification of the main aquifers, evaluation of the groundwater resources and determination of rules for their protection and exploitation. Using these instructions a first synthetic hydrogeological mapping was conducted by the CGS between 1982 and 1987. The main result of this mapping and research period was the publication of the National Hydrogeological Map at the scale 1:200,000. A complete series includes 19 map sheets printed in the official national topographic grid system (Fig.6.2.2 and 6.2.3). These maps illustrate groundwater data and geological characteristics of rocks (basic stratigraphy, lithology, boundary of artesian basin, hydrogeological structures, main springs, mineral springs, mineral water wells, faults, thrust line, isohypses of the groundwater in the Cretaceous Basin and permeability).

The basic map elements were represented as hydrogeological structures based on hydrogeology, geomorphology and structural geology. Colours express hydrogeological structures, section lines show permeability types. This map style shows general information concerning aquifer position and its significance and utility. The hydrological maps were completed with groundwater chemistry maps at the same scale 1:200,000 covering the Czechoslovak territory. These maps schematically illustrate the groundwater chemical types, mineralisation, and artificial hydrogeological objects.

**Figure 6.2.3** Overview of a sheet of the National Hydrogeological Map at the scale 1:200,000

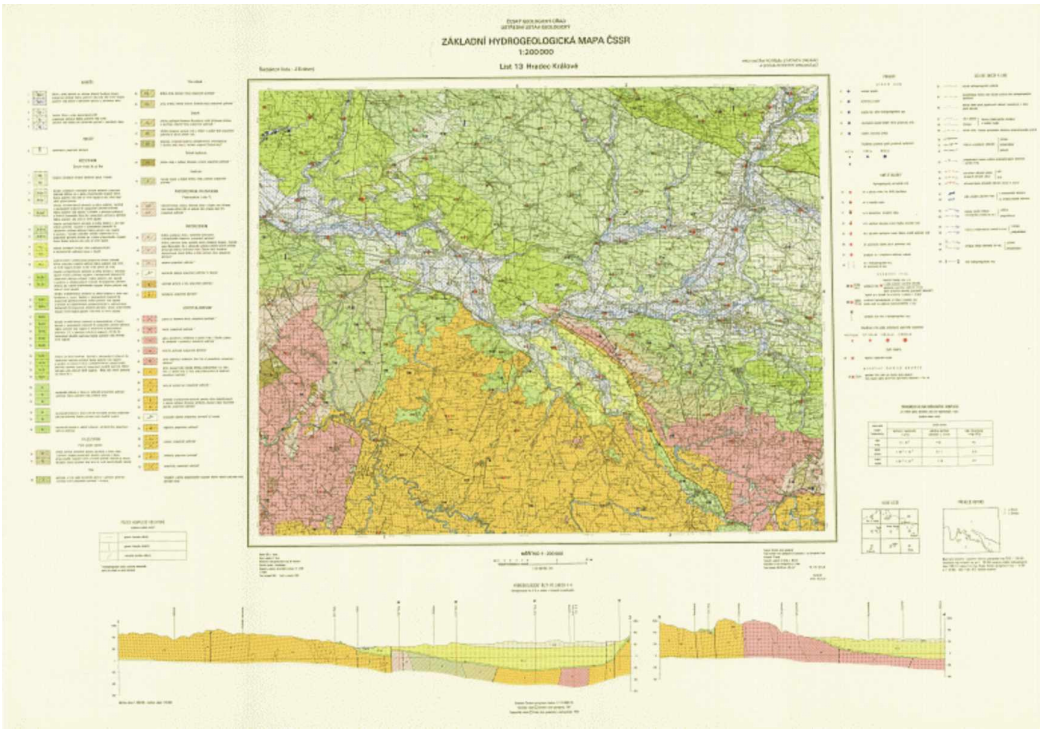
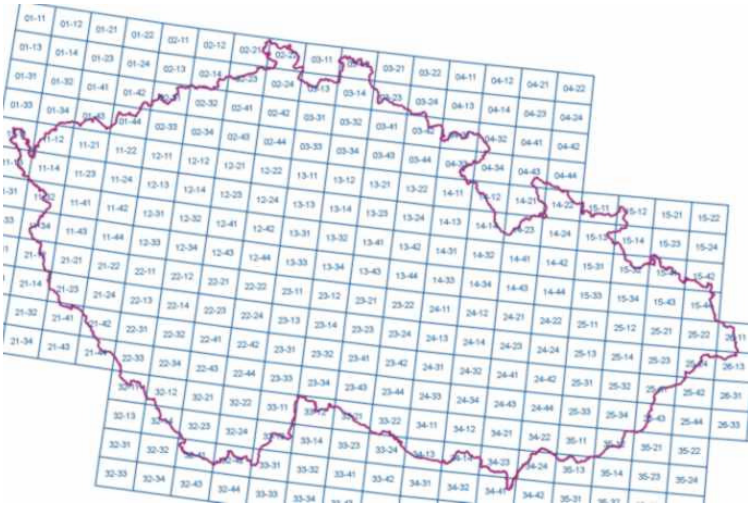


**Figure 6.2.4** Sheet distribution at the scale 1:50,000



Later the CGS initiated the elaboration of a new edition of the **Hydrogeological Map at the scale 1:50,000** (Fig. 6.2.4 and 6.2.5). The Czech Republic is covered by 211 sheets at this scale. These maps were created as an important part of the new detailed map set encompassing geological, hydro geological and environmental features. This map series provides widely updated knowledge of the position and extension of the main aquifers and permeable rock formations, including a selection of water points (springs, wells, boreholes, galleries) and the main public works affecting superficial hydrology. This series is compatible with the norms and standard legend of IAH, IAHS and UNESCO (1983).

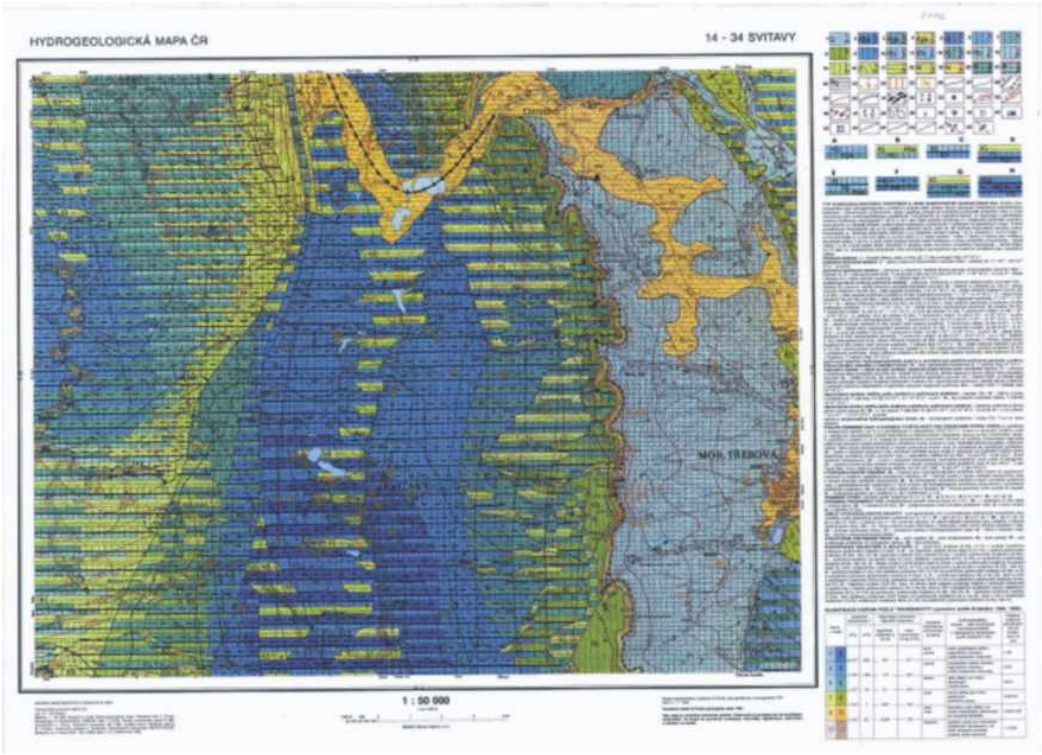



**Figure 6.2.5** Overview of a sheet of the National Hydrogeological Map at the scale 1:50,000

## Digital Maps

The Czech Republic does not have any digital hydrogeological maps. There are only raster digital maps of hydrogeology and hydrochemicals at the scale 1:1,000, 000, 1:200,000 and 1:50,000.

2000-2005 GIS technology was initiated at T.G. Masaryk Water Research Institute and CGC Hydrogeological Zones 2005 (groundwater bodies). The scope of hydrogeological zoning was to define suitable units for national water policy and assessment of groundwater resources (Fig. 6.2.6). The delineation has mainly been derived from digital map bases for geology, water management and the cartographic base, most of them at scale 1:50,000. The final hydrogeological zone database was processed in two GIS levels: the first assigned for public use, containing boundaries, designation of zones and their characteristics, the second one for use by specialists containing detailed data of types of boundary delineation (e.g. groundwater divide, geological or lithological or tectonic lines, hydrogeological flow lines, stream course) and the source from which the proper part of the line has been derived (nation-wide databases like geological databases, geographic databases, hydrological databases).

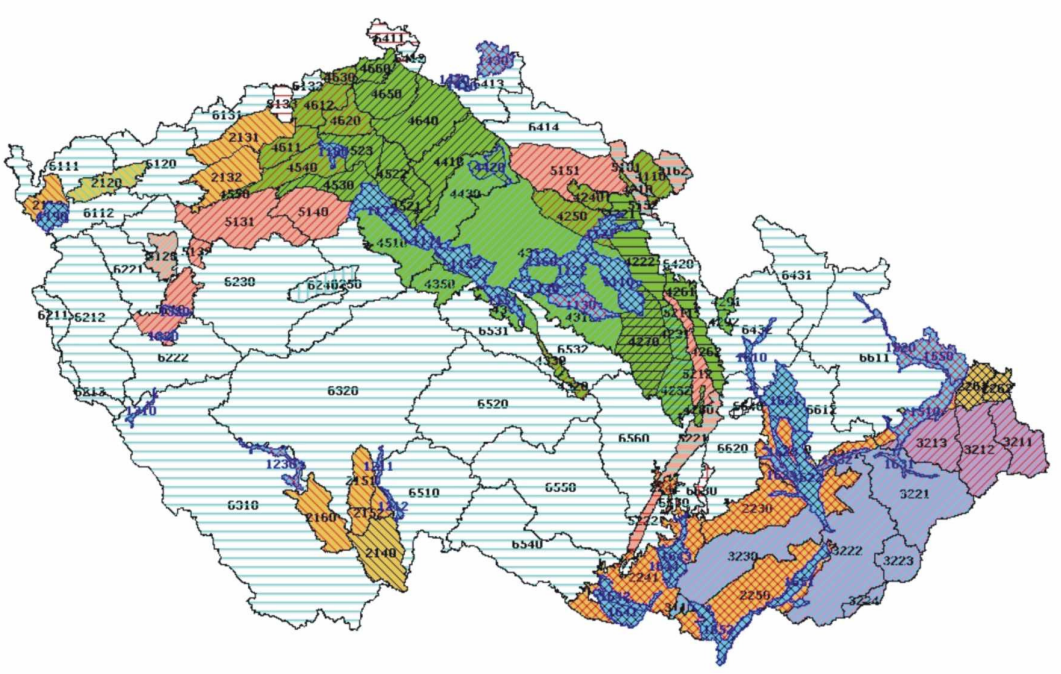



**Figure 6.2.6** Schematic hydrogeological map and groundwater bodies of the Czech Republic.

## 6.3 Denmark

Since 1984 GEUS has used Geographic Information Systems (GIS) for automated mapping and geographic analysis. Since 1993 these task has been organised through a GIS-laboratory which is both an expertise network and an actual laboratory at the Geological Data Centre.

The basic GIS-software is today Arc/Info and ArcView supplemented by MapInfo and specialised systems as Z-Map+. Moreover GIS-facilities are today implemented in many other computer systems such as database interfaces and modelling tools.

The main tasks at the GIS-laboratory are:

- Production of new digital geological maps
- Conversion of traditional geological maps to digital form
- Maintaining the map databases at GEUS
- Installing and updating GIS-software at GEUS
- Making GIS analysis and illustrations for GEUS projects with such needs
- Marketing and sale of digital maps, GIS analysis and related products
- Development of software routines for solving ad hoc problems related to GIS
- Contact for external partners concerning GIS-related tasks

### Digital map products

Surface geological maps are maintained in scale 1:200.000 (nation wide) and in scale 1:25.000 (covering 84% of Denmark).

The maps in 1:25.000 are compiled from thousands of field samples, while maps in 1:200.000 are generalised from the better scale and supplemented with data from less detailed sources.

Hydrological digital maps with build-in network-topology showing water streams, lakes, monitoring stations and catchments' areas are maintained for the national water quality monitoring program (NOVANA).

Many other digital maps has been produced: PreQuaternary geological map, ice cover map of the Nordic countries, geomorphological maps and maps showing borehole information.

### Other GIS products

Digital terrain models for the land surface as well as the preQuaternary surface has been developed and can be combined with many map themes developed in the Ministry of the Environment or bought from the National Survey and Cadastre.

GIS calculations and analysis are commonly used for research or merely illustration purposes.

All digital maps (if not confident) are sold in projections and GIS-formats chosen by the customer which is often a county, a municipality or an engineering company. Most new maps are printed on cd-roms with textual descriptions and metadata included.

## GIS on the Internet

GEUS offers digital maps via the Internet. Moreover metadata and descriptions of GEUS' maps and databases exist on the Internet.

## Hydrogeological mapping

Groundwater is an important resource in Denmark and constitutes 99% of the national water supply for domestic, agricultural and industrial use. GEUS works primarily on the protection and viable exploitation of freshwater resources. This is accomplished through the acquisition of scientific knowledge of the processes and parameters controlling groundwater flow and solute transport. More specifically, it works on research and consulting projects in the areas of recharge, groundwater extraction, groundwater resources evaluation, groundwater protection, flow and transport in fractured glacial tills and chalk, groundwater/surfacewater interaction, groundwater restoration and groundwater monitoring. GEUS has expertise in the assessment of the quantity and quality of groundwater resources at the regional-scale through the development of a national water resources model (DK Model) and the national water quality monitoring program (NOVANA).

The Groundwater Mapping Department will develop and implement standards and methods for groundwater mapping, and assist the Environmental Centres to create geological and hydrogeological models for the fee-financed mapping and planning tasks.

The Groundwater Mapping Department also takes over the project management of GEUS' groundwater monitoring as well as the responsibility for the yearly reporting of the groundwater monitoring results.

## 6.4 France

### Chronology of hydrogeological cartography in France

In 1930, Edouard Imbeaux made the systematic hydrogeological description of most French areas. A groundwater atlas, published in 1970 by the DATAR and BRGM, primarily consisted of diagrammatic hydrogeological maps of the administrative areas of France, geological logs and bibliographical lists. The "hydrogeological map of France, 1: 1500,000" was published in 1980 by the BRGM with a short guideline report. A lot of maps have been produced in different areas of France since the 1960s at different scales (1:50,000, 1:100,000…), not covering the whole territory systematically with a homogenous scale. Generally maps are being made, at local or regional level, in relation to project opportunities in the field of groundwater management.

### Elaboration of the groundwater bodies national referential

In France, the first studies on the need for aquifer definition and limits began in the 1960s.
J. MARGAT and L. MONITION proposed the concept of the aquifer system. In 1976, J.Margat completed the 1: 1,000,000 map of the main aquifer systems that are important at regional scale – then with M.J. LIENHARDT the map of the main hydrogeological domains, which allows sectors without large aquifer systems to be considered. After 1980, this initial national map was improved, but the criteria used were not the same everywhere.
Taking into account this development and the generalisation of Geographical Information Systems (GIS), the construction of the mapping groundwater referential, at national level, was started in 1995 - it is called BD RHF (Data Base related to the French hydrogeological referential).

This national referential of the groundwater bodies (Fig. 6.4.1), in its first version, was produced by the BRGM, with the data gathered from the hydrogeologists at the national water agencies and the regional board of the Ministry of Environment (DIREN). In the French overseas territories, hydrogeologists from the regional geological surveys provided the data under the control of the local DIREN.

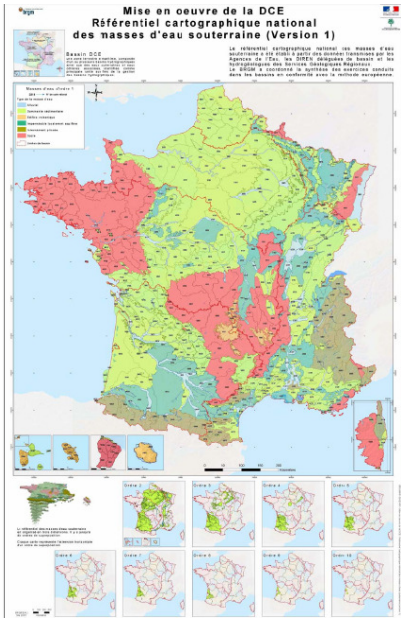



**Figure 6.4.1** National referential of the groundwater bodies

For each hydrogeological entity, a synthetic file was prepared with a description, according to the SANDRE standards and to the national specific nomenclature from the work of J. MARGAT, with an individual localisation map (PDF).

BRGM used the following national referentials:

- BDCarthage v3 (10/2003) IGN,
- BDRHF®v1 (2002) RNDE,
- Geological Map of France, 1: 1,000,000 (2003), BRGM,
- Geological Map 1:50,000 from geological maps printed or scanned, BRGM

The cartographic referential for metropolitan France consists of

533 groundwater bodies in which 498 are outcropping entities. A second version is being done, with three levels of entity details.

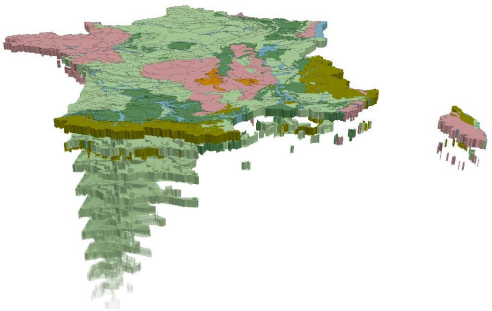


**Fig. 6.4.2** Groundwater bodies in 3D

The first two dimensions describe the horizontal limits of the groundwater bodies. The third dimension (Fig. 6.4.2) describes the order of superposition of the groundwater bodies, which varies, in the current state, from 1 (first groundwater bodies met from the surface in the original grounds) to 10 (maximum order of superposition met in the Adour Garonne basin).

The purpose of version 2 of this referential is to identify, qualify the hydrogeological entities of the French territory, and to plot the map, according to three levels of progressive details, namely the national scale (1:1,000,000), regional (1:250,000) and local (1:50,000). The scale of work is 1:50,000.

BD RHF® is a primarily cartographic database, developed within the framework of the information system on water, with the following elements:

- descriptive files of entities
- cartographic layers of the entities
- hydrogeological logs, piezometry
- polygons that represent the outcropping parts of the hydrogeologic entities and the parts under cover.

This work is being done with the global framework of the public information system: “a geographical public national referential has to be shared and exploited within a large number of users. It is used as a basis for the production of the specific data to each organisation, and allows the exchange of information between users” (National Council of Geographical Information, May 2002).

The European Framework Directive, by introducing the concept of “groundwater bodies”, leads the Member States to work out their approach for these. France wishes to implement it according to the BD RHF referential.

### GroundWater Information System - ADES - http://www.ades.eaufrance.fr/

ADES is the national database which gathers, on a public internet site, quantitative and qualitative information related to groundwater, with the following objectives:

- to constitute a tool for collecting and storing groundwater data
- to be exploitable by a large number of partners
- to allow the treatments for the action of each partner

- to have a follow-up of the patrimonial state of the resources, in order to answer the groundwater policy
- to adopt, at national level, a principle of transparency and accessibility to the groundwater data.

ADES is a specific tool for the requirements of local groundwater management needs and the European Framework Directive: groundwater body monitoring, assessment of policies and management plans.

It makes it possible to know the localisation of the monitoring networks and access quantitative data (water levels) and qualitative data (concentration of many parameters in water).

Data, periodically updated, are available for each monitoring network, each hydrographic basin, each department and each aquifer, through tables or graphs. For the moment, it does not contain any hydrogeological map.

## 6.5 Hungary

### Evolution and development of hydrogeological mapping at the Geological Institute of Hungary (MAFI)

One of the main activity of the Geological Institute of Hungary (MAFI) is the geological mapping. Within the frame of systematic mapping geological map series are created on different topics in different scales. Surface geological map series covering the whole country, in scale 1:100 000, were produced lately. This map series are available both in digital and printed form, it is accessible on CD and through the webpage of MAFI (www.mafi.hu).

Generally hydrogeological maps are created related to different research projects, and there is no systematic hydrogeological mapping in the Institute. Accessibility to these maps depends on the project procurer. Nowadays, all maps are created in digital forms in the Institute; the older maps are available in printed form.

One of the most important printed thematical hydrogeological map series is Hydrogeological Atlas of Hungary. It consists of 73 theme maps, in scale 1:1,000,000, and some regions in 1:100,000 scale. Thematic maps are: aquifer thickness and basin maps, water chemistry maps, pressure head maps of subsurface water. Furthermore, region-wide cross-sections are also available.

Hydrogeological map of Hungary is available in printed (Fig. 6.5.1) and raster form. It is part of the National Atlas of Hungary (1:1,000,000).

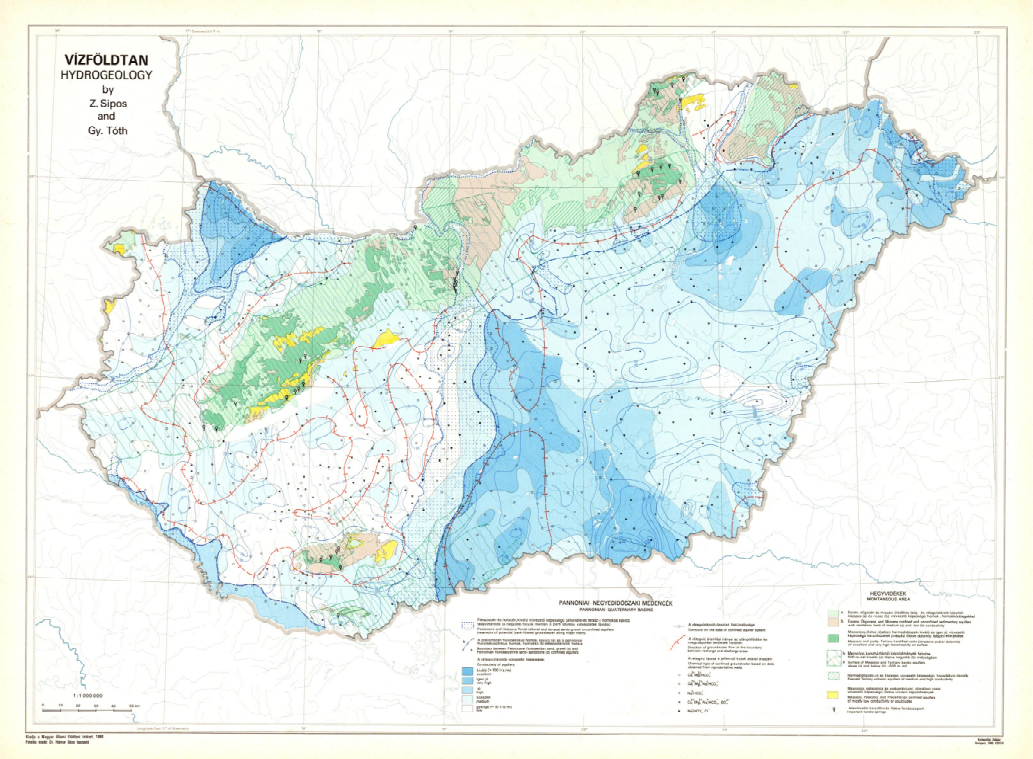



**Figure 6.5.1** Hydrogeological map of Hungary (1989)

One of the most significant map series that made in international cooperation are the maps of DANREG project (Fig. 6.5.2). The main objective of the Danube Region Environmental Geological Program (DANREG) was to adjust the geological and geophysical data available in the cross-border region of the three partner countries (Slovakia, Austria and Hungary) in a harmonised framework with particular emphasis on the area along Danube River running across the three capitals. The project facilitated the harmonised interpretation of data providing thus considerable help to decision makers engaged in land management of the area. The end product of the project consisted of an environmental thematic map series and an explanatory book representing excellent examples of a co-operative project that had been carried out in an area wit comparatively uniform geology but divided by state boundaries. There are two hydrogeologically important maps: the geothermal potential map and the hydrogeological map.

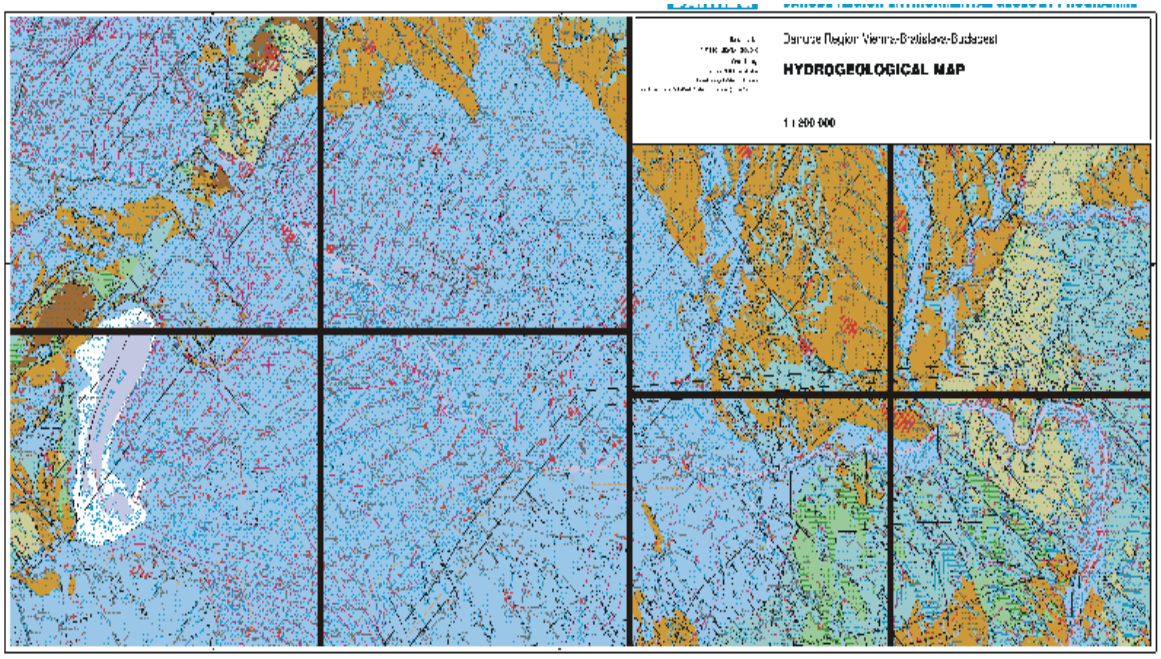



**Figure 6.5.2** Hydrogeological map of the DANREG region

One of the most important lessons of the co-operation is that the consistent use of international standards is indispensable in geosciences as well. The map series are available on CD and through the MAFI webpage.

The most recent international map edited in the Institute is the Budapest D5 sheet of the Hydrogeological Map Series of Europe. This map series is managed by UNESCO. The D5 sheet, covering the area of thirteen participating countries, is ready in the first digital version. Presently, the map is under acceptance.

## *6.6 Italy (Emilia Romagna Region)*

### Hydrogeological maps in the Emilia-Romagna Region (Italy)

Since its establishment in 1976, the Emilia-Romagna Region has ploughed considerable resources into improving land management-related knowledge and tools. For this reason the Geological, Seismic and Soil Survey (SGSS) of the Emilia-Romagna Region has produced a wide set of geological maps, such as the geological maps at 1:10,000 scale in the mountain area of Emilia-Romagna and the geological maps at 1:25,000 and 1:50,000 scale for the whole regional territory (as part of the National Geological Cartography Project - CARG project). Geological maps are available online at http://geo.regione.emilia-romagna.it.

The geological data collected by SGSS has made it possible, first of all, to create a new 3D model of the aquifers of the Emilia-Romagna plain. Based on this, in 1998 the region published the volume "Groundwater reserves in the Emilia-Romagna Region" which represents the first set of hydrogeological maps of the Emilia-Romagna alluvial plain. Since that time numerous projects have been launched in partnership with both public and private bodies; in 2005 a set of hydrogeological maps related to the implementation of the Water Framework Directive were published.

### Groundwater reserves in the Emilia-Romagna Region

During the second half of 1990, together with ENI-AGIP, the most important oil company in Italy, an important study was conducted in order to identify the main aquifer in the subsurface of the Emilia-Romagna Alluvial Plain. This major project involved the study of approximately 30,000 km of seismic lines, hundreds of stratigraphies of continuous coring boreholes, water wells and oil wells. The study provided a detailed understanding of the overall hydrostratigraphy of the alluvial aquifer: three main aquifers were recognised, named A, B and C and dated from middle Pleistocene to Holocene. Other important results were:

1) the definition of the 3D architecture of the different aquifers and aquitards
2) the identification of the groundwater strategic reserve as the largest and most protected aquifers
3) the mapping of the recharge areas for the different aquifers
4) the computation of the hydrogeological balance at regional scale.

Two maps were compiled for each of the three aquifers recognised (in total six maps): one for the thickness of the porous – permeable sediments, the other for the depth of the bottom of the aquifer (Figs. 6.6.1 and 6.6.2). Each map was printed at 1:250,000 scale.

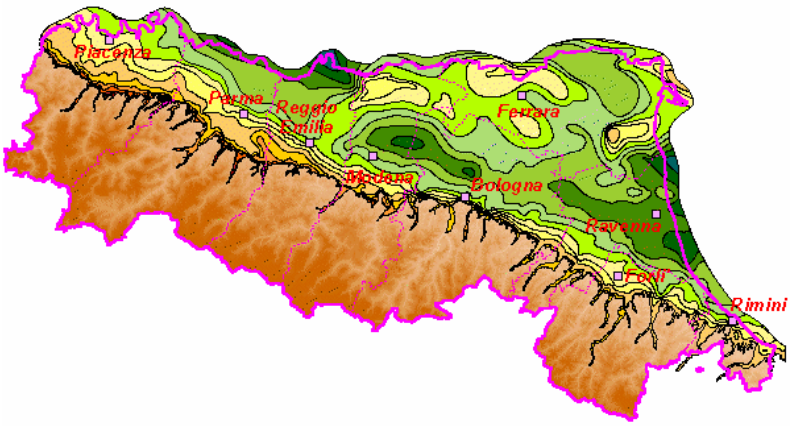



**Figure 6.6.1** Trend of the bottom of Unit A

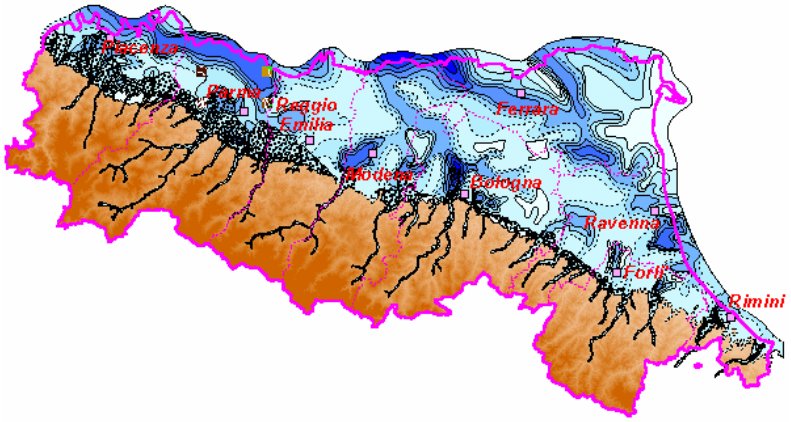



**Figure 6.6.2** Thickness of the porous – permeable sediments in Unit A

Maps also include a first version of the recharge areas for three aquifers, and an evaluation of the recharge based on the different kind of soils.

The volume "Groundwater reserves in the Emilia-Romagna Region" includes a booklet that explains the geological evolution of the sedimentary basin, the hydrostratigraphic framework and it contains some data on hydraulic conductivity, porosity and the storage coefficient for the three aquifers. Moreover, the booklet reports some practical applications of the maps, such as the evaluation of the aquifer discharge, or the identification of the recharge areas for a pumping centre.

The volume also includes two sheets with selected geological cross sections showing the geometry of the subsurface and the relations between the aquifers.
Maps, geological cross sections and booklet are available only in printed format, a summary in pdf format is available, only in Italian, at:
http://www.regione.emilia-romagna.it/wcm/geologia/canali/cartografia.htm
The publication of "Groundwater reserves in the Emilia-Romagna Region" provides a better understanding of the whole alluvial aquifer and supports all the following works related to the implementation of the Water Framework Directive.

## Hydrogeological maps for the implementation of the Water Framework Directive (WFD)

The Italian law currently in force (D.Lgs. 152/99, which anticipated the WFD in Italy) states that Italian Regions must draw up a River Basin Management Plan. This Plan was drafted in tandem with implementation of the WFD and led to the production of some hydrogeological maps, which are now enclosed directly in the Plan.

## Groundwater protected areas; recharge areas

As provided in the River Basin Management Plan, in order to protect and improve the quality of groundwater resources intended for human consumption, Regions must identify the protection zones. The definition of protection zone is based upon geological, hydrogeological and hydrochemical analysis. The Groundwater protected areas map at 1:250,000 scale is a legal part of the River Basin Management Plan of the Emilia-Romagna Region, and protection measures applied concern agriculture and cattle breeding activities, urbanisation and industrial activities.

## Nitrate Vulnerable Zones from agricultural source

This map was compiled according to the Council Directive 91/676/EEC ("Nitrates Directive") and was recently enclosed in the River Basin Management Plan. Well-known nitrate vulnerable zones are defined in order to manage agricultural activities with respect to nitrate pollution in groundwater. In the Emilia-Romagna Region, nitrate vulnerable zones were defined on the basis of geological, hydrogeological and hydrochemical analysis; for this reason they are quite similar in terms of spatial location to the groundwater protected areas mentioned previously.

## Definition of groundwater bodies

As explicitly required by the WFD, the groundwater bodies related to the Emilia-Romagna alluvial plain aquifer were pinpointed and mapped. Three main groundwater bodies were defined and mapped within the most superficial aquifer (A aquifer) on the basis of geological, hydrogeological, hydrochemical and isopote data. The map is available only as part of the documentation of the River Basin Management Plan.

## Digital map

The maps reported above are also available in digital vector format. "Groundwater reserves in the Emilia-Romagna Region" are ARC/INFO coverages.

"Definition of the groundwater bodies" is a SHAPE file and is stored on the SGSS server.

The other maps: "Agricultural Nitrate Vulnerable Zones" and "Groundwater protected areas" are SHAPE files downloadable from the website:

http://serviziambiente.regione.emilia-romagna.it/PTA/jsp/index.jsp.

## 6.7 Lithuania

Hydrogeological maps scale 1:200,000 were made in Soviet time (1960-1980) according to a standardised method. They are published (paper format only) and available at Geological Archives of LGT (to look or copy, fee only for paper) (in Russian language).

A specific project “Revision and renewal of State hydrogeological maps at scale 1:200,000 on sheets 20-39/60-79 and 20-39/40-59”started in 2006 (Fig. 6.7.1). Results (methods, legends) will be the basis for a revision of all the territory of Lithuania. In principle it is programmed that these maps will be digital.

Hydrogeological mapping at scale 1:50,000 (starting from 1997) was completed in 6 mapping areas, this makes just ~11% of Lithuania. Maps were made using MapInfo software on GIS base. Standards were set for paper maps, but are still under development regarding how digital information should be organised.

Existing digital layers are presently not continuous. They could migrate from one map to another, but changes in their geometry may be expected depending on the specific mapping area under study.

Each mapping area is supported with hydrogeological cross sections, catalogue of factual material (wells, dug wells, well-fields, measurements, etc.), and a memoir (in Lithuanian).

Maps and memoir are available on paper format and CD (separate) at Geological Archives of LGT. Maps in CD are formed from MapInfo tabs stored in it. It is possible to make a copy (by written request) of CD (a fee is charged on material and service).

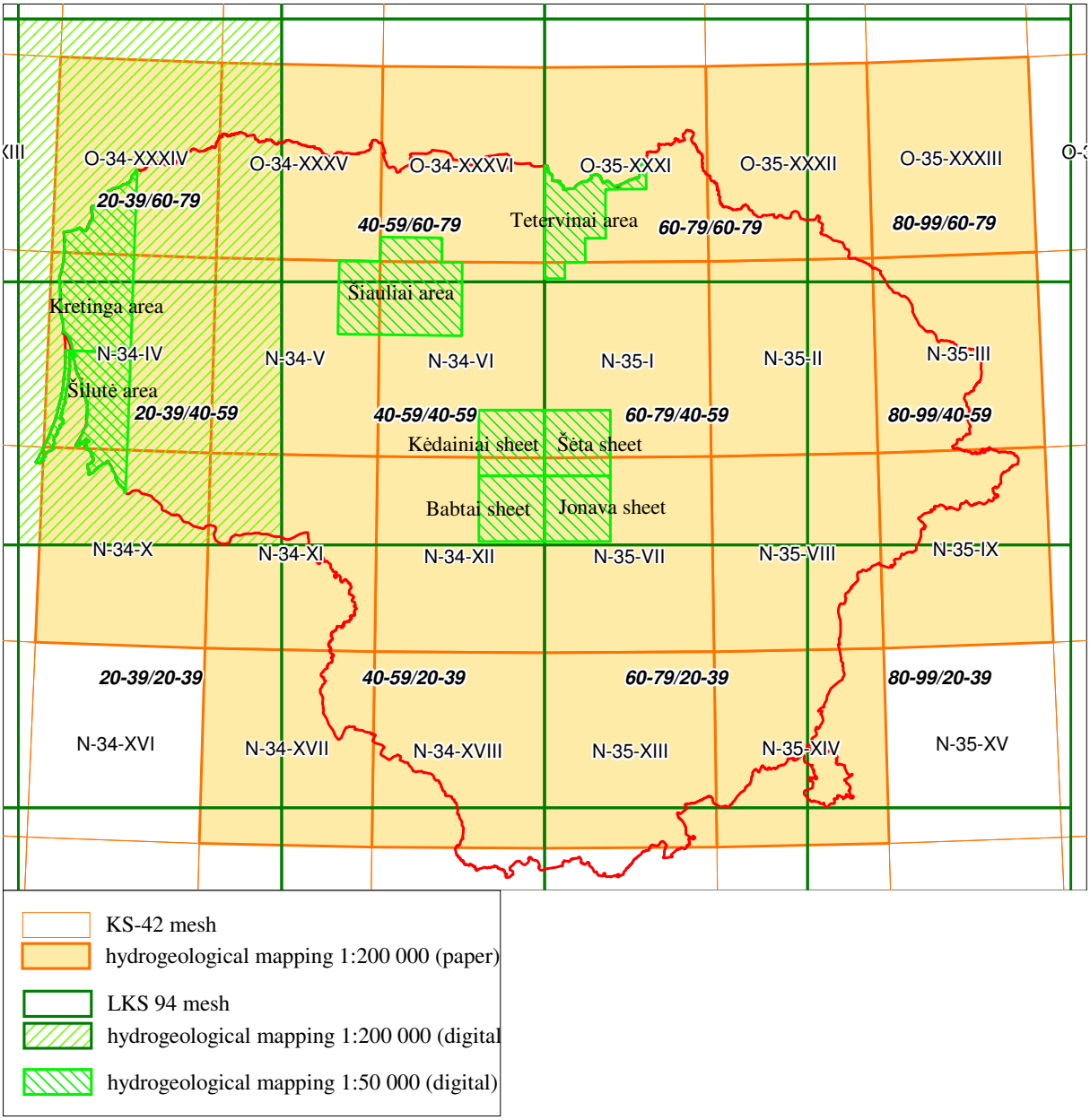



**Figure 6.7.1** Hydrogeological mapping in Lithuania (LKS-94 projection)

## 6.8 The Netherlands

Data and Information of the Dutch Subsurface and Groundwater

As a result of its studies of the subsurface of the Netherlands, TNO Built Environment and Geosciences Geological Survey of the Netherlands has millions of data on this subsurface. This geoscientific information is made available to companies, governments, educational institutions and private individuals. To facilitate this activity, TNO has developed DINOLoket (DINOShop): a databank that gives you instant access to subsurface data (Fig. 6.8.1).

DINOLoket has three portals:

- DINOData
  data of the Dutch Subsurface
- DINOMap
  geomaps, GIS systems/models and 3D viewer
- DINOServices
  specialised/custom made data services.

•DINOData
Entering via the DINOData portal, you gain access to the largest databank on the Dutch subsurface. This geological databank contains data on hundreds of thousands of boreholes, millions of groundwater levels, quality analyses, VES measurements, surface-water levels, borehole measurements, seismic 2D and 3D data, oil and gas drillings, and more.
For immediate access to subsurface data, go to www.dinoloket.nl, and request a user name and password.

Geology
Boreholes/wells
DINOLoket contains hundreds of thousands of quality-controlled boreholes. These boreholes extend to 300 metres below ground level. New boreholes are added daily and their repeated use ensures that the data are constantly being evaluated and improved.

Soundings
DINOLoket stores the data from thousands of soundings of the subsurface of the Netherlands. They provide decisive data about the subsurface layers and load-bearing capacity.

VES measurements
Some 12,000 VES measurements are available in DINOLoket. VES stands for Vertical Electrical Soundings, geoelectrical measurements that provide information on the lithological structure of the subsurface and salt levels in the groundwater up to 150 metres below ground level.

Groundwater and Soil
Groundwater levels
Dozens of millions of groundwater levels and some 100,000-quality analyses have been stored in DINOLoket. These are also constantly being added to and their quality controlled.

•DINOMap
DINOMap gives you access to geological information presented in map form. These maps are based on models of the subsurface. TNO has developed three models, each of which can be viewed in three different ways.

The model is the Digital Geological Model of the Netherlands. This national layer model of the subsurface maps the spatial position and thickness of the Quaternary and Late Tertiary lithostratigraphic units. Roughly speaking, these account for the upper 1,000 metres of the subsurface. This model provides a framework for applications within the field, for example, of hydrology, geomechanics, geochemistry and mineral extraction.

The familiar Regional Geohydrological Information System (REGIS) has been updated in a new 3D hydrogeological subsurface model. This model provides the user with detailed information on the hydrogeological structure of the subsurface.

The hydrogeological model, which is based on the new lithostratigraphic structure of the Digital Geological Model of the Netherlands, distinguishes 46 clayey, peaty and complex hydrogeological units and 60 sandy hydrogeological units.

These models may be viewed as a website in atlas form, as a GIS database, whereby map layers can be added to the existing map shapes, and by using a 3D viewer, whereby it is possible to 'walk through' a spatial image of the structure of the subsurface in different ways. The viewer TNO has developed for this purpose is available as a free download to DINOLoket visitors.

At the moment, the 3D representation of the models is viewed with an application that must be downloaded and installed. The data that this viewer displays are selected via DINOLoket and, like the viewer, are free to download.

Users can choose the part of the Netherlands for which they want to view map data. The viewer for the deep subsurface is already available; the version for Geology and Groundwater and Soil is under development.

•DINOServices
DINOServices is the portal to the internet services that use DINO's data. Among other things, this information can be used for permanent monitoring (active level management) and proactive warning (for example, when standards for drought damage are exceeded).

DINOServices offers the following options:
- telemetry: the portal to current groundwater levels for 25 measurement sites in the province of North Brabant
- Gelderland water atlas (inc. water policy, spatial planning, geology, monitoring networks)
- selecting data in the Netherlands by postal code (under development)
- detailed profile of the subsurface at an arbitrary location
- groundwater level prediction based on weather forecasts and historical groundwater data.

| Datatype | Theme | | |
|---|---|---|---|
| | Oil and Gas | Geology | Groundwater and Soil |
| Boreholes (meta data only) | ● | | |
| 2D seismic lines (meta data only) | ● | | |
| 2D seismic surveys (meta data only) | ● | | |
| 3D seismic surveys (meta data only) | ● | | |
| Wells (meta data only) | ● | | |
| Licences | ● | | |
| Boreholes onshore | | ● | |
| Borehole measurements | | ● | |
| Soundings | | ● | |
| VES measurements | | ● | |
| Boreholes offshore | | ● | |
| Groundwater levels | | | ● |
| Groundwater quality measurements | | | ● |
| Groundwater quality analyses | | | ● |
| Surface water | | | ● |
| **Maps** | | | |
| Oil and gas map of the Netherlands | ● | | |
| Geological Atlas of the Netherlands onshore | ● | ● | |
| 15 geological maps of the Netherlands onshore | ● | ● | |
| Geological summary map | | ● | |
| Geological map (scale 1:50,000) | | ● | |
| Geological maps | | ● | |
| **Models/systems** | | | |
| Digital Geological Model of the Netherlands | | ● | |
| Hydrogeological Subsurface Model | | | ● |
| **Software** | | | |
| Boris and Profiler (Software for borehole descriptions) | | ● | |
| Geo 3D Viewer (Software for visualising data) | ● | ● | |
| **Standards** | | | |
| Lithostratigraphic Nomenclature Shallow | | ● | |
| Lithostratigraphic Nomenclature Deep | ● | ● | |
| **Catalogue** | | | |
| Geoscientific publications | ● | ● | ● |
| Sales catalogue | ● | ● | ● |
| **Links** | | | |
| Geodatabank | | ● | |
| Subsurface Databank of Flanders (Belgium) | | ● | |
| Oil & Gas in the Netherlands | ● | | |
| Soil data | | ● | |

**Figure 6.8.1** Information available at DINOLoket

Background

DINOLoket is the one-stop-shop for Data and Information on the Dutch Subsurface (the DINO databank). It is intended to contribute to the sustainable management and use of the subsurface and its natural resources.

As an information system, DINO has been set up to enable TNO Built Environment and Geosciences Geological Survey of the Netherlands to fulfil the information task assigned to it by the Dutch government. This task is being carried out on behalf of the following ministries: Economic Affairs; Spatial Planning, Housing and the Environment; Transport, Public Works and Water Management; Agriculture, Nature and Food Quality; and Education, Culture and Science. The task is recorded in the Mining Act and the Groundwater Act. It comprises the collection, acquisition, archiving, quality assurance, analysis, interpretation and provision of data and information on the Dutch subsurface. The open access policy with the one-stop-shop provision of public data for marginal costs is a founding principle of the task. Every day the databank is expanded with new data. The performance of the information task is demand-driven.

The decision as to the direction DINOLoket should take is shared by the NITG Board, the GeoInformation Commission (GIC), which draws up the main points of the Information Programme, and a user's board. The latter provides the user's perspective. Represented on the board are consultancies, research institutions, water boards, provinces and education. This approach enables DINOLoket to address the needs and questions of society.

In the same way as the Dutch Land Registry is the office responsible for land registry data, DINO is a candidate for the Base Registration of subsurface data (LMO: Legally Mandated Organisation).

DINOLoket is not a commercial activity. It exists to improve the availability of data on the Dutch Subsurface and boost its use. As part of e-government (electronic government), efforts are being made to stimulate economic activities based on this use. The user groups for the Loket (=Shop) include governments (national, provincial, and local) as well as companies and private individuals.

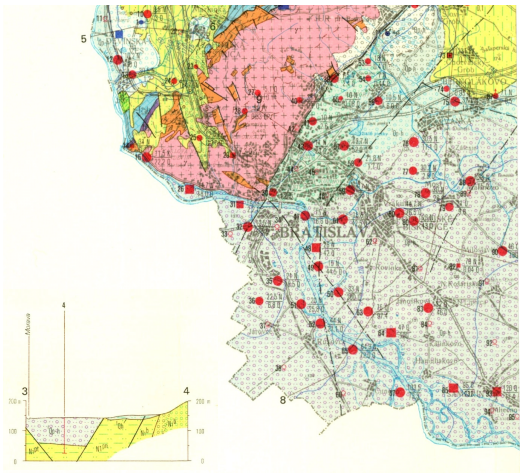
Business users wishing to access the data require a service subscription. Private individuals and those using the data for study purposes may apply for a free subscription. No charge is made for the data itself.

## *6.9 Slovakia*

### Hydrogeological mapping at the State Geological Institute of Dionyz Stur (SGUDS), Slovakia

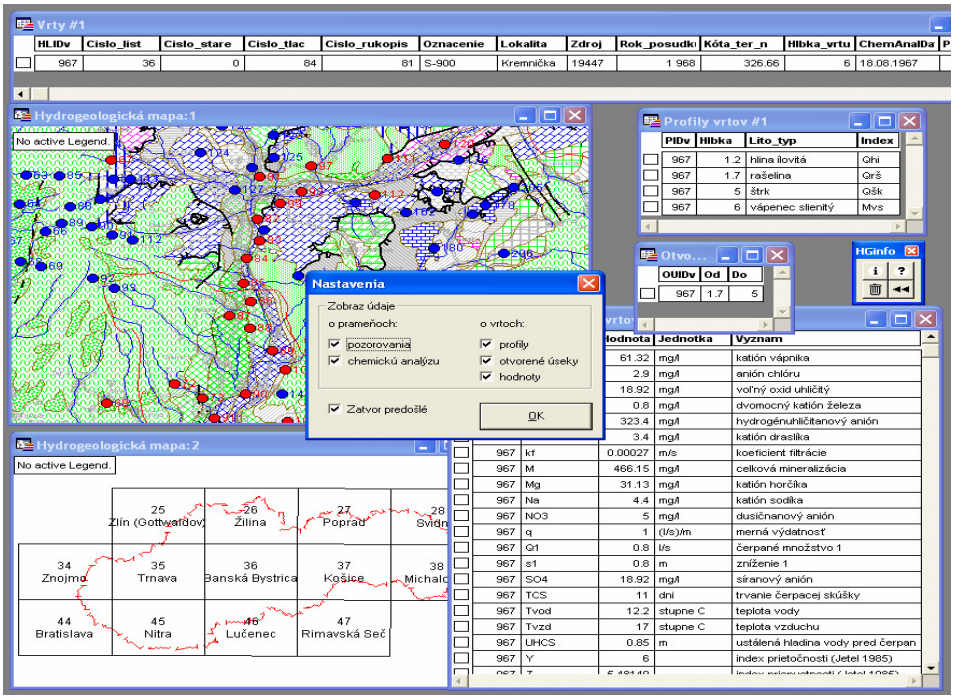
The State Geological Institute of Dionyz Stur has a long tradition in hydrogeological mapping. The whole territory of Slovakia has been hydrogeologically mapped at the scale 1:200,000 and results were issued in 1980 in a series of 12 paper map sheets (Fig. 6.9.1). A book with comprehensive explanations accompanies every map sheet.

**Figure 6.9.1** Hydrogeological map 1:200,000



These map sheets were digitized in 1999 and together with databases of springs and hydrogeological boreholes brought into a common GIS system called HGInfo, based on MapInfo technology (Fig. 6.9.2).

**Figure 6.9.2** Hydrogeological information system HGInfo, scale 1:200,000



In 2002 the Landscape Atlas of the Slovak Republic was published. As part of it, a map with the hydrogeological situation of the whole country at scale 1:1,000,000 was issued (Fig. 6.9.3).

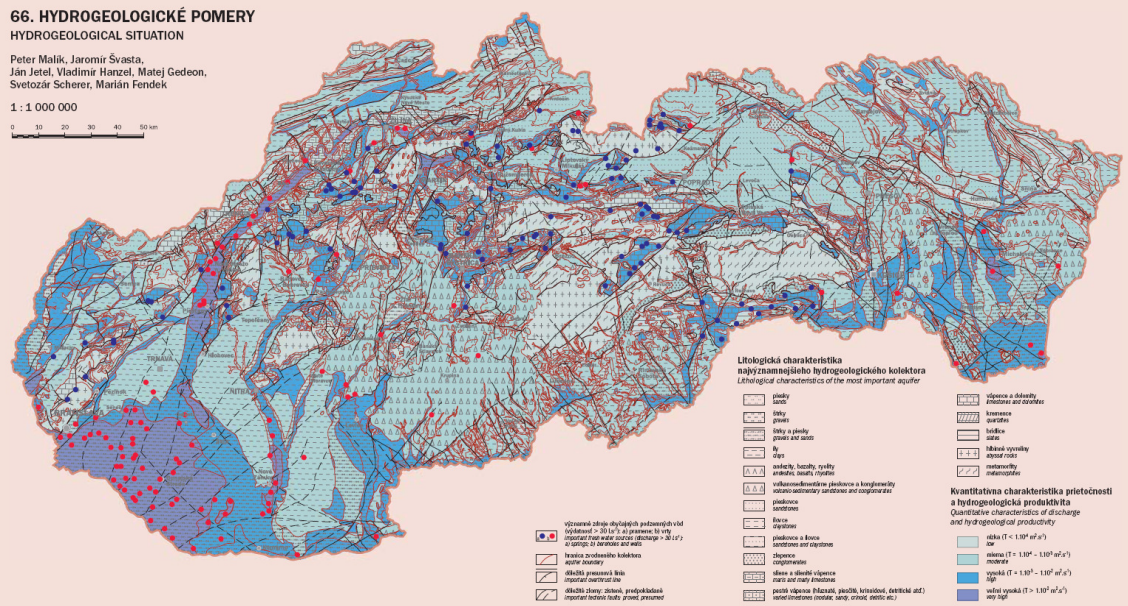
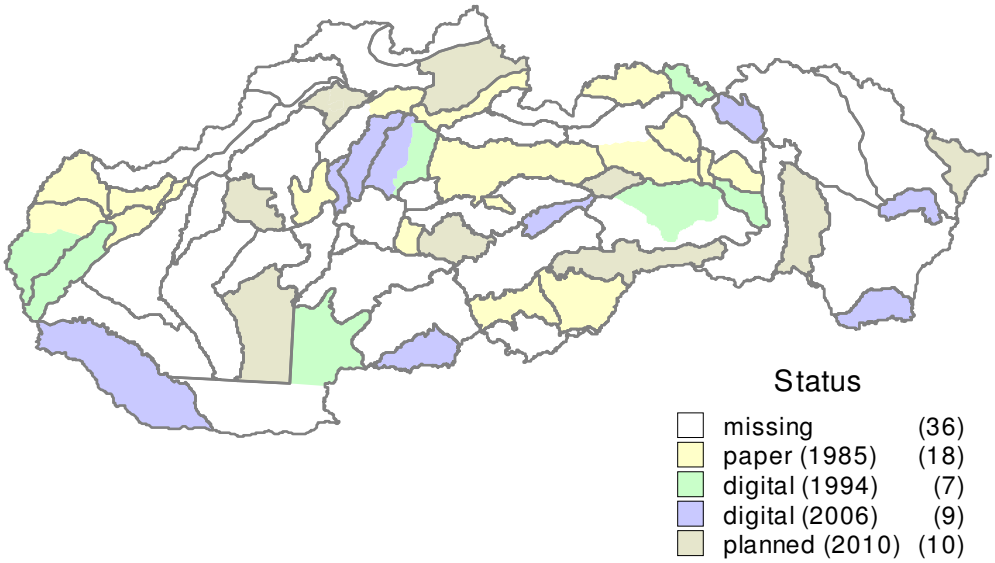



**Figure 6.9.3** Landscape Atlas of the Slovak Republic: Hydrogeological situation, 1:1,000,000

The main hydrogeological mapping activities are contained on a series of basic hydrogeological maps at scale 1:50,000 (Figs.6.9.4 to 6.9.6). Mapping is being done by regions, not map sheets. Until 1985, only paper maps were published. From 1994 onwards, every region has also been prepared in GIS format. All maps possess the same legend and symbology, according to the guidelines of the Ministry of the Environment.

**Figure 6.9.4** Coverage and status of basic hydrogeological maps, 1:50,000



Every hydrogeological map is accompanied by a hydrogeochemical map of the same scale. A very important part of these maps is the database of springs, the most complete database ever gathered in the country.

**Figure 6.9.5** Examples of basic hydrogeological maps, 1:50,000

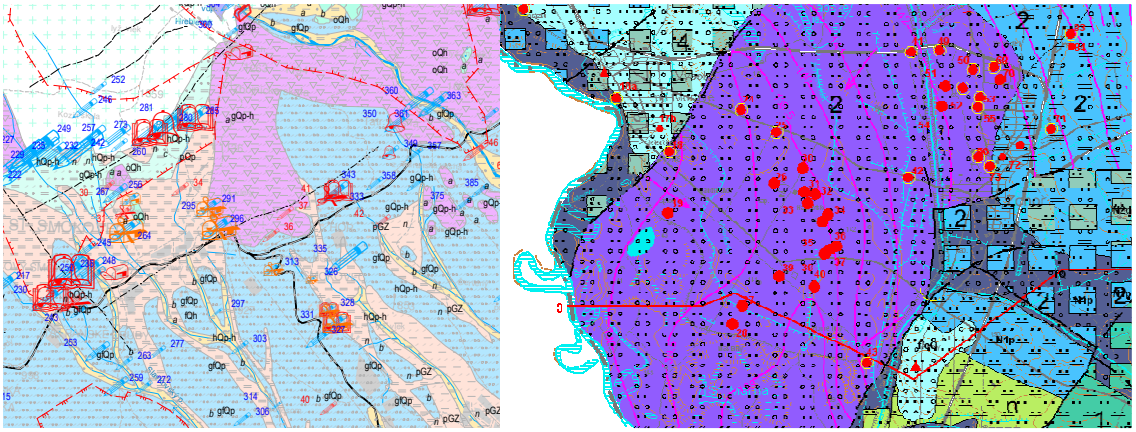
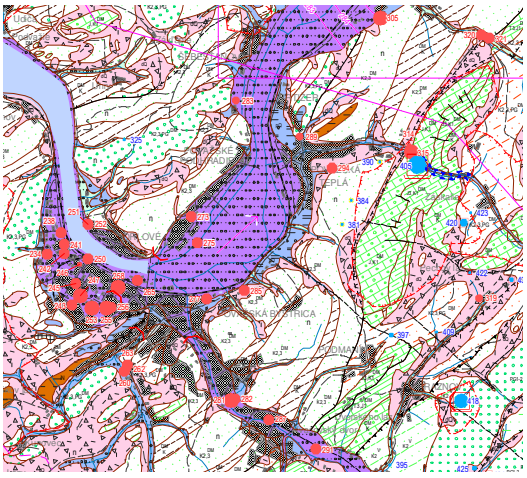
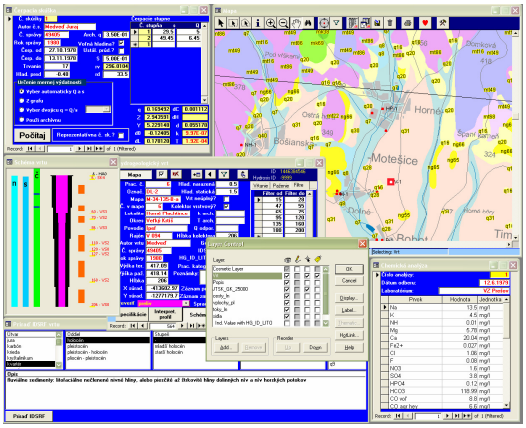


**Figure 6.9.6** Basic hydrogeological map of Slovakia scale 1:50,000



At the present time the institution is in the process of developing a centralised geographical database of all geological data (Fig. 6.9.7). Hydrogeological databases will also be incorporated into the system called GeoIS. The system is based on the Oracle database servers, ArcSDE and ArcIMS. The expected date of the first testing operation is Summer 2007. From then on all existing hydrogeological maps and databases will be continually transferred into the new system. The system will eventually become a part of a larger information system, spanning across several ministries.

**Figure 6.9.7** Database of hydrogeological boreholes



Another source of data available today in digital format is the database of hydrogeological boreholes. The database is stored in Oracle server, with the front-end application developed in Microsoft Access. It is directly connected to GIS. Today it contains over 22,000 boreholes.

## *6.10 Slovenia*

### Development and progress of hydrogeological mapping at the Geological Survey of Slovenia (GeoZS)

**The Geological Survey of Slovenia (GeoZS)** is a public research institute founded by the Slovenian Government in 1946. The Actual Geological Survey of Slovenia consists of different Research programme groups: *Sedimentology, mineralogy and petrography, Paleontology and stratigraphy, Geological maps / regional geology, Mineral resources, Geochemistry and environmental geology, Groundwater / hydrogeology, Geological information centre.* The most important tasks in the Department of hydrogeology hydrogeological map production are activities concerning Cadastre of boreholes and wells, Cadastre of springs, Groundwater reserves assessments, Water resource management plans (Evidence of water protection areas, Production of hydrogeological maps, Production of hydrogeochemical maps). Computer-based management of databases was initiated in the late eighties, establishing the first hydrogeochemical database in 1989.

### *Paper Map Series*

The important intensive detailed geological mapping activities in the early period were conducted for 30 years (1957-1987). In this period the basic Geological map was printed at the scale of 1:100,000 covering the whole territory of the state. Mapping was performed on the working topographic maps 1:25,000. These basic maps represent the base for most medium-scale thematic maps produced by GeoZS.

In 1964 the first *Guidelines for the basic hydrogeological map 1:25,000* were published. Following these Guidelines working sheets of the Hydrogeological map were produced at the scale of 1:200,000 in 1969, covering the whole state territory. The important step of hydrogeological cartography was done by UNESCO's patronage and IAH international standard legend from 1970 and 1983. The aim was the elaboration of the *Hydrogeological map of Europe 1:1,500,000*. Following these standards and recommendations, the Hydrogeological map of Slovenia was produced at the scale 1:200,000 and published at the scale 1:400,000 (1976) and 1:500,000 (1983). GeoZS started to produce the new large scale Hydrogeological maps 1:25,000 in 1988. The next updated and emphasised edition of the *Guidelines for Hydrogeological map elaboration* was published in 1990. The latest Hydrogeological map of Slovenia was produced in 2004, following the IAH publication *Hydrogeological Maps – A Guide and a Standard Legend* edition from 1995.

### Hydrogeological Map of Slovenia 1:200,000

The hydrogeological map of Slovenia 1:200,000 from 1969 was produced according to the Guidelines for the basic hydrogeological map 1:25,000 (1964). It was published in two sheets covering the whole territory with legend and was not published at this scale.

## Hydrogeological Map of Slovenia 1:400.000

Hydrogeological map of Slovenia 1:400,000 was published in 1976 (Fig. 6.10.1). It was used as the graphical visualisation for water management publication issues at that time.

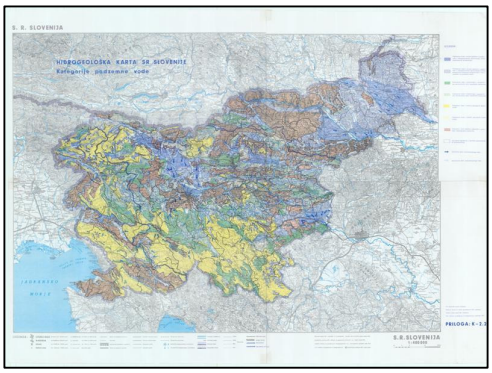
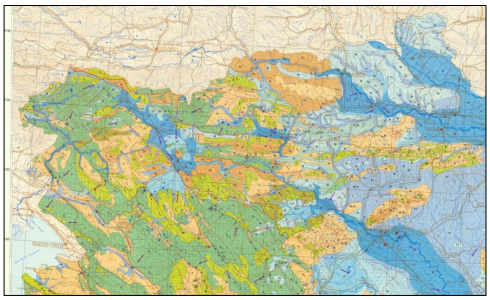


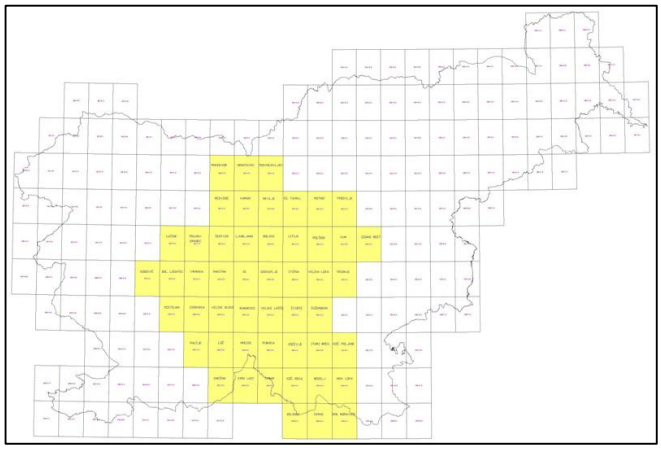
**Fig. 6.10.1** Hydrogeological map of Slovenia 1:400,000

## Hydrogeological Map of Slovenia 1:500,000



Following the standards and recommendations by UNESCO's patronage and IAH international standard legend from 1970 and 1983, the Hydrogeological map of Slovenia was published at the scale 1:500,000 (1983) (Fig. 6.10.2). It was produced as a synthesis of the more detailed studies performed till then. The main initiative was also the contribution to the *Hydrogeological map of Europe 1:1,500,000*.

**Figure 6.10.2** Hydrogeological map of Slovenia



## Hydrogeological Map of Slovenia 1:25,000

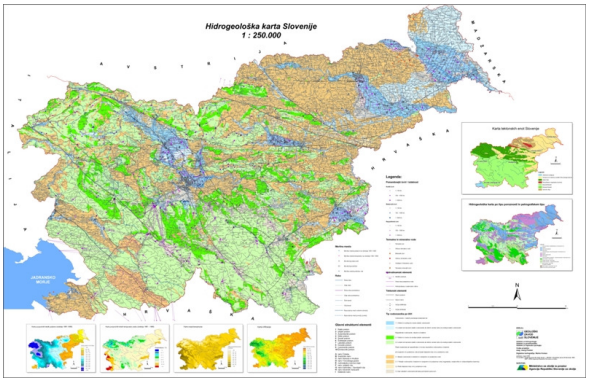
GeoZS initiated the elaboration of the Hydrogeological Map 1:25,000 in 1989 (Fig. 6.10.3). Only 50 (25% of 201 sheets) sheets were printed as working sheets (not published and not publicly available). Each sheet is printed in two layers (1-hydrogeological and 2-water supply systems). Further development of this map depends on GIS tool development of the geological map currently being renewed by GeoZS.

**Figure 6.10.3** Sheets printed at scale 1:25,000

### *Digital Maps*

The first digital Hydrogeological map using Geographical Information Systems (GIS) was introduced and published in 1997 (1:250,000). The use of GIS as well as the design and elaboration of digital mapping enabled GeoZS to produce the first digital Vulnerability map at the same scale.

The actual (2004) digital National Hydrogeological map 1:250,000 follows the International Association of Hydrogeologists (IAH) and UNESCO Guide and standard legend from 1995 (Fig. 6.10.4). It covers the whole territory of Slovenia. A variety of accompanying maps / layers were produced (i.e. LAWA classification of geological layers, infiltration rate, evapotranspiration rate, tracer experiment connections, pressures and others).



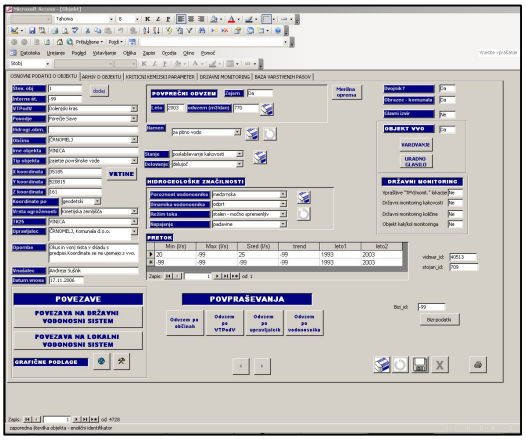

The map is available in the interactive nature protection atlas on the Environmental agency of Slovenia internet site and is also available in digital format at GeoZS. The actual (2004) digital National Hydrogeological map 1:250,000 is also the base for the Groundwater body characterisation at national level and a part of the *National hydrogeological database for the groundwater body characterisation of the Republic of Slovenia*.

**Figure 6.10.4** National Hydrogeological map 1:250,000

### Groundwater Information System

In 2001, the *National hydrogeological database for groundwater body characterisation of the Republic of Slovenia* was conceptualised as an expert base of *the Groundwater Information System.*

In 2006, the Groundwater Information Systems were implemented in the GeoZS intranet and support to the Ministry of environment and Environmental agency of Slovenia. A pilot information system has been in use since 2004 available to the mentioned institutions. The core the information system is the IS HIDRO concept developed in 2003 at GeoZS and based mainly upon former Cadastre of boreholes and wells, Cadastre of springs, Groundwater reserve assessments, Evidence of water protection areas and hydrogeochemical data (Figs. 6.10.5 and 6.10.6).




of

**Fig. 6.10.5** National hydrogeological database


The cartographic information incorporated into the *National hydrogeological database for the groundwater body characterisation of the Republic of Slovenia* corresponds to the Hydrogeological Map of Slovenia 1:250,000, the Lithostratigraphic map of Slovenia and the Structural-tectonic map of Slovenia at the same scale.

**Fig. 6.10.6** Information incorporated into the National hydrogeological database

## *6.11 Spain*

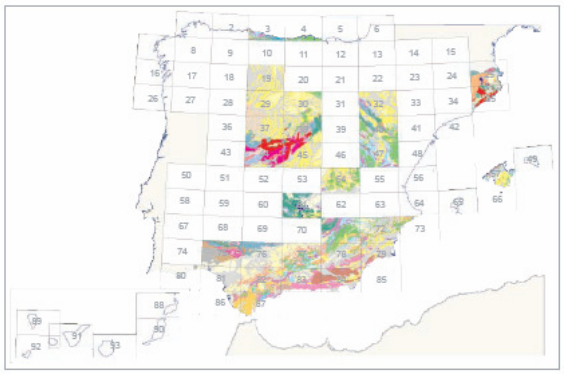
### Development and progress of hydrogeological mapping at the Geological Survey of Spain (IGME)

The preparation and publication of the National Geological Map was the mission that led to the foundation of IGME in 1849 and is today one of its most important functions. The inventory and description of mineral medicinal springs in Spain and the hydrogeological studies conducted in 1906 in the Tajo river basin are two examples of the importance given to groundwater in these initial years of cartographic developments at IGME. Hydrogeological mapping has always been considered an essential element for the knowledge and management of the territory and groundwater resources, and the first vital step for R&D in this field at IGME.

### Paper Map Series

Between 1970 and 1983 IGME conducted a systematic study of the national territory in Spain, the National Plan of Groundwater Investigation, aimed at identifying the main aquifers, evaluating their groundwater resources and giving recommendations for their protection and exploitation. Using this information as a base, a first synthetic hydrogeological mapping initiative was done by IGME in 1979 with the publication of the **National Hydrogeological Map 1:200,000** (Fig. 6.11.1). A complete series of the 93 sheets of the official national topographic grid were planned, although the map was only published for the regions that had more complete and abundant information.

**Figure 6.11.1** National Hydrogeological Map 1:200,000



This mapping series was prepared in accordance with the standards that UNESCO recommended in 1970, further revised in 1983 by the International Association of Hydrogeologists (IAH), the International Association of Hydrological Sciences (IAHS) and UNESCO.
Simultaneously, IGME started to prepare the **Hydrogeological Map 1:50,000** (Fig.6.11.2). Only 11 sheets were published due to the renewed impetus from the **National Geological Map 1:50,000, MAGNA** (1,150 sheets) in 1990, which caused the information on hydrogeology and groundwater resources to be included in this geological map series as complementary information.

**Figure 6.11.2** Hydrogeological Map of Spain 1:1,000,000

In 1990 IGME published the **Hydrogeological Map of Spain 1:1,000,000** as a synthesis of earlier more detailed studies. This series provided a global updated view of the location and extension of the main aquifers and permeable formations, a selection of water points (springs, wells, boreholes, galleries) and the main

public works affecting superficial hydrology. This series also complies with the IAH, IAHS and UNESCO (1983) norms and standard legend. The last edition (2000) included a geographical representation of the polygons that identify the hydrogeological units used for the groundwater resource management plans. This version was published with a CD-Rom containing the digital version of the map and a file presenting the data of the aquifers present in each unit in a structured way.

Other mapping products are the regional (Andalusia and Galicia, covering the southern and northern parts of the border between Portugal and Spain, respectively) and provincial Hydrogeological Atlases, produced under the auspices of the Deputations or Autonomous Communities in collaboration with IGME, mainly since the 1990s.

IGME collaborated in the production of 4 of the 27 sheets of the **International Hydrogeological Map of Europe 1:1,500,000**, under the auspices of IAH, supported by the Commission for the Geological Map of the World, and published in 2006 by the Government of the Federal Republic of Germany through the Bundesansastalt für Geowissebchaften und Rohstoffe and UNESCO.

## Digital Maps

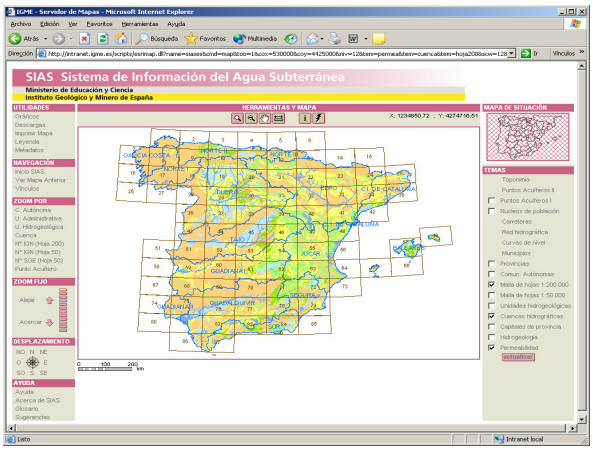
The introduction of Geographical Information Systems (GIS) in the mid-nineties currently allow us to have permanently updated mapping, thereby overcoming the drawbacks of traditional mapping on paper and changes in hydrogeological data over time. The use of GIS as well as the design and preparation of digital mapping for almost each hydrogeological project at the Institution is as real for IGME as it is for the rest of the world.

GIS is facilitating not only the preparation but also the dissemination of these maps and cartographic products as well. Via the institution's website (http://www.igme.es/internet/sistemas_infor/i_prin_SIG.asp), IGME has currently made the following hydrogeological cartography in digital format available to the public: **Hydrogeological Map of Spain 1:1,000,000, Hydrogeological Map of Spain 1:200,000, Map for the correct Location of Urban Solid Waste Landfill Sites 1:50,000**, as national hydrogeological or singular thematic maps; and the **Hydrogeological Map of Galicia 1:200,000** and the **Hydrogeological Atlas of the Autonomous Community of Madrid** as regional and provincial hydrogeological maps.

One of the most recent developments regarding digital hydrogeological mapping was the preparation of the **Lithostratigraphic and Permeability Map 1:200,000** for the whole national territory in 2006 by IGME in agreement with the Ministry of Environment to support the implementation of the Water Framework Directive.

## Groundwater Information Systems

**Figure 6.11.3** Groundwater Information System of Spain (SIAS)




In 2005, the Groundwater Information System of Spain was implemented on IGME's web (Fig. 6.11.3). A pilot system had been operating since 2004 for the Autonomous Community of Andalusia and some provinces.

**SIAS** offers potential users working in hydrogeology and groundwater the possibility of accessing via the internet the inventory of water points and related databases (piezometric levels, pumping rates, chemical analyses,...), as well as downloading the results of the queries, and generating graphs and spatial representations using the capabilities of **SIAS** as a GIS (http://www.igme.es/internet/ServiciosMapas/siasespana/sias-es.html).

The cartographic information incorporated in **SIAS** corresponds to the Hydrogeological Map of Spain 1:1,000,000 for **SIAS-ESPAÑA**, and the Hydrogeological Map of Andalusia 1:400,000 and the Hydrogeological Maps of Seville, Huelva and Cadiz 1:200,000 for the **SIAS** of Andalucia and these three provinces.

## *6.12 Sweden*

### Hydrogeological mapping at the Geological Survey of Sweden, SGU

Since the beginning of the 1980s the survey has systematically collected data for important aquifers. In Sweden the main assets are in glacio-fluvial deposits, and in the southern part also sedimentary rock. The first programme, Ah series, mainly collected known similar data stored at consulting companies, local- and regional authorities. Information was compiled and matched at scale 1:250,000. The regional mapping series consist of 24 maps; one for each county, but due to changes in administrative borders Sweden only has 20 counties today. This programme ended in 2005 when the last part of Sweden was covered (Table 6.12.1). One project within this programme compiled a national map at a scale of 1:1,000,000. This map is available on the web via the geological survey's map service. The others are available as printed maps. All maps are now digitised and stored as vector data in SGU's databases.

The public map services are using ArcIMS and ArcSDE (ESRI) and Oracle as the database. Most of the map services are WMS-services and the number is continually increasing. For the other services we do have a viewer.

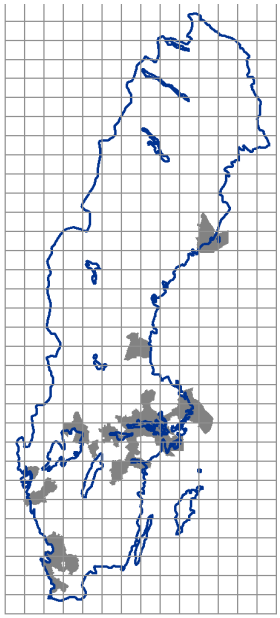


**Figure 6.12.1** In 2006 it was possible to order local data from 55 municipalities.

**Table 6.12.1** The following map services are accessible via the geological survey's public map service:

| |
|---|
| Aggregate and industrial minerals |
| Bedrock |
| Biogeochemistry, copper |
| Drilled wells archive |
| Geophysical maps |
| Geoobservations |
| Groundwater |
| Groundwater network |
| Gravel and Till database |
| Quaternary deposits |
| Natural Well archive |
| Soil geochemistry, copper |
| Ground geophysics |
| Environmental monitoring sediments |
| Environmental monitoring groundwater |
| Mineral and bedrock resources |
| Age database |

In 1994 a mapping programme at scale 1:50,000 was started. This programme includes field investigations such as geophysics and drillings done by the survey. The purpose of the programme is to provide adequate hydrogeological data needed for local and regional planning such as the municipality general plan and the implementation of the Water Framework Directive. The mapping concentrates on groundwater bodies in the most populated areas in Sweden. More than 50 (out of 290) municipalities are covered by this type of data (Fig. 6.12.1). The data mainly describe the quantitative aspects of groundwater. In recent years demand has also increased for information from flow pattern, groundwater quality and more precise delineation of separate

groundwater bodies and recharge areas. The mapping has adopted the new requirements, but only a few groundwater bodies have complete data.

# 7 Assessment of results

## *7.1 Types of hydrogeological maps (purpose, scale, format)*

The results of the inventory done in the first stage of the eWater Project and stored in a database (Questionnaire WP6.mdb in Annex 1) provide an initial catalogue of the hydrogeological maps and models available in the participating countries.

This inventory is the starting point for a comparative analysis of the most important characteristics of the maps and models regarding their contents, formats, scales, coverage, projection systems, legends, availability, etc. This analysis is aimed at making a proposal on what maps and models from the different countries could be used as the base for the eWater portal.

The catalogue of hydrogeological maps and their main characteristics (map format, map type, percentage done, scale and date of publication-digitisation) is summarised in Table 7.1.1. A distinction is made between paper and vector digital maps. Raster maps (layers resulted from a gridding process) are also distinguished from simple scanned maps.

Of the 74 maps included in this table, 45 entries are national cartography (the most interesting for the eWater project). 19 are regional, 6 are local and 3 are European initiatives.

Regarding the year of publication / digitisation, 84% of the inventoried information is for the period from 1990 to date (and future forecasts to complete cartography elaboration planning during eWater). Approximately 42% of the dates included in the Table 7.1.1 record the year of digitisation as 2000 or after.

It can be said that the main or initial aim of the inventoried cartographies in a first instance was to gain in-depth knowledge of the characterisation of hydrogeological formations from the point of view of lithostratigraphy and permeability. Other maps inventoried deal with definition of groundwater bodies to comply with the requirements of the Water Framework Directive, inventories of points, control networks, chemical quality of the waters, piezometric levels, vulnerability to groundwater pollution, exploitation of resources, groundwater resources, rain infiltration, runoff, evapotranspiration, etc…

Table 7.1.1 Catalogue of hydrogeological maps

| Institution | Map | Map name | Map format | Map type | Map coverage | Percentage done | Scale | Publication/ Digitisation Year |
|---|---|---|---|---|---|---|---|---|
| **SGSS (Italy E.Romagna)** | 1 | Riserve Idriche Sotterranee della Regione Emilia-Romagna | Paper<br>Vector | Map Series | Regional | 100<br>50 | 250,000 | 1998<br>2000 |
| **SGUDS (Slovak Republic)** | 1 | Basic hydrogeological maps of CSSR 1:200,000 | Paper | Map Series | National | 100 | 200,000 | I988<br>- |
| | 2 | Basic hydrogeological map of CSSR 1:200,000 | Vector | Singular | National | 100 | 200,000 | 1988<br>1998 |
| | 3 | Basic hydrogeological maps 1:50,000 1985 | Paper | Map Series | Regional | 15 | 50,000 | 1985<br>- |
| | 4 | Basic hydrogeological maps 1:50,000 1994 | Paper<br>Raster | Map Series | Regional | 8<br>8 | 50,000 | 1994<br>2001 |
| | 5 | Basic hydrogeological maps 1:50,000 2006 | Vector | Map Series | Regional | 9 | 50,000 | 2006<br>2006 |
| | 6 | Planned basic hydrogeological maps 1:50,000 | Vector | Map Series | Regional | 11 | 50,000 | 2010<br>2010 |
| **MAFI (Hungary)** | 1 | The 1:100,000-scale geological map of Hungary | Vector<br>Raster * | Singular | National | 100<br>100 | 100,000 | 2005<br>2005 |
| | 2 | Geological, environmental geological and hydrogeological maps of Hungary | Vector | Map Series | National | 100 | 500,000 | 1990<br>2002 |
| | 3 | The 1:100,000- and 1:200,000-scale geological and environmental geological map series of the DANube REGion (DANREG) | Vector<br>Raster * | Map Series | Regional | 100<br>100 | 200,000 | 2000<br>1999 |
| | 4 | Hydrogeological Map of Europe, Budapest sheet | Vector<br>Raster* | Singular | Regional | 100<br>100 | 1,500,000 | 2006<br>2005 |

(*) Scanned paper map

Table 7.1.1 Catalogue of hydrogeological maps (cont. 1)

| Institution | Map | Map name | Map format | Map type | Map coverage | Percentage done | Scale | Publication/ Digitisation Year |
|---|---|---|---|---|---|---|---|---|
| **GBA (Austria)** | 1 | Hydrogeologische Karte von Österreich 1:500.000 | Paper<br>Vector<br>Raster* | Singular | National<br><br>100 | 100<br>100<br>100 | 500,000 | 2006<br>2003<br>2003 |
| **GEUS (Denmark)** | 1 | Basisdata map | Raster* | Map Series | National | - | 50,000 | -<br>2006 |
| | 2 | Hydrological reference | Vector | Singular | National | - | 25,000 | -<br>1995 |
| | 3 | DK model | Vector | Map Series | National | - | | - |
| **LGT (Lithuania)** | 1 | Hydrogeological map of the Quaternary and pre-Quaternary deposits (Lithuania) | Paper | Map Series | National | 1 | 200,000 | 1962/86<br>- |
| | 2 | Hydrogeological map of the pre-Quaternary aquifers (sheets 20-39/60-79 and 20-39/40-59) | Paper<br>Vector | Map Series | National | 16<br>16 | 200,000 | 2007<br>2006 |
| | 3 | Depth to shallow groundwater | Paper<br>Vector | Map Series | Regional | 1<br>1 | 50,000 | 2000<br>1999 |
| | 4 | Hydrochemical composition of shallow groundwater | Paper<br>Vector | Map Series | Regional | 2<br>2 | 50,000 | 2000<br>2000 |
| | 5 | Map of shallow groundwater surface | Paper<br>Vector | Map Series | Regional | 1<br>1 | 50,000 | 2000<br>2000 |
| | 6 | Quality classes and surface of shallow groundwater | Paper<br>Vector | Map Series | Regional | 3<br>3 | 50,000 | 2000<br>1999 |
| | 7 | Thickness of vadose zone (Sheets No. 2131, 2132, 2133, 2134, 3111, 3112, 3114 joint) | Paper<br>Vector | Map Series | Regional | 3<br>3 | 50,000 | 1997<br>1997 |

Table 7.1.1 Catalogue of hydrogeological maps (cont.2)

| Institution | Map | Map name | Map format | Map type | Map coverage | Percentage done | Scale | Publication/ Digitisation Year |
|---|---|---|---|---|---|---|---|---|
| **IGME (Spain)** | 1 | Hydrogeological Map of Spain 1:1,000,000 | Paper<br>Vector | Map Series | National | 100<br>100 | 1,000,000 | 1991<br>1999 |
| | 2 | Lithostratigraphic and Permeability Map of Spain 1:200,000 | Paper<br>Vector | Singular | National | 100<br>100 | 200,000 | 2006<br>2005 |
| | 3 | Hydrogeological Map of Spain 1:200,00 (34 sheets) | Paper<br>Raster* | Map Series | National | 37<br>37 | 200,000 | 1982-97 |
| | 4 | Hydrogeological Map scale 1:200,000 (Madrid sheet) | Paper<br>Vector | Map Series | National | 1.07 | 200,000 | 1991<br>1997 |
| | 5 | Hydrogeological Map of Spain 1:50,000 (11 sheets) | Paper | Map Series | National | 1 | 50,000 | 1982-97 |
| | 6 | Hydrogeological Map of Andalusia 1:400,000 | Paper<br>Vector | Singular | Regional | 100<br>100 | 400,000 | 1998<br>1999 |
| | 7 | Hydrogeological Map of Seville. Scale 1:100,000 | Vector | Singular | Local | 100<br>100 | 100,000 | 2003<br>2002 |
| | 9 | Hydrogeological Map of Huelva. Scale 1:100,000 | Vector | Singular | Local | 100<br>100 | 100,000 | -<br>2002 |
| | 10 | Hydrogeological Map of Cadiz. Scale 1:100,000 | Vector | Singular | Local | 100<br>100 | 100,000 | 2006<br>2004 |
| | 11 | Hydrogeological Map of Galicia. Scale 1:200,000 | Paper<br>Vector | Singular | Regional | 100<br>100 | 200,000 | -<br>2004 |
| | 12 | Groundwater bodies | Vector | Singular | National | 100 | - | -<br>2005 |

Table 7.1.1 Catalogue of hydrogeological maps (cont. 3)

| Institution | Map | Map name | Map format | Map type | Map coverage | Percentage done | Scale | Publication/ Digitisation Year |
|---|---|---|---|---|---|---|---|---|
| **BRGM (France)** | 1 | Hydrogeological map of France (aquifer systems, Margat J.) | Paper | Singular | National | 100 | 1,500,000 | 1980 |
| | 2 | Groundwater quality map of France | Paper | Singular | National | 100 | 1,500,000 | 1994 |
| | 3 | Groundwater vulnerability map of France | Paper | Singular | National | 100 | 1,000,000 | 1970 |
| | 4 | Mineral water and spring waters in France | Paper | Singular | National | 100 | 1,000,000 | 2004 |
| | 5 | Chemical quality of groundwater | Paper | Singular | National | 100 | 1,000,000 | 1977 |
| | 6 | Hydrogeological map of France (26 sheets) | Paper | Map Series | Local | - | 50,000 | 1963-80 |
| | 7 | Groundwater vulnerability map (38 sheets) | Paper | Map Series | Local | - | 50,000 | 1973-94 |
| | 8 | Hydrogeological map of the Paris basin (2 sheets) | Paper | Singular | Regional | 100 | 500,000 | 1967 |
| | 9 | Hydrogeological synthesis of Languedoc Roussillon | Digital | Singular | Regional | - | - | 2005 |
| | 10 | Groundwater bodies | Vector | Singular | National | 100 | - | 2005 |
| | … | (Other maps in paper format) | | | | | | |

Table 7.1.1 Catalogue of hydrogeological maps (cont. 4)

| Institution | Map | Map name | Map format | Map type | Map coverage | Percentage done | Scale | Publication/ Digitisation Year |
|---|---|---|---|---|---|---|---|---|
| **SGU (Sweden)** | 1 | Ah (Regional Hydrogeological map) | Paper<br>Vector<br>Raster * | Map Series | Regional<br>100 | 100<br>100 | 250,000 | 2005 |
| | 2 | Ah (National Hydrogeological map) | Paper<br>Vector<br>Raster * | Singular | National<br>100 | 100<br>100 | 1,000,000 | - |
| **GeoZS (Slovenia)** | 1 | Hydrogeological map | Paper<br>Vector | Singular | National | 100<br>100 | 250,000 | -<br>2004 |
| | 2 | Vulnerability maps | Paper<br>Raster (GRID) | Singular | National | 100<br>100 | 250,000 | -<br>2005 |
| | 3 | Hydrogeological map Karavanke | Paper<br>Vector | Singular | Local | 100<br>100 | 25,000 | -<br>2004 |
| | 4 | Infiltration rates | Paper<br>Raster (GRID) | Singular | National | 100<br>100 | 250,000 | -<br>2003 |
| | 5 | Evapotranspiration | Paper<br>Raster (GRID) | Singular | National | 100<br>100 | 250,000 | -<br>2003 |
| | 6 | Precipitation | Paper<br>Raster (GRID) | Singular | National | 100<br>100 | 250,000 | -<br>2003 |
| | 7 | Pressures | Paper<br>Raster (GRID) | Singular | National | 100<br>100 | 250,000 | -<br>2005 |
| | 8 | Groundwater bodies | Paper<br>Vector | Singular | National | 100<br>100 | 250,000 | -<br>2005 |
| | 9 | Water protection areas | Paper<br>Vector | Singular | National | 100<br>100 | 25,000 | -<br>2006 |
| | 10 | Groundwater level on alluvial aquifers | Paper<br>Vector | Singular | National | 100<br>100 | 250,000 | -<br>2003 |

(*) Scanned paper map

Table 7.1.1 Catalogue of hydrogeological maps (cont. 5)

| Institution | Map | Map name | Map format | Map type | Map coverage | Percentage done | Scale | Publication/ Digitisation Year |
|---|---|---|---|---|---|---|---|---|
| **The Czech Republic** | 1 | Hydrogeological map | Paper<br>Raster * | Map Series | National | 100<br>100 | 50,000 | 1999<br>2003 |
| | 2 | Hydrogeological map | Paper<br>Raster* | Map Series | National | 100<br>100 | 200,000 | 1987<br>2003 |
| **Geofond (ČGS)** | 3 | Hydrochemical map | Paper<br>Raster | Map Series | National | 100<br>100 | 200,000 | 1982<br>2003 |
| | 4 | Hydrogeological Zones of the CZ | Vector | Map Series | National | 100 | 50,000 | 2005<br>2005 |
| | 5 | Hydrogeological map of the CZ | Paper<br>Raster | Singular | National | -<br>- | 1,000,000 | 1965<br>2000 |
| **Geofond (VÚV)** | 6 | Water management map | Paper<br>Raster*<br>Vector | Map Series | National | 100<br>100<br>100 | 50,000 | 1985<br>1999 |
| **Geofond (ČHMÚ)** | 7 | Groundwater runoff map (schematic base flow map) | Paper | Singular | National | 100 | 1,500,000 | 1981 |
| | 8 | Maps of groundwater monitoring network | Vector | Map Series | National | 100 | 50,000 | - |
| | 9 | Map of quality of groundwater | Vector | Map Series | - | - | 50,000 | - |

(*) Scanned paper map

Table 7.1.1 Catalogue of hydrogeological maps (cont. 6)

| Institution | Map | Map name | Map format | Map type | Map coverage | Percentage done | Scale | Publication/ Digitisation Year |
|---|---|---|---|---|---|---|---|---|
| **The Netherlands** | 1 | Vulnerability groundwater Europe | Paper<br>Raster * | Singular | Europe | 100<br>100 | 10,000,000 | 1994 |
| | 2 | Fresh-Salt interface (TNO) | Raster (Grid)<br>Vector | Singular | National | 20 | 100,000 | 2007 |
| | 3 | Over-exploitation of groundwater | Paper<br>Vector | Singular | Europe | 100<br>100 | 10,000,000 | 2001<br>2001 |
| | 4 | Groundwater protection areas | Vector | Map Series | Regional | 100 | 100,000 | |
| | 5 | Groundwater classes** | Vector | Map Series | Regional | 100 | 250,000<br>50,000 | 2000<br>2002 |
| | 6 | Groundwater well locations (TNO) | Vector | Singular | National | 100 | 10,000 | 1990<br>1990 |
| | 7 | Hydrogeological model of the Netherlands (TNO) | Raster (GRID) | Singular | National | 85 | 100,000 | 2007<br>2007 |
| | 8 | Continuous model of groundwater level | Raster (GRID) | Singular | National | 100 | 1,000 | 2008<br>2008 |
| | 9 | Hydrogeological map of the Netherlands | Paper | Map Series | National | 100 | 50,000 | 1990 |
| | 10 | International Hydrogeological Map of Europe | Paper<br>Raster* | Map Series | Europe | 90<br>- | 1,500,000 | 1996<br>2006 |

(*) Scanned paper map

(**) Variation of ground water level relatively to the Earth surface level (www.bodemdata.nl)

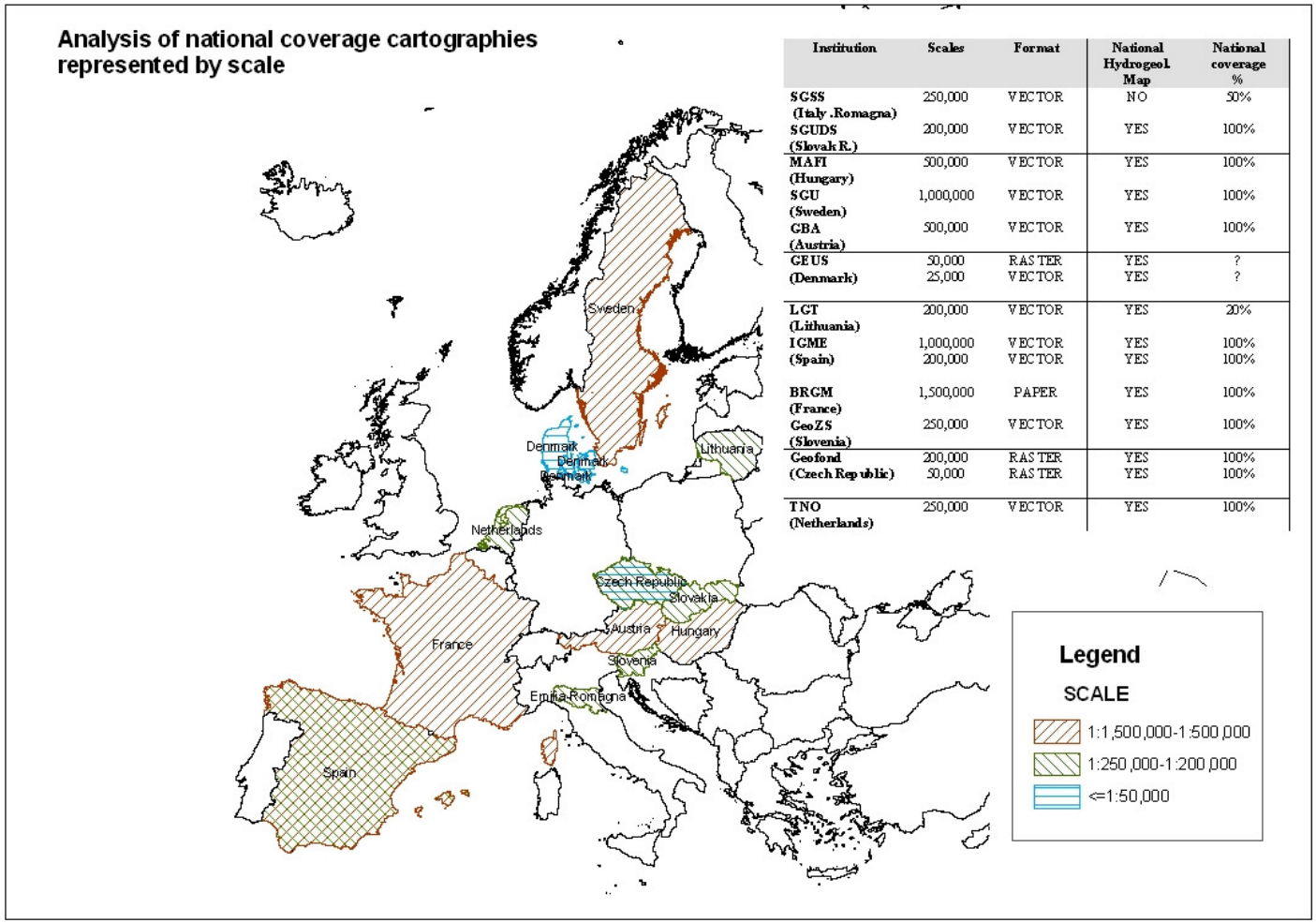
## 7.2 Coverage (area and cross-border)

Considering the aims of the eWater project, the focus was first put on the national map series available in each partner's country, and its scale and coverage.

The national hydrogeological cartographic products inventoried are shown in Figures 7.2.1 and 7.2.2 and grouped by scale. The inset table contains a summary of the main characteristics of these maps. Almost all the participating countries have produced some hydrogeological map series with 100% coverage, while some countries have this product at two different scales (Denmark, the Czech Republic, Spain).

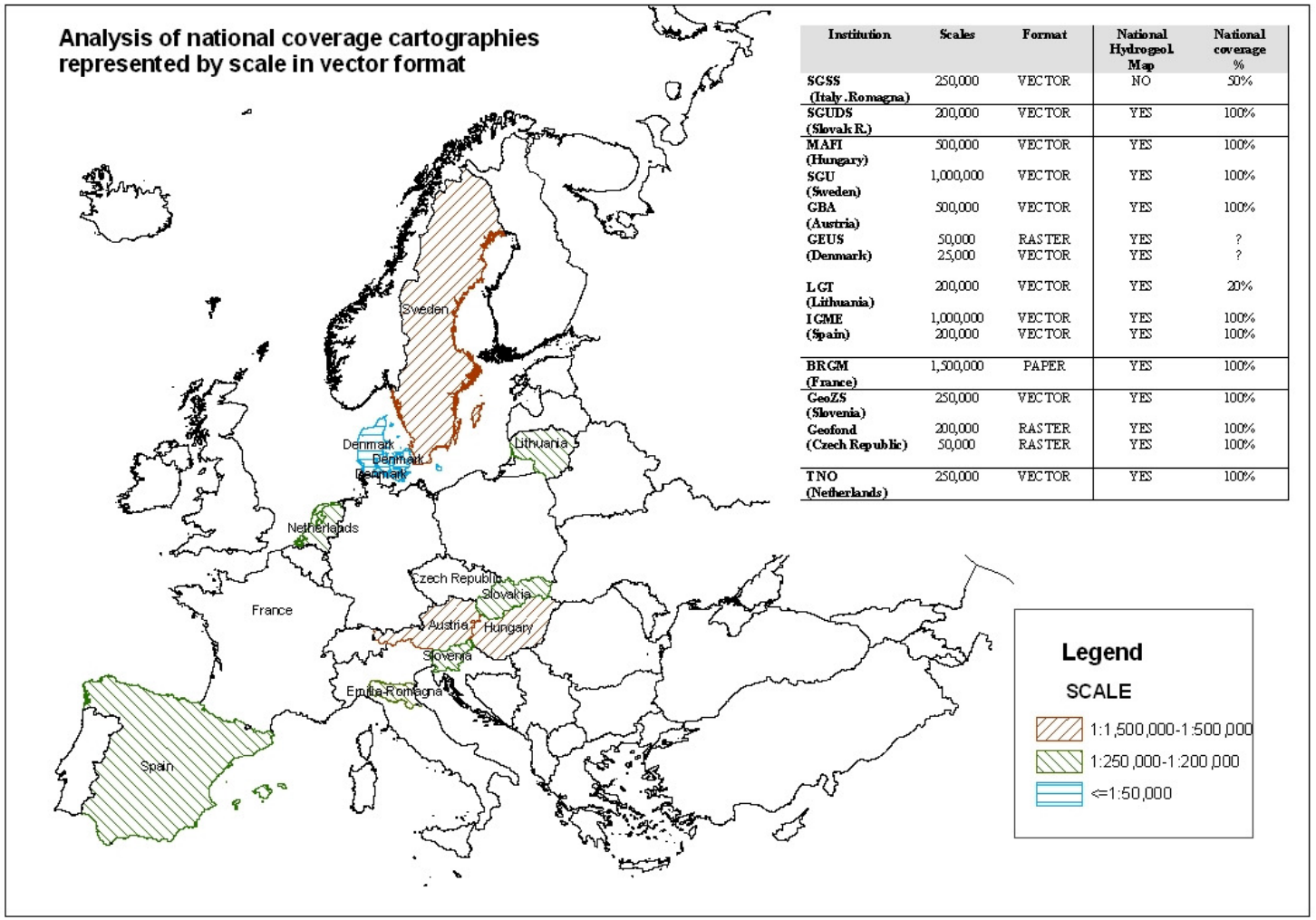
At first sight (Figure 7.2.1), all the national map series are shown irrespective of their format (paper, digital) and grouped in three different scale intervals with a different grid. The first interval (1:1,500,000-1:500,000) includes, at the bottom, the smallest scales corresponding to the largest countries (France, Sweden and Spain) and, at the top, medium-size countries such as Austria or Hungary. The next interval groups together medium-scale cartographies (1:250,000-1:200,000) for the rest of the countries (the Netherlands, Lithuania, the Czech Republic, Slovakia, Slovenia, Emilia-Romagna (Italy), and Spain). The group including the most detailed maps, with scales equal or less than 1:50,000, includes Denmark and, in part, the Czech Republic.

Taking into account that further harmonisation and interoperability considerations will have to focus on map series produced under the vector format, this series type inventoried by the countries participating in this project is shown in Figure 7.2.2.




| Institution | Scales | Format | National Hydrogeol Map | National coverage % |
|---|---|---|---|---|
| SGSS (Italy .Romagna) | 250,000 | VECTOR | NO | 50% |
| SGUDS (Slovak R.) | 200,000 | VECTOR | YES | 100% |
| MAFI (Hungary) | 500,000 | VECTOR | YES | 100% |
| SGU (Sweden) | 1,000,000 | VECTOR | YES | 100% |
| GBA (Austria) | 500,000 | VECTOR | YES | 100% |
| GEUS (Denmark) | 50,000<br>25,000 | RASTER<br>VECTOR | YES<br>YES | ?<br>? |
| LGT (Lithuania) | 200,000 | VECTOR | YES | 20% |
| IGME (Spain) | 1,000,000<br>200,000 | VECTOR<br>VECTOR | YES<br>YES | 100%<br>100% |
| BRGM (France) | 1,500,000 | PAPER | YES | 100% |
| GeoZS (Slovenia) | 250,000 | VECTOR | YES | 100% |
| Geofond (Czech Republic) | 200,000<br>50,000 | RASTER<br>RASTER | YES<br>YES | 100%<br>100% |
| TNO (Netherlands) | 250,000 | VECTOR | YES | 100% |

**Figure 7.2.1** Analysis of national hydrogeological cartographies by scale




| Institution | Scales | Format | National Hydrogeol. Map | National coverage % |
|---|---|---|---|---|
| SGSS (Italy .Romagna) | 250,000 | VECTOR | NO | 50% |
| SGUDS (Slovak R.) | 200,000 | VECTOR | YES | 100% |
| MAFI (Hungary) | 500,000 | VECTOR | YES | 100% |
| SGU (Sweden) | 1,000,000 | VECTOR | YES | 100% |
| GBA (Austria) | 500,000 | VECTOR | YES | 100% |
| GEUS (Denmark) | 50,000<br>25,000 | RASTER<br>VECTOR | YES<br>YES | ?<br>? |
| LGT (Lithuania) | 200,000 | VECTOR | YES | 20% |
| IGME (Spain) | 1,000,000<br>200,000 | VECTOR<br>VECTOR | YES<br>YES | 100%<br>100% |
| BRGM (France) | 1,500,000 | PAPER | YES | 100% |
| GeoZS (Slovenia) | 250,000 | VECTOR | YES | 100% |
| Geofond (Czech Republic) | 200,000<br>50,000 | RASTER<br>RASTER | YES<br>YES | 100%<br>100% |
| TNO (Netherlands) | 250,000 | VECTOR | YES | 100% |

**Figure 7.2.2** Analysis of national hydrogeological cartographies by scale in vector format

A graphical representation of the major cross-border areas of the eWater participating countries is shown in Figure 7.2.3 and the scales of the hydrogeological maps available at both sides of the border are identified. Green arrows represent similar scales at both sides of the border, while red arrows represent different scales at both sides of the border. Obviously, maps with similar scales may represent different objects and, therefore, cross-border harmonisation will not necessarily be easy. The analysis of this particular issue is the objective of the second stage of WP6.

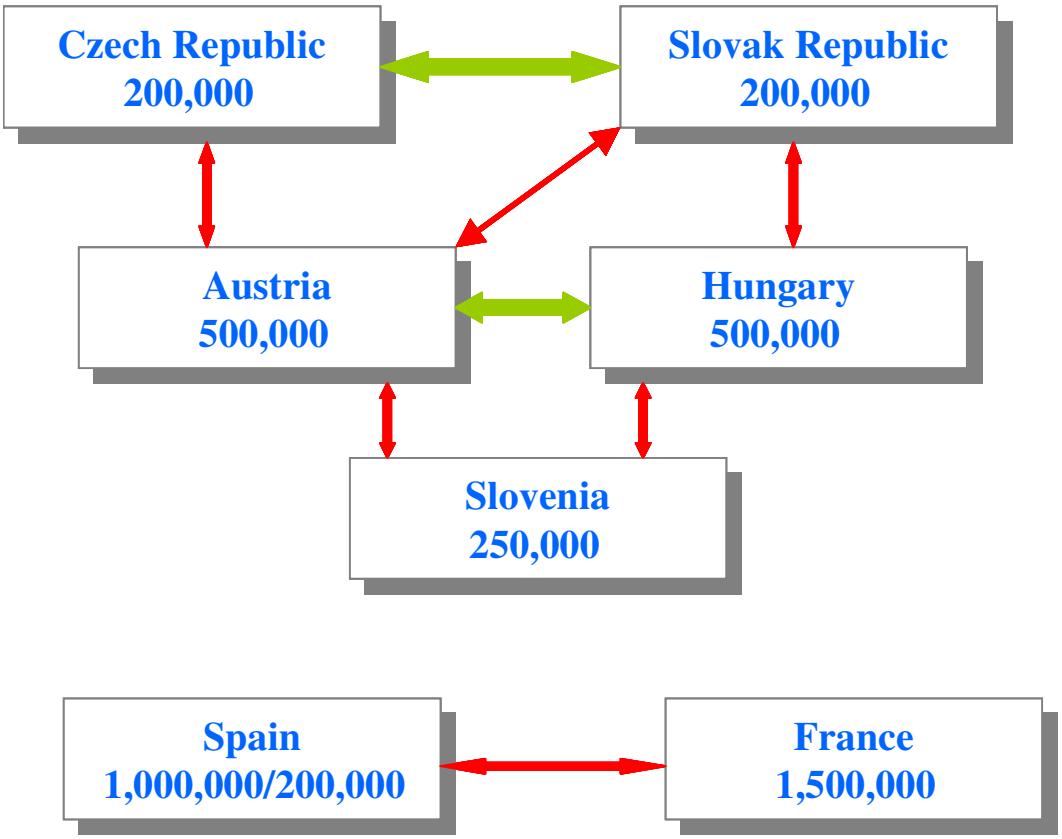



**Figure 7.2.3** eWater cross-border hydrogeological map scales

## 7.3 Accessibility

Policies on accessibility of geological and hydrogeological information are different in the European Geological Surveys, ranging from free and open access to the public to payment and restricted use. This depends mainly on the ownership of the information (the way the information has been gathered) and the funding frameworks of the institutions.

Regarding eWater, the present level of accessibility via the internet to the participating Geological Surveys' georeferenced cartographic information was deemed one important question to be answered in the Questionnaire for the inventory of hydrogeological maps.

From the results of the survey, it can be concluded that only a small part of the hydrogeological cartographic information, hydrogeological maps with national coverage in most instances, is available via the internet, and it is only true for half of the participating countries. Table 7.3.1 shows the situation of the digital maps available in the partners' Geological Survey hydrogeological inventory Databases.

Table 7.3.2 shows a more completed list of the national hydrogeological maps (paper and digital format) available in all the participating countries and their level of accessibility, even when this is only local. URLs are indicated where appropriate.

Table 7.3.1.- Digital maps available via the internet in the participating countries

| Accessibility | | | | | |
|---|---|---|---|---|---|
| **Country** | **Institution** | **Map Name** | **Map Format** | **Level** | **Legal Availability** |
| Sweden | SGU | Ah - National | Paper and digital | Internet | No |
| Hungary | MAFI | The 1:100,000-scale geological map of Hungary | Digital | Internet | No |
| Spain | IGME | Hydrogeological Map of Spain 1:1,000,000 | Paper and digital | Internet | Yes |
| The Netherlands | TNO | Groundwater well locations | Digital | Internet | Yes |
| Slovenia | GeoZS | Hydrogeological map | Digital | Internet | Yes |
| Austria | GBA | Hydrogeologische Karte von Österreich 1:500,000 | Paper and digital | Internet | Yes |

Table 7.3.2.- Hydrogeological maps of national coverage available in the participating countries and level of accessibility

| Partner | Map | Scale | Coverage | URL |
|---|---|---|---|---|
| **GBA (Austria)** | Hydrogeologische Karte von Österreich | 1:500,000 | 100 | http://www.geologie.ac.at |
| **Geofond (Czech Republic)** | Hydrogeological maps in paper (1) and paper and raster (2) formats | (1) 1:200,000<br>(2) 1:50,000 | 100<br>100 | Local accessibility<br>Local accessibility |
| **GEUS (Denmark)** | Hydrogeological Reference | 1:25,000 | 100 | Local accessibility |
| **BRGM (France)** | Groundwater bodies | | 100 | http://sandre.eaufrance.fr/geonetwork/srv/fr/metadata.show?id=596&currTab=simple |
| **MAFI (Hungary)** | Geological, environmental geological and hydrogeological maps of Hungary | 1:500,000 | 100 | Local accessibility |
| **SGSS (Emilia Romagna, Italy)** | Ground Water Resources of the Emilia-Romagna region | 1:250,000 | 50 | Local accessibility |
| **LGT (Lithuania)** | Hydrogeological map of the preQuaternary deposits | 1:200,000 | 16 sheets | Local accessibility |
| **TNO (The Netherlands)** | Hydrogeological model of The Netherlands | 1:250,000 | 100 | http://dinoloket.nitg.tno.nl |
| **GeoZS (Slovenia)** | Hydrogeological Map | 1:250.000 | 100 | http://www.geo-zs.si |
| **(Slovak Republic)** | Basic Hydrogeological Map of CSSR | 1:200,000 | 100 | Local accessibility |
| **IGME (Spain)** | Hydrogeological Map of Spain | 1:1.000.000 | 100 | http://www.igme.es/internet/ServiciosMapas/siasespana/sias-es.html |
| **SGU (Sweden)** | National Hydrogeological Map | 1:1,000,000 | 100 | http://www.sgu.se |

## 7.4 Harmonisation

The analysis in this paragraph provides deeper insight into the aspects considered relevant when potential enhancement of the interoperability of the digital cartographic information available in the partner countries via eWater is addressed. These aspects determining the degree of approximation to the Geological Survey standards are analysed in the following groups:

- Operating systems and software supporting the digital cartographies
- Projection systems used for these cartographies
- Analysis of the legends used for polygons, lines and points in the inventoried digital cartography
- Preliminary comparative analysis of the contents and hydrogeological classifications.

The computer equipment, operating systems and specific software used by the participating Geological Surveys to implement the information systems on hydrogeology and the digital hydrogeological cartographies are standard in the area of geoscientific and Earth Science information (see Table 7.4.1).

Table 7.4.1 GIS Applications and Operating Systems

| Institution | Country | Application | Operating System |
|---|---|---|---|
| **BRGM** | France | ArcGIS | Windows XP |
| **Geofond** | Czech Republic | - | - |
| **GBA** | Austria | Oracle, ArcIMS | UNIX, WINDOWS |
| **GeoZs** | Slovenia | ArcGIS, ArcIMS, AutoDeskMAP | Microsoft Windows |
| **GEUS** | Denmark | - | Windows 2003 server |
| **GSSR** | Slovakia | MapInfo Professional | Windows |
| **IGME** | Spain | ArcGIS | Windows, LINUX, HP-UX |
| **LTG** | Lithuania | MapInfo | Windows |
| **MAFI** | Hungary | MicroStation; Intergraph MGE; ESRI ArcGIS | Microsoft XP |
| **SGSS** | Italy. Emilia Romagna | ArcGIS, ArcView | Win2K, XP |
| **SGU** | Sweden | ArcGIS 9 | Windows XP |
| **TNO B&O** | The Netherlands | ArcGIS | UNIX, WindowsNT |

The Windows operating system is widely used in its different versions, followed by Unix. ESRI products are the most commonly used as a specific application for GIS, followed by Mapinfo. Given this situation, the formats of the files storing and managing the georeferenced information and the associated databases and the types of files to exchange information will not be a problem if the digital cartographies have to be combined.

Regarding the projection systems used in the partner countries, less homogeneity is found (see Table 7.4.2), ranging from the EUREF89 system in Denmark, formulated as a reference in INSPIRE and adopted in the developments taking place under the Water Framework Directive, to local projection systems used in some countries. Only Spain and Italy (Emilia Romagna) coincide for the reference UTM ED50.

Table 7.4.2 Projection Systems

| Institution | Map Projection System |
|---|---|
| **SGSS (Italy E.Romagna)** | UTM ED 50 |
| **SGUDS (Slovak Republic)** | S-JTSK (Krovak) |
| **MAFI (Hungary)** | Uniform Hungarian National Projection System (EOV) |
| **SGU (Sweden)** | RT 90 2,5 gon V |
| **GBA (Austria)** | Coord. System: GCS_Bessel_1841, Datum: D_Bessel_1841, Prime Meridian: 0, Angular Unit: Degree |
| **GEUS (Denmark)** | EUREF89 |
| **LGT (Lithuania)** | LKS-94 |
| **IGME (Spain)** | ED_50 UTM Zone_30N / 28N |
| **BRGM (France)** | Universal Transversal Mercator UTM fuseau 32 |
| **GeoZS (Slovenia)** | SI-D48 (Gauß-Krüger) |
| **Geofond (Czech Rep.)** | S-JTSK Krovak |
| **TNO (The Netherlands)** | RDN |

A comparative analysis has been initiated for the hydrogeological classifications and contents of the hydrogeological vector maps compiled. The aim of this analysis was to obtain some indications on how to build a potential high-level legend that could facilitate harmonisation among countries.

Two approaches with a different scope have been followed:

- On the one hand, the analysis was done on the national coverage digital layer information grouped by organisation. The information compiled under the Groups: ***Content lay*****er** and ***Attribute layer*** of the Questionnaire is organised in table format in Annex II. It contains the layers with the hydrogeological content and their attributes, including considerations and comments which, at a second stage of the analysis, may allow some more definite conclusions to be drawn on possible harmonisation of the cartographies available and identify the attributes under which the unifications and relationships could be established.

- On the other hand, from the information compiled under the Group ***Legend*** *on the Questionnaire,* three summarised tables have been designed, one for each type of element represented (point, line and polygon entities). These tables lead to simple characterisation of each layer in its graphical representation and make it possible to know whether the layer corresponds to hydrogeological standards formulated by International Organisations (AIH, UNESCO, etc…) or not.

**Point entities**

The legends used for points deal mostly with inventories of water points, specifically with the nature or type of point (spring, well,…). Points that belong to monitoring networks are also regularly shown in cartographic representations. Guides and standards are normally used in most geological surveys to symbolise this information to the public.

Table 7.4.3 Point legend

| Point legend | | | | |
|---|---|---|---|---|
| **Country** | **Institution** | **Contents** | **Standard legend type** | **Point Legend type** |
| **Slovakia** | State Geological Institute of Dionyz Stur | Locations of springs | | Type (well, spring, borehole,...) |
| | | Locations of hydrogeological boreholes | | Type (well, spring, borehole,...) |
| | | Other important hydrogeological objects | | Type (well, spring, borehole,...) |
| | | Springs | | Combination of attributes |
| | | Hydrogeological boreholes | | Combination of attributes |
| | | Other important hydrogeological objects | | Combination of attributes |
| | | Karstic features | | Type (well, spring, borehole,...) |
| **Sweden** | Geological Survey of Sweden | Springs and other hydrogeological point objects | Other | Type (well, spring, borehole,...) |
| | | Springs and other hydrogeological point objects | Other | Type (well, spring, borehole,...) |
| **Lithuania** | Lietuvos geologijos tarnyba | Wells and well fields | Other | Abstraction |
| **Austria** | Geologische Bundesanstalt | Mapping of special details | IAH & UNESCO 1995 | Combination of attributes |
| **Spain** | Instituto Geológico y Minero de España | Selected Groundwater inventoried points | IGS, IAHS, IAH & UNESCO 1970 | Type (well, spring, borehole,...) |

| Point legend | | | | |
|---|---|---|---|---|
| **Country** | **Institution** | **Contents** | **Standard legend type** | **Point Legend type** |
| **Spain (cont.)** | Instituto Geológico y Minero de España (cont.) | IGME Groundwater Database of wells, springs and monitoring points of chemical and groundwater level monitoring included on sheet number 45 | IGS, IAHS, IAH & UNESCO 1970 | Type (well, spring, borehole,...) and monitoring network |
| | | River flow-rate network stations included in sheet number 45. | IGS, IAHS, IAH & UNESCO 1970 | Monitoring network (flow rates) |
| | | Chemical quality network stations, monitoring rivers and channels included in sheet number 45 | IGS, IAHS, IAH & UNESCO 1970 | Monitoring network (quality) |
| | | Rainfall meteorological stations and temperature and rainfall meteorological stations included in sheet number 45 (scale 1:200,000 | IGS, IAHS, IAH & UNESCO 1970 | Monitoring network (meteorological) |
| | | Specific transmissivity values in m2/day in Madrid hydrogeological sheet number 45 | IGS, IAHS, IAH & UNESCO 1970 | |

**Line entities**

Linear layers compiled in the Questionnaire can generally be classified under three groups (Table 7.4.4):

- Hydrogeological contacts
- Groundwater divides, piezometric lines and flow directions
- Isocontents (information relative to the chemical quality of the groundwater)

In general, guides and standards (AIH, UNESCO,…) are used to represent lines in hydrogeological maps, although other representations are also inventoried.

Table 7.4.4 Line legend

| Line legend | | | | | |
|---|---|---|---|---|---|
| **Country** | **Institution** | **Contents** | **Standard legend type** | **Contact line type** | **Line legend type** |
| **Sweden** | Geological Survey of Sweden | Water dividers and other hydrogeological line objects | Other | | Flow Lines |
| | | Water dividers and other hydrogeological line objects | Other | | Flow Lines |
| **Lithuania** | Lietuvos geologijos tarnyba | Distribution of aquifers and aquitards (below pre-Quaternary surface) | Other | Geological | Water divides |
| | | Piezometric level of confined aquifers | Other | | Water level isolines |
| **Slovakia** | State Geological Institute of Dionyz Stur | Directions of groundwater flow | | | Flow Lines |
| | | Groundwater contours | | | Water level isolines |
| | | Hydrogeologic al borders | | Hydrogeological | |
| | | Groundwater divides | | | Water divides |
| | | Groundwater contours | | | Water level isolines |
| | | Directions of groundwater flow | | | Flow Lines |
| **Austria** | Geologische Bundesanstalt | tectonic lines | IAH & UNESCO 1995 | | |
| **Spain** | Instituto Geológico y Minero de España | Hydrogeological contacts | | | |
| | | Folding structures of Galicia | IGS, IAHS, IAH & UNESCO 1970 | Geological | Folding structures |
| | | Lines between hydrogeological cartographic units and fractures | IGS, IAHS, IAH & UNESCO 1970 | Geological | |

| Line legend | | | | | |
|---|---|---|---|---|---|
| **Country** | **Institution** | **Contents** | **Standard legend type** | **Contact line type** | **Line legend type** |
| **Spain (cont.)** | Instituto Geológico y Minero de España (cont.) | Isopiezes and flow lines of the aquifers included in hydrogeological sheet number 45 | IGS, IAHS, IAH & UNESCO 1970 | Hydrogeological | Water level isolines |
| | | Average annual isohyets in mm. | IGS, IAHS, IAH & UNESCO 1970 | Hydrogeological | Isohyets |
| | | Isotransmissivity lines | IGS, IAHS, IAH & UNESCO 1970 | Hydrogeological | Water quality isoline |

**Polygon entities**

Analysing the types of legends compiled, several groups of cartographies can be established as a function of the attributes of the layers being represented:

- Some legends represent lithology, permeability, productivity, and chrono-stratigraphy together on several occasions. In theory, these maps may enable attributes to be compared better (Table 7.4.5) .
- Legends that represent only lithology
- Legends that represent only permeabilities
- Legends that represent only chrono-stratigraphy
- Legends that represent only information relative to groundwater resources

Most maps follow standard legends, although some representations designed specifically by individual Geological Surveys are also found.

Table 7.4.5 Polygon Legend

| Polygon legend | | | | |
|---|---|---|---|---|
| **Country** | **Institution** | **Contents** | **Standard legend type** | **Aquifer legend type** |
| **Lithuania** | Lietuvos geologijos tarnyba | Transmissivity | Other | Permeability |
| | | Hydrochemical type (according to Aliokin classification) of groundwater | Other | |
| **Italy Emilia Romagna** | Servizio Geologico | Cumulative thickness of porous-permeable deposits. Potential direct recharge area. Aquifer group A | Other | Lithology |
| | | Cumulative thickness of porous-permeable deposits. Potential direct recharge area. Aquifer group B | Other | Lithology |
| | | Cumulative thickness of porous-permeable deposits. Potential direct recharge area. Aquifer group C | Other | Lithology |
| | | Aquifer bottom depth. Fresh water/salt water interface depth. Aquifer group A | Other | Chronostratigraphy |
| | | Aquifer bottom depth. Fresh water/salt water interface depth. Aquifer group B | Other | Chronostratigraphy |
| | | Aquifer bottom depth. Fresh water/salt water interface depth. Aquifer group C | Other | Chronostratigraphy |
| **Sweden** | Geological Survey of Sweden | Estimated exploitation potential of Groundwater in bedrock | IGS, IAHS, IAH & UNESCO 1970 | Amount of groundwater resources |
| | | Estimated Groundwater conditions in Quaternary deposits | IGS, IAHS, IAH & UNESCO 1970 | Amount of groundwater resources |
| | | Estimated exploitation potential of Groundwater in bedrock | IGS, IAHS, IAH & UNESCO 1970 | Amount of groundwater resources |
| **Sweden (cont.)** | Geological Survey of Sweden (cont.) | Estimated Groundwater conditions in Quaternary deposits | IGS, IAHS, IAH & UNESCO 1970 | Amount of groundwater resources |

| Polygon legend | | | | |
|---|---|---|---|---|
| **Country** | **Institution** | **Contents** | **Standard legend type** | **Aquifer legend type** |
| **Hungary** | Magyar Állami Földtani Intézet (Geological Institute of Hungary) | Surface geological formations | Other | |
| | | Status of the uppermost aquifer | | Lithology and Permeability |
| | | Geothermal potential | | |
| | | Status of the uppermost aquifer | IAH & UNESCO 1970 | Lithology and Permeability |
| **Lithuania** | Lietuvos geologijos tarnyba | Distribution of aquifers and aquitards (in pre-Quaternary surface) | Other | Lithology and Permeability |
| | | Productivity of aquifers (Yield of wells) | Other | Productivity |
| **Slovakia** | State Geological Institute of Dionyz Stur | Covering groundwater bodies | | Other |
| | | Groundwater bodies | | Other |
| | Geološki zavod Slovenije | Hydrogeology | IAH & UNESCO 1995 | |
| **Austria** | Geologische Bundesanstalt | Aquifer type | IAH & UNESCO 1995 | Amount of groundwater resources |
| | | Lithology | IAH & UNESCO 1995 | Lithology |
| **Spain** | Instituto Geológico y Minero de España | Hydrogeological cartographic units of Iberian Peninsula and Balearic islands | IGS, IAHS, IAH & UNESCO 1970 | Lithology, Permeability and Productivity |
| | | Hydrogeological legend on lithology, permeability and chronostratigraphy information of the cartographic units | IGS, IAHS, IAH & UNESCO 1970 | Lithology, Permeability, Productivity and Chronostratigraphy. |
| | | Hydrogeological cartographic units of the Canary Islands | IGS, IAHS, IAH & UNESCO 1970 | Lithology, Permeability and Productivity |
| **Spain (cont.)** | Instituto Geológico y Minero de España (cont.) | Hydrogeological cartographic units | | |
| | | Hydrogeological units of Galicia | IGS, IAHS, IAH & UNESCO 1970 | Lithology, Permeability and Chronostratigraphy |

| Polygon legend | | | | |
|---|---|---|---|---|
| **Country** | **Institution** | **Contents** | **Standard legend type** | **Aquifer legend type** |
| | | Groundwater bodies below another groundwater body | | Lithology |
| | | Groundwater bodies on another groundwater body | | Lithology |
| | | Aquifer systems | | |
| | | Hydrogeological cartographic units | IGS, IAHS, IAH & UNESCO 1970 | Lithology, Permeability, Productivity and Chronostratigraphy. |
| | | Zoning in degrees of vulnerability according to the permeability of the lithology on Madrid sheet | IGS, IAHS, IAH & UNESCO 1970 | Permeability |

In theory, from the analysis of the legends and the symbolisation gathered in the Table ***Legend*** on the questionnaire, it could be deduced that the in-depth study stage of the layers and their attributes to broach potential harmonisation recommendations would be quite simple and have positive results for the eWater objectives. However, the initial analyses (initiated with Annex II) do not seem optimistic for the attributes, since it is finally at this level of detail where matchings have to be done to achieve possible harmonisation.

### *7.5 Interoperability*

Generally, interoperability related to Information Systems is defined as the capability to communicate, execute applications or exchange data among several functional units, and users do not require expertise knowledge to perform these tasks

In the area of the Spatial Information System, interoperability is normalised by ISO 19128 “Geographic Information –Web Map Server Interface” (“Web Map Services WMS Implementation Specification v1.3” of the Open Geospatial Consortium, OGC).

Therefore, a layer is considered interoperable when it is compliant with the OGC standard to design a Web Map Server. WMS defines the performance of a service that produces maps of spatially referenced data dynamically from geographical information.

This International Standard defines three operations, GetCapabilities, GetMap and GetFeatureInfo, the first two are mandatory and produce the basic WMS, and the last one is optional and defines the Queryable service. These operations are performed upon request to the corresponding WMS

The operation GetCapability gives us information on the layers available from the service, regarding the boundaries of information, styles to draw these layers, legends, coordinate

reference system, etc. This information is needed in order to perform the following two operations.

GetMap returns a map with an image in any of the established format (JPEG, GIF, PNG, etc.), with a transparent background to facilitate overlaying on other images returned from different services that may or may not coincide in their spatial boundaries.

The GetFeatureInfo operation is designed to provide WMS customers with more information on map features that were returned by previous Map requests.

Almost one hundred digital hydrogeological maps have been inventoried in eWater project. Apparently only one map in the Netherlands (TNO), showing well locations in several provinces bordering with Germany, conforms with the OGC standard for interoperability (Table 7.5.1) . This service is a “Queryable Service” as far as it implements the three operations.

Table 7.5.1 Interoperability

| Interoperability | | | | | | |
|---|---|---|---|---|---|---|
| **Country** | **Organisation** | **Specification OWG** | **GetCapabilites** | **GetMap** | **GetFeatureInfo** | **Layer Name** |
| **The Netherlands** | TNO B&O | Yes | Yes | Yes | Yes | Well locations |

**eWater objectives on interoperability**

In order to fulfil the objectives of the project, several layers of selected areas from countries sharing borders should be made interoperable. These layers should have similar information and scale and implement at least the two mandatory OGC operations. The project should also consider the possibilities of legend harmonisation for selected maps, e.g. by means of Styled Layer Descriptor specification.

A detailed analysis of the information gathered in the inventory is necessary in order to select the layer to be harmonised. This analysis will be part of the next stage of the project.

# 8 Conclusions

The results of the Survey conducted in eWater have provided a first glimpse of the hydrogeological maps available in the twelve project-partner countries, about half of the countries in the European Union. This information has been structured in a Database, from which any user may easily find important information describing the main initiatives done in this respect by the main organisations responsible for hydrogeological mapping in these countries.

This Database of hydrogeological maps provides information on their main characteristics regarding format (paper, digital: raster or vector), scale, coverage, legend (hydrogeological objects represented), projection system, metadata, and availability. It contains some 300 hydrogeological maps available at the Geological Surveys of Austria, Denmark, Emilia Romagna (Italy), France, Hungary, the Netherlands, the Czech Republic, Lithuania, Slovakia, Slovenia, Spain, and Sweden. All these Geological Surveys have entered the data into the Database themselves and highlighted the main characteristics of their hydrogeological maps available in paper and digital format.

This Database constitutes a powerful tool for querying and exploiting the information that it contains. It not only allows the information already compiled in the eWater project to be updated, but also for other EU countries to participate in this initiative in the future.

A summary of the information gathered produces the following numbers:

- 279 Maps in the catalogue (in paper and digital format)
- 91 Digital maps
- 186 layers in digital maps
- 68 records of legends (17 point legends, 17 line legends and 34 polygon legends).

This inventory and Database are a vital step towards interoperability of digital maps. It provides an answer to the question about what the maps are that we have, and what their defining characteristics are, an answer that will allow us to pose the next question about how to enhance their interoperability in the right framework. Before we had the results of this survey, we could only speculate about the situation in Europe for hydrogeological mapping and what recommendations could be proposed from eWater on interoperability.

The inventoried hydrogeological maps have been prepared in these 12 European Geological Surveys (11 national and 1 regional) with a wide range of purposes and addressing numerous users. A major shift occurred in the last decade of hydrogeological cartography: a change from paper maps to vector maps (layers) and, more recently, to information systems (GIS based) and models (in 3D) with associated hydrogeological databases (water points, water levels, water quality). Notwithstanding these advances, further efforts are still needed in most European Geological Surveys to convert the traditional cartographic products into digital information.

Harmonisation and interoperability issues have been identified for the participating countries and the major cross-border areas in eWater.

Interoperability in terms of data exchange can be understood as a problem to be solved fundamentally by computer science (a layer is considered interoperable when it is compliant with the OGC standard to design a Web Map Server, that has three basic operations: GetCapabilities, GetMap and GetFeatureInfo). A solution to this problem, as well as analysis of the associated technical and managerial implications for the participating Geological Surveys will be considered during the design of the prototype for the eWater system.

A more complex and difficult question is semantic interoperability of maps across borders. In this context for digital maps at both sides of the borders we should consider layer contents and attributes, scales or levels of detail in the representations. Studying the structured Database will make it possible to check, at a second stage of the analysis, if it will be possible to give some recommendations about semantic interoperability of hydrogeological maps.

Major international efforts (WHYMAP - guide and standard legend for hydrogeological maps) have been shown to be valuable when small-scale views (European) are pursued. This Standard Legend has also been successfully applied at large scales in many parts of the world. However, harmonisation requirements stemming from some larger scale cross-border projects with specific objectives and aimed at specific users need to be further refined. In most instances specific bilateral or multilateral projects need to be designed for this purpose. It must be stressed that such harmonisation initiatives are playing an important role as a mediating tool between hydrogeology specialists and the target audience, as several recent UNESCO programmes reveal. eWater is aimed at contributing in this direction in the European Union.

In recent years, the Geological Surveys of European Union member countries have had to take into account and adapt to INSPIRE (Infrastructure for Spatial Information in the Community). This initiative aims to provide implementing measures in order to facilitate the use of spatial data from different sources across the Member States. These measures should be designed to make the spatial data sets interoperable. All Member States must meet the “interoperability” conditions required by INSPIRE in the medium term. The trend envisaged for the near future is to advance towards cross-border information systems.

The eWater project has already prompted the participating Geological Surveys to move in this direction. It is providing potential users of the spatial hydrogeological data with a significant amount of structured information and knowledge on how these data have been represented in hydrogeological maps in the past and how they are currently represented and managed.

# 9 Bibliography

Struckmeier, W. F. and Margat, J. (Ed.) (1995) Hydrogeological Maps. A guide and a standard legend. Int. Assoc. Hydrogeol., International Contributions to Hydrogeology: Vol. 17. Hannover.

Vogt, J. (2002) Implementing the GIS elements of the Water Framework Directive. EUR 20544 EN. European Commission, Join Research Center. http://eurolandscape.jrc.it

IGME (2000) Estudio e Investigación en las Ciencias de la Tierra. 150 aniversario del IGME (1849-1999).

IGME (2000) Boletín Geológico y Minero. Volumen Especial: Cartografía Volumen 111

Open Geospatial Consortium (2004) OpenGIS® Web Map Service (WMS) Implementation Specification V. 1.3.0, 85 pp. http://www.opengeospatial.org/standards/wms

Proposal for a Directive of the European Parliament and of the Council establishing an infrastructure for spatial information in the Community (INSPIRE). (2004). http://www.ec-gis.org/inspire

Arnold, G. E. & Buzas, Z. ( 2005) Economic Commission for Europe Inventory of Transboundary Ground Water in Europe. In: Groundwater Vol 43/5 pp. 669-678

Aureli, A. & Ganoulis, J. (2005) The UNESCO Project on Internationally Shared Aquifer Resources Management (UNESCO/ISARM) Overview and Recent Developments. http://www.inweb.gr/workshops/UNESCO_ISARM/UNESCO_ISARM.pdf
UNECE (1999) Inventory of Transboundary Groundwaters. UNECE Task Force on Monitoring and Assessment- Lelystad.

WISE Newsletter Issue no4 – December 2006(2006) ISSN-1725-390X. http://ec.europa.eu/environment/water/water-framework/pdf/wfd_newsletter_4.pdf

Infrastructure for Spatial Information in Europe: INSPIRE. Internet: http://inspire.jrc.it/home.html

ISO Technical Committee on Geographic Information / Geomatics 211, 2003. International Standard: Geographic Information – Metadata. ISO 19115.

DT Metadata – Draft Implementing Rules for Metadata.(2007) 104 pp. INSPIRE http://inspire.jrc.it/reports/ImplementingRules/draftINSPIREMetadataIRv2_20070202.pdf

Directive of the European Parliament and of the Council. Establishing an infrastructure for spatial information in the Community (INSPIRE) (2004). 2004/0175 (COD).
{SEC (2004)980} http://inspire.jrc.it/home.html

# Annexes

Annex I: Database inventory of hydrogeological maps and models (eWater Questionnaire WP6. mdb – on CD enclosed)

Annex II: Types of information contained in the digital layers inventoried in eWater - on CD enclosed