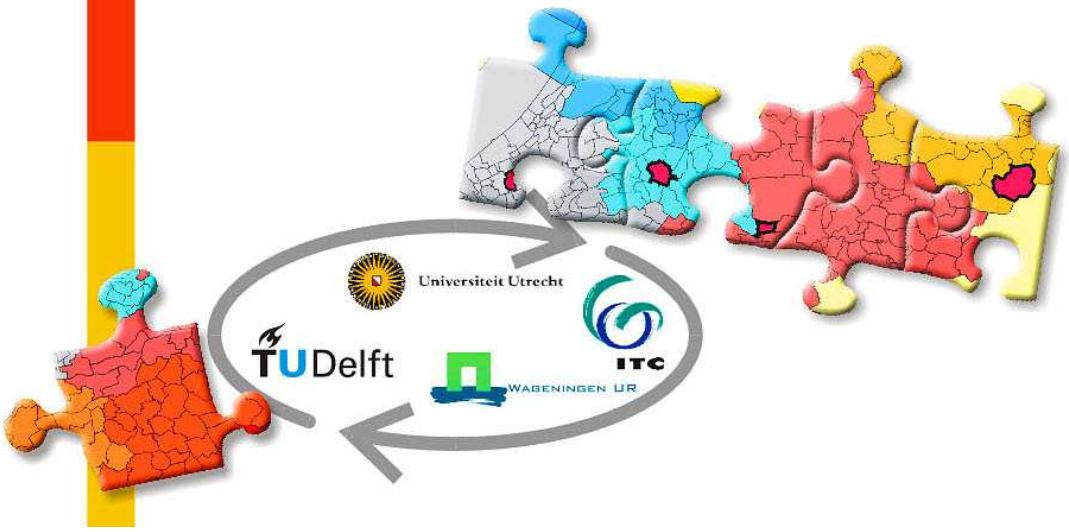
GIMA

Geographical Information Management and Applications

INSPIRE-compliant web services

The case of Narew National Park, Poland

Paweł Sudra



Master of Science Thesis

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Abstract

The main objective of this research project was to assess the quality and feasibility of the guidelines for INSPIRE Network Services. The completeness, clarity, consistency and ease-of implementation of the guidelines were considered. Part of this assessment is also the question: how can INSPIRE compliance be tested and measured? The topic was tackled both from a theoretical and a practical point of view.

The theoretical part of the project included a detailed investigation and assessment of the INSPIRE requirements and recommendations as regards: technical architecture of the services, functionality of the particular network services, quality of services, rights management issues, elements of spatial data and metadata models. This part of the project has been finalized with the synthesis of the guidelines derived from the INSPIRE documentation.

The review of the INSPIRE documents showed that these guidelines are specific and clear enough in most points, however not yet complete. The status of work as regards the technical guidelines for particular INSPIRE Network Services is different. The topic which calls for particular attention is the adaptation of the INSPIRE services to SOAP bindings. Another item that is needed and that is currently missing in the guidelines is the provision of more strict rules for compliance testing (Abstract Test Suites (ATS) for INSPIRE services and data) and quality of service (QoS) testing.

The practical part of the project was the implementation of some prototype View and Download services. For the implementation of the prototype services existing software was chosen, namely GeoServer, one of the spatial data server products implementing the OGC standards. The specific scenario chosen for the case study are web services for a national park. The spatial data for the prototype was acquired from the resources of the Narew National Park (Poland).

The prototype was realized in order to validate and evaluate whether the Implementing Rules and other guidelines contained all necessary information to set up INSPIRE compliant web services, with special attention to the question how this 'compliance' can be measured using both manual and automated testing methods. First, the prototype has been evaluated for the compliance with INSPIRE guidelines by manual inspection of the prototype services. Secondly, the compliance test methodology proposed by OGC has been used to perform automated tests on the GeoServer instance.

The evaluation of the prototype showed that the web services provided with GeoServer fulfill the majority of requirements for View/Download Services through the WMS/WFS functionalities (mandatory operation parameters, offered output formats etc.) Some elements need to be configured within GeoServer (e.g. the required spatial reference system, layer/feature type names that conform to the INSPIRE data specifications). Still, some INSPIRE-specific extensions to the functionality provided by GeoServer are needed for both services (support of the SOAP/POST methods for the service operations, solutions for multilingual aspects of services and rights management). Another requirement for the INSPIRE-conformant web services is that the spatial data and metadata are provided compliant with the data models required by INSPIRE.

The study on compliance testing methodologies is followed by the recommendation that the standards and testing programs from ISO and OGC can be of particular relevance for the development of Abstract Test Suites for INSPIRE services. The reference framework for INSPIRE compliance testing can be partially based on the OGC Compliance & Interoperability Testing & Evaluation Initiative (CITE) testing program. The OGC tests are especially suitable as reference since the core technical specifications for implementation of the particular INSPIRE Network Services are the OGC web services specifications.

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List of abbreviations and terms

Abbreviations

ATS – Abstract Test Suite
CITE – Compliance & Interoperability Testing & Evaluation Initiative
COM – Component Object Model
CORBA – Common Object Request Broker Architecture
CRS – Coordinate Reference System
CS-W – Catalogue Service for the Web
DCOM – Distributed Component Object Model
DT – Drafting Team *(of INSPIRE)*
ETS – Executable Test Suite
EU – European Union
FGDC – Federal Geographic Data Committee *(in the United States)*
FE – Filter Encoding
FTP – File Transfer Protocol
GI – Geographic(al) Information
GIS – Geographic(al) Information System(s)
GII – Geographic(al) Information Infrastructure
GML – Geography Markup Language
GSDI – Global Spatial Data Infrastructure
HTTP – Hypertext Transfer Protocol
HTTPS – Hypertext Transfer Protocol Secure
ICT – Information and Communication Technologies
IDL – Interface Definition Language
IOC TF – Initial Operating Capability Task Force *(of INSPIRE)*
IR – Implementing Rule *(INSPIRE document)*
INSPIRE – INfrastructure for SPatial InfoRmation in Europe
ISO – International Organization for Standardization
ISO TC/211 – ISO Technical Committee - Geographic Information/Geomatics
LAN – Local Area Network
LMO – Legally Mandated Organization *(of INSPIRE)*
MIME – Multipurpose Internet Mail Extensions
MS – Member State *(of European Union)*
MTOM – Message Transmission Optimization Mechanism
NS – Network Service
NSDI – National Spatial Data Infrastructure
OASIS – Organization for the Advancement of Structured Information Standards
OGC – Open Geospatial Consortium
OMG – Object Management Group
OWS – OGC Web Service Common
QoS – Quality of Service
REST – Representational State Transfer
RM – Rights Management
RMI – Remote Method Invocation
RPC – Remote Procedure Call
SDI – Spatial Data Infrastructure
SDIC – Spatial Data Interest Community *(of INSPIRE)*
SLD – Styled Layer Descriptor
SMTP – Simple Mail Transfer Protocol
SOA – Service Oriented Architecture
SOAP – Simple Object Access Protocol
SQL – Structured Query Language

TG – Technical Guidance *(INSPIRE document)*
UDDI – Universal Description Discovery and Integration
UML – Unified Modeling Language
URL – Uniform Resource Locator
URN – Uniform Resource Name
W3C – World Wide Web Consortium
WCS – Web Coverage Service
WCTS – Web Coordinate Transformation Service
WFS – Web Feature Service
WMS – Web Map Service
WPS – Web Processing Service
WS-BPEL – Business Process Execution Language for Web Services
WS-I – Web Services Interoperability Organization
WSA – Web Services Architecture
WSDL – Web Service Description Language
XML – Extensible Markup Language
XOP – XML-binary Optimized Packaging

Terms and definitions

Some terms used in this thesis may be ambiguous. Several terms are also used as synonyms in the context of this thesis.

- compliance testing = conformance testing
- (the) Commission = European Commission
- (the) Community = European Union
- discovery service = catalogue service = metadata catalogue
- EU-level = Community level → *level of European Union*
- geographic data = geodata = geospatial data = spatial data = geographic information = geo-information = spatial information *('spatial'/'geographic' and 'data'/'information' have slightly different meanings; for more details, see: chapter 2.4)*
- geoportal = WebGIS → *an access point to GIServices available on the Web (see: chapter 2.6); <the term 'WebGIS' is also used in a different context as a synonym of Internet GIS!>*
- GIServices = GI web services = GI network services = geo-information services = geospatial services = geographic services
- invoke service = invoking service
- INSPIRE-compliant = INSPIRE-conformant
- INSPIRE Directive = (the) Directive = Directive 2007/02/EC
- Internet GIS = WebGIS = GeoWeb → *Geographic Information systems (or services) available via the Internet or, specifically, via the Web (see: chapter 2.1) <the term 'WebGIS' is also used in a different context as a synonym of a geoportal!>*
- Member States → *Member States of the European Union*
- metadata → *'data about data or services'; specifically: data describing geographic data or geographic services*
- open source software → *the software with open access to its source code, as regards its modification and distribution (usually also free software), according to the software licence*
- (the) Park = Narew National Park → *case study area for this thesis*
- spatial data server = map server = web mapping application → *e.g. GeoServer, MapServer*
- spatial database = GIS database = geographic database
- the author = the researcher → *the author of this thesis*
- view service = map view service = mapping service
- web mapping → *the process of designing, implementing, generating and delivering maps on the Web*
- web services = network services
- World Wide Web = the Web

1. Introduction

The purpose of this chapter is to introduce the research project. The particular sections deal with: the main research problem and its background (section 1.1), specific research objectives and deliverables (section 1.2), scope of the research, including thesis plan and methodology (section 1.3). In the last section it is also mentioned which research problems related to the main research topics are out of scope in this research.

1.1 Problem statement

Internet GIS in its short history has been undergoing rapid changes. At the beginning it was confined to serving static maps on the web, with no interactivity at the user's side. The other option for the data providers was to put GIS datasets for download on their FTP servers. Currently Internet GIS is realized mostly through distributed geographic information services. This change followed the general development path of Geographic Information Systems: from traditional, centralized GISystems, through GISystems based on a client/server architecture to distributed GIServices. Web services based on distributed computing architecture permit dynamic combinations and linkages of geodata objects and GIS programs via networking and without the constraints of traditional client/server relationships (Peng Z., Tsou M., 2003). In this way, the Internet opens superb possibilities for the users of geographic information to explore, analyze and process the data they are interested in. Furthermore, increasingly new tools are made available which facilitate the creation of web mapping sites and services. Many of them are free and open source solutions with a full functionality comparable to the proprietary ones. Many open source mapping and GIS projects use the latest open standards for interoperability and tend to implement them much faster than the commercial products (Mitchell T., 2005). Opportunities for creation of GIServices are nowadays as broad as never before.

Web services and geoportals can become fundamental elements of SDI's (Spatial Data Infrastructures) / GII's (Geographic Information Infrastructures) if they are compliant with specified common standards. INSPIRE (INfrastructure for SPatial InfoRmation in Europe) is an European GII following a Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community. INSPIRE requirements and recommendations should be adhered to when the spatial data is served from the public registers. In the European countries the process of translation and application of the INSPIRE implementation rules is currently on its way. The first step in this process is the accommodation of the law related to geodesy, cartography and geoinformation in the Member States of the European Union to the requirements of the Directive (Gaździcki J., 2007). This should be seen with reference to INSPIRE as a distributed infrastructure – one which is to be based on the infrastructures of spatial information established and operated by the Member States.

The INSPIRE specifications have impact on different elements of geographic information infrastructures, including data, network services and metadata. The Directive does not oblige particular countries to collect new spatial data. However it does call for interoperability of spatial data and services, and where practicable, for harmonization of datasets held by or on behalf of public authorities. It also sets the standards for discovery services and metadata ("data about data and services"). The foundation of many of these specifications is laid down

on the OGC (Open Geospatial Consortium) consensus standards and ISO (International Organization for Standardization) standards for geographic information.

National parks are institutions which function within the framework of public sector. They are the most important nodes in the national systems of protected areas. For the purpose of proper management of protected areas on the national level it is desirable that their GIS databases follow a common data model. Spatial data model for the GIS of protected areas should be a flexible, open-structure solution enabling future extensions. Spatial databases (data warehouses) created according to such model should work as SDI nodes on different levels of spatial data infrastructures. (Litwin L., Guzik M., 2004). In this context the INSPIRE Data Specifications are providing some relevant setting norms. Although on the national level the internal models for databases of national parks may be different, during data exchange on the European level, a common model conformant with INSPIRE requirements shall be used. Model mapping and data transformation procedures are needed to convert the source data to the INSPIRE-conformant model.

An element complementary to a GIS database of a national park can be an interactive geoportal which may serve different groups of users – national park managers, civil servants, scientists, tourists. Such portal may be very useful as a reference for planning in environmental management, spatial development, scientific research. It may be also the source of information for the users who would like to plan their trip, by looking for hiking and walking routes, bicycle tracks, kayak trails, habitats of particular species, monuments of architecture or backpacker hostels.

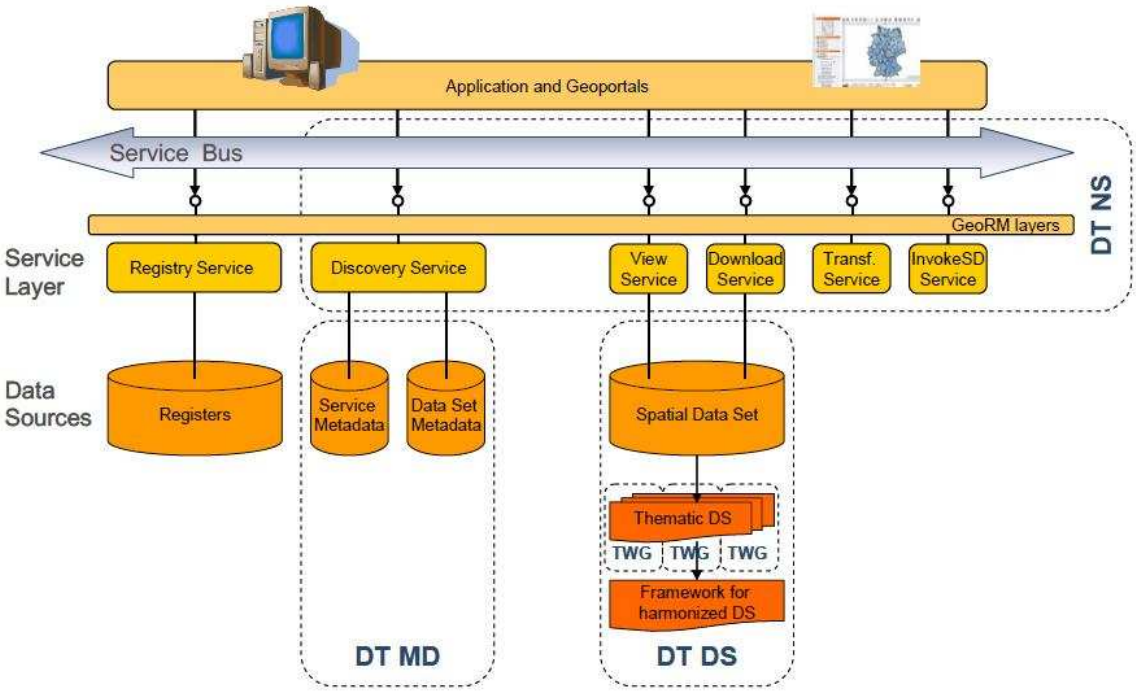


Fig.1 INSPIRE Technical Architecture overview
(INSPIRE Technical Architecture – Overview, 2007)

INSPIRE requires that the data and services in the member states of European Union are made available through INSPIRE-compliant network services. According to the *Article 11* of the INSPIRE Directive:
'1. Member States shall establish and operate a network of the following services for the spatial data sets and services for which metadata have been created in accordance with this Directive:
(a) discovery services […]
(b) view services […]
(c) download services […]
(d) transformation services […]
(e) services allowing spatial data services to be invoked.'

Fig.1 presents the technical architecture of the INSPIRE infrastructure including particular types of network services and their relations with other components of the infrastructure.

The EU-level access to the INSPIRE services may be provided via the INSPIRE geoportal, that will allow to access seamlessly integrated data from different Member States. However, the Member States may also offer further access points with INSPIRE services available to different user groups. As stated in the *Article 15* of the INSPIRE Directive:
'1. The Commission shall establish and operate an Inspire geoportal at Community level.
2. Member States shall provide access to the services referred to in Article 11(1) through the Inspire geo-portal referred to in paragraph 1. Member States may also provide access to those services through their own access points.'

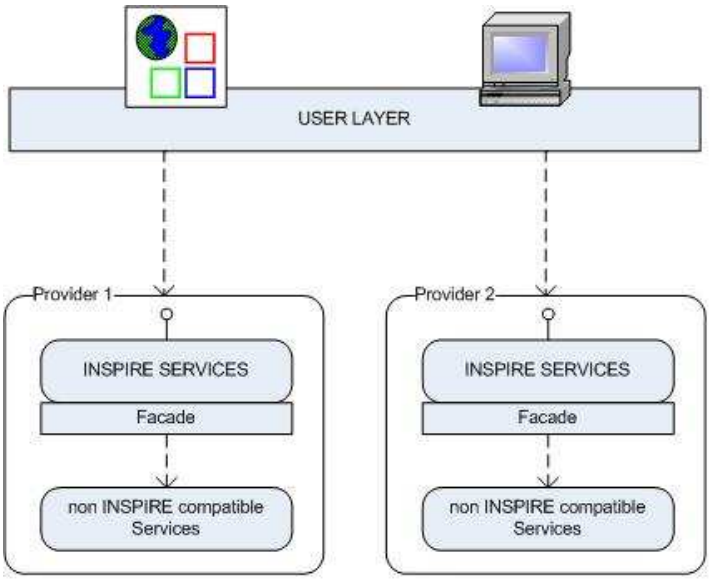


Fig.2 INSPIRE services as a mediator between non-INSPIRE-compliant services and EU-level users
(Florczyk A. *et. al.*, 2009)

The INSPIRE Network Services can be seen as a mediator between the services provided locally by the Member States or offered by third parties (and not compliant with INSPIRE) and their EU-level usage for example via the INSPIRE geoportal. Technically, as recommended by the INSPIRE Network Services Architecture (v.3.0, 2008), data and services can be made available through INSPIRE-compliant network services in two ways. Firstly, an

INSPIRE-compliant service can be chained to an existing service to provide data after transformation through network services on the EU-level. The service chaining of INSPIRE-compliant and non INSPIRE compatible services is done with the use of so-called 'facade' components or layers (Fig.2) (see also: Florczyk A. *et. al.*, 2009).

Second possibility is to establish a new INSPIRE-compliant service linked to the existing data source – assumed the data can be provided INSPIRE-compliant. The aim of this project is to research is it possible to realize this second objective in practice. The feasibility of implementation of INSPIRE-compliant services will be evaluated based on the guidelines provided in the INSPIRE documentation. The quality of the guidelines and standards given has been subject to thorough assessment during the research. The case study problem, providing an additional context for the research, is of establishing web services for a national park.

1.2 Research objectives

The major objective posed in this research is to answer the following question:
"What is the quality of the guidelines for implementation of INSPIRE-compliant web services?"

By 'web services' is meant a set of services accessible via a geoportal located on the Web and designed specifically for a concrete purpose (in the context of this research – for a national park) and for specific user groups. These services should be chained together through a common architecture and should provide such capabilities to the users as: metadata discovery, data download, map data viewing/analysis, data transformation, invoking services.

By 'INSPIRE compliant' is meant – conformant to the INSPIRE requirements and recommendations especially those related to the network services architecture and particular types of network services, as well as relevant elements of data and metadata specifications.

To effectively conduct a research on this topic and provide an example of applications of the INSPIRE guidelines, a 'case study' area has been chosen. The case study for this research is an implementation of a small prototype of web services for the Narew National Park, Poland (http://www.npn.pl). The area has been chosen due to the personal interests of the researcher. The researcher has possessed an excessive knowledge on the study area during his masters research at the Faculty of Geography and Regional Studies, Warsaw University. The GIS data from the Management Plan of the Narew National Park has been made available to the researcher.

The Narew National Park, located in the Northeast Poland, was established to protect the swampy Narew valley and its unique anastomosing river system, rich in flora and fauna. This is one of the largest and best preserved areas of wetlands in Poland. The Narew National Park has a GIS-based thematic database since 2002. However it has no existing geoportal for dissemination of spatial information on the Web.

In the context of this research, the case study area (Narew National Park) and the problem in question is real. Also the results of this research may be used with benefit to the Park. However the major role of the case study is to support the evaluation of the central research question – the problem of quality of the guidelines for implementation of INSPIRE-compliant web services, and to validate the proposed guidelines with a specific technical solution. The

results of this research shall be generic – applicable not only to Narew National Park or other national parks but to different kinds of GI web services. Moreover, the assessment of the quality of the INSPIRE guidelines may provide added value to the INSPIRE documentation (suggestions for future improvements of the documents).

The central research question of this project can be divided into the following sub questions (problems):

a. What is meant by INSPIRE-compliance (or INSPIRE-conformance)? How can this term be understood in the context of web services, data, metadata? Which requirements/recommendations laid down in the INSPIRE documents should be fulfilled in order for the web services to be 'INSPIRE-compliant'? In particular:
    - What are the guidelines for the conformance of the web services to the INSPIRE Network Architecture and recommended SOAP framework for Network Services?
    - What are the guidelines for the compliance with Implementing Rules for specific types of services (Download, View, Discovery, Transformation, and Invoke Services – with a particular emphasis in this thesis put on the first two types)?
    - What requirements/recommendations does INSPIRE have for data and metadata which are of particular relevance for Network Services?
b. What is the quality of these guidelines? Are the requirements/recommendations complete? Are they specific enough, clear and consistent?
c. How to test conformance of the services to INSPIRE in practice? Are there guidelines for conformance testing? Are they clear and exhaustive? How could these guidelines be improved? Are the guidelines suitable for automation of the test procedures?
d. Is it feasible to establish INSPIRE-compliant web services (taking into account the current state of play of INSPIRE specifications and the existing technological solutions)?

Further chapters of this thesis describe the steps undertaken to tackle the research objectives. Chapter 2 introduces the background of the project and chapter 3 – the specific case study area. In chapter 4, the elements of INSPIRE-compliant web services are identified and synthesized. To support the evaluation of the central research question and provide a field for conformance testing, a small prototype of web services has been realized. The detailed description of the prototype development and evaluation can be found in chapter 5. The theoretical and practical study on conformance testing can be found in chapter 6. Summary and evaluation of the research is included in chapter 7. More information about particular chapters is provided in section 1.3 (Methodology).

The main concern of the research is the technical framework for interoperability of the web services (including specific protocols/interfaces to be used), as well as the functionality of web services. The issues of quality of services, their security and access rules will be discussed briefly. The data and metadata models will be considered as relevant elements of the thematic content of the information provided through the web services. Nevertheless all should be seen in the light of the proposed technical and functional framework.

The research was aimed to bring its specific deliverables, namely:

1. a synthesis of requirements/recommendations for the implementation of INSPIRE-compliant web services specified in the INSPIRE documentation

2. a prototype of INSPIRE-compliant web services, implemented with a chosen software solution for network services, based on a small subset of GIS data from Narew National Park (chosen datasets for the Administrative Units, Hydrography and Protected Sites data themes)
3. evaluation of existing INSPIRE guidelines (requirements/recommendations, conformance tests), evaluation of feasibility of implementation of INSPIRE-compliant network services, suggestions for improvement of the conformance tests & other guidelines.

1.3 Thesis plan and methodology

1.3.1 Scope of the research

The thesis plan reflects the methodology undertaken in the framework of the research. Particular chapters of the thesis are a result of specific phases of the research project.

Chapter 1: "Introduction" – this one, includes introduction to the research problem, objectives, thesis plan and methodology.

Chapter 2: "Problem background" is a result of the *Analysis (general)* phase of the project.
In this part of the research, introducing the relevant concepts and definitions, the following topics have been touched upon:

- Internet GIS and web mapping principles
- Web Services Architecture (SOAP and its alternatives) – a framework for all kinds web services
- Standards for GI web services – OGC and ISO
- Geographic Information Infrastructures / Spatial Data Infrastructures
- INSPIRE directive – basic outline and provisions
- A brief review of existing geoportals/web services for national parks (chosen examples) with a special emphasis put on the standards they use, including the projects that aim to implement INSPIRE-compliant solutions.

This part of the research has been based on the study of relevant scientific literature, technical documentation and web resources (including existing web services).

Chapter 3: "Case study area" is a result of the *Analysis (case study area)* phase of the project.

This short analytical phase was a study related to the case study area. The case study is relevant mostly for the prototype development phase (see: chapter 5).
The following elements have been included in this part:

- Presentation of the study area: Narew National Park
- Review of (spatial) data available from the Management Plan of the Narew National Park (including data models and standards used)
- Discussion on the needs for a geoportal for the Narew National Park (taking into account the needs of specific user groups e.g. national park managers, civil servants, scientists, tourists)

The information for this chapter was gained by the review of the literature, web resources and study of the GIS database of the Narew National Park.

Chapter 4: "Conceptual study on the INSPIRE services" is a result of the *Conceptual study (synthesis)* phase of the research.

The aim of this part of the research was the identification and synthesis of the guidelines (requirements/recommendations) for the implementation of INSPIRE-compliant web services. The guidelines identified are related in particular to the technical architecture and functionality of the services, but also to the aspects of quality of services, rights management, data models and metadata.

The research activities were based on a thorough study of INSPIRE legislation, implementing rules, technical guidelines and other relevant documents. The INSPIRE documentation is being prepared by experts from INSPIRE Drafting Teams in five major blocks: Network Services, Metadata, Data Specifications, Data Sharing, Monitoring and Reporting. The first block mentioned is of crucial relevance for this research, therefore the guidelines for INSPIRE Network Services were subject to the most thorough study. The second and third blocks were considered to the extent that is relevant for implementation of INSPIRE-compliant web services. For instance, metadata standards are relevant for implementation of a Discovery Service and spatial data models are of importance for implementation of a View Service or Transformation Service.

In this research a special emphasis has been put on the View Service and Download Service. Discovery Service was also considered. The guidelines for the Transformation and Invoke Services have been discussed only briefly. The first reason for these choices is pragmatic. As the INSPIRE guidelines documents are the best developed for the first three types of services (see: chapter 4), a more comprehensive evaluation of the guidelines can be made. The availability of extended guidelines for the View, Download and Discovery Services was also helpful in the process of prototype design and implementation.

Although the Discovery Service was also considered, finally the View Service and Download Service have been chosen for the extended study and prototype development. The reason was because both services can be implemented with the same software application – in the case of this research: GeoServer (a compliant implementation of OGC WFS and WMS services).

Finally, the reason for the choice made to focus on these two groups of services is that the View Service and the Download Service seem to be particularly useful for the users of a geoportal of a national park. View Service (map service) is the most popular and widely used type of geographic service on the Web, since it provides a map view with browsing/analytical capabilities. Its functionality is probably the most interesting for the users of web services for a national park (especially tourists). More advanced users (scientists, spatial planners etc.) may, however, wish to download GIS data from the data repository of the national park for analysis on their own machines with the use of Download Service. However, Discovery Service (catalogue service) is also an important service since it deals with metadata. Through metadata the users can identify the content of spatial data sets, assess their quality, fitness for use and terms of use.

The conceptual study is finalized with the identification of the crucial guidelines for the INSPIRE-compliant View and Download Services. These guidelines are providing a grounds for the prototype implementation.

Chapter 5: "Prototype of INSPIRE-compliant web services (View and Download Service)" is a result of the *Prototype implementation* phase of the research.

To validate and evaluate the feasibility of implementation of INSPIRE-compliant web services in accordance with the guidelines identified in the conceptual part (chapter 4), a prototype of web services has been realized. The prototype can be seen as a support in answering the major research questions. The final evaluation of the research (chapter 7) is made based both on the theoretical (chapter 4) and practical (chapters 5, 6) parts of the study.

The prototype was aimed to be an implementation of sample 'INSPIRE-compliant' web services based on real GIS data and specific scenario. The spatial data was acquired from the resources of the Narew National Park. More information on the GIS database of the Narew National Park can be found in section 3.2.

The datasets used in the prototype development correspond to the chosen data themes from the Annex 1 of the INSPIRE Directive. Transforming the spatial data to the INSPIRE model is out of scope of this research. However, it has been discussed how could the spatial datasets for the Narew National Park be mapped and transformed so that the information provided through the web services was compliant to the INSPIRE data specifications (see: chapter 5, sub-section 5.2.1).

The implementation of the prototype services has not been done 'from the scratch'. That means that the existing software solution have been chosen which is a compliant implementation of OGC web services (Web Map Service and Web Feature Service). The software solution chosen is GeoServer 1.7 (http://geoserver.org/display/GEOS/GeoServer+1.7.0). The process included the following steps: data selection, data conversion/transformation, metadata creation, installation of GeoServer on a web server, configuration of GeoServer and the web services, testing of services via the Internet and evaluation.

The prototype realized with the use of GeoServer has been evaluated for the compliance with INSPIRE guidelines. The evaluation was done by means of a manual inspection (the automated testing methods were inspected as well, however this topic is described in chapter 6). The findings from chapter 4 have been used as a guidance. The evaluation of the prototype embraces major elements of the INSPIRE services – technical protocols, functionality, reference systems, output formats, data and metadata. The evaluation of the prototype, included in chapter 5 comprises some elements of the preliminary evaluation of the research.

Due to courtesy of Delft University of Technology, the internal web server of TU Delft has been be used for setting up the prototype web services. The prototype is available for trial/testing with client applications that are able to handle WMS and WFS requests.

Chapter 6: "Compliance testing of INSPIRE Network Services (View and Download Service)" is a result of the *Compliance testing* phase of the project.

The aim of this part of the research was to conduct a study on methodologies for compliance testing of INSPIRE Network Services, in order to provide feedback for the final research evaluation. The identification of compliance testing guidelines is very helpful in the development of INSPIRE-compliant web services, since such guidelines provide clear directions on what is meant by conformance/compliance in particular context. The guidelines may be in the form of test suits providing a step-by-step guidance for testing of web services

compliances. The issue under consideration was also how to perform compliance testing in a possibly automated way.

The *Compliance testing* phase and, consequently, chapter 6, can be divided into theoretical and practical parts. It starts with an introduction to the topic of testing of software applications and compliance testing. The discussion follows to the understanding of 'compliance' of web services in the context of INSPIRE. Next, a brief review of relevant testing methodologies and standards is presented in the context of INSPIRE Network Services. For the practical part, one testing method (OGC test suite for WMS) has been chosen. The compliance testing is discussed with reference to the tests performed on GeoServer 1.7, however with the use of specific test data (not the actual data from the Park).

The summary of this chapter includes a general evaluation of current test strategies and tools. As a part of the evaluation, it is discussed which elements of the prototype could be tested with the use of OGC compliance tests for web services. Furthermore, recommendations are provided for the methodology of compliance testing of INSPIRE Network Services (in particular: View and Download Services).

Chapter 7: "Summary" is a result of the *Synthesis and evaluation* phase of the project.

The research is finalized with conclusions and recommendations. Conclusions are based on the study of the outcome of the whole research, including conceptual study, prototype implementation and compliance testing phases. The recommendations shall be useful for the implementation of real web services for the Narew National Park. Nevertheless the aim is to provide generic recommendations based on the outcome of the research (applicable to different web services, and not only of national parks). This summarizes the research and gives answers to the major research question. The conclusions provide a synthetic assessment of the quality of the guidelines for implementation of INSPIRE-compliant web services. The question is also answered is it feasible to establish INSPIRE-compliant web services. Some recommendations for improvements of the INSPIRE documents have been also provided based on the outcome of the research. These are, in particular, suggestions for the development of INSPIRE guidelines for conformance testing.

1.3.2 Out of scope

Technical implementation of a full set of INSPIRE-compliant web services for Narew National Park is out of scope. The research is focused on the problem of INSPIRE-compliant web services which is scientifically important and also practical. However, the research is not focused on the development of the production version of the actual geoportal. Nevertheless, the conceptual study has been validated and evaluated with a prototype based on a small subset of GIS data from the Park and implemented through chosen software application (GeoServer).

A proposal of a complete cartographic form of the maps for the mapping service (INSPIRE View Service) is not included in the research. The same remark applies to the proposal of the graphical layout/web design of the geoportal website. The research is focused on the technical framework for interoperability of web services, functionality of the services and relevant elements of data/metadata models. Cartographic guidelines were taken into account as long as they conform to the INSPIRE requirements/recommendations. There is no explicit requirement in the Directive about portrayal. However it is considered as a part of the

interoperability necessity that the datasets belonging to the same theme shall be rendered following the same portrayal rules, in a default rendering style, when the data is portrayed using a INSPIRE View Service (Draft Implementing Rules on INSPIRE View Services, v.3.0, 2008). Rules for layers and styles to be used for portrayal of the spatial object types are being defined in Data Specifications for particular INSPIRE themes.

Spatial data and metadata are the core resources for INSPIRE Network Services. The spatial data and corresponding metadata shall be compliant with the INSPIRE models. However, a detailed study on the compliance of data and metadata is out of scope of this research. The transformation of existing datasets for the prototype to the INSPIRE model is also beyond the scope of this research. This topic has been discussed accordingly however it is not within the major scope of the research.

A proposal of specific vendor-related software solutions for implementation of INSPIRE-compliant web services is out of scope of this research. It is not an intention of the researcher to promote solutions of a specific vendor. The prototype has been implemented using GeoServer 1.7 which is one of leading open-source web mapping applications (spatial data servers).

2. Problem background

Relevant background of the research problem will be presented in this chapter. The discussion starts with principles of Internet GIS (section 2.1). The technical framework and standards for general purpose web services (section 2.2) and GI web services (section 2.3) are introduced. After describing the context of Geographic Information Infrastructures (section 2.4), the fundamentals of INSPIRE as an European GII are described. Finally, in section 2.5 the context of web services for protected areas is presented.

2.1 Internet GIS and web mapping

The discussion on GI (Geographic Information) web services has to start with an introduction to the concept of Internet GIS and its applications. The new technologies that have emerged when the Internet became widely used in the early 1990s, pushed forward the progress of Geographic Information Systems towards more interoperable, efficient and flexible solutions. The main advantage were new opportunities for data and information sharing realized through catalogue services, geodata clearinghouses, search engines and geoportals. The concept of Internet GIS as a distributed GIS is that the users can access the GIS analysis tools and data from anywhere provided that they have access to the Internet. On the other hand, the system architecture of Internet GIS may be based on distributed components available in multi-server environment (see a very early example of Internet GIS: Geoshop (1997)).

The development of GIS technology has evolved from mainframe GIS to desktop GIS to distributed GIS, which includes Internet GIS and wireless mobile GIS (Fig.3). Distributed GIS is also referred to as distributed GIServices while mainframe GIS and desktop GIS are called GISystems (Peng Z., Tsou M., 2003).

Fig.3 A development path of distributed GIS
(redrawn; original figure: Peng Z., Tsou M., 2003)

Mainframe GIS refers to an early model of GIS computing where all data and analytical modules were located on a mainframe server with terminal access. Desktop GIS is a model relying on GIS programs located on desktop computers. In this model, all GIS data,

functionality and user interface is located on one desktop computer. It is also possible that the users share data within an organizational LAN however a GIS software application has to be installed on each desktop computer. This is where the border lies between traditional GISystems and Client/Server GISystems. The latter are based on desktop GIS applications as well, however client-side components are separated from server-side components (e.g. databases). The clients are able to access servers remotely by using distributed computing techniques or database connectivity techniques (Peng Z., Tsou M., 2003).

Distributed GIServices are a step further since they are set up on a more advanced networking architecture which works very similar to P2P (peer-to-peer) computing. There is no clear distinction between servers and clients. Every 'GIS node' of the network holds GIS applications and geographic data and may become a client (service requester) or a server (service provider) based on the task being performed (Fig. 4) (Peng Z., Tsou M., 2003). In addition the focus in computing is on the 'services' thus tools available on-line which serve for data management, browsing, upload, download, analysis, processing, interpretation and visualization.

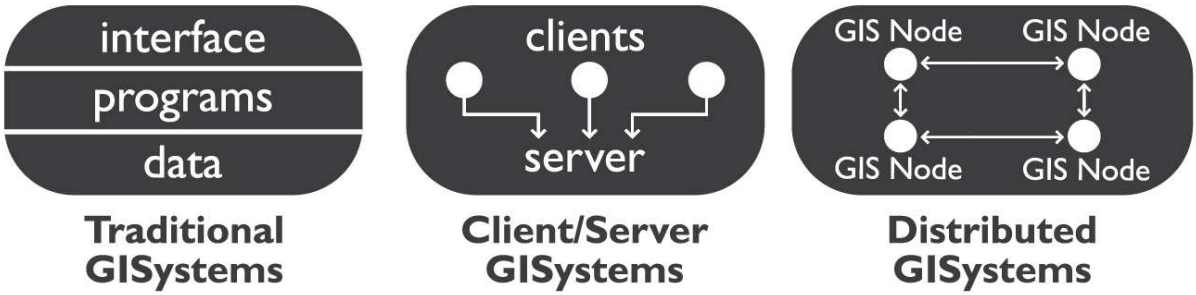


Fig. 4 Three types of GIS architecture
(redrawn; original figure: Peng Z., Tsou M., 2003)

Distributed GIS is a broad term representing both Internet GIS and mobile GIS. Their common characteristic is a distributed and dynamic framework. Mobile GIS is, in short, GIS accessible through wireless personal electronic devices, often equipped with GPS positioning modules. Internet GIS is also a broader term than Web GIS. Web GIS (also called with the term 'GeoWeb'), is Internet GIS based on the World Wide Web (WWW) – a networking application supporting a HyperText Transfer Protocol (HTTP) that is one of the major means of information exchange over the Internet. Internet GIS may, but not necessarily has to use the Web as a client to access data, perform analyses and present their results (Peng Z., Tsou M., 2003).

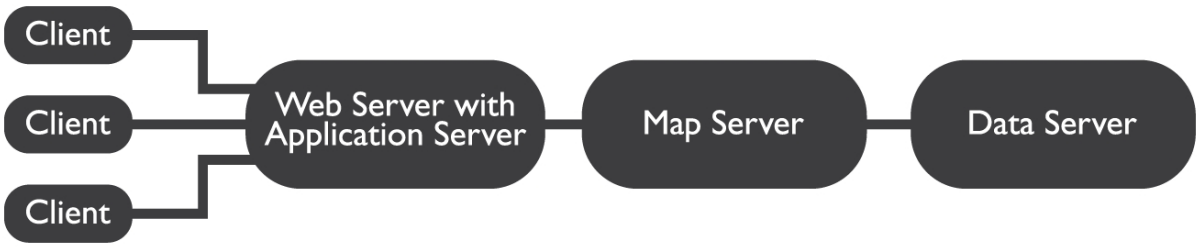


Fig. 5 Basic components in Internet GIS
(redrawn; original figure: Peng Z., Tsou M., 2003)

GI web services can be based on many different networking architectures, however in general the Internet GIS used to provide data and services has four major components: the client, web server with application server, map server and data server (Fig. 5) (Peng Z., Tsou M., 2003). The data server retrieves and manages data from a database or a file system. The map server processes geographic data and prepares the output of the processing. The web server serves static websites and invokes services. The web server communicates with the map server through the application server. The application server has a special role of managing server transactions, load balance and security. The client sends requests to the web server, receives output of processing from the server and presents it to the user. The client may be also capable of performing part of the data processing.

The concepts of a 'thin' and 'thick' client (Fig.6) are also important in the context of Internet GIS. In case of the thin client most of the processing is done on the server side and the client serves basically as a user interface for the user to input requests and to present output from the server. A thick client is a powerful client application with processing capabilities. In this case the server usually sends data to the clients but most of the data analyses are done on the client side. The Web – a primary networking application of the Internet is still usually a thin client but can be also a medium or even thick client especially in the case when a web browser is used along with Java applets, ActiveX controls or other add-ons. Desktop GIS programs which can access data remotely via the Internet are usually thick clients.

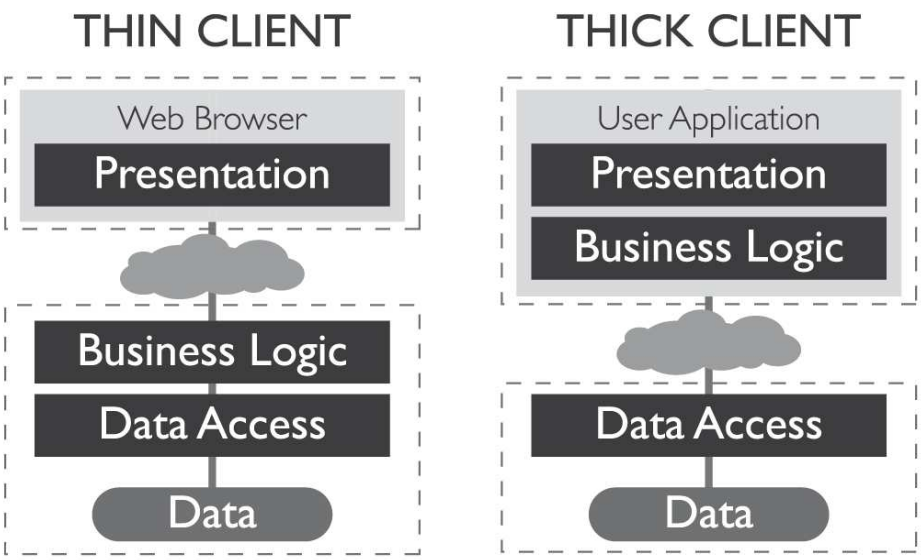


Fig.6 Thin and thick client models

Internet GIS has a wide range of applications. Among them are services for data download, clearinghouse networks, catalogue services, GIS data portals, mapping applications, applications for online data processing, location-based services, route planning services. The users of Internet GIS are able to exchange geographic data, search for metadata, browse maps, find places and objects on the maps, perform queries and analyses on the maps, plan their travel routes and many more. However, the Internet GIS is, in common opinion, linked in particular with web mapping – or simply with publishing maps on the Web. Distributed GIServices are in fact a final stage of evolution of web mapping which started with static map publishing (Fig.7), followed by static web mapping, interactive web mapping (Fig.8) up to contemporary GI network services which are also map-based.

Fig.7 Static map image can be published on a website or invoked with a web mapping service. Example: static map of Borneo island, Indonesia (http://www.e-borneo.com/travel/map_2_large.jpg)

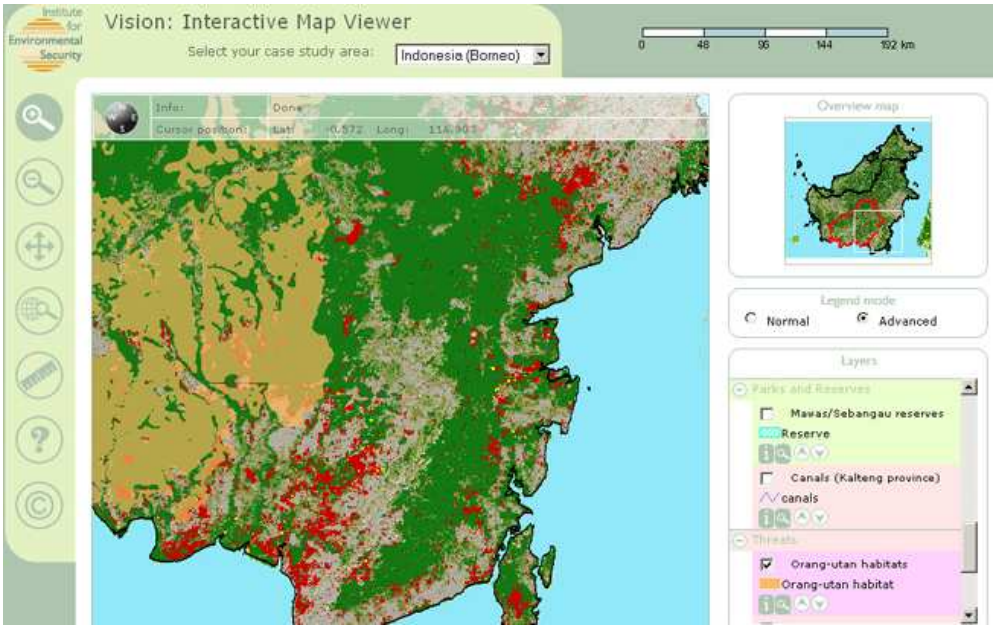


Fig.8 Interactive map viewer with browsing and analytical capabilities. Example: interactive map of Borneo Island, Indonesia (http://www.envirosecurity.org/images/espa/Vision_Interactive_Map_Viewer.jpg)

A single web mapping application is still a GIS program with limited functionality. For a web mapping application or other GI web service to become embedded into a real distributed GIS, a sophisticated distributed-component technology has to be used, supported with relevant standards (Peng Z., Tsou M., 2003). In the next section such technical framework for GI web services will be introduced.

2.2 Service Oriented Architecture – a framework for web services

Network services are, in essence, applications or, in other words, pieces of business logic that have their interfaces available on the Internet and are accessible through standard Internet protocols, such as HTTP or SMTP (Chappel D., Jewell T., 2002). The Internet GIS provided by the means of network services has to be based on a network hardware infrastructure which includes networking devices and utilities – servers, workstations, routers, modems, cables. The other type of infrastructure that is needed to make network services work is software infrastructure.

A Service Oriented Architecture is based on interaction of service clients and service providers over the Internet. The client can find services in a service registry. Services perform different types of data processing and are invoked by the clients. Services within the framework of SOA may be also clients of other services. Many services coupled together can form complex processing workflows. The primary demands for a SOA are efficiency, reliability and security. SOA's focus on creating generic services that can be reused across many applications in a language-, platform- and vendor-neutral way (Davis S., 2007).

The implementation of SOA that is becoming to be a standard framework for (not only GI) network services is a Web Services Architecture based on SOAP protocol (see: sub-section 2.2.1). Some alternative approaches are described in sub-section 2.2.2.

2.2.1 Web Services Architecture

Web services are components of a distributed technology based on the World Wide Web which perform specific processing tasks. The terms 'network services' and 'web services' are almost synonymous with this difference that for the latter the basic networking application is the Web. The Web Services Architecture standards are being developed primarily by two organizations: World Wide Web Consortium (W3C; http://www.w3.org) and Organization for the Advancement of Structured Information Standards (OASIS; http://www.oasis-open.org). According to the W3C Web Services definition (Web Services Architecture, 2004, http://www.w3.org/TR/ws-arch), a Web service is a software system designed to support interoperable machine-to-machine interaction over a network.

Web Services Architecture (WSA) involves several interrelated technological specifications for distributed computing on the Web. The most prominent of the specifications forming the 'Web Services Protocol Stack' are:

- XML (eXtensible Markup Language) – a language for structured data encoding
  - based on a simple and concise syntax
  - platform independent
  - has versions/extensions for different types of data (defined according to XML schemas)
- SOAP (Simple Object Access Protocol) – a protocol for information exchange and remote procedure calling in distributed environment
  - provides basic messaging framework for WSA
  - uses XML to code messages
  - usually uses HTTP/HTTPS as underlying transfer protocol
- WSDL (Web Service Definition Language) – a language for service description
  - is based on XML

- describes operations, messages, network protocols, message formats of web services

- UDDI (Universal Description, Discovery and Integration) – a registry of web services
  - platform-independent, XML-based
  - service registration includes contact information (White Pages), industrial categorization (Yellow Pages) and technical information (Green Pages).

The same, aforementioned definition of web services from the W3C Working Group states that "A Web service has an interface described in a machine-processable format (specifically WSDL). Other systems interact with the Web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards" (Web Services Architecture, 2004). Web Services Interoperability Organization (WS-I; http://www.ws-i.org) is an organization (industry consortium) that publishes profiles of web services specifications, use cases and test tools to help the deployment of profile compliant web services.

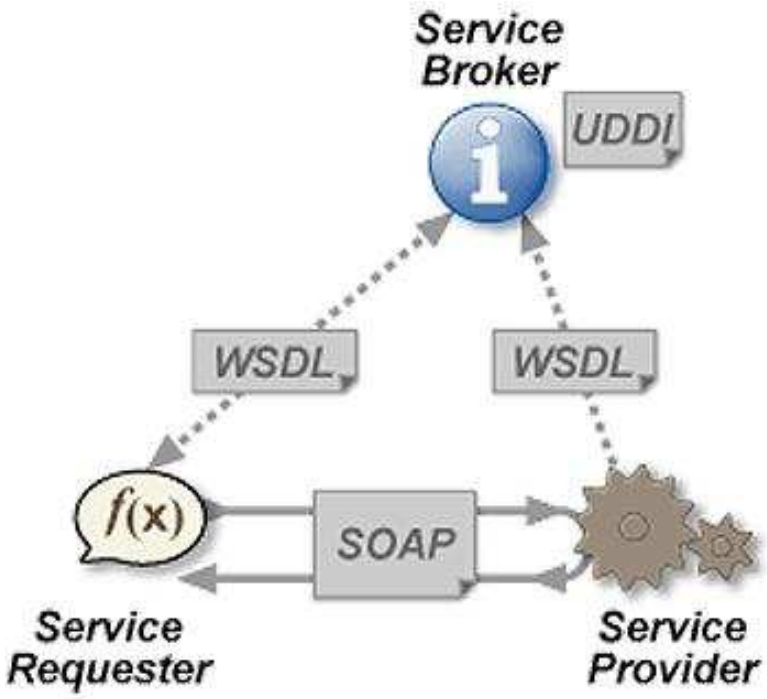


Fig.9 Web Services Architecture
(http://en.wikipedia.org/wiki/Web_service)

Fig.9 presents the basics of how the Web Services operate. Both the Service Requester and the Service Provider get the service interface code from the Service Broker over the Internet. The service request and the response from the provider are transferred using SOAP protocol. They receive the service interface code by the means of WSDL document which is retrieved from the UDDI registry.

2.2.2 Alternative approaches

The World Wide Web Consortium suggests the usage of SOAP as a messaging protocol for web services. The other standards mentioned (XML, WSDL, UDDI) are bound with the SOAP and form the foundation of the Web Services Architecture as defined in the consecutive WS-I profiles. However alternative approaches to distributed computing on the Web do exist.

An important distributed computing framework is CORBA (Common Object Request Broker Architecture; http://www.omg.org/spec/CORBA/3.1). The main goal of CORBA is to allow distributed business applications to work seamlessly together across the network. CORBA has been developed by Object Management Group (http://www.omg.org) – an international non-profit computer industry consortium. The protocol for client interaction is defined through a single implementation language-independent specification – the IDL. CORBA is especially powerful in support for object-oriented modeling. It has also high extensibility for development of new processing components (Peng Z., Tsou M., 2003). CORBA systems can be also providers of Web Services since there is a standard for mapping from IDL to WSDL. CORBA is still in the phase of development (current version 3.0) with its first version (1.0) dating back to 1991. However in the recent years the Web Services Architecture became a serious counterbalance to CORBA.

Some other distributed computing environments are proprietary technologies that have been developed by software producers. An example is DCOM (Distributed Component Object Model) – a technology for communication among distributed software components over network which was developed by Microsoft and was a major competitor to CORBA. DCOM became a part of COM+ application server infrastructure. However eventually Microsoft ceased support to DCOM in favor of the new .NET Framework (http://msdn.microsoft.com/netframework). Another example of a distributed computing technology is Java/Remote Method Invocation (RMI) developed by Sun Microsystems Inc (http://developers.sun.com). The Java Remote Method Invocation (RMI) system allows an object running in one Java virtual machine to invoke methods on an object running in another Java virtual machine. RMI provides for remote communication between programs written in the Java programming language.

Finally, a simpler approach can be used as a software framework for web services – that is RESTful services (where REST stands for Representational State Transfer), which rely on stateless, cacheable communication between clients and servers. RESTful web services do not require XML encoding, SOAP encapsulation of messages or WSDL service-API definitions. They use HTTP-based methods like PUT, GET, DELETE or POST as a primary means of communication. RESTful web services are still very popular and often better integrated with web browsers and other applications operating on the Web. In general, RESTful services are well suited for basic, ad hoc integration scenarios, while WSA solutions are more flexible and address advanced quality of service requirements commonly occurring in enterprise computing (Pautasso *et. al.*, 2008).

In this section some basic standards for general purpose network services architecture have been described. The primary conclusion is that for the functioning of GI web services a generic Service Oriented Architecture is needed and the WSA seems to be the most contemporary, platform-independent approach. The next section deals with specific standards for GI web services that are developed by two standardization organizations – ISO and OGC.

2.3 Standards for GI web services

There are two major standardization organizations that develop and maintain standards for the geographic information, including standards for the GI web services. These are: Open Geospatial Consortium (OGC) (see: sub-section 2.3.1) and International Organization for Standardization (ISO) (see: sub-section 2.3.2). A discussion on GIServices inevitably has to refer to these standards.

2.3.1 OGC

Open Geospatial Consortium is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geographic and location based services (http://www.opengeospatial.org). OGC, founded in 1994, is currently (February 2010) based on a collaboration of 395 private companies, governmental agencies, non-governmental organizations and research institutes. The goal of OGC is to support interoperable solutions for the GI community. OGC is also known as OpenGIS Consortium.

The OpenGIS Web Services Common (WS-Common) Interface Standard is a specification of operation parameters and data structures which are common to all OGC Web Service (OWS) standards. The standard normalizes the ways in which operation requests and responses handle such elements as bounding boxes, exception processing, URL requests, URN expressions, and key value encoding (http://www.opengeospatial.org).

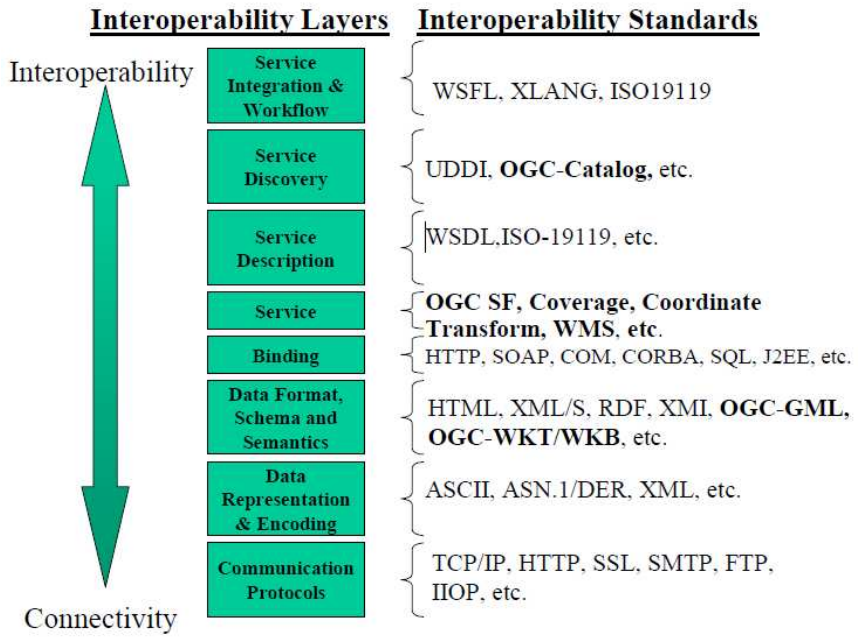


Fig.10 Service Interoperability Stack according to OGC
(OGC Web Services Architecture, 2003)

OGC defines services and provides implementation specifications for their interfaces/protocols (Fig.10). Similarly to SOAP-based services, XML encoding is used for protocol description and HTTP is a standard low-level protocol for data transfer. The alternative of WSDL is GetCapabilities operation which is used to retrieve automatic

description of a particular OGC service. The alternative of UDDI as a registry of web services are the OGC Catalogue Service-Web (CSW) services. It is worth to mention that these alternative specifications to mainstream ICT solutions were developed by OGC before the advent of the specifications from the 'WSA-stack' (WSDL, UDDI etc.).

The OGC Web Service standards which are of particular importance for GI web services are:

- Web Map Service (WMS) – current version: WMS 1.3.0
    - a protocol for dissemination of map images compiled on demand from geographic data on the Web
    - defines three operations: GetCapabilities, GetMap, GetFeatureInfo
    - Styled Layer Descriptor Profile for WMS (1.1.0) and Symbology Encoding (1.1.0) standards are supplementary specifications that extend the WMS and define a language to allow user-defined styling and symbolization of map data layers
- Web Feature Service (WFS) – current version: WFS 1.1.0
    - a protocol for dissemination of geographic data stored in vector format
    - the basic WFS defines three operations for querying and retrieval of features: GetCapabilities, DescribeFeatureType, GetFeature
    - a transactional Web Feature Service (WFS-T) provides additional operations for creation, deletion, and updating of features
    - Filter Encoding (FE), version 1.1, is a supplementary specification that defines filter expressions for extracting subsets of features from vector data
- Web Coverage Service (WCS) – current version 1.1.2
    - a protocol for dissemination of geographic data stored in raster format (coverages)
    - defines three operations: GetCapabilities, DescribeCoverage, GetCoverage
- Web Processing Service (WPS) – current version 1.0.0
    - a standard providing rules for calculations realized by geoprocessing services (including inputs and outputs)
    - standardizes a way to publish, find and bind to processes
    - defines three operations: GetCapabilities, DescribeProcess and Execute
- Catalogue Service (CSW) – current version 2.0.2
    - defines standardized interfaces for discovery, browsing and query of metadata (descriptive information about geographic data and services)
- Simple Features – current version 1.2.0
    - a standard for digital storage of geographic data in vector format
    - defines basic types of feature geometries (no topology)
- Geography Markup Language (GML) – current version 3.2.1
    - an universal language for geographic data modeling, storage and exchange
    - based on XML syntax
    - primarily limited to vector data, currently (version 3.2.1) offers a support as well for: topology, temporal aspects, raster data, Digital Terrain Models, cartographic representations

OGC standards are voluntary however they are widely adopted since they are built on a consensus of the leaders of the GI community. Several of them became accepted as ISO standards, however ISO also develops its own standards for geographic information.

2.3.2 ISO

International Organization for Standardization (http://www.iso.org), founded in 1947 and widely known as ISO is an non-governmental organization which sets international standards in a variety of domains. The members of ISO are representatives of standards organizations from particular countries. Respecting ISO norms is voluntary however many of them become law – either in a form of national standards or international treaties. ISO builds its authority on wide international representation of members, consensus development of norms and the understanding of influence of normalization on the economics.

In the structure of ISO are many Technical Committees that deal with specific standardization domains. In the domain of geographic information, the respective committee is ISO TC/211 Geographic Information/Geomatics. The standards specify methods, tools and services for spatial data management, access, acquisition, transfer, processing, analysis and presentation. They are known as standards of the ISO19100 series.

Some examples of important standards for Geographic Information from ISO are: ISO 19103 – Unified Modeling Language, ISO 19107 – Spatial Schema, ISO 19109 – Rules for Application Schema, ISO 19110 – Methodology for Feature Cataloguing, ISO 19115 – Metadata, ISO 19139 – Metadata – XML Schema Implementation, ISO 19119 – Services (including services metadata).

Among the bodies involved in the work of ISO TC/211 there are national standardization bodies, as well as international professional and sectoral bodies. One of the bodies involved is also the OGC. Several OGC specifications have already become ISO standards. Examples are: Geography Markup Language (ISO 19136), Web Map Service (Web Map server interface – ISO 19128), Web Feature Service (ISO 19142), Filter Encoding (ISO 19143).

The primary role of standards, both those developed by OGC and ISO is to support interoperability of geographic information and services. This allows the users of geoinformation to communicate, execute applications, manipulate and transfer data in an efficient and intuitive manner. The issue of interoperability of geographic data and services leads to the discussion on Geographic Information Infrastructures – the topic of the next section.

2.4 Geographic Information Infrastructures

Geographic Information Infrastructures (GII's) form a framework for geographic information exchange. The term 'Spatial Data Infrastructures' (SDI's) is often used as well as a synonym. In fact there is a slight difference in meaning. 'Information' is more then 'data' – it is data with a value added due to processing and human interpretation. 'Geographic' is usually understood as synonymous to 'spatial', however the former term is more precise then the latter. 'Geographic' means having a location defined in relation to the surface of Earth. 'Spatial' means having a location defined in space, that can be geographical space, but can be also the Universe, a space in a microscale such as human body or virtually any kind of reference space. Finally, 'infrastructure' can be defined as the basic physical and organizational structures needed for the operation of a society or enterprise (http://www.askoxford.com/concise_oed/infrastructure). The author founds the term Geographic Information Infrastructure (GII) more appropriate, however the term Spatial Data

Infrastructure (SDI) seems to be used even more frequently, also in the context of INSPIRE. In this thesis both terms will be used interchangeably.

There is no one accepted definition of GII. Many different definitions can be found instead. Citing several definitions gives the best overview what the Geographic Information Infrastructure is or should be. According to the Federal Geographic Data Committee (FGDC) – an interagency committee that coordinates the development of the National Spatial Data Infrastructure (NSDI) in the United States, the (National) Spatial Data Infrastructure is "an umbrella of policies, standards and procedures under which organizations and technologies interact to foster more efficient use, management and production of geospatial data" (FGDC, 1997). A definition that has been coined during the Second GSDI Conference states that the (Global) Spatial Data Infrastructure "encompasses policies, organizational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives" (GSDI, 1997).

Many different definitions of GII's exist according to particular authors or organizations. They take a bit different perspectives but the core idea is similar. Van Loenen (2006) classifies these definitions into four groups. The identificational definitions justify the investment in GII as a policy framework for the exchange of geographic information which is unique and crucial for the economics. The technological definitions put emphasis on such elements of the infrastructures as data, technologies, protocols, access systems and standards – that is on what producers offer to the users of geographic information. The organizational definitions describe GII's in a broader sense taking into account, besides the technology, their institutional and organizational context (including policies, organizations, financial and human resources). Finally, definitions looking at the topic from the productional perspective, describe GII's as a dynamic concept where suppliers and users of geographic information interact. Fig. 11 presents what, all in all, can be regarded as basic components of GII's.

Fig.11 Components of a GII (van Loenen B., 2006)

It shall be indicated that GII's have a strong relationship with the Internet GIS. A component of a GII is typically a geoportal or a geodata clearinghouse – a single access point to basic data resources of particular GII. Numerous local or specialized data access points can be provided as well. GII's operate in general on the basis of the Internet – making use of its technical facilities, protocols and proper standards. They are primarily a means of data sharing however they also embed different services for data analysis and processing. As regards the data sharing within GII's, standards for harmonized data models and themes are needed. Semantically meaningful models are necessary in order to stimulate interoperability (van Oosterom P., Zlatanova S. (ed.), 2008).

Spatial data collected by various public agencies, private sector, non-profit organizations and academia are available in different scales of reference – local, national, regional, global. GII's are also developed on different political and administrative levels. A kind of hierarchy is formed (Fig.12). There are projects of GII's from local or even corporate levels up to regional and global ones. The levels are inter-connected.

Fig.12 GII hierarchy
(Rajabifard A. *et. al*., 2003, ch.2)

The international (regional/global) level is very specific since on this level countries cooperate with each other in different fields where the spatial data is involved, including business and economic development, solving social problems, environmental management, regional/global mapping and others (Rajabifard A. *et. al.*, 2003, ch.2). One of the most prominent initiatives of international cooperation is the project of the European Comission of the European Union to develop a Geographic Information Infrastructure on the European level, known as INSPIRE.

2.5 INSPIRE Directive

Infrastructure for Spatial Information in the European Community (INSPIRE) (Fig.13) has been established under the Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 which entered into force on 15 May 2007. INSPIRE Directive is a Framework Directive which lays down general rules to establish a European Union spatial infrastructure which will enable the sharing of environmental spatial information among public sector organizations and better facilitate public access to spatial information across Europe (http://inspire.jrc.ec.europa.eu). The potential users of geo-information provided through INSPIRE include governmental agencies and public administration, utility and public services, commercial and professional users, research and educational institutions, non-governmental and non-profit organizations and individual citizens.

Fig.13 INSPIRE logo

The history of INSPIRE initiative dates back to 2001 when the first INSPIRE (E-ESDI) expert group was convened in Brussels. In 2002 a Memorandum of Understanding regarding the Infrastructure of Spatial Information in Europe was issued signed by three members of the European Commission. Working Groups started drafting legislative documents. First INSPIRE Position Papers were prepared in 2002 as well. In 2003, the European Commission launched an open consultation on proposal for a Framework Directive of INSPIRE. Impact Assessment of the Directive was also prepared leading to conclusions that the project will yield significant benefits in the environmental sector. In July 2004, the proposal for the Directive was adopted by the Commission. In 2005 it has been identified that the wider stakeholder involvement is necessary for the definition and preparation of the detailed Implementing Rules needed for application of the Directive. An open call was launched in March 2005 for the registration of Spatial Data Interest Communities (SDIC) and Legally Mandated Organizations (LMO) from particular countries which would participate in the drafting process. SDICs and LMOs where asked to put forward experts and reference material to support the preparation of the Implementing Rules. The Drafting Teams responsible for the preparation of Implementation Rules started their work in October 2005. A process of intensive consultations between the Council of Europe, the European Parliament and the Commission took place in 2006. In November 2006 the formal conciliation process began which lead to the adoption of the Directive 2007/2/EC and its entry into force on 15 May 2007 (http://inspire.jrc.ec.europa.eu).

The primary motivation for establishment of a pan-European GII is interoperability and shared use of spatial data and services between public authorities for the performance of public tasks, in particular in the context of environmental policies. Several major problems with interoperability of geoinformation among member countries of the European Union can been identified. These are:

- a variety of data formats (maps in digital and analogue forms, satellite imagery and aerial photographs, databases, reports, statistical data), file formats and encodings
- lack of harmonization of spatial reference systems
- differences in data models and data semantics (understanding of terms, definitions), vocabularies and registries
- lack of consistency of map scales, dataset resolutions, and data representation levels
- differences in data quality (accuracy, precision, temporal aspects)
- geographical gaps in coverage of particular datasets with a lot of data duplication at the same time
- a variety of portrayal rules, symbologies
- insufficient documentation of data leading to problems with data identification and interpretation; differences in metadata standards
- incompatible information systems.

The problems with interoperability at the data and services level are mirrored with the problems with interoperability at the organizational and institutional level and often result from them. There is a lack of coordination of geographic information strategies across borders and between particular levels of government. Another issues are data access and dissemination limitations due to copyright, licensing and pricing restrictions. The situation is different in particular countries and causes serious economic problems.

The vision of INSPIRE regarding geographic information is based on several common principles:
1. Data should be collected once and maintained at the level where this can be done most effectively.
2. It should be possible to combine seamlessly spatial information from different sources across Europe and share it between many users and applications.
3. It should be possible for information collected at one level to be shared between all the different levels, detailed for detailed investigations, general for strategic purposes.
4. Geographic information needed for good governance at all levels should be readily and transparently available
5. It should be easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.
(http://inspire.jrc.ec.europa.eu/index.cfm/pageid/48)

The Infrastructure for Spatial Information in the European Community is to be based on the infrastructures for geographic information established and operated by the Member States of the European Union. This is in compliance with the concept of distributed infrastructure and the hierarchical structure of GII's. INSPIRE does not require particular countries to collect new spatial data on particular themes. As such, even data harmonization is not an obligation. This means that data models and standards at the national level do not need to change due to INSPIRE nevertheless INSPIRE requirements and recommendations should be adhered to when the data is served from public registries at the European level. The scope of the INSPIRE Directive are *'spatial data held by or on behalf of a public authority operating*

down to the lowest level of government when laws or regulations require their collection or dissemination' (*Recital (12); Article 4.6*). In total INSPIRE covers 34 Spatial Data Themes defined in three Annexes. The Directive does not refer directly to the data and services served by the private sector and does not put obligations on them. INSPIRE does not affect existing intellectual property rights (Smits P., 2008). Finally it does not claim that all data and services should become available for free. The rule of free access applies for discovery services for metadata and viewing services. However for data download, depending on different conditions, charging may still apply.

INSPIRE remains in particular relation with some other directives of the European Union. The first is the Aarhus Convention of The United Nations Economic Commission for Europe (UNECE) which has been adopted by the European Union in the form of two directives (Directive 2003/4/EC and Directive 2003/35/EC) and which addresses the public access to environmental information. The second is the PSI Directive (Directive 2003/98/EC) which addresses the re-use of public sector information by third parties.

As INSPIRE is a Framework Directive, detailed implementation guidelines should be provided in a form of additional documents. These are theme-specific legislative acts, Implementing Rules (IR), Technical Guidance (TG) documents and others (technical reports, surveys, dictionaries, models, application schemas etc.).
INSPIRE documents (all available at the website: http://inspire.jrc.ec.europa.eu) are related to the five basic components of interoperability. These are:

- Metadata
- Data Specifications (Interoperability of spatial data sets and services)
- Network Services (Discovery, View, Download, Transform, Invoke Services)
- Data and Service Sharing (policies)
- Monitoring and Reporting (coordination and complementary measures)

Detailed requirements and recommendations of the INSPIRE documents regarding particular components of interoperability will be discussed in the context of INSPIRE-compliant web services in chapter 4.

In the process of preparation of the INSPIRE implementation documents there is a special role of Drafting Teams (DT) which are responsible for writing the Implementing Rules for each of the five INSPIRE components. During this process (Fig.14), Drafting Teams analyze and review the reference material prepared by the Spatial Data Interest Communities (SDIC) and Legally Mandated Organizations (LMO). SDICs and LMOs have several roles – preparation of user requirement analyses and technical specifications, provision of experts to the DTs, participation in the review process of the IRs (pilot projects, cost/benefit analyses), contribution to awareness raising and training. Note that Drafting Teams do not develop new technical specifications since they should be based on existing standards. Drafting Teams provide recommendations and suggestions to the Consolidation Team which is responsible for revision and testing of the proposed specifications. IRs are submitted to the Comitology Committee which revises and registers proposals and final versions of INSPIRE documents. Once accepted, IRs are published as a regulation in the Official Journal and become legislative acts in the Member States of European Union.

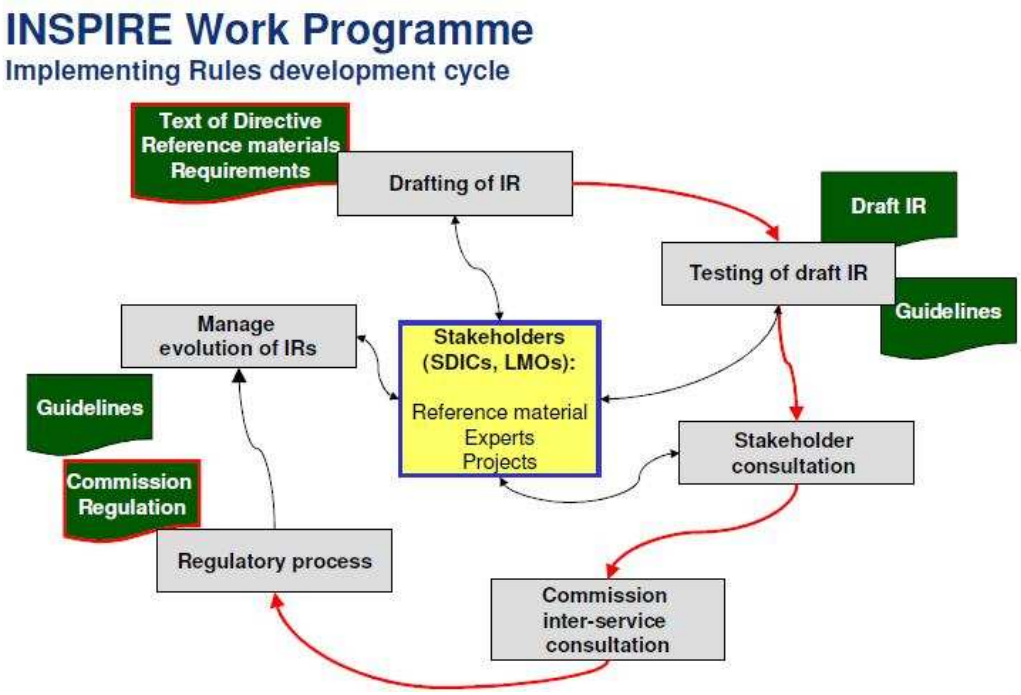


Fig.14 INSPIRE Work Programme – Implementing Rules Development Cycle (Rizzi D., 2009)

Since the entry of INSPIRE Directive into force, the phase of transposition of the regulations of the Directive into national legislation in particular countries of the European Union has began. The Deadline for transposition into National legislation was 15 May 2009.[1] 26 June 2007 was the date of establishment of INSPIRE Comitology Committee responsible for the adoption of Implementation Rules. A process for extensive stakeholder participation in preparation of the Implementing Rules has been set-up, which is described in the INSPIRE Work Programme Transposition Phase 2007-2009.

INSPIRE Metadata Regulation entered into force in December 2008 and the INSPIRE Metadata Implementing Rules: Technical Guidelines were published on the INSPIRE web site in February 2009. For the Data component, documents providing conceptual framework have been developed. Development of data specifications for particular data themes is in progress. Data Specifications for data themes from Annex 1 of the Directive were finalized, in their third versions in September 2009. The Draft Commission Regulation implementing the INSPIRE Directive as regards interoperability of spatial datasets and services has been finally accepted in December 2009. Call for Expression of Interest for participation in development of INSPIRE data specifications for Annex II & III Data Themes has been launched in November 2009.

For Network Services, the work started first with IRs for Discovery and View Services, later on with Download and Transformation Services. Only minor work has been done on Invoke Services. First IRs (for Discovery and View Services) were approved by the Committee on 19 December 2008. Technical Guidelines for particular types of Network Services are in the phase of development. Commission Regulation implementing the INSPIRE Directive as regards the network services (Discovery and View Services) entered into force in October

[1] Information on the status of transposition of the INSPIRE Directive in the Member States can be found on: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:72007L0002:EN:NOT

2009. The Draft Commission Regulation amending the former regulation as regards Download and Transformation Services has been accepted in December 2009.

Preparation of IRs for Data Sharing is in progress. The Draft Regulation on INSPIRE Data and Service Sharing was submitted to the INSPIRE Committee in June 2009 and obtained a positive opinion. For Monitoring and Reporting, IRs were adopted as a Commission decision in June 2009. An updated version of Guidelines for Monitoring and Reporting was published in July 2009. The presented state of play of INSPIRE is as of February 2010 (see also: INSPIRE Status Report November 2009). The implementation phase of the INSPIRE project has been scheduled until May 2019 (see: http://inspire.jrc.ec.europa.eu/index.cfm/pageid/44, INSPIRE Road Map).

The INSPIRE Directive makes an obligation for the establishment of the European geoportal to make available INSPIRE Network Services (primarily Discovery and View Services) and INSPIRE/ISO compliant on-line metadata editor. The geoportal provides also a platform to assess the specifications that are being proposed by the Drafting Teams through interoperability tests. The prototype geoportal can be found at the website: http://www.inspire-geoportal.eu.

2.6 Web services for protected areas

The main research topic of this project are INSPIRE-compliant web services, however a particular reference is made to the web services of national parks. The case study for the practical part of this research (prototype implementation) are the web services for Narew National Park (Poland) which has a GIS database for internal use but does not have a map view service or other GI web services available through its website.

Web services for a national park are usually made accessible by the means of a kind of geoportal. Every national park may develop such geoportal on its own. Map service (View service in INSPIRE terms) is usually provided. A service for data download is an additional option. For some geoportals, a catalogue service for metadata searching (Discovery service in INSPIRE terms) is provided. Sometimes it is also possible to perform some data transformation.

A geoportal of a national park may offer functions comparable to a geoportal of a different spatial unit e.g. a municipality. The specifics of web services for a national park is related to the main areas of activities in these protected areas – environmental management and conservation, scientific research, tourism. A WebGIS of a protected area is usually built on top of existing GIS database used for the management of this area, however it may include links to external sources of data and external services as well (e.g. environmental agencies, mapping agencies). In Annex A of this thesis, a brief overview of several interesting projects of web services and geoportals for protected areas (in particular national parks) is presented.

3. Case study area

Narew National Park is the case study area for this research. The case study (web services for a specific national park) has been chosen primarily to implement the prototype (see: chapter 5) and to provide examples of applications of INSPIRE guidelines. In this chapter, a short characteristics of the Park will be presented (section 3.1). Next, the structure and content of the existing GIS database of the Park (a part of the Management Plan of Narew National Park) will be described (section 3.2). At the end of this chapter a short discussion will be made about the user needs for a new geoportal (WebGIS) and the web services for the study area (section 3.3).

3.1 Narew National Park – characteristics of the case study area[2]

The Narew National Park is located in the North-Eastern part of Poland, Podlasie region, near the city of Białystok (Fig.15). The park was established on July 1, 1996 and encompasses a part of the marshy valley of the upper Narew river. The area covered by the park is 6810 ha, with a buffer zone of 15408 ha. Narew is the fifth longest river in Poland (484 km long, with 448 km flowing through Poland). The river has its source in Belarus in the Eastern part of Białowieża Forest and flows westward through the wooded plains and marshlands. The length of the river within the park area is approximately 46 km and the width of the river valley – 2 to 4 km.

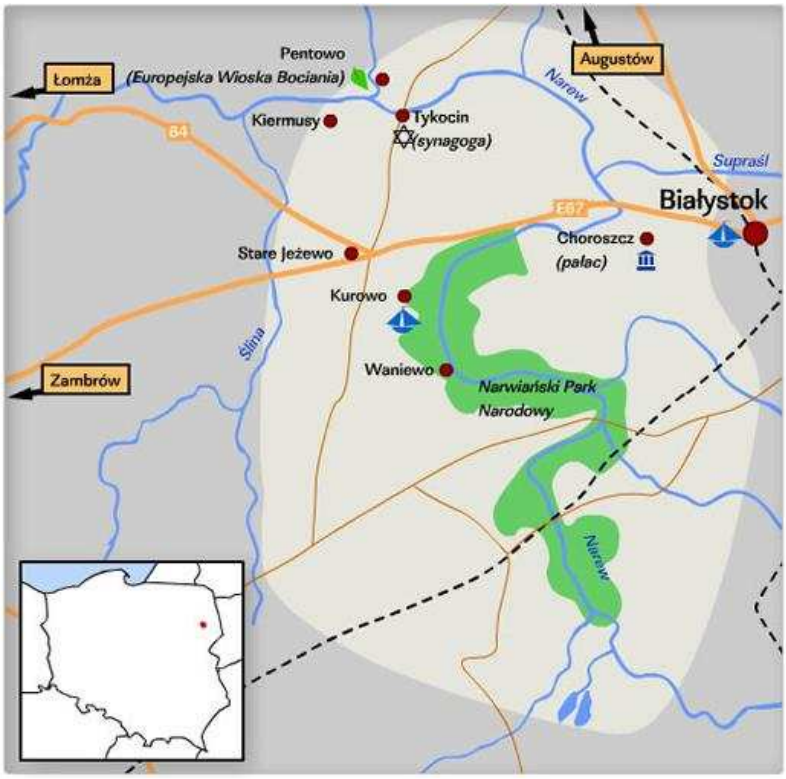


Fig.15 Narew National Park and its location in Poland
(http://www.staypoland.com/img/maps/107_pl.jpg)

[2] Section based on the information provided in the information booklet "Narew National Park. 10 years in serving people and nature", ed. Roszkowski W., Kurowo, 2006.

Narew in the area of Narew National Park is an unique example of an 'anostomosing' river. It is a labirynth of numerous irregulary shaped, interconnected riverbeds and interchannel wetland areas (Fig.16). There are only a few examples of anostomosing river systems in the World, including parts of the river systems of Okawango in Africa, Ob in Russia and Saskatchewan in Canada. Due to the specifics of this area it is sometimes called a "Polish Amazon".

Fig.16 Narew river valley in summer (fot. Wiktor Wołkow)

The valley of the river in the Narew National Park is flat and marshy with a gradient of ca. 22 cm/km. The bottom of the valley is covered with peat whose average thickness is 1 m. The interchannel wetland areas and the areas surrounding the riverbeds are overgrown with the dominating reed (*Phragmites australis*) and sedges (*Carex*). Meadows of manna grass (Glyceria fluitans) and canary grass (*Phalaris arundinacea*) can be also found. The sandy banks of the valley are overgrown with osier-willow (*Salix cinerea Salix*) thickets. The vegetation of the Narew National Park is rich in species which are under protection of Polish law.

A very precious asset of the park is its varied wetland birdlife. 203 bird species, out of which 154 are species breeding in this area, have been spotted in the park and its buffer zone. 35 of these species are endangered in Poland and can be found in the second edition of the Polish Red Book of Threatened Animal Species (2002). 11 of this species are subject to special protection in Europe, as listed in the annex to the Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds, commonly referred to as the Birds Directive. The area of Narew National Park, with its buffer zone is a Special Protection Area within "Natura 2000" – the network of protected sites in European Union. The park has also become a wetland site protected by the Ramsar Convention **(**The Convention on Wetlands of International Importance, especially as Waterfowl Habitat).

The park has its headquarters in the village of Kurowo, in an antique manor house surrounded by an old rural park with numerous nature monuments. Cultural attractions of the park are mostly represented by buildings such as numerous traditional village huts, ancient crosses by the roads and windmills. Tourism activities in the park and its surroundings include bird watching, kayaking and cycling. The educational function of the Narew National Park is based on environmental exhibitions, educational workshops and outdoors activities.

3.2 GIS database of Narew National Park

The GIS database of the Narew National Park is a part of the Management Plan of the Narew National Park. The database was created in 2002 and it has not been updated ever since. The creator of the GIS database was "ProGIS" company from Białystok. Scientific employees of the Department of Landscape Ecology, Białystok Technical University (MSc Eng. Andrzej Kamocki – project coordinator, Ph.D Eng. Paweł Próchnicki) were involved in the creation of the database. A variety of sources of information was used to create the database.

The Geographic Information System can be used for such purposes as: recognition of the state of environment – analysis of spatial patterns, analysis of data from environmental monitoring, planning management and conservation activities, simulation and modeling of changes in the environment, cartographic editing for publications and the Web.
The database includes raster, vector and tabular data in the following thematic groups:

- Reference data
    - Ortophotoimagery
    - Cadastral maps
    - Topographic maps

- Thematic data
    - Land ecosystems
    - Soils and Geology
    - Water resources
    - Water ecosystems
    - Fauna
    - Landscape resources and spatial management
    - Cultural resources
    - Tourist infrastructure

Majority of the spatial datasets cover the area of the Narew National Park and its buffer zone.
The vector data is available in separate files in Bentley Microstation .dgn format (cadastral data and all thematic data). All tabular data supplementary to the vector spatial data is available through a relational database: Microsoft Access Database (.mdb). Ortophotoimagery is available in Bentley Microstation raster image format .hmr. This is a digital ortophotomap in the scale 1:10 000 based on infrared aerial photographs. Topographic maps are simply scanned and georeferenced paper maps (GeoTIFF format) from 1986, in the scale 1:10 000 and in the Polish reference system PUWG 1965. The data can be read by majority of GIS software applications, such as Geomedia (Intergraph), ArcView/ArcInfo (ESRI), MapInfo.

3.3 Geoportal for Narew National Park in the light of the user needs

The Narew National Park has the GIS database for the internal use however it does not have a WebGIS or geoportal for dissemination of geographic data and services. A real user needs analysis has not been conducted since it is not in the scope of this research. Nevertheless it can be recognized that the creation of such a geoportal would be desirable.

A static map of the park available on the Web (Fig.17) does not fulfill the needs of the users due to the limited amount of information it holds. Tourists visiting the park can use more detailed paper topographic maps or their versions with additional tourist information during a trip. Paper maps are still a valuable and handy source of geographic information especially for tourists and all groups of people dealing with fieldwork. However, an interactive mapping application available through web services could serve the users with new powerful tools for exploration of spatial data.

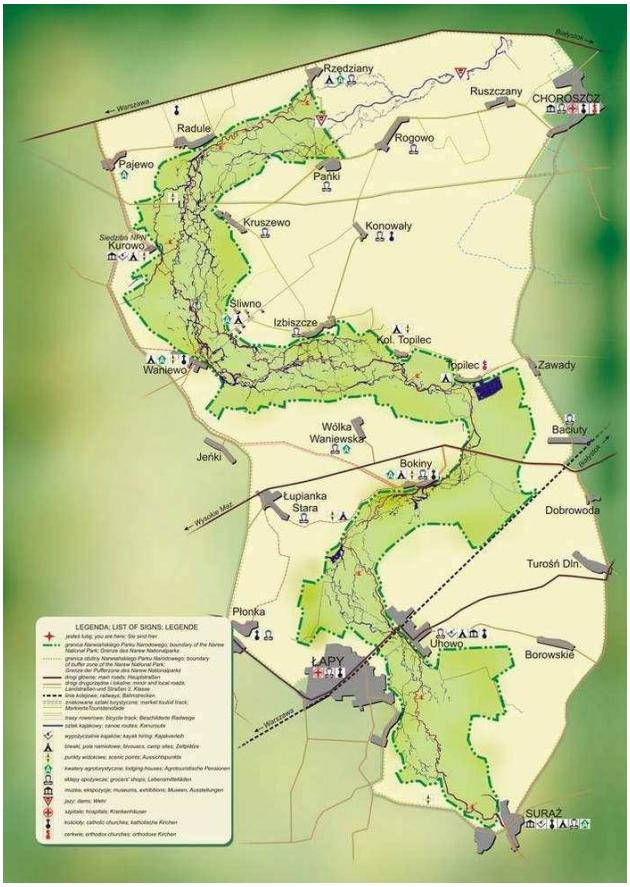


Fig.17 Narew National Park – static map available on the official website
(http://www.npn.pl/img.php?img=http://npn.pl/img/mapa01d.jpg)

Such interactive map service could allow the user to switch on and off thematic data layers, explore their content, identify objects in the map. It broadens enormously the amount of information available to the user, who can explore for instance hydrographic data, vegetation data or data about tourist infrastructure in details. The other issue is interactivity – a possibility of making queries about the objects in the map, performing measurements or even

simple spatial analyses. Also more dynamic data could be added, presenting temporal changes in the area, weather conditions etc.

A geoportal of a national park is usually based on the internal GIS database as a primary source of data, however links to external data and services can make such application even more interesting and valuable source of information. This could be data made available by mapping agencies, environmental agencies, private companies etc. Data from external sources can be overlaid with other data for instance with the use of the OGC-compliant Web Map Service. In case of the geoportal of the Narew National Park such additional data could be for instance WMS data from the Polish National Geoportal (http://geoportal.gov.pl) which provides a free access to continously extended resources of reference data for the whole area of Poland (cadastral, topographic, ortophotoimagery).

Mapping applications can be supplemented with additional multimedia features. Hyperlinks can be provided through some objects in the map to such features as text, graphics, digital video, digital audio or computer animation. For a Web-based multimedia GIS, a linking mechanism is needed between a Web-based GIS application developed to manipulate spatial environmental database including georeferenced images and digital maps and Web-based interactive multimedia application designed to manipulate multimedia information (Shunfu Hu, 2002). Implementation of multimedia information in the map service of the Narew National Park would be very interesting for tourists but also very educative for the youth.

In addition to the map service, other services are worth to implement. It is possible that the users of the geoportal of the Narew National Park would like to view and compose thematic maps on the Web, but also to download some specific datasets from the GIS database of the Park for use on their own machines e.g. hydrologists could be especially interested in detailed data on water resources and botanists - in data on land and water ecosystems. The data access rights, licensing and pricing issues should be defined for data download. A catalogue (discovery) service shall be also implemented as a complementary service to the view and download services. This is a very important service which provides the users with the datasets metadata (basic information on the datasets, their technical properties, thematic, spatial and temporal scope, quality, terms of retrieval and use, contact information to the data creator, owner and distributor).

As it can be observed from the above, the geoportal for the Narew National Park would serve diverse groups of users. The primary group are tourists and all people interested in the nature of the park. These people would be in particular the users of the map (view) service and possibly of the multimedia applications. The view service could be also a means of a Web-based environmental education. The other group would be students, scientists, people from non-governmental organizations, municipalities cooperating with the park etc. For those people, a view service is also useful, however they could be especially interested in the download service and catalogue (discovery) service for detailed examination of specific data suited to their needs.

4. Conceptual study on the INSPIRE services

The identification of guidelines for the INSPIRE-compliant web services will be made starting from the overview of the technical architecture providing a framework for their interoperability (section 4.1). From the technical architecture, the discussion will follow to the elements of data (section 4.2) and metadata (section 4.3) models, next to the specific types of web services (section 4.4), the issue of quality of services (section 4.5) and, finally, to the issue of the rights management, licensing and data access policies (section 4.6). The crucial guidelines (requirements and recommendations) for the INSPIRE-compliant web services derived from the INSPIRE documentation will be marked **bold** in the text of this chapter. The conceptual study will be finalized with the synthesis of the guidelines for INSPIRE-compliant web services (section 4.7).

4.1 Technical architecture[3]

The INSPIRE Directive defines the technical elements of the infrastructure for spatial information to be comprised of *'metadata, spatial data sets and spatial data services, network services and technologies'* (INSPIRE Directive, *Article 3.1*). Fig. 18 provides a simplified overview of key elements in the technical architecture of INSPIRE and the responsibilities of particular Drafting Teams. This figure has been already presented as Fig.1 in chapter 1, to introduce the concept of technical architecture of INSPIRE.

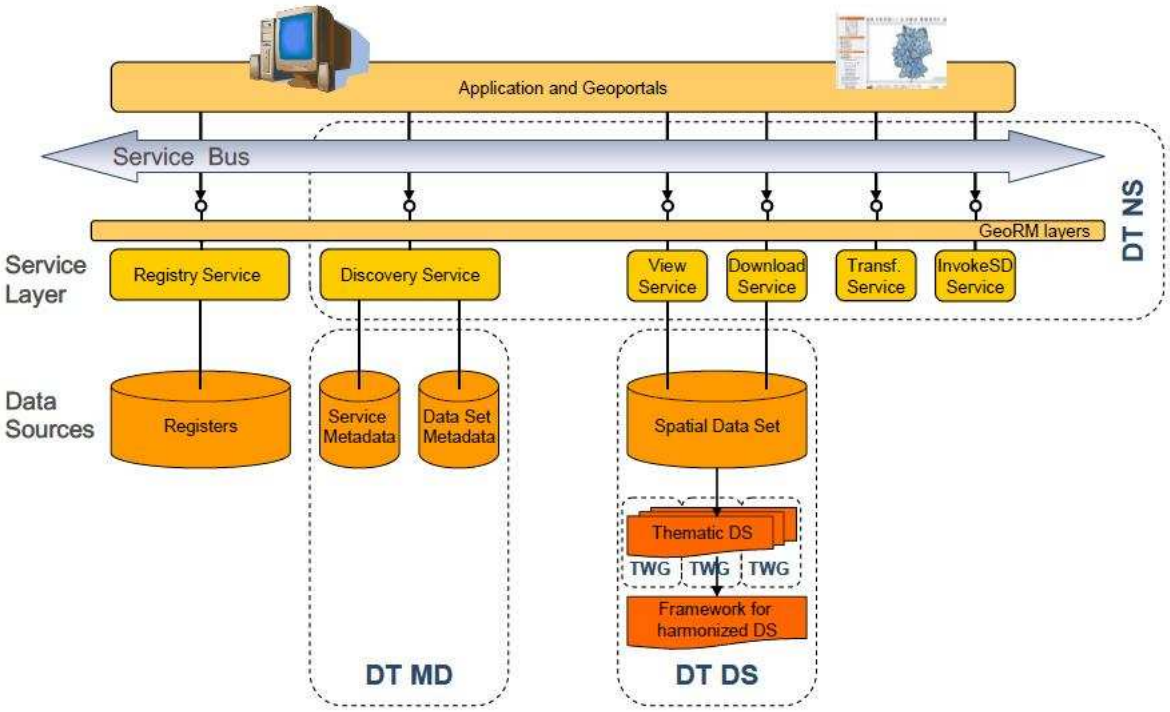


Fig.18 INSPIRE Technical Architecture Overview
(INSPIRE Technical Architecture - Overview, 2007)

[3] Significant part of this section is based on the information provided in "INSPIRE Network Services Architecture" document (2008). References to other documents and literature are provided in the text.

The core resource of the infrastructure shown in the diagram is the Spatial[4] Data in spatial data sets. All the other resources are only needed to find, access, interpret or use the spatial objects in the spatial data sets.

The Metadata is used for data and services description – it supports the discovery, and to a certain extent also the evaluation and use of spatial data. Apart from the Data Set Metadata, there is also the Service Metadata (service descriptions), allowing humans and applications to discover specific instances of web services in the infrastructure. Registers (Feature Concept Dictionary and Glossary) serve basically to clarify the terms and definitions used in INSPIRE.

The web services, or Network Services in INSPIRE terms, are a means for access and processing of all spatial data and metadata. These are, as defined by the INSPIRE Directive: Discovery Service (bind directly to the metadata resources), View, Download and Transformation Services (bind directly to the spatial data resources), Invoke service.

The INSPIRE Directive requires that:
Inspire shall build upon infrastructures for spatial information established and operated by the Member States. (Article 1).
The Directive defines particular types of Network Services in the following way:
Member States shall establish and operate a network of the following services for the spatial data sets and services for which metadata have been created in accordance with this Directive:
(a) discovery services making it possible to search for spatial data sets and services on the basis of the content of the corresponding metadata and to display the content of the metadata;
(b) view services making it possible, as a minimum, to display, navigate, zoom in/out, pan, or overlay viewable spatial data sets and to display legend information and any relevant content of metadata;
(c) download services, enabling copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly;
(d) transformation services, enabling spatial data sets to be transformed with a view to achieving interoperability;
(e) services allowing spatial data services to be invoked.
Those services shall take into account relevant user requirements and shall be easy to use, available to the public and accessible via the Internet or any other appropriate means of telecommunication.(Article 11).
It also relates to the provision of spatial data and services:
Member States shall ensure that public authorities are given the technical possibility to link their spatial data sets and services to the network referred to in Article 11(1). This service shall also be made available upon request to third parties whose spatial data sets and services comply with implementing rules laying down obligations with regard, in particular, to metadata, network services and interoperability. (Article 12).
The INSPIRE Geoportal and other access points are defined as the nodes of the infrastructure:
Member States shall provide access to the services referred to in Article 11(1) through the Inspire geoportal referred to in paragraph 1. Member States may also provide access to those services through their own access points. (Article 15(2))

[4] The use of the word "spatial" in INSPIRE is unfortunate as the meaning goes beyond the meaning of "geographic" – which is understood to be the intended scope. Therefore, "spatial data" is understood as a synonym for the term "geographic information" as used in the ISO 19100 series of International Standards. (INSPIRE Network Architecture) (see also: section 2.4).

The particular Network Services Implementing Rules which make the provisions of the INSPIRE Directive more specific, refer to and standardize such aspects of the Network Services as: general architectural model, technical architectures and protocols, security issues, quality of services indicators, multilingual aspects, compliance with services metadata, end users' needs.

Although INSPIRE services can be used in many variations, the typical workflow follows the fundamental "publish-find-bind" pattern. Fig.19 depicts the workflow according to this pattern and the related services. However, users can also invoke services directly, and not necessarily following the "publish-find-bind" pattern.

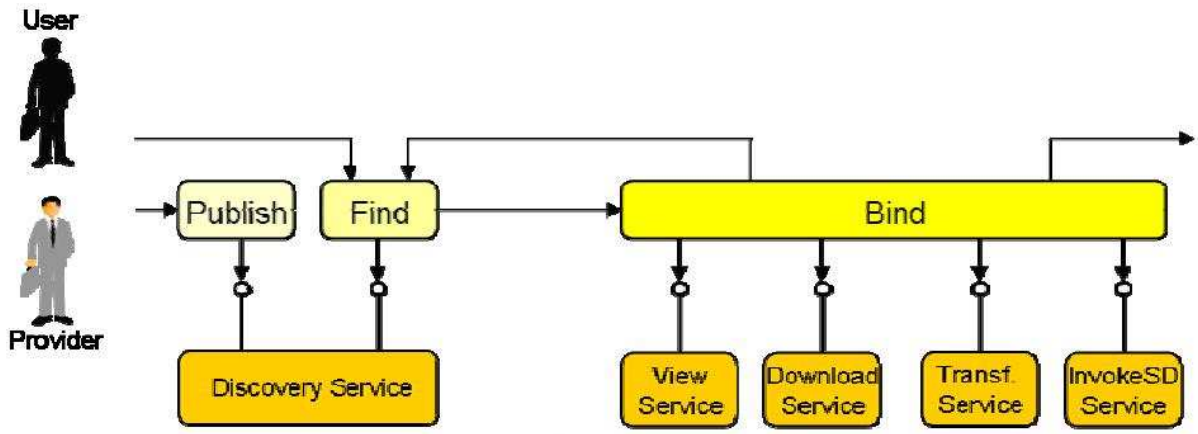


Fig.19 Publish-Find-Bind pattern
(INSPIRE Technical Architecture - Overview, 2007)

The GeoRM (Rights Management) layers provide overall workflow control of the Network Services, consisting of authentication, authorization, pricing, billing, licensing and other organizational aspects common to all INSPIRE services (see: section 4.6).

The particular instances of INSPIRE Network Services will form a pan-European GI Service Bus. The Service bus consists of:

- different providers from European countries offering INSPIRE-compliant web services through local/regional/national GII's
- servers exposing the functionality of INSPIRE Network Services for machine-to-machine communication
- the INSPIRE Geoportal at the Community level, but also additional, facultative access points (clients/portals) offered by the Member States serving applications solving tasks for specific user groups via INSPIRE services.

The case chosen for this research is a study on web services accessible through such a local access point (geoportal) in one of the Member States (MS) and offering a specific functionality, all in compliance with requirements and recommendations for INSPIRE Network Services. However, the same services offered through a local access point can be linked to an access point on a MS level or even to the INSPIRE Geoportal, due to the use of proper standards (protocols).

The INSPIRE Network Service Architecture is designed to be a Service Oriented Architecture with the components providing and receiving services communicating via the INSPIRE service bus. The INSPIRE architecture needs to support not only direct communication between clients and services, but as workflows utilizing services in a chained manner. Therefore the communication protocols and interface bindings had to be defined for use in INSPIRE, following the SOA-approach.

The Service-Oriented Architecture to be used in INSPIRE has been defined in the INSPIRE Network Architecture document: "As the INSPIRE directive advises to utilize existing standards, OGC service bindings are taken as a guidance. Existing OGC Web Services (OWS) support a mix of protocols and technology bindings. These are Key-Value-Pairs send via HTTP/GET, XML send via HTTP/POST, SOAP via HTTP/POST and combinations. In addition the World Wide Web Consortium (W3C) suggests the usage of SOAP as a messaging protocol for web services. INSPIRE services should utilize one standard technology binding for all service types. In order to streamline integration and implementation as well as getting a maximum benefit from the offered services, a mix of technologies is to be avoided. Taking all requirements, opportunities and risks into account, **the default communication-protocol and binding technology for INSPIRE services should be SOAP (document/literal)**." This is not an obligation but recommendation of the INSPIRE Network Architecture. **Specific profiles of network services based both on SOAP and on RESTful service protocols (HTTP GET and POST) are defined in Technical Guidance documents for particular types of services** (see: section 4.4).

SOAP is a standard information technology for Service Oriented Architecture, it offers a cross-platform development and working environment for web services, it provides a means to chain services in automated workflows, it can be extended by management functionalities such as geo rights management services. SOAP along with complementary standards of the Web Services Architecture (XML, WSDL, UDDI) constitute a profile referred to by a variety of development tools (e.g. .NET, Java Web Service development pack, Axis). Therefore their usage should guarantee the sustainability of the development process. (INSPIRE Network Services SOAP Framework, 2008). All these arguments decided on the choice of SOAP and WSA as the service binding technology in INSPIRE.

While using the SOAP service interface, the INSPIRE-compliant web services shall still use OGC service specifications. OGC services have been designed and proposed when SOAP was not a standard yet, so the compliance of their specifications with SOAP has not been foreseen. However, a way to support HTTP GET and POST-based services while developing the SOAP approach is to define an easy and generic approach to provide these services with a SOAP binding, which would enable a transformation of any HTTP GET and POST services to a SOAP service in a way transparent to the client application.

OGC has issued several discussion papers to discover the feasibility and usefulness of enabling SOAP communication in OGC services, in particular OpenGIS 'Wrapping OGC HTTP-GET and -POST Services with SOAP' – Discussion Paper [OGC 07-158] and 'OWS 5 SOAP/WSDL Common Engineering Report' [OGC 08-009r1]. Since June 2006, all future revisions of existing and all new OWS (OGC Web Services) interface specifications should include an optional SOAP (messaging) binding and should express that binding in WSDL. For the foreseeable future, existing HTTP/GET and HTTP/POST bindings are, however, maintained in the OGC specifications. OWS specifications shall indicate that servers may optionally implement SOAP 1.2 transfer of all operation requests and responses, using the

same XML encodings as specified for use with HTTP/GET and HTTP/POST. HTTP GET/POST and SOAP bindings for OGC Web Services will probably co-exist in parallel for a long time (OpenGIS Specification Best Practices Paper, 2006).

SOAP specifications (http://www.w3.org/TR/soap) allow different data encodings. According to the OWS 2 Common Architecture: WSDL SOAP UDDI (2005): "A WSDL SOAP binding can be either an RPC style binding or a document style binding." This choice is related to the way how the SOAP payload (contents of the <soap:Body> element) is structured. "Furthermore, A SOAP binding can have an encoded use or a literal use." The use attribute specifies the serialization rules of the SOAP message. "Of the four resulting combinations, **document/literal binding was chosen for OGC messages**, because it is the one that matches best the way transport layers are designed in current OGC services (XML messages validated by OGC schemas) and because it allows for direct use of OGC schemas in the SOAP messaging scheme". Several other OGC documents (including the OWS 5 SOAP/WSDL Common Engineering Report (2008)) follow this approach and recommend or require document/literal style for SOAP bindings in OGC Web Services.

The problem with the development of SOAP/WSDL based geo-information services is still of the lack of support by the development tools. Since the original OGC interface specifications were based on HTTP/GET or HTTP/POST protocols, there were sparse attempts to use SOAP/WSDL for geo-information services. This trend is changing also due to the INSPIRE recommendations. Pilot projects for the development and testing of SOAP-based geo-information services have begun – an example are the projects for INSPIRE Discovery and View Services from the Dutch NSDI executive committee – Geonovum (see: sub-section 6.3.4).

There are basically two steps in supporting SOAP: to add a definition of the SOAP binding to the WSDL description of the service and to add a support for SOAP document/literal envelope. Several common rules have been identified for the OGC Web Services to be compliant with SOAP:

- For SOAP transfer, each XML-encoded operation request shall be encapsulated in the <*Body*> element of a SOAP envelope; in other words, the *SOAP-Body* shall be used only for transmitting the actual OWS service request.
- When the operation request is sent using SOAP, an implementing server shall return operation responses and error messages using only SOAP transfer.
- All compliant OWS servers shall specify the URLs to which SOAP-encoded operation requests may be sent, within the *OperationsMetadata* section of a service metadata (Capabilities) XML document (SOAP HTTP Binding Status, 2008).

As an underlying protocol for data transfer over the internet SOAP shall use HTTP 1.1. "SOAP on HTTP offers all the flexibility needed in terms of message complexity and allows to leverage the XML schema definitions of the existing services. HTTP is suitable for both the Message-Exchange-Patterns that can be required by INSPIRE services: *one-way* and *request-response*, providing all the needed functionalities. HTTPS could be used as well as the low-level protocol instead of HTTP to improve security (INSPIRE NS SOAP Framework, 2008).

XML 1.0 shall be used for serializing SOAP envelopes. XML processors should be able to support both the "UTF-8" and "UTF-16" character encodings for the interoperability reasons, according to the WS-I Profile. However "UTF-8" is the preferred choice for SOAP messaging in INSPIRE Network Services (INSPIRE NS SOAP Framework, 2008).

Finally, for the exchange of large amounts of binary data, the *Message Transportation Optimization Mechanism* (MTOM) shall be used, in conjunction with *XML-binary Optimized Packaging* (XOP). XOP is going to be used encapsulated inside MIME (*Multipurpose Internet Mail Extensions*) messages. These rules are not applicable to all INSPIRE services, as not all of them will need to handle large amounts of binary data. They will be applicable to the instances of Download or View Services, which may need to handle such vast spatial datasets, and be able to send it to the client in an answer to the service invocation. Binary data (e.g. images in *.jpg or *.gif formats or large documents) would be transferred as attachments to SOAP messages (INSPIRE NS SOAP Framework, 2008).

In case of large XML data, like GML, the proposed choice is just to encapsulate it in the body of the SOAP message, without performing additional data optimization or data encoding for the transmission. Two other alternatives are also considered – Binary XML optimization to enhance the transmission performances (however this is not yet a wide-spread standard) or sending the XML data in a binary encoded attachment to the SOAP message, e.g. in a zip archive (however this way of transmission is not transparent to service users as it requires data conversion/de-conversion) (INSPIRE NS SOAP Framework, 2008).

As a conclusion, a common framework for INSPIRE-compliant web services based on SOAP technical architecture, includes the following requirements:
• **XML 1.0, SOAP 1.1 and WSDL 1.1 (WS-I Basic Profile 1.2)**, to be superseded in foreseeable future by **SOAP1.2/WSDL2.0 (WS-I Basic Profile 2.0)**.
• **Document-Literal wrapped data-encoding**
• **MTOM (1.0) + XOP (1.0) on MIME (1.0) for binary data transport and XML compression**
• **HTTP (1.1) as underlying transport protocol**; HTTPS could be used as lower level protocol to improve security
• **use of a common SOAP Header** (extension recommended for solving problems with: security, download checksums, artifacts signatures, multilingualism metadata)
• **faults messages should be managed inside SOAP bodies** (INSPIRE NS SOAP Framework, 2008).

The primary challenge is the integration of particular services based on INSPIRE Network Services specifications (and, consequently, on OGC Web Services specifications) within the framework of SOAP architecture, as it is a novel approach for geo-information services. The fact that a set of guidelines documents have been issued for the SOAP framework for INSPIRE Network Services (including 'INSPIRE Network Services SOAP Framework' Technical Report (2008)) brings the adoption of this approach closer to the reality. Specifically for the INSPIRE Discovery and View Services a guidance document have been produced. That is the 'SOAP primer for INSPIRE Discovery and View Services' (2009) providing simple examples of the proposed INSPIRE SOAP framework and additional clarifications. Furthermore 'Proposals for the documentation of the communication of the View and Discovery Service using the Web Service Description Language' (2009) have been made available.

As regards the support from the INSPIRE Team for the implementation of INSPIRE-compliant network services, the Initial Operating Capability Task Force (IOC TF) was set up in June 2009 to help and support Member States in the implementation of INSPIRE services and to ensure interoperability with the INSPIRE geoportal of the European Commission. The

IOC TF consists of the representatives, from all Member States, responsible for the architecture design and the service implementation of the National GIIs. The initial focus of the IOC TF is on the implementation of the INSPIRE Discovery and View Services. The IOC TF met for the first time in Rotterdam on the 18 June 2009 during the INSPIRE conference (INSPIRE Status Report, November 2009), followed by teleconferences and meetings in Ispra (10 November 2009) and Vienna (19 January 2010).

4.2 Spatial data

Spatial (geographic) data in spatial datasets is the core resource of a Geographic Information Infrastructure, such as INSPIRE. The web services fully compliant with INSPIRE should handle geographic data which is also compliant with the profile specified in the INSPIRE Data Specifications and other relevant INSPIRE documents on the interoperability of spatial datasets and services. In this section, only a rough outlook will be made on the topic of INSPIRE guidelines for the conformance of spatial data, in the context of the use of the data in INSPIRE-compliant web services. The sole topic of spatial data compliant with the profile of INSPIRE requires more in-depth consideration and further studies.

The INSPIRE Directive defines thematic scope of the spatial data that shall be standardized. The following Spatial Data Themes have been laid down in three Annexes to the Directive:

Annex I
1. Coordinate reference systems
2. Geographical grid systems
3. Geographical names
4. Administrative units
5. Addresses
6. Cadastral parcels
7. Transport networks
8. Hydrography
9. Protected sites

Annex II
1. Elevation
2. Land cover
3. Ortho-imagery
4. Geology

Annex III
1. Statistical units
2. Buildings
3. Soil
4. Land use
5. Human health and safety
6. Utility and governmental services
7. Environmental monitoring facilities
8. Production and industrial facilities
9. Agricultural and aquaculture facilities
10. Population distribution –demography
11. Area management/restriction/regulation zones & reporting units

12. Natural risk zones
13. Atmospheric conditions
14. Meteorological geographical features
15. Oceanographic geographical features
16. Sea regions
17. Bio-geographical regions
18. Habitats and biotopes
19. Species distribution
20. Energy resources
21. Mineral resources

The development of INSPIRE Implementing Rules for harmonized spatial data follows a two-step approach. The first step was the development of a conceptual framework and specification methodology laid down in the following documents:

- Definition of Annex Themes and Scope (D 2.3)
- Generic Conceptual Model (D 2.5)
- Methodology for the development of data specifications (D 2.6)
- Guidelines for the encoding of the spatial data (D 2.7).

The second step comprises the development of Data Specifications for each data theme listed in the Annexes of the Directive. Other, supportive, documents include: INSPIRE Feature Concept Dictionary, INSPIRE Glossary, INSPIRE Consolidated UML Model, GML Application Schemas, INSPIRE Code List Dictionaries.

Harmonized spatial data specifications shall be developed for the data referring to all three Annexes. According to the INSPIRE Technical Architecture (2008): "Only spatial data sets that conform to data specifications for Annex themes that are adopted INSPIRE Implementing Rules will be considered fully integrated in the infrastructure." However, the adoption dates of the implementation rules for data themes defined in particular Annexes are different. The data from Annex 1 has the priority, as it can be considered basic spatial reference data. Data Specifications (Guidelines) for particular Annex 1 data themes have been made available in September 2009. Furthermore, the 'Draft Commission Regulation implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services' has been made available in December 2009. This document includes legally based implementing rules for INSPIRE-compliant spatial data.

According to the INSPIRE Roadmap (http://inspire.jrc.ec.europa.eu/index.cfm/pageid/44), following the articles of the INSPIRE Directive (*Article 9(a) and 9(b)*), the adoption of Implementation Rules for the interoperability of spatial data sets and services by the INSPIRE Committee as regards the Annex II and III data themes is planned until 15 May 2012. The Data Specifications shall be also more detailed on the attribute level for the data from Annexes I and II than for the data from Annex III (see: *Article 8* of the Directive). Since the guidelines for Annex II and III are, at the moment of writing (February 2010), not yet available, only the data referring to the Annex I of the Directive can be provided according to the INSPIRE guidelines and tested for compliance. In the prototype implemented for this research, also the spatial data corresponding to the INSPIRE Annex 1 data themes has been used.

The problem of harmonization of geo-information in Europe has to be solved by common agreements on the data structure and content for the exchange on European level. Consistency within, but also between, data themes, scales (levels of details) and borders shall be

considered. A number of individual aspects of data interoperability has been identified. These aspects are known as data harmonization components or data interoperability components.

The following components call for standardization in the INSPIRE Data Specifications:
(A) INSPIRE principles,
(B) Terminology,
(C) Reference model,
(D) Rules for application schemas and feature catalogues,
(E) Spatial and Temporal aspects,
(F) Multi-lingual text and cultural adaptability,
(G) Coordinate referencing and units model,
(H) Object referencing modelling,
(I) Identifier management,
(J) Data transformation,
(K) Portrayal model,
(L) Registers and registries,
(M) Metadata,
(N) Maintenance,
(O) Quality,
(P) Data transfer,
(Q) Consistency between data,
(R) Multiple representations,
(S) Data capturing,
(T) Conformance.
('Draft Structure and Content of the Implementing Rules on Interoperability of Spatial Data Sets and Services', 2008)

All the above mentioned components shall be regarded in drafting particular INSPIRE Data Specifications. For the spatial data to be compliant with the harmonized model required by INSPIRE, all these aspects need to be taken into account. However, in the INSPIRE Network Services Architecture (2008), an important notification is made: "The logical schema of the spatial data set may and will often differ from the specification of the spatial object types in the data specification. In this case, and in the context of real-time transformation, a service will transform queries and data between the logical schema of the spatial data set and the published INSPIRE application schema on-the-fly. This transformation can be performed e.g. by the download service offering access to the data set or a separate transformation service."

The Guidelines for the encoding of spatial data (D2.7) specify the encoding rules for the data provided corresponding to the Annexes (I, II and III) of the INSPIRE Directive. All valid encoding rules given in the document conform to ISO 19118:2005 Geographic Information – Encoding standard. **The default encoding standard for the spatial data is ISO 19136:2007 – Geographic Information Markup Language.** ISO 19136 is an XML encoding in compliance with ISO 19118 for the transport and storage of geographic information modelled in accordance with the conceptual modelling framework used in the ISO 19100 series of International Standards and including both the spatial and non-spatial properties of geographic features. ISO 19136 is based on the Geography Markup Language (GML) specification developed by the Open Geospatial Consortium (OGC). Additional or alternative encoding rules may be specified for each application schema. For instance, for encoding of large datasets, GML is not efficient and an alternative, binary encoding may be needed to improve performance.

For the compliance as regards particular Spatial Data Themes, specific requirements and recommendations apply, as stated in the INSPIRE Data Specification documents. These requirements will not be examined in here in details, as it is out of scope of this research. The topic of the spatial data compliance to the INSPIRE requirements is also discussed in the chapter 5 – Prototype implementation.

4.3 Metadata

Metadata is, in simplest terms, „data about data or services". Metadata describing geographic datasets should include information about data formats and standards, reference systems, object types and their attributes, quality of data in terms of accuracy, precision and currency, data lineage, property rights, copyrights and conditions of access and use of the data. Metadata is crucial for the users of geographic information, since it helps them to find data fitting to their needs, recognize the informational scope and quality of the data and assess potential applications of the data. Metadata is useful not only for the users of geographic information but also for organizations responsible for handling the data, as it facilitates enormously the data management.

The metadata may relate not only to the spatial data but also to the services. The INSPIRE Directive states that the '*member states should provide descriptions of available spatial datasets and services in the form of metadata'* and '*ensure that that metadata are created for the spatial data sets and services corresponding to the themes listed in Annexes I, II and III, and that those metadata are kept up to date' (Article 5 (1))*. It also asks for the establishment of *'discovery services making it possible to search for spatial data sets and services on the basis of the content of the corresponding metadata and to display the content of the metadata' (Article 11 (1)).* Both dataset metadata and service metadata can be managed and searched using a catalogue service, or in terms of INSPIRE – a Discovery Service. This type of INSPIRE Network Service will be examined in more details in the next section (sub-section 4.4.1).

For the proper and effective use and interpretation of metadata, it is important that they should be standardized. ISO Technical Committee 211 (ISO/TC 211) Geographic Information/Geomatics has defined special standards on metadata for geographic information. The basic abstract norm defining the metadata model description is 'ISO 19115 Geographic information-Metadata'. Another ISO norm, 'ISO/CD TS 19139 Geographic information-Metadata-XML schema implementation' is a technical specification defining an implementation model for the abstract model described with ISO 19115, using UML (Unified Modeling Language) and corresponding XML Schema (XSD) for the data description. 'ISO 19119 Geographic Information – Services' is, in turn, a norm defining standards for geographic information services, including service architecture, service taxonomy, service chaining and, finally, service metadata model. Service metadata is specific type of metadata, describing service instances, their operations and properties.

The legal document regarding metadata and complementary to the INSPIRE Directive is the 'Commission Regulation (EC) No 1205/2008 of 3 December 2008 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards metadata', also known as 'INSPIRE Metadata Regulation'. According to the Article 1, the INSPIRE Metadata Regulation sets out the requirements for the creation and maintenance of metadata for spatial

data sets, spatial data set series and spatial data services corresponding to the themes listed in Annexes I, II and III to Directive 2007/2/EC. **The INSPIRE Metadata Regulation defines metadata elements or groups of metadata elements that shall be comprised by the metadata for spatial data sets, spatial data set series and spatial data services**, as well as sets out rules for the creation and maintenance of such metadata. Groups of metadata elements include: Identification, Classification of spatial data sets and services, Keywords, Geographic Location, Temporal Reference, Quality and validity, Conformity, Constraints related to access and use, Organizations responsible for the establishment, management, maintenance and distribution of spatial data sets and services and Metadata on metadata.

The INSPIRE Metadata Regulation defines the metadata profile on a general level, not bound to a concrete implementation specification. Specific rules for the implementation of the INSPIRE metadata profile have been defined in the 'INSPIRE Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119 (Revised edition)'. According to *Article 5(4)* of Directive 2007/2/EC, the INSPIRE Metadata Implementing Rules *'shall take account of relevant, existing international standards and user requirements in particular with relation to validation metadata'*. **In the context of the metadata for spatial data and spatial data services, the standards EN ISO 19115 and EN ISO 19119 have been identified as important standards.** The aim of the document with INSPIRE Metadata Implementing Rules is to define how the INSPIRE Metadata Regulation can be implemented using EN ISO 19115 and EN ISO 19119. In the Annex A of the document, the **XML ISO/TS 19139 encoding of INSPIRE metadata elements, based on XML Schemas derived from the UML models of ISO 19115 and ISO 19119 is defined.**

INSPIRE-compliant metadata shall follow the profile of ISO standards for metadata, in particular ISO 19115 and ISO 19119. However, the following remarks shall be made, as identified in the INSPIRE Metadata Implementing Rules after the process of standards mapping (comparison of the core requirements of ISO 19115 and INSPIRE):

• The conformance of an ISO 19115 metadata set to the ISO 19115 Core does not guarantee the conformance to INSPIRE;

• The use of these guidelines to create INSPIRE metadata ensures that the metadata is not in conflict with ISO 19115. However, full conformance to ISO 19115 implies the provision of additional metadata elements which are not required by INSPIRE.

The details of the profile for INSPIRE-compliant metadata, including the obligatory and optional metadata components, can be derived from the document on INSPIRE Metadata Implementing Rules.

For the users of geographic information, an INSPIRE metadata editor (http://www.inspire-geoportal.eu/InspireEditor) has been made available through the INSPIRE Geoportal. The INSPIRE Metadata editor makes it possible to create INSPIRE compliant metadata and to download it as an XML file.

Detailed examination of elements of INSPIRE-compliant metadata is out of scope in this research. Some information on the metadata is also provided in the chapter 5 describing the prototype implementation, as simple metadata descriptions have been created for specific spatial datasets used for the prototype.

4.4 Network Services

The INSPIRE Directive [2007/2/EC] defines five types of web services that shall be implemented within the framework of the INSPIRE infrastructure. In the nomenclature of INSPIRE, these are Network Services. The following services shall be implemented: Discovery Service, View Service, Download Service, Transformation Service, Invoke Service.

Specific INSPIRE Network Services, as enlisted in the text of the Directive 2007/02/EC (see: *Article 11*), have their interfaces and operations defined in several documents. The framework for all INSPIRE Network Services is defined by the INSPIRE Network Architecture (2008) and, as regards the SOA-based architecture, by the INSPIRE SOAP Framework (2008).

As regards the legal acts regulating the implementation of INSPIRE services, the 'INSPIRE Discovery and View Services Regulation' (EC 976/2009) was adopted by the Commission on the 19 October 2009. The regulation has been published in the Official Journal of the European Union and entered into force on the 20th day following its publication. The 'Draft Commission Regulation amending Regulation (EC) No 976/2009 as regards download services and transformation services' was adopted by the Commission on the 23 November 2009.

Implementing Rules (IR) – version 3.0 and Technical Guidance (TG) documents – version 2.0 are already available for the Discovery, View, Download and Transformation Services. For the Transformation Services, the available Technical Guidance document relates only to the Coordinate Transformation Services. Almost no work has been done on Invoke Spatial Data Services (no IR and TG available; only preliminary surveys). The state presented is as of February 2010.

A special emphasis in this research has been put on INSPIRE View and Download Services. This applies to the conceptual study (sub-sections 4.4.2, 4.4.3) and, in particular, to the prototype implementation (chapter 5). The prototype implements OGC WMS and WFS services (based on standard REST protocol bindings; not within the SOAP framework) using a small subset of spatial data from the Narew National Park (park borders, communes, rivers and streams, wells). In chapter 5, a discussion is made on the compliance of the prototype with the INSPIRE Download and View Services guidelines. Furthermore, in this section of the conceptual study (identification of the guidelines) extended information is also provided on Discovery Services (sub-section 4.4.1). Transformation Services (sub-section 4.4.4) and Invoke Services (sub-section 4.4.5) are described briefly.

4.4.1 Discovery Service

The INSPIRE Directive [2007/2/EC] asks Member States to *'establish and operate a network of services'* for the discovery of spatial data sets and services *'for which metadata have been created'*. Discovery services should *'make it possible to search for spatial data sets and services on the basis of the content of the corresponding metadata and to display the content of the metadata. […] Those services shall take into account relevant user requirements and shall be easy to use, available to the public and accessible via the Internet or any other appropriate means of telecommunication' (Article 11(1)). Member States shall ensure that the services referred to in points (a) and (b) of Article 11(1)* (discovery services and view services) *are available to the public free of charge (Article 14(1))*.

One of the capabilities of the discovery service shall be also a mechanism to enable public authorities to make their dataset metadata and services metadata available on the Internet (linked to the infrastructure and operable). The INSPIRE Directive specifies that the *'Member States shall ensure that public authorities are given the technical possibility to link their spatial datasets and services to the network' (Article 12)*. This requirement applies to all types of INSPIRE Network Services including the discovery services.

Fig. 20 INSPIRE and ISO-compliant Discovery Service – example from the geoportal of Krkonoše/Karkonosze National Parks (Czech Republic/Poland)
(http://mapy.krnap.cz/metadata/index.php?project=micka&)

Summarizing, INSPIRE-compliant Discovery Services (Fig.20), shall be used to support discovery, evaluation and use of spatial data and services through their metadata properties (Fig.21). Discovery services are also referred to within the GI community as: catalogue services, spatial data directories, clearinghouses, geographic catalogues or geodata discovery services (Draft Implementing Rules for INSPIRE Discovery Services, v.3.0).

Fig. 20 presents an interface of the INSPIRE and ISO-compliant Discovery Service of Krkonoše/Karkonosze National Parks (Czech Republic/Poland). This Discovery Service offers the following predefined profiles: ISO 19115 mandatory elements, ISO 19115 core elements, INSPIRE profile, 'MICKA' profile (INSPIRE elements with added ones for common use, ISO/DC (ISO 19115 elements covering the ISO 15836 Dublin Core profile), Full ISO 19115 standard.

The INSPIRE Discovery Service shall be in conformance with the requirements and characteristics set out in Annex II of 'The INSPIRE Discovery and View Services Regulation' (Commission Regulation (EC) No 976/2009 of 19 October 2009 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the network services). The requirements for Discovery Services are strictly bound to the INSPIRE Metadata requirements, since the metadata profile reflects the functionality of the catalogue/discovery services used for the metadata search an management.

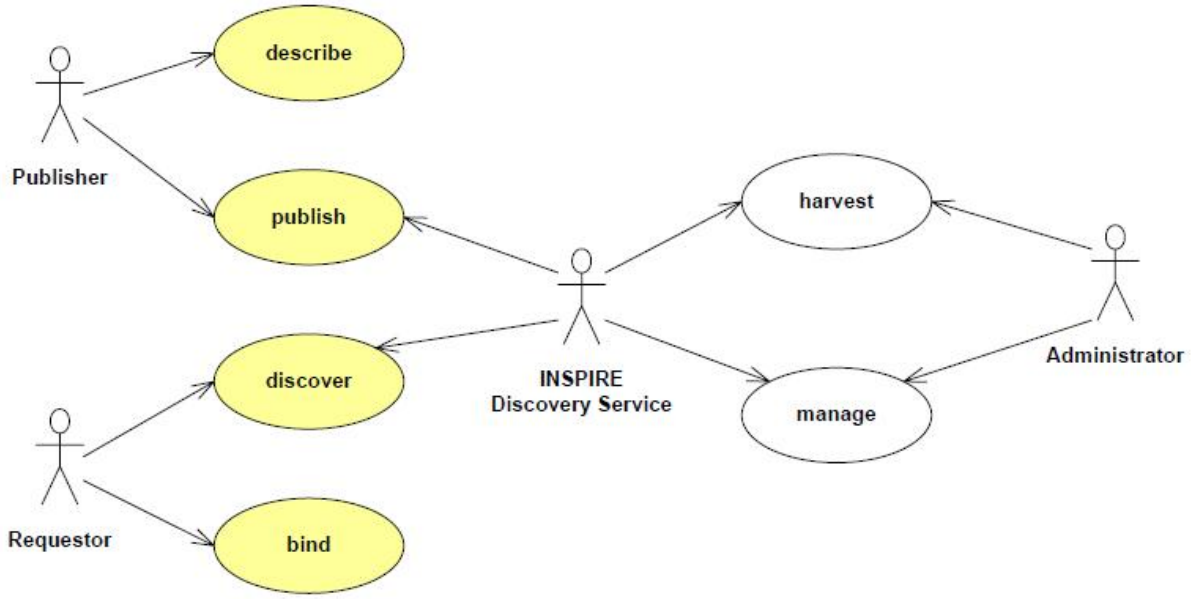


Fig.21 INSPIRE Discovery Service use cases
(Draft Technical Guidance Document for INSPIRE Discovery Services, v.1.0)

The basic requirements for the Discovery Services concern the metadata search criteria that shall be available and the service operations along with their request and response parameters.

The Discovery Service Implementing Rules do not cover any client application using a Discovery Service. Client application definition is out of scope.

In order to be in conformity with the minimum set of search criteria set out in *Article 11(2)* of the Directive 2007/2/EC, **the Discovery Service shall support searches with the INSPIRE metadata elements listed in Table 1.**

Minimum search criteria	**INSPIRE metadata elements**
keywords	Keyword
classification of spatial data and services; (For spatial data sets and spatial data set series)	Topic category
classification of spatial data and services (For spatial data services)	Spatial data service type
the quality and validity of spatial data sets	Lineage
the quality and validity of spatial data sets	Spatial resolution
degree of conformity with the implementing rules provided for in Article 7(1) of Directive 2007/2/EC	Specification

Minimum search criteria	INSPIRE metadata elements
degree of conformity with the implementing rules provided for in Article 7(1) of Directive 2007/2/EC	Degree
geographical location	Geographic bounding box
conditions applying to the access to and use of spatial data sets and services	Conditions applying to access and use
conditions applying to the access to and use of spatial data sets and services	Limitations on public access
the public authorities responsible for the establishment, management, maintenance and distribution of spatial data sets and services	Responsible party
the public authorities responsible for the establishment, management, maintenance and distribution of spatial data sets and services	Responsible party role

Table 1 - Discovery Service search criteria
('The INSPIRE Discovery and View Services Regulation' (EC 976/2009), Annex II)

Apart from the criteria listed in Table 1, **the following INSPIRE metadata elements or set of elements shall be also available as search criteria:**
(a) Resource Title;
(b) Resource Abstract;
(c) Resource Type;
(d) Unique Resource Identifier;
(e) Temporal Reference.

To allow for discovering resources through a combination of search criteria, logical and comparison operators shall be supported. To allow for discovering resources based on the geographic location of the resource, the spatial operator 'Intersects' shall be supported. The spatial operator 'Intersects' requires the Geographic Bounding Box INSPIRE metadata element to intersect a defined Area of Interest.
('The INSPIRE Discovery and View Services Regulation' (EC 976/2009), Annex II)

In order to be in conformity with *Article 11(1)* and *Article 12* of the Directive 2007/2/EC, the Discovery Service shall provide the operations listed in Table 2.

Operation	Role
Get Discovery Service Metadata	Provides all necessary information about the metadata discovery service and describes service capabilities.
Discover Metadata	The Discover Metadata operation allows requesting INSPIRE metadata elements of resources based on a query statement to be retrieved from the target Discovery Service.
Publish Metadata	The Publish Metadata operation allows to edit INSPIRE metadata elements of resources in the Discovery Service (push or pull metadata mechanisms). Editing meaning insert, update and delete
Link Discovery Service	The Link Discovery Service function allows the declaration of the availability of a Discovery Service for the Discovery of resources through the Member State Discovery Service while maintaining the resource metadata at the owner location

Table 2 – Discovery Service operations
('The INSPIRE Discovery and View Services Regulation' (EC 976/2009), Annex II)

The requirements given above as regards the specifications for Discovery Services are defined only on abstract, conceptual level. Instructions to implement a Discovery Service according to the current technology and existing standards have been given in a separate document: Technical Guidance for INSPIRE Discovery Services (v.2.0). For the specific Quality of Service (QoS) requirements for the Discovery Services - refer to section 4.5 of this thesis.

According to the Technical Guidance for INSPIRE Discovery Services, v.2, **the base specification of an INSPIRE Discovery Service is OpenGIS Catalogue Services Specification 2.0.2 - ISO Metadata Application Profile for CSW 2.0 [CSW ISO AP]**. The OGC Catalogue Services Specification [CSW ISO AP] defines common interfaces to discover, browse, and query metadata about geographic data and services. In the OGC Catalogue Services Specification basic operations are defined in three classes: *service operations* which are operations a client may use to interrogate the service to determine its capabilities; *discovery operations* which a client may use to determine the information model of the catalogue and query catalogue records; and *management operations* which are used to create or change records in the catalogue. The basic operations include: GetCapabilities, DescribeRecord, GetDomain, GetRecords, GetRecordByID, Transaction and Harvest. [CSW ISO AP] as the fundamental implementation specification for the INSPIRE Discovery Services is based on the ISO 19115 information model for dataset metadata and the ISO 19119 information model for service metadata.

Although the [CSW ISO AP] specification lays down the basic behaviour of an INSPIRE Discovery Service some aspects needed to be extended with respect to the requirements of the INSPIRE Directive and the INSPIRE Metadata Regulation (EC) No 1205/2008. These aspects are: Discovery Service Operations, Discovery Service Queryables (search criteria), Multilingual Aspects. Particular sections of the Technical Guidance for INSPIRE Discovery Services (v.2.0) specify required extensions to the given specifications.

An INSPIRE Discovery Service shall implement the SOAP binding for all discovery service operations as defined in [CSW ISO AP]. In addition to [CSW ISO AP] the SOAP binding for the GetCapabilities operation shall be implemented for the INSPIRE Discovery service**. An INSPIRE Discovery Service shall describe its interface in a WSDL document conforming to WSDL 1.1.** A sample WSDL document describing the INSPIRE Discovery Service interface can be found at http://schemas.opengis.net/csw/2.0.2/examples/wsdl/2.0.2 (Technical Guidance for INSPIRE Discovery Services, v.2.0).

For the INSPIRE Discovery Service, and for the View Service, an additional guidance document has been provided. SOAP Primer for INSPIRE Discovery and View Services (2009) demonstrates the use of the proposed INSPIRE SOAP Framework for the INSPIRE Discovery and View services. The SOAP Primer focuses on the analysis of the WSDL itself (for both the Discovery and View services), explaining its parts and characteristics, as well as on the analysis of SOAP request and response messages, including headers and potential attachments. Moreover, the SOAP Primer is providing examples of user scenarios, with specific code samples. Proposals for the documentation of the communication of the View and Discovery Service using the Web Service Description Language are also available via the INSPIRE website.

4.4.2 View Service

The INSPIRE Directive [2007/2/EC] asks Member States to establish and operate *'view services making it possible, as a minimum, to display, navigate, zoom in/out, pan or overlay viewable spatial data sets and to display legend information and any relevant content of metadata.[…] Those services shall take into account relevant user requirements and shall be easy to use, available to the public and accessible via the Internet or any other appropriate means of telecommunication' (Article 11(1).*

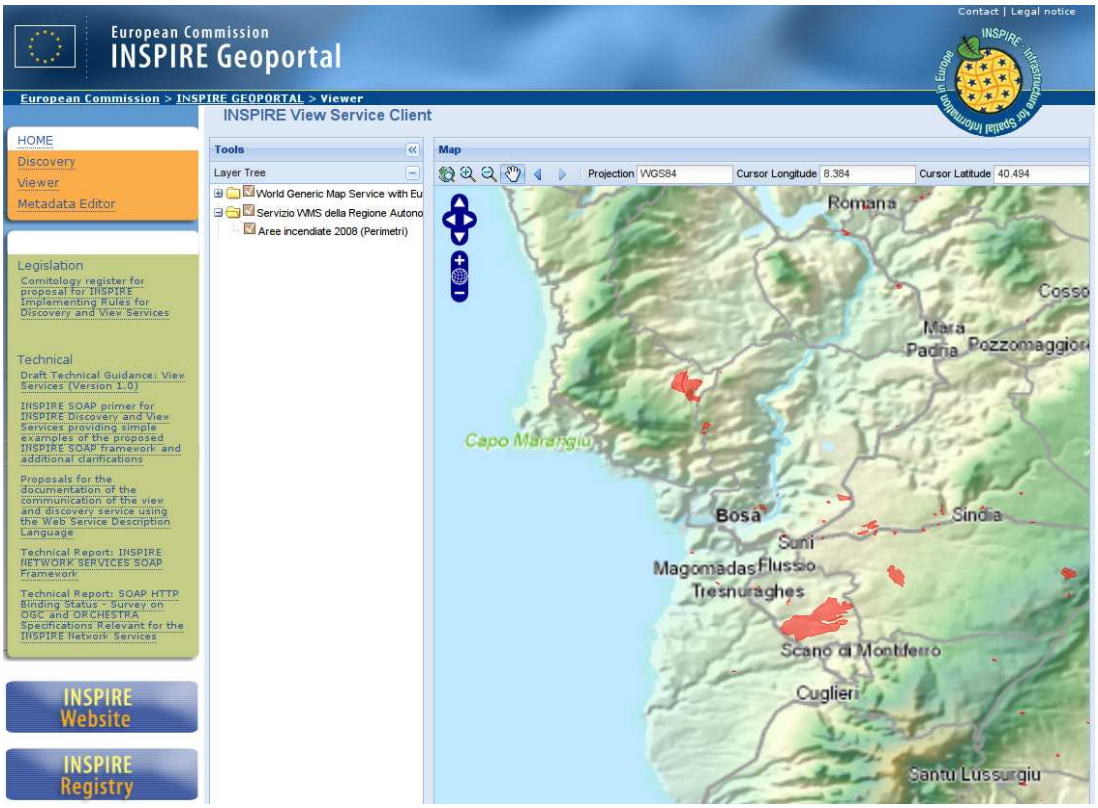


Fig.22 INSPIRE View Service – request map result in a client application (INSPIRE Geoportal)
(http://gallery.osgeo.org/images/MapFish_EUJRC.png)

INSPIRE View Service, or – in other terms – a map service, is a web service to provide a visual representation of geographic (reference and thematic) information by creating a spatially-referenced image (a map) of these data using specific styling/portrayal rules (Fig.22). The geo-referenced data provided through the INSPIRE View Service should belong to the themes covered by the INSPIRE Directive annexes. This spatial data shall be compliant with INSPIRE Data Specifications. With the View Service it should be possible for the user to retrieve the services metadata, browse the maps composed of the chosen data and, to retrieve attribute information about particular features displayed on these maps (Fig.23).

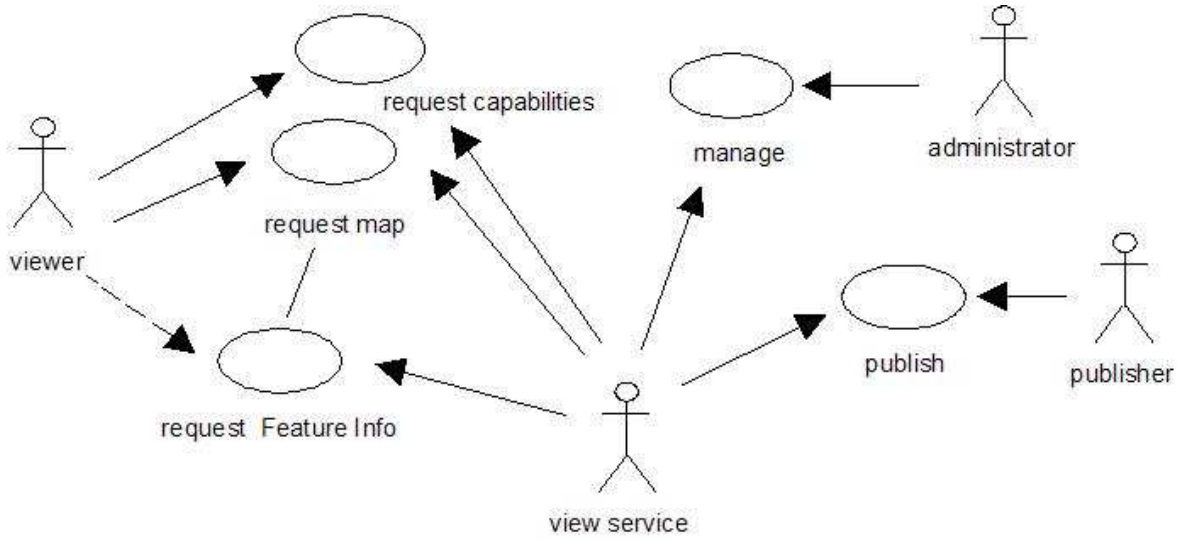


Fig.23 INSPIRE View Service use cases
(Technical Guidance to implement INSPIRE View Services, v.2.0)

As stated in the *Article 14(1*) of the INSPIRE Directive [2007/2/EC]: '*Member States shall ensure that the services referred to in points (a) and (b) of Article 11(1)* (discovery services and view services) *are available to the public free of charge)*. In the context of the view services the INSPIRE Directive also mentions that the *'Member States may allow a public authority supplying a service […] to apply charges where such charges secure the maintenance of spatial datasets and corresponding data services, especially in cases involving very large volumes of frequently updated data. Data made available through the view services referred […] may be in a form preventing their reuse for commercial purposes' (Article 14(2,3))*.

The INSPIRE View Service shall be in conformance with the requirements and characteristics set out in Annex III of the Commission Regulation (EC) No 976/2009 of 19 October 2009 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the network services ['The INSPIRE Discovery and View Services Regulation'].

The basic requirements for the Discovery Services concern the service operations along with their requests and request parameters, as well as other specific characteristics of the services and the data served by the means of these services.

The View Service Implementing Rules do not cover any client application using a View Service. Client application definition is out of scope.

In order to be in conformity with *Article 11(1)* and *Article 12* of the Directive 2007/2/EC, the View Service shall provide the operations listed in Table 3.

Operation	Role
Get View Service Metadata	Provides all necessary information about the service and describes service capabilities.
Get Map	Returns a map containing the geographic and thematic information coming from the available spatial datasets. This map is an image spatially referenced.
Link View Service	Allows a Public Authority or a Third Party to declare a view Service for the viewing of its resources through the Member State View Service while maintaining the viewing capability at the Public Authority or the Third party location.

Table 3 - View Service operations
('The INSPIRE Discovery and View Services Regulation' (EC 976/2009), Annex III)

The following request and response parameters shall be available for particular View Service operations:

Get View Service Metadata operation

Get View Service Metadata request

Get View Service Metadata request parameters

The Get View Service Metadata request parameter indicates the natural language requested for the content of the Get View Service Metadata Response

Get View Service Metadata response Parameters

The Get View Service Metadata Response shall contain the following set of parameters:

- View Service Metadata
- Operations Metadata
- Languages
- Layers Metadata.

View Service Metadata Parameters

The View Service Metadata parameters shall at least contain the INSPIRE metadata elements of the View Service (e.g. Resource title, Abstract, Resource type, Keywords, Conditions on access and use, Limitations on public access, Responsible organization)

Operations Metadata parameters

The Operation Metadata parameter describes the operations of the view Service and shall contain as a minimum a description of the data exchanged and the network address of each operation.

Languages Parameters

Two language parameters shall be provided:

- the Response Language parameter indicating the natural language used in the Get Service Metadata Response parameters
- the Supported Languages parameter containing the list of the natural languages supported by this service.

Layer Metadata Parameters

The metadata elements / layer specific parameters listed in Table 4 shall be provided for each layer.

Metadata element	**Description**
Resource Title	The title of the layer, used for human communication, for presentation of the layer e.g. in a menu
Resource Abstract	Layer abstract
Keyword	Additional Keywords
Geographic Bounding Box	The minimum bounding rectangle in all supported Coordinate Reference Systems of the area covered by the Layer.
Unique Resource Identifier	The Unique Resource Identifier of the resource used to create the layer.
Name	Harmonized name of the layer
Coordinate Reference Systems	List of Coordinate Reference Systems in which the layer is available.
Styles	List of the rendering styles available for the layer. A Style shall be composed of a title and a Unique Identifier.
Legend URL	Location of the legend for each style, language and dimension pairs.
Dimension Pairs	Indicates the supported two dimensional axis pairs for multi dimensional spatial data sets and spatial data sets series

Table 4 – Get View Service Metadata operation – metadata elements
('The INSPIRE Discovery and View Services Regulation' (EC 976/2009), Annex III)

Get Map Operation

Get Map Request

Get Map request parameters

The Get Map request parameters listed in Table 5 shall be provided.

Parameter	**Description**
Layers	List of layer names to be included in the map (incl. ordering of the layers)
Styles	List of style to be used for each layer.
Coordinate Reference System	Coordinate Reference System of the map.
Bounding box	The 4 corner Coordinate of the two dimensional map for the selected Dimension pair and in the selected Coordinate Reference System
Image width	The map width in pixels

Image height	The map height in pixels
Image format	The output image format.
Language	language to be used for the response
Dimension Pair	The two dimensional axis to be used for the map For example a geographical dimension and time

Table 5 – Get Map request parameters
('The INSPIRE Discovery and View Services Regulation' (EC 976/2009), Annex III)

Link View Service Operation

Link View Service Request

Link View Service Request Parameter

The Link View Service parameter shall provide all information about the Public Authority's or Third Party's View Service compliant with this regulation, enabling the Member State View Service to get a map from the Public Authority's or Third Party's View Service and to collate it with other maps.

The View Service shall also have the following characteristics:

1. Coordinate Reference Systems

The layers shall be simultaneously viewed using a single Coordinate reference system and the View Service shall support at least the Coordinate Reference Systems in Annex I, point 1 of Directive 2007/2/EC

2. Image Format

The View Service shall support at least one of the following image formats:

- the Portable Network Graphics (PNG) format;
- the Graphics Interchange Format (GIF), without compression.

Other types of file formats supported by WMS (Web Map Service), e.g. GML files, are also acceptable in the context of INSPIRE View Service.

The operations, operation requests and parameters given above have been derived from the Commission Regulation (EC) No 976/2009 of 19 October 2009 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the network services ['The INSPIRE Discovery and View Services Regulation']. The document with Draft Implementing Rules for INSPIRE View Services (v.3.0) defined more detailed requirements for the INSPIRE View Service. The requirements concern the View Service functions and their request and response parameters. **Furthermore, the Implementing Rules provide requirements for the following elements of View Services:**

- Nature of the Metadata
- Coordinate Reference System
- Temporal data dimension
- Other dimensions selection and display
- Output Format
- Datasets and Layers
- Styling

- Legend availability and handling
- Useful scale range
- Multilingualism
- Geo Rights Management.

Quality of View Service requirements are also within the scope of Implementing Rules. For the specific Quality of Service (QoS) requirements for the View Services - refer to section 4.5 of this thesis.

An additional (optional) operation defined in the Implementing Rules, that can be implemented in the View Service is 'Get Feature Information' which returns information about the features displayed on the map at the point selected by the user. According to the Implementing Rules the extension for this operation may be chargeable (in reference to the *Article 14* of the Directive). Unfortunately the required request and response parameters for 'Get Feature Information' operation have not been defined in the Implementing Rules nor in 'The INSPIRE Discovery and View Services Regulation'.

According to the Technical Guidance to implement INSPIRE View Services (v.2.0), the **'ISO 19128:2005(E) : Geographic Information — Web map server interface' standard has been identified as the most relevant standard to implement INSPIRE View Services** on the grounds of its stability and widespread use.

The ISO 19128:2005: Geographic Information — Web map server interface standard is based on the Web Map Service (WMS) standard developed by the Open Geospatial Consortium. The OpenGIS Web Map Service (WMS) Implementation Specification can be found at: http://www.opengeospatial.org/standards/wms (the most current complete Implementation Specification – WMS 1.3.0). The OpenGIS Web Map Service Interface Standard (WMS) provides a simple HTTP/HTTPS interface (protocol) for requesting georeferenced map images from one or more distributed spatial databases. A WMS Get Map request defines the thematic layer(s) of geographic data and the area of interest to be processed. Other parameters include the desired coordinate reference system, and the output image width and height. The response to the request is one or more georeferenced map images that can be displayed in a browser application. A composite map can be created from several map layers which cover the same area. A result map image of WMS is a rendered representation of the actual vector data. WMS-produced maps are generally rendered in a raster pictorial format such as PNG, GIF or JPEG, or occasionally as vector-based graphical elements in Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (WebCGM) formats.

Web Map Service operations can be invoked using a web browser by submitting requests in the form of Uniform Resource Locators (URLs). Three types of standard operations are available:

- GetCapabilities - returns service-level metadata (parameters of the WMS and the available layers)
- GetMap – returns a map image with geographic and dimensional parameters as requested
- GetFeatureInfo (optional) – returns information about particular features shown on a map.

The major advantage of the Web Map Service (WMS) is that it defines a simple standard which enables the creation of a network of distributed map servers from which clients can build customized maps.

According to the Technical Guidance for implementation of INSPIRE View Services (v.2.0), **the mandatory operations for the INSPIRE View Service are mapped into the ISO 19128 (WMS) operations in the following way (Table 6):**

INSPIRE View Service operations	ISO 19128:2005 WMS operations
Get Service Metadata	Get Capabilities
Get Map	Get Map
Link View Service	Use Discovery Service, "Discover Metadata" operation

Table 6 Mapping INSPIRE View Service operations to ISO 19128:2005 WMS operations
(Technical Guidance for implementation of INSPIRE View Services (v.2.0))

Two other OGC de facto standards for the portrayal of geographic information are associated with the ISO 19128:2005 (WMS), and are **supplementary specifications for the implementation of INSPIRE View Services:**

- **'OpenGIS Styled Layer Descriptor Profile of the Web Map Service Implementation Specification'** (05-078r4) and its corrigendum1 for OGC Implementation Specification SLD 1.1.0 (07-123r1). Styled Layer Descriptor (SLD) used with the Web Map Service (WMS) makes it possible to for the client to retrieve feature data and apply explicit user-defined styling and symbolization in order to render a map. This is different from the basic WMS profile which permits to classify geographic information into "Layers" and offers only a finite number of predefined "Styles" in which to display those layers.
- **'OpenGIS Symbology Encoding Implementation Specification'** (05-077r4), which is a language used for styling feature and coverage data, and independent of any service interface specification.

These two implementation specifications are complementary in the context of INSPIRE View Service. Their use is recommended however if the user does not specify the style, then default style defined for the portrayal of specific layer will be used

Although the ISO 19128 (WMS) specification, along with the supplementary OGC specifications, lays down the basic behaviour of an INSPIRE View Service, some aspects needed to be extended or profiled with respect to the requirements of the INSPIRE Directive and the Implementing Rules for View services. **The required extensions to the given specifications have been defined in the document with Technical Guidance for implementation of INSPIRE View Services (v.2.0).**

The extension is needed in particular for the use of SOAP messaging protocol (an alternative to standard WMS relying on RESTful protocol bindings). As ISO 19128:2005(E) does not define a SOAP binding, the use of SOAP, according to the INSPIRE Network Services Architecture is defined in the 'SOAP Primer for INSPIRE Discovery and View Services' (2009) and the 'Proposals for the documentation of the communication of the View and Discovery Service using the Web Service Description Language' (2009).

As stated in the ISO 19128:2005(E) standard support for the HTTP GET method is mandatory, the use of the GET method is recommended for the view service operations. In order to make provisions for the SOAP framework, the use of the HTTP POST method is recommended once a decision is taken on the use of the SOAP protocol, this decision shall be

recorded in further amendments of the 'Technical Guidance for implementation of INSPIRE View Services' document (still pending at the moment of writing). **The following profiles are recommended for an INSPIRE-compliant View service implementation :**

- **Basic profile:** support of GET method for the "Get Service Metadata", "Get Map" and "Link View Service"
- **Standard profile:** basic profile and support of the GetFeatureInfo operation through the GET method
- **SOAP profile:** basic profile plus support of the SOAP/POST method for the three mandatory View service operations
- **Advanced SOAP profile:** SOAP profile plus support of the GetFeatureInfo operation through the SOAP/POST method.

4.4.3 Download Service

Download Services shall be established within the INSPIRE infrastructure *'to enable copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly' [...] 'Those services shall take into account relevant user requirements and shall be easy to use, available to the public and accessible via the Internet or any other appropriate means of telecommunication'* (INSPIRE Directive [2007/2/EC], *Article 11(1)*). According to the *Article 14(2,3)* of the INSPIRE Directive, in particular cases charges may be applied for the use of Download Services and the available data may be in a form preventing their reuse for commercial purposes.

An INSPIRE Download Service is a web service that provides access to geographic information in data sets belonging to the themes covered by the INSPIRE Directive Annexes (I, II, III) and to the spatial objects conforming to spatial object types specified by the 'INSPIRE Implementing Rules on the interoperability of spatial data sets and services' (2009). The basic documents defining the requirements and recommendations for INSPIRE Download Services are: Draft Implementing Rules for INSPIRE Download Services (v.3.0, 2009) (abstract level guidelines) and Draft Technical Guidance for INSPIRE Download Services, (v.2.0, 2009) (technical implementation guidelines).

The Draft Implementing Rules for INSPIRE Download Services (v.3.0) document defines two basic types of Download Services - download services for pre-defined datasets or pre-defined parts of datasets (Fig.24), **and direct access download services including a query capability** (Fig.25). While with the former it is only possible to download predefined datasets (or parts of datasets), the latter allow to download selections of spatial objects based upon a query (typically from a spatial database). Five basic functions of Download Services are defined and described in details. These are: Get Download Service Metadata, Get Spatial Objects, Describe Spatial Object Types, Define Query, and Link Download Service. Define Query function is only applicable to the direct access Download Services. Describe Spatial Object Types function is mandatory for the direct access download services and optional for the download services for pre-defined datasets or parts of datasets. All other functions are mandatory in both cases.

The mandatory and optional functions for both direct access and non-direct access download services are defined as in Table 7:

Function	Description	non-direct access	direct access
Get Download Service Metadata	Provides metadata about the service and data sets offered by the service to a user and describes service capabilities. Shall at least contain the INSPIRE metadata elements defined for spatial data services as described by the Metadata Implementing Rule.	M	M
Get Spatial Objects	The Get Spatial Objects operation allows spatial object instances to be retrieved. In the case of non-direct access, the operation will retrieve a predefined data set or a pre-defined part of a data set. In the case of download service of a pre-defined data set or predefined part of data set, the operation shall return spatial objects in at least one of the CRSs defined by the Implementing Rule the Annex 1 theme coordinate reference systems. In the case of direct access, the retrieval can be based on an optional query defined by the Define Query operation. The operation shall support user requested CRS belonging to the INSPIRE defined CRSs.	M	M
Describe Spatial Object Types	The Describe Spatial object Type operation generates a description of the spatial object types that the service offers. In the case of download service of a pre-defined data set or predefined part of data set, the function shall return the description of the complete set of spatial object types contained in the data set or part of data set. In the case of a direct access download service, the function can have as parameter a set of named spatial object types for which the description is requested.	O	M
Define Query	Defines a query to be used in the Get Spatial Objects operation. This function is applicable only in the case of direct access download service. The predicates shall express selection criteria based upon the model of the data sets as defined by an INSPIRE Implementing Rule on the interoperability of spatial data sets and services. The capability to define a query is mandatory, but a query can be omitted in a concrete Get Spatial Objects request.	n.a.	M
Link Download Service	Allows the declaration of a Download Service for downloading of its resources through the Member State Download Service while maintaining the downloading capability at the Public Authority or the Third party location.	M	M

M – mandatory; O – optional; n.a. – not applicable

Table 7 – Download services functions
(Draft Implementing Rules for INSPIRE Download Services, v.3.0)

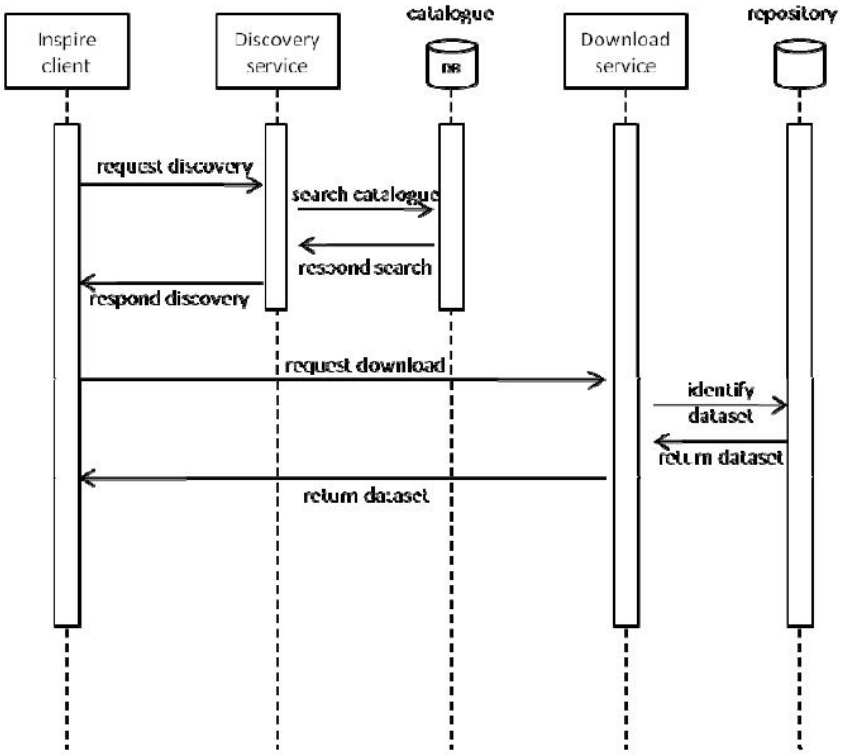


Fig.24 Simple sequence diagram of download service for pre-defined data sets or pre-defined parts of data sets
(Draft Technical Guidance for INSPIRE Download Services, v.2.0)

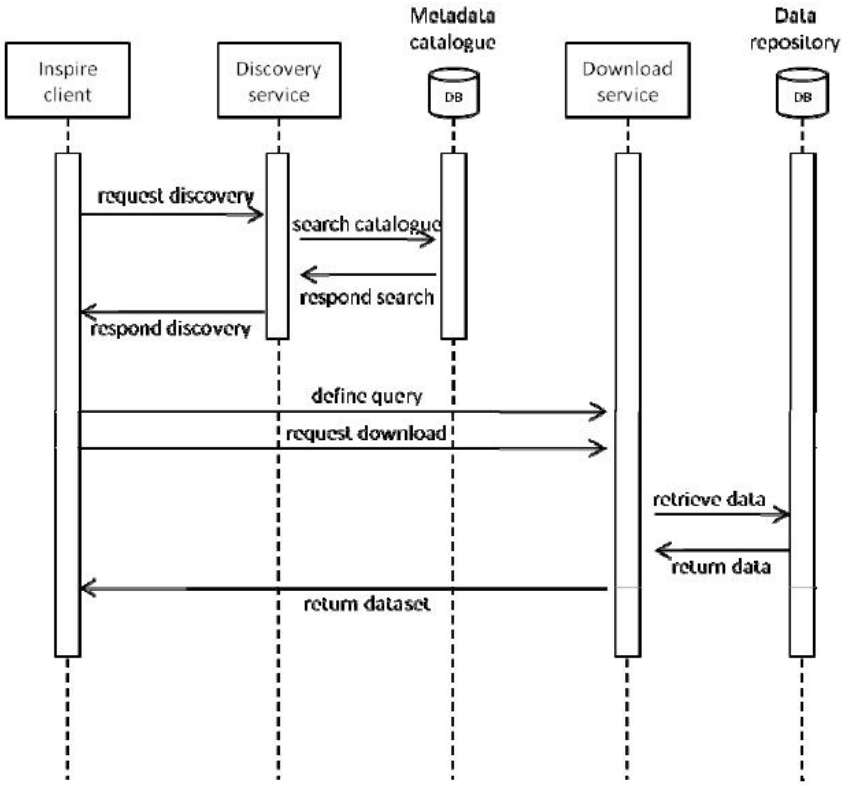


Fig.25 Simple sequence diagram illustrating direct access download service, (not all operations are described in this diagram)
(Draft Technical Guidance for INSPIRE Download Services, v.2.0)

The other aspects discussed in the Implementing Rules are: nature of the metadata, coordinate reference systems, temporal data dimension, download output format, multingualism, geo rights management. Finally, specific requirements for quality of Download Services are defined. For the Quality of Service (QoS) requirements for the Download Services, the section 4.5 of this thesis shall be referred to.

The Draft Technical Guidance for INSPIRE Download Services (v.2.0) provides guidelines for the technical service interfaces for the INSPIRE Download Services. The guidelines are based on the abstract model established in the Draft Implementing Rules for INSPIRE Download Services. **In the case of download services for pre-defined datasets, simple HTTP protocol can be used for data download (HTTPS for secure connection) and GML as described in ISO 19136 for data encoding. The data download through the Web Feature Service (WFS), as specified in ISO/DIS 19142 is also possible.** The CRS shall be conforming to the implementing rule for Annex I Coordinate reference systems. The data set can be transformed to another CRS by applying an INSPIRE conformant transformation service if required.

Direct access download services are a more advanced type, in which case the geographic data is typically stored in a repository (e.g. a database) and accessible only through middleware. The client application interacts directly with the repository e.g. retrieving parts of the repository based upon a query. **It is recommended to implement the direct access download services using the Web Feature Service, (WFS), as specified in ISO/DIS 19142, and with the query capabilities based on Filter Encoding (FE) standard, as specified in ISO/DIS 19143.** These versions of WFS and FE are jointly developed by OGC and ISO/TC 211, and represent the latest versions of the specifications. WFS and FE have the capability of serving all download service requirements for the data corresponding to the Annex I themes of the INSPIRE Directive. If later data specifications relating to Annex II or Annex III themes should require additional functionality, like those covered by the OGC Web Coverage Service (WCS), extensions to the Technical Guidance document will be given. For more details on the technical implementation of the Download Service, the Draft Technical Guidance for INSPIRE Download Services (v.2.0) shall be referred to.

An implementation of Download services using WFS, shall conform to WFS conformance classes according to the Draft Technical Guidance for INSPIRE Download Services (v.2.0). In the Technical Guidance document several conformance classess are defined using RESTful protocols and SOAP bindings. The server shall conform to at least one of the HTTP GET, HTTP POST or SOAP conformance classes. It is mandatory for the server to handle SOAP (implementation of XML encoded requests and results within SOAP envelopes).

4.4.4 Transformation Service

Transformation Services shall be established *'to enable spatial data sets to be transformed with a view to achieving interoperability'* (INSPIRE Directive [2007/2/EC], *Article 11(1)*). A Transformation Service is usually not to be made directly accessible for the general public. Transformation of the spatial data model 'on a fly' through a Transformation Service is an alternative for a permanent adaptation of the existing non-INSPIRE-conformant spatial data sets to the theme-specific INSPIRE data model. This implies that Transformation Service has an especially important role in the context of the Download Service, as a tool for achieving

data conformity on the service level through transformed data sets. A Transformation Service can be also potentially combined with the other INSPIRE content access service types: Discovery and View and Services, to make them interoperable according to the established Implementing Rules.

The basic documents defining the requirements and recommendations for INSPIRE Download Services are: Draft Implementing Rules for INSPIRE Transformation Services, version 3.0 (abstract level guidelines) and Draft Technical Guidance for INSPIRE Coordinate Transformation Services, version 2.0 (technical implementation guidelines).

The Draft Implementing Rules for INSPIRE Transformation Services, v.2.0 document defines main transformation types that a Transformation Service could perform in the INSPIRE service context. These are: file format transformations, language translations, geometric transformations and schema translations. In future concrete Technical Guidance documents shall be compiled for different transformation types, as seen appropriate. The Implementing Rules define common transformation operations for all transformation types. These are: Get Service Metadata, Transform, Is Transformable, Get Transformation, Put Transformation. In the document, specific Quality of Service (QoS) requirements for Transformation Services are also defined (see also: section 4.5 of this thesis). For the moment of writing of this thesis (February 2010), a Draft Technical Guidance document has been published only for the geometric transformations, and more precisely for its subcategory – coordinate transformations (Draft Technical Guidance for INSPIRE Coordinate Transformation Services, v.2.0).

The Technical Guidance document incorporates the only mandatory operation Transform defined in the OGC Discussion Paper 'Web Coordinate Transformation Service' (WCTS) as an Application Profile of the OGC Implementation Specification 'Web Processing Service' (WPS). The IsTransformable operation of the WCTS is implemented as an optional parameter of the main transformation operation. All other optional operations of the WCTS interface are omitted. WPS defines a generic Web-based processing service interface for geodata. Specific processes can be specified as Application Profiles (AP) of the WPS. It has been decided to define the INSPIRE Coordinate Transformation Service by specifying the WCTS's Transform operation as an AP of the WPS specification.

4.4.5 Invoke Service

Invoke Services, that are thought as a chaining mechanism between other types of services, have not yet been discussed in details in the documents prepared by the INSPIRE Drafting Teams. Implementation Rules and Technical Guidance documents are still to be developed. However, the 'INSPIRE Invoke Services: Survey on requirements, challenges and recent research findings supporting the development of the Invoke spatial data service specification' (2009) has been published. This study investigates the requirements and challenges for the development of INSPIRE Invoke services specifications. Invoke services provide a mean for invoking INSPIRE spatial data services, therefore the dependencies between the Invoke services and other INSPIRE network services are reflected in this study. In particular, the issue of spatial data service interoperability arrangements is considered.

Technical solutions for the implementation of the Invoke Services are discussed as well. WS-BPEL (Web Services Business Process Execution Language), developed by OASIS[5], is a web services orchestration technology advised to be used by the INSPIRE Invoke Services. WS-BPEL is requiring the WSDL description for all the services involved in the workflow and for the workflow service itself that will be executed and exposed through a workflow engine. BPEL provides constructs for the programming applications, including the basic activities like service invocation, error handling, and conditional statements, but also the constructs for the sequential or parallel composition of activities. It also includes operations for manipulating messages whose structure is automatically derived from the WSDL of used services, in order to reuse the messages in other service invocations.

As regards the INSPIRE Invoke service interface: considering the flexibility of the OGC Web Processing Service specification, and that the Invoke operation will vary significantly depending on the linked spatial data service, the usage of WPS standard could be beneficial to the Invoke service interface and encoding. However, some aspects like asynchronous invocations and WSDL description may require some further extensions. As regards the interfaces of INSPIRE spatial data services: WSDL or similar documents shall be used to describe spatial data services. WSDL accepts bindings to HTTP GET and POST request methods but is also often used in combination with SOAP and an XML Schema to provide web services over the Internet. Extensions at the OGC capabilities documents or creation of a separate spatial data service register are possible solutions. ('INSPIRE Invoke Services: Survey…' (2009)).

4.5 Quality of services

Apart from the technical architecture as a framework for web services (see: section 4.1), there are also other issues common to all INSPIRE Network Services for which the INSPIRE Directive and the complementary INSPIRE documents put requirements and recommendations. Those issues include the rights management, licensing and data access policies. This topic is discussed in section 4.6 dealing with the GeoRM (Rights Management) aspects of the INSPIRE Network Architecture. The other issue relevant to all web services is quality of services. Quality of services consists of several elements. For each of these elements specific quality indicators (criteria) shall be defined.

The INSPIRE Directive asks Member States in *Article 16 (a)* that *'the services of the network should work in accordance with commonly agreed specifications and minimum performance criteria in order to ensure the interoperability of the infrastructures established by the Member States'*. To define these minimum performance criteria (quality indicators), Quality of Service (QoS) requirements are introduced for the network services. The requirements introduce minimal criteria and associated measures to make the INSPIRE Network Services efficiently operational.

The 'Commision Regulation (EC) No 976/2009 of 19 October 2009 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the Network Services' (Annex 1) specifies acceptable values of measures for the quality criteria for INSPIRE Discovery and View Services. The quality criteria and measures have been extended to the INSPIRE Download and Transformation Services with the 'Draft Commission Regulation

[5] OASIS – Organization for the Advancement of Structured Information Standards (http://www.oasis-open.org) is a not-for-profit consortium that drives the development, convergence and adoption of open standards for the global information society (see also: subsection 2.2.1).

amending Regulation (EC) No 976/2009 as regards download services and transformation services'. **The following criteria are applicable:**

1. Performance

The response time for sending the initial response to a Discovery service request (for metadata sets) shall be maximum 3 seconds in normal situation.

For a 470 Kilobytes image (e.g. 800x600 pixels with a colour depth of 8 bits), the response time for sending the initial response to a Get Map Request to a view service shall be maximum 5 seconds in normal situation.

Normal situation represents periods out of peak load. It is set at 90% of the time.

For the Get Download Service Metadata operation, the response time for sending the initial response shall be maximum 10 seconds in normal situation.

For the Get Spatial Data Set operation and for the Get Spatial Object operation, and for a query consisting exclusively of a bounding box, the response time for sending the initial response shall be maximum 30 seconds in normal situation then, and still in normal situation, the download service shall maintain a sustained response greater than 0.5 Megabytes per second or greater than 500 Spatial Objects per second.

For the Describe Spatial Data Set operation and for the Describe Spatial Object Type operation, the response time for sending the initial response shall be maximum 10 seconds in normal situation then, and still in normal situation, the download service shall maintain a sustained response greater than 0.5 Megabytes per second or greater than 500 descriptions of Spatial Objects per second.

2. Capacity

The minimum number of served simultaneous requests to a discovery service according to the performance Quality of Service shall be 30 per second.

The minimum number of served simultaneous service requests to a view service according to the performance quality of service shall be 20 per second.

The minimum number of served simultaneous requests to a download service to be served in accordance with the quality of service performance criteria shall be 10 requests per second. The number of requests processed in parallel may be limited to 50.

The minimum number of simultaneous requests to a transformation service to be served in accordance with the quality of service performance criteria shall be 5 requests per second.

3. Availability

The probability of a Network Service to be available shall be 99% of the time.

The Commission Regulation also states: "Third party Network Services linked pursuant to *Article 12* of Directive 2007/2/EC shall not be taken into account in the quality of service appraisal to avoid the potential deterioration due to the cascading effects".

The Quality of Service criteria are elements of service testing for INSPIRE compliance. Methods for testing of the criteria values (measures) have been mentioned in the INSPIRE Network Services Architecture document (2008). For the Performance and Capacity, network stress tools shall be used to measure the indicators at the Member States servers level. Availability of the service (and its operations) can be monitored either by the network tools or by the service itself (in a form of log), which must be accessible by the INSPIRE monitoring measures.

The INSPIRE Network Services Architecture defines three additional (recommended) quality elements but the exact quality criteria for these elements have not been given. These are: Security (authorization, encrypting messages, access control), Reliability (ability of a web service to perform its required functions under stated conditions for a specified time interval) and Compliance (conformance with the rules, the law, compliance with standards, and the established service level agreement). It shall be noticed that the exact criteria and associated measures cannot be given straightforward as they are difficult or often impossible to quantify. The following recommendations are given, as an example, for the INSPIRE Discovery Service in the Technical Guidance (v.2.0) document:

- Reliability. It is recommended to check the INSPIRE metadata specifications conformity through the use of reference tests. In order to allow comparison between responses, it is also recommended to provide reference metadatasets.
- Security. It is recommended the Discovery service to be certified with regard to security regulations.
- Regulatory (compliance). It is recommended to check the INSPIRE Discovery service specifications through the use of reference tests.

The compliance criterion is specific as it provides in itself some criteria for INSPIRE web services conformance testing. The compliance criterion defines whether the service is compliant with INSPIRE Implementing Rules. **The compliance is checked based on the following sub-criteria** (as defined by the INSPIRE Network Services Architecture)**:**

- **the service version,**
- **existence of the mandatory operations,**
- **correct handling of the mandatory parameters of operations,**
- **correct format and versions (when applicable) of the results returned by the mandatory operations,**
- **compliance with INSPIRE data models for themes defined by the directive annexes.**

These compliance criteria are applicable and common to all Network Services and shall be primarily taken into account in the compliance testing process.

Furthermore, a report 'Services State of Play Compliance Testing and Interoperability Checking' (2007) has been published. The report was issued when the INSPIRE Network Services Architecture (2.0) document was already available but before drafting the Implementing Rules and Technical Guidance for the particular types of Network Services. The main purpose of this report was to provide an overview of available software solutions and products for web services development, management, monitoring, orchestration and, primarily, for testing of the performance and functional behavior of web services. The topic has been discussed in the light of the INSPIRE requirements for service interoperability and compliancy. This document shall be updated as new network tools are already available.

4.6 Rights Management

The INSPIRE Network Architecture (2008) specifies that an additional Rights Management (RM) Layer will function within the framework of INSPIRE services architecture. Rights management service functions allow controlling access to INSPIRE services and to define terms and conditions under which access will be granted (authentication, authorization, licencing, e-commerce etc.) Therefore security and data access/transfer issues should be discussed in relation to the Rights Management Services.

INSPIRE Rights Management services shall be introduced to manage different kinds of rights (legal, business contracts, access keys) between applications (INSPIRE Geoportals and other access points) and the INSPIRE infrastructure. In particular, the Rights Management (RM) layer constitutes a common infrastructure for the INSPIRE Network Services access control. The technology used shall ensure functionalities to provide access under priorly defined conditions, business models and policies.

In the case if rights management is needed, the basic "publish-find-bind" (see: Fig.19 – section 4.1) process workflow is extended with an "agree" phase (Fig.26). The negotiation of terms and conditions of access between the client and the provider of INSPIRE services has to happen prior to the "bind" phase.

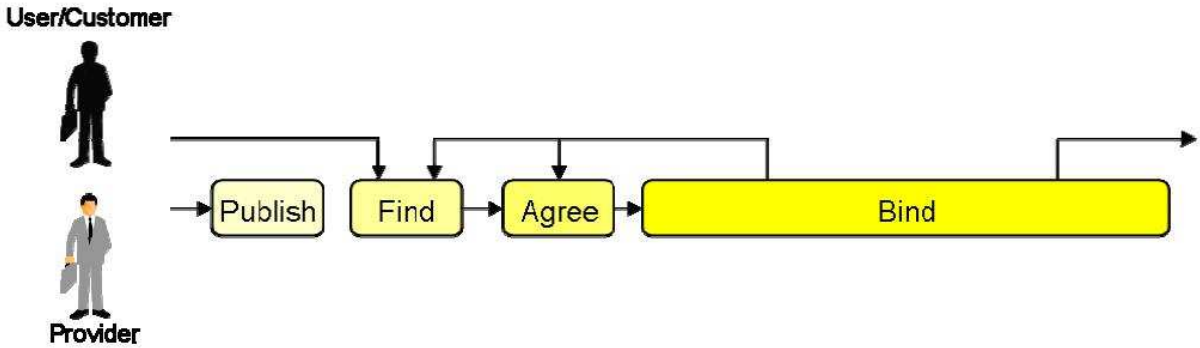


Fig.26 Publish-find-agree-bind process phases
(INSPIRE Network Services Architecture, 2008)

The access control functions are applicable to all types of INSPIRE Network Services, though not obligatory for each particular case. Technically, according to the INSPIRE Network Architecture (2008), in case of the services using SOAP bindings, a **RightsManagementKey attached to the SOAP header of the communication is required to support the rights management in the INSPIRE services infrastructure.** RightsManagementKey is a SOAP header element containing application-specific information regarding rights management (authentication, pricing etc.) and encapsulated in the body of SOAP envelope. **INSPIRE service requests** (possibly extended with further data such as license or identity information coded in the RightsManagementKey) **can be passed through rights management functionalities of particular web services.** These functionalities act based on established rights management policies to control the communication and/or trigger additional workflows.

In Fig.27, the relationship of the Rights Management services with other components of the INSPIRE infrastructure has been shown. The Rights Management layer provides workflow control over the infrastructure, based on authorization and authentification, which are directly related to the licensing and pricing agreements. It should be noted that the INSPIRE Directive does not affect the existence or ownership of public authorities' intellectual property rights. The rights management functionality is needed to allow the INSPIRE network services to invoke e-commerce services, as required by the INSPIRE Directive [*Recital (17), Article 14(2), 14(4)*].

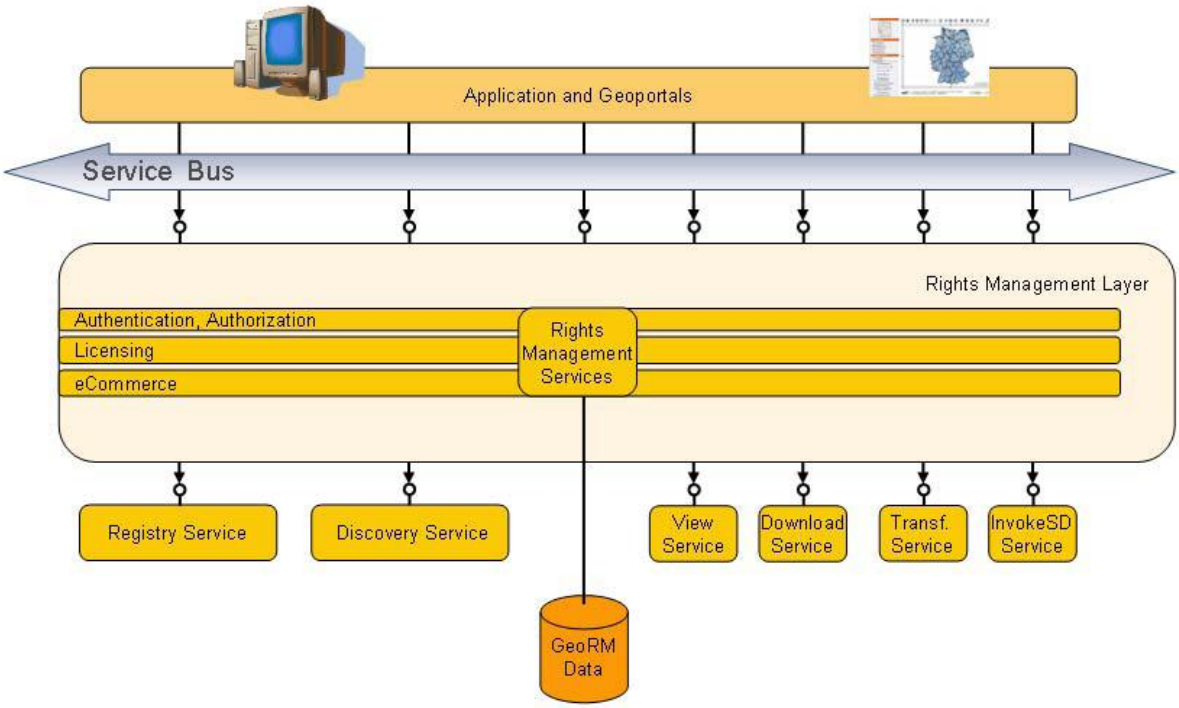


Fig.27 Rights Management Layer in the INSPIRE Services Architecture
(INSPIRE Network Services Architecture, 2008)

According to the INSPIRE Network Architecture, **the key functionality of the rights management layer shall be implemented based on the OGC abstract specification (Topic 18): OpenGIS 'Geospatial Digital Rights Management Reference Model' (GeoDRM RM)** (OGC 06-004r3);**.** This standard specifies a policy and technology neutral framework for the electronic licensing of spatial data and services.

Regarding the access conditions to the Discovery and View Services, the INSPIRE Directive requires free public access to those services (*Article 14.1*) except if the conditions in *Article 14.2*. of the INSPIRE Directive are met for the View Services. Charges may be applied for the access to the View Service if they are required for the maintenance of spatial data sets and corresponding data services, especially in cases involving very large volumes of frequently updated data. In this case, data made available through the View Services may be in a form preventing their reuse for commercial purposes (*Article 14.3*). When charges for the use of the View, Download or Invoke Services are applied, e-commerce services shall be made available. Such services may be covered by disclaimers, click-licences or, where necessary, licences (*Article 14.4*).

4.7 Synthesis of the guidelines for INSPIRE-compliant web services

Based on the guidelines (requirements/recommendations) identified in the INSPIRE documents and described in the sections 4.1 – 4.6, a synthesis can be made of the components of INSPIRE-compliant web services. The aim of this synthesis is to answer the question 'what is meant by INSPIRE-compliance?' in the context of network services, specifically View Service and Download Service. Which requirements/recommendations need to be met for the web services to be INSPIRE-compliant?

The synthesis of the INSPIRE guidelines was used to construct a table (Table 8), which enlists the core groups of requirements that shall be fulfilled by a compliant implementation of INSPIRE Download and View Services. The summary of requirements for compliance presented in this table is not bound to a specific compliance testing methodology. It has been prepared through the review of INSPIRE documentation and extraction of the core guidelines. For a more detailed synthesis see also Annex B of this thesis.

	requirements	**Download Service**	**View Service**
1	Support of GET method	M	M
2	Support of SOAP/POST methods	O[I]	O[I]
3	Implementation of ISO 19128 (WMS) standard	n.a.	M
4	Implementation of OGC 'Styled Layer Descriptor for WMS' and OGC 'Symbology Encoding' standards	n.a.	O
5	Implementation of ISO/DIS 19142 (WFS) and ISO/DIS 19143 (FE)	M/C[II]	n.a.
6	Get Service Metadata operation	M	M
7	Get Map operation	n.a.	M
8	Get Feature Info operation	n.a.	O
9	Get Spatial Objects operation	M	n.a.
10	Describe Spatial Object Types operation	C[III]	n.a.
11	Define Query operation	C[IV]	n.a.
12	Link Download/View Service operation	M	M
13	Output format: GML 3.2.1 (ISO 19136)	M	O
14	Output formats: PNG, JPEG	O[V]	M
15	INSPIRE-compliant (harmonized) dataset and layer names	M[VI]	M[VI]
16	Coordinate reference systems (compliant with ETRS89/ITRS)	M[VII]	M[VII]
17	Temporal data dimension	C[VIII]	C[VIII]
18	INSPIRE-default portrayal rules	n.a.	M[IX]
19	Multilingual elements	M	M
20	Rights Management layer	O	O
21	Quality of services (performance, capacity, availability)	M	M
22	INSPIRE-compliant data model	M	M
23	INSPIRE-compliant metadata (ISO 19115/19119, ISO CD/TS 19139)	M	M

M – mandatory; O – optional; C – conditional; n.a. – not applicable

Table 8 – Synthesis of INSPIRE requirements for Download and View Services

[I] Support of GET method is mandatory. Support of POST method as well as SOAP profile is recommended. Several different profiles are recommended for View and Download Services. The relevant Technical Guidance documents (v.2.0) shall be referred to for details of these profiles.

[II] Implementation of ISO/DIS 19142 (WFS) and ISO/DIS 19143 (FE) standards is mandatory for direct access download services. Non-direct access downloads services (for predefined datasets or parts of datasets) can be also served with a simple HTTP download of file-based datasets with GML data encoding.

[III] Describe Spatial Object Types operation is mandatory for direct access download services. For non-direct access download services this operation is optional.

[IV] Define Query operation is mandatory for direct access download services. For non-direct access download services this operation is not applicable.

[V] Raster output formats (e.g. PNG, JPEG) may be also used in specific cases (orthophotoimagery, elevation grid data etc.).

[VI] Harmonized dataset and layer names can be found in particular Data Specifications.

[VII] Geographical coordinates reference systems based on ETRS89 shall be used for continental Europe. For overseas European territories, geographical coordinates reference systems based on ITRS shall be used.

[VIII] Requirements for temporal aspects of spatial data.

[IX] A very minimum default portrayal style is defined for INSPIRE data themes. Waiting these 'harmonized' styles and if providers do not want to use the too poor "INSPIRE:DEFAULT" style, they may use their available national or thematic styles. User defined styling may be also applied with the use of OGC 'Styled Layer Descriptor for WMS' and OGC 'Symbology Encoding'.

5. Prototype of INSPIRE-compliant web services (View and Download Service)

In this chapter, a description of the prototype development and evaluation for this research is included. The prototype is an implementation of some Download and View Services with the GeoServer application, using samples of spatial data from the Narew National Park. In section 5.1 basic information about the prototype and its purpose is included. Section 5.2 describes the process of building the prototype. In section 5.3 the prototype evaluation based on manual inspection is presented. Section 5.4 includes specific recommendations for GeoServer based on the evaluation of the prototype.

5.1 Basic information

The major aim of this thesis research was to assess the quality of the guidelines for implementation and testing of INSPIRE-compliant web services. A part of this problem is the actual feasibility of such implementations. To clarify this it is necessary to evaluate if existing software tools already support the implementation of GI services conformant with INSPIRE requirements and recommendations. In order to evaluate the existing solutions the functionality of GeoServer application for serving spatial data on the Web has been inspected and a small prototype of INSPIRE View and Download Services has been realized. GeoServer has been chosen for this research as it is one of the leading spatial data servers implementing the OGC standards, that the View and Download Service are relying on, namely Web Map Service (WMS) and Web Feature Service (WFS). Therefore it is possible to investigate the relation of services implemented in GeoServer to the INSPIRE guidelines.

This practical part of the research served two major purposes:

- to check in practice how INSPIRE-compliant web services could be implemented according to the guidelines identified in the conceptual study (see: Table 8, section 4.7)
- to provide a basis for compliance testing and evaluation (the final part of the research, see: chapters 6,7).

The practical part (prototype) can be seen as a relevant supplement to the conceptual part (chapter 4).

The prototype realized is not completely compliant with INSPIRE guidelines. The idea behind it was rather to check what can be done with the use of existing software in a fairly straightforward way to provide services which are INSPIRE-conformant. On the other hand – to evaluate what is difficult or not really feasible to be done with the use of existing application to provide INSPIRE-conformant services. The implementation of fully INSPIRE-compliant web services was out of scope. The prototype serves as a support for the evaluation part of the research.

The prototype has been realized with the use of GeoServer which is an open source spatial data server software written in Java. The application is available for download from the website http://geoserver.org. GeoServer allows users to share and edit geographic data and is a reference implementation of OGC (Open Geospatial Consortium) standards, such as WFS (Web Feature Service), WCS (Web Coverage Service) and WMS (Web Map Service). The competing open source application implementing the OGC standards is MapServer from

University of Minnesota. The commercial server software (web mapping applications) include ArcIMS (ESRI), GeoMedia Web Map and several other solutions.

Since GeoServer is a ready-made application for publishing of spatial data according to the OGC standards, there was no need to do all the work for the prototype 'from the scratch'. The prototype development has been limited to the inspection of GeoServer's functionality, appropriate configuration of the application and handling of the provided spatial data, and testing of the prototype. Fig.28 presents the prototype service architecture. Detailed information about building the prototype is included in section 5.2.

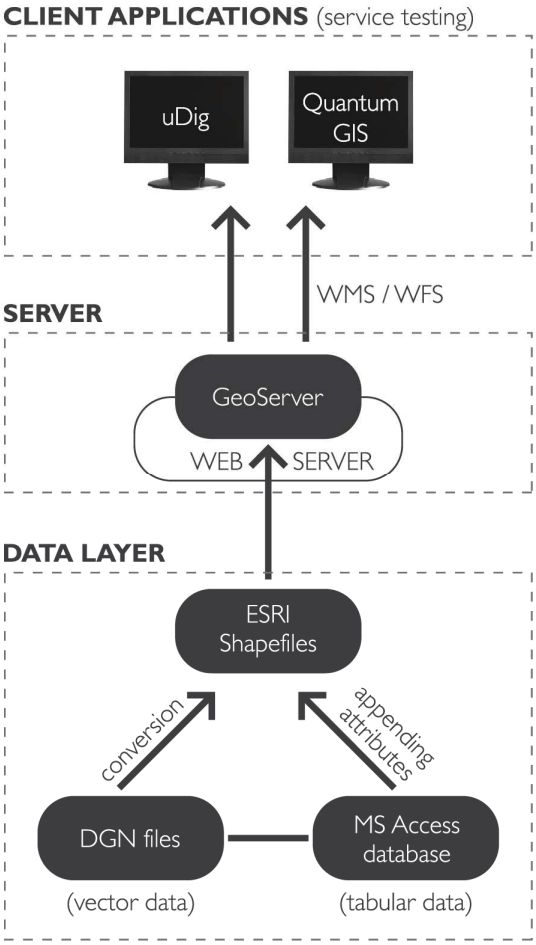


Fig.28 Prototype services architecture

The two INSPIRE web services chosen for the prototype are View Service and Download Service. The basic relevant standard identified for the implementation of INSPIRE View Service is ISO 19128:2005 Geographic information – Web map server. For the INSPIRE Download Service the basic relevant standard is ISO/DIS 19142 Geographic information - Web feature service.

The View and Download Service have been chosen for several reasons. Firstly, they are both based on the standards implemented in GeoServer (WMS, WFS) so their functionality can be tested in a single application. Another reason is pragmatic – they have already well developed INSPIRE documentation. At the moment of writing (February 2010) Implementation Rules for both types of services are available in their versions 3.0 and Technical Guidance documents in their versions 2.0. Finally, the third reason for this choice is that both the View

Service and Download Service seem to be relevant for the case study. The users of web services for national park typically are interested in browsing and analyzing map images (functionality of View Service). However more experienced users may also have their interest in downloading raw GIS data for further manipulation in their own applications (functionality of Download Service).

Another very relevant type of INSPIRE services is Discovery Service. It allows for discovery of metadata related to spatial data and spatial data services from diverse resources. The reference standard for INSPIRE Discovery Service is OpenGIS Catalogue Services Specification 2.0.2 - ISO Metadata Application Profile for CSW 2.0

At the moment of writing, the INSPIRE Discovery Service has also a diverse documentation including Implementing Rules, v.3.0, Technical Guidance, v.2.0, as well as documentation for its implementation based on SOAP and WS-I standards (similarly to View Service, see: chapter 4.4 and SOAP Primer for Discovery and View Services). However its implementation is not possible in GeoServer and calls for different software applications. Due to the limited scope of this research, the implementation of INSPIRE Discovery Service has been left out of this research.

For the INSPIRE View Service and INSPIRE Download Service investigated in this prototype, the spatial data has been acquired from the resources of GIS data produced for the Management Plan of the Narew National Park. Several different data sets have been chosen. It has to be noted that this is only sample data which is not perfect with regards both to the content and the structure. For this reason several problems occurred with making the services fully INSPIRE-compliant, especially when it comes to the data model (see: sub-section 5.2.1). The relevant findings about the data and services implemented are described in the further sections of this chapter, in particular in section 5.3 with the prototype evaluation.

In the further sections (5.2, 5.3), the information is included about the steps undertaken to implement the prototype. Along with the description of the work process, references to the INSPIRE requirements and recommendations are provided. It has been described which elements of the INSPIRE-compliant web services were included in the prototype, which were not, what were the reasons for these choices. In section 5.3 a table is presented (Table 9), to summarize which of the requirements for INSPIRE-compliant web services identified in the chapter 4 (see: Table 8) have been fulfilled by the prototype.

Finally, several relevant points are given as the findings about the feasibility of implementation of INSPIRE-compliant web services and recommendations for the improvement of GeoServer and the prototype (section 5.4). The information found in the sections 5.3 and 5.4 may be regarded as a preliminary evaluation of the research. The second evaluation part can be found in chapter 6 (section 6.5) and includes recommendations for compliance testing of INSPIRE network services. The final evaluation of the research is presented in chapter 7 (conclusions and recommendations).

5.2 Building of the prototype

The prototype development process consisted of three phases: spatial data and metadata preparation (sub-section 5.2.1), setting up and configuration of the services in GeoServer (sub-section 5.2.2) and testing of the prototype services with chosen GIS applications (sub-section 5.2.3).

5.2.1 Data Preparation

The first prerequisite for the INSPIRE-compliant web services is that the spatial data (and the corresponding metadata) is conformant with the INSPIRE guidelines. The reason is that the data is an input for the services and the core resource of the INSPIRE infrastructure.

In the context of INSPIRE and the scope of the Implementing Rules, datasets which shall be served by INSPIRE-compliant network services are restricted to the categories defined by the Annexes I-III of the INSPIRE Directive (see: *Article 4*). For those datasets metadata shall exist and be updated according to *Article 5* of the Directive. The spatial datasets shall be interoperable and harmonized according to *Articles 7-10* of the Directive.

The spatial data chosen for this prototype comes from the Management Plan of Narew National Park. The specific datasets were selected so as to be corresponding to the INSPIRE Annex I data themes. The reason is that the Data Specifications (v.3.0) for INSPIRE Annex I data themes have already been elaborated (at the moment of writing) so it is possible to compare the existing data models with the recommended INSPIRE data model.

A review of the available data has been made and the following datasets were selected:

- Communes.dgn (polygons) → included: communes in the national park and its buffer zone; **corresponding thematically to INSPIRE Annex I data theme Administrative Units**
- NP_Area.dgn (polygons) → included: area of the national park; **corresponding thematically to INSPIRE Annex I data theme Protected Sites**
- Streams.dgn (polygons) → included: river beds and streams in the national park; **corresponding thematically to INSPIRE data Annex I theme Hydrography**

- Wells.dgn (points) → included: wells (points of groundwater extraction and monitoring) in the national park and its buffer zone; **corresponding thematically to INSPIRE Annex I data theme Hydrography (as a placeholder) and INSPIRE Annex II data theme Geology.**

The spatial (vector) data was available in Bentley Microstation DGN files. Corresponding tabular data could be found in MS Access database ("narewpn.mdb"). Some data pre-processing was needed before using it with the GeoServer application. The following steps were undertaken:

- Extraction of specific features from the source datasets. This was done with the use of Bentley Microstation application. "Communes.dgn" and "NP_Area.dgn" were derived from a single file "gr_gmin.dgn". "Streams.dgn" is a result of extraction of river network from the file "all_syt.dgn" which includes different elements of topographical

and land cover information. “Wells.dgn” was derived from “hydrogeo.dgn” which includes various hydrogeological features.

- Conversion of DGN files to ESRI Shapefiles (SHP). This was done because in GeoServer it is possible to manipulate shapefiles but not DGN files. The DGN files were imported in ArcMap (ArcView 9.2 with extensions) to a new geodatabase with the use of “Import from CAD” tool. Next, the chosen feature classes from the geodatabase were exported to shapefiles with the use of “Export data” operation. The shapefiles were saved under the same names as corresponding DGN files.

- Appending attribute data. In the particular shapefiles, the only tabular information available was the automatically created data on geometry of features. The additional attribute data was partly appended from the tables of the MS Access database “narewpn.mdb” (Join Tables operation in ArcMap), partly added manually as new attribute data records in the existing tables. The attribute data includes e.g. groundwater chemistry parameters for “Wells.shp” or names of communes for “Communes.shp”. The attribute names have been changed to English.

- Data re-projection. This was done as a step in making the data more INSPIRE-compliant. All spatial datasets in INSPIRE shall use coordinate reference systems based on the European reference system ETRS1989 for the areas in continental Europe. As it can be read in the document with Draft Structure and Content of the Implementing Rules on Interoperability of Spatial Data Sets and Services: **“For the horizontal component, for the areas within the geographical scope of the European Terrestrial Reference System 1989 (ETRS89) shall be used”** (Requirement 17). Furthermore, several recommended map projections are given. **“The ETRS89 Transverse Mercator (ETRS-TMzn) shall be used for conformal mapping at scales larger than 1:500,000”** (Requirement 24). These requirements and recommendations are repeated in particular Data Specifications. Taking these guidelines into account, in ArcMap a re-projection of data was made. First, the reference system in which the source data was present has been defined with the Define Projection tool (Polish reference system “PUWG 1965 – zone III”). Next, the data has been re-projected to a new reference system – “ETRS 1989 UTM Zone 34 N” (as recommended by INSPIRE).

- Renaming files. Finally, the shapefiles have been renamed to make their names more correspondent to the names of feature types defined in the INSPIRE Data Specifications and recommended for particular layers (see: sub-section 5.2.2). The following new file names have been applied for convenience reasons:
    - Communes.shp → **AdministrativeUnit.shp**
    - NP_Area.shp → **ProtectedSite.shp**
    - Streams.shp → **PhysicalWaters.Waterbodies.shp**
    - Wells.shp → **AquiferNode.shp**.

In Fig. 29, all four data layers have been visualized in ArcMap. A tabular information is visible in this screenshot for one of the layers (AdministrativeUnit).

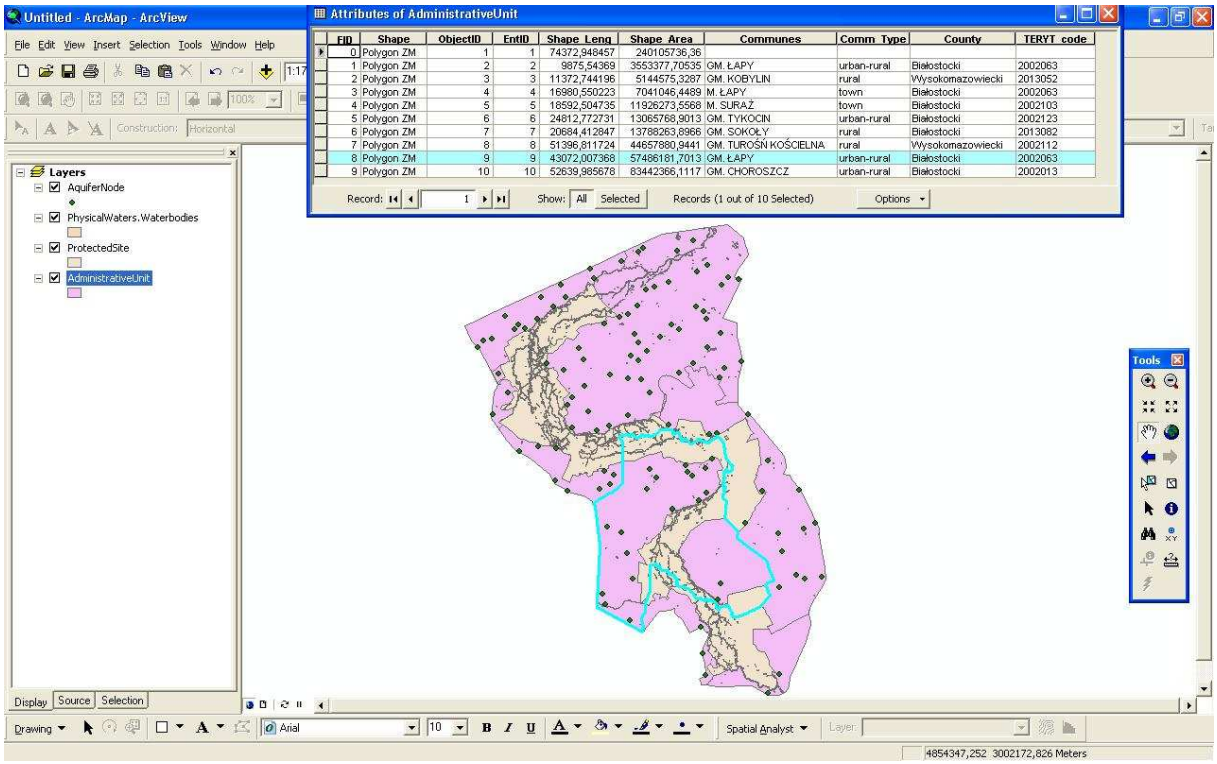


Fig.29 Shapefiles with data from Narew National Park visualized as data layers in ArcMap

The spatial data has been pre-processed in the way described above however it has not been adapted completely to the INSPIRE data model. The data has been inspected and the relevant INSPIRE Data Specifications have been examined (Administrative Units, Hydrography, Protected Sites; version 3.0). **It has been recognized that to make the data compliant with the INSPIRE guidelines, among others, the following major changes shall be applied:**

- **The structure and model of the data (feature types, attribute classes, attributes, attribute values, domains, relationships) shall be compliant with the INSPIRE requirements.** This is not the case for spatial data from Narew National Park. The data was captured and processed in a way that it received specific feature types, attributes, attribute values. Transformation of the data to INSPIRE model is not straightforward. In some cases it is not possible to perform such transformation due to limitations in the source data. In other cases, specific software tools shall be used. Within the framework of ESDIN - European Spatial Data Infrastructure Network project (http://www.esdin.eu), mapping tools are developed to help Member States of European Union to prepare their country profiles of INSPIRE application schemas, mapping/matching attribute tables and other relevant transformation of the data. The deliverables include UML models and modeling guidelines and data mapping tables in XML. More information can be found on the project website.

- **Data quality as recommended by INSPIRE shall be ensured.** The data quality consists of several elements: completeness, logical consistency, positional accuracy, thematic accuracy. However all the elements of data quality are limited by the data capture conditions. The quality of the source data cannot be enhanced once the data is captured and maintained. The spatial data from the Management Plan of Narew National Park has also certain, limited quality which can be a constraint in making it

compliant to the INSPIRE data quality recommendations. However, to evaluate this the source data should be further investigated and compared with the data quality requirements set out in the particular Data Specifications.

- **Recommended default portrayal styles for the data shall be ensured.** This is not a requirement but rather a recommendation since the Member States may apply their own predefined national or thematic styles for the data if they consider the default styles too poor or if the harmonized styles are not yet available. The default portrayal styles are defined in particular INSPIRE Data Specifications. Of course, the styling is not an attribute of the data itself. The portrayal rules are applicable in the context of INSPIRE View Service. The changes applied in portrayal of the data for the prototype are described in section 5.3.

Metadata of the spatial data shall be also prepared in an INSPIRE-compliant manner. The process is not difficult. The INSPIRE Metadata Editor has been made available through the INSPIRE Community Geoportal. The INSPIRE Medata Editor (accessible at: http://www.inspire-geoportal.eu/InspireEditor) is currently a prototype allowing users to create metadata that are compliant with the INSPIRE Implementing Rules. The metadata created with INSPIRE Metadata Editor is also compliant with EN ISO 19115 and 19119. The metadata records created are conformant to ISO/TS 19139 which is a specification for XML Schema implementation of ISO 19115 based metadata. Users of the Metadata Editor can validate the metadata they create and save the metadata records as XML files on their local machines. The metadata created with INSPIRE Metadata Editor have been successfully validated against the INSPIRE Geoportal Catalogue and other catalogue applications, such as GeoNetwork. (http://www.epractice.eu/en/news/284685). INSPIRE Metadata Editor is still a prototype and shall not be used in a productional environment.

For this project, sample metadata records have been prepared for particular spatial datasets. The following metadata files have been created:

- AdministrativeUnit_metadata.xml
- AquiferNode_metadata.xml
- PhysicalWaters.Waterbodies_metadata.xml
- ProtectedSite_metadata.xml.

All metadata files were created with the use of INSPIRE Metadata Editor (Fig. 30).

The metadata files are not directly accessible with the prototype set up in GeoServer. However, the URL's to metadata files (metadata paths) corresponding to particular data layers (Feature Types) are provided as one of the parameters in the definition of these data layers in the Feature Type Editor in GeoServer (see: Fig.32). Therefore these metadata paths can be found in Get Capabilities response for the WMS and WFS.

In Annex C, an extract from sample INSPIRE-compliant metadata XML file has been shown (AdministrativeUnit_metadata.xml).

The metadata files can be retrieved directly through the following URL's:

- http://casagrande.geo.tudelft.nl:8088/geoserver/www/metadata/AdministrativeUnit_metadata.xml
- http://casagrande.geo.tudelft.nl:8088/geoserver/www/metadata/AquiferNode_metadata.xml

- http://casagrande.geo.tudelft.nl:8088/geoserver/www/metadata/PhysicalWaters.Waterbodies_metadata.xml
- http://casagrande.geo.tudelft.nl:8088/geoserver/www/metadata/ProtectedSite_metadata.xml.

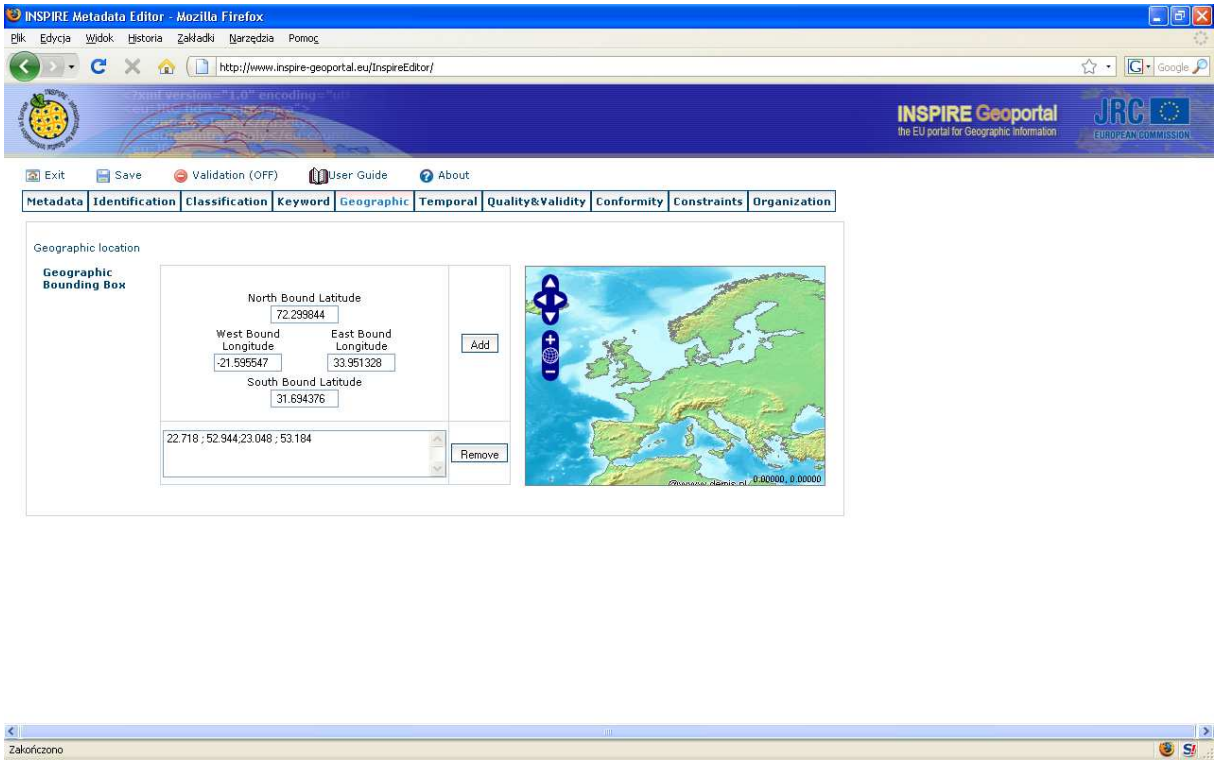


Fig.30 INSPIRE Metadata Editor
(http://www.inspire-geoportal.eu/InspireEditor)

5.2.2 Hosting INSPIRE View/Download Services with GeoServer

After the data preparation phase, the time has come to connect the input data to GeoServer and set up the sample services. GeoServer is a compliant implementation of WMS (Web Map Service) 1.1.1 with SLD (Styled Layer Descriptor) 1.0 extension for dynamic styling. It is also a reference implementation of WFS (Web Feature Service) 1.1.0, supporting all WFS operations including Transaction. The aim of this practical part was to check how WMS in GeoServer implements the guidelines for INSPIRE View Service. Also, how WFS in GeoServer implements the guidelines for INSPIRE Download Service. The work started with setting up WMS. However, the settings for WFS in GeoServer are very similar. Only several elements of configuration needed to be changed.

The tests were made at first with GeoServer installed on localhost, and the second time with GeoServer installed on a web server to provide access to the services on the Web. On local machine GeoServer 2.0 RC-1 has been installed along with JDK 6 (Java SE Development Kit 6su16). The data was loaded into GeoServer and the sample services have been tested. The procedure for setting up the services on the web server was very similar. The services set up on the web server are still up and running (accessible). The procedure of setting up these services will be described.

The WMS and WFS services have been set up on the web server hosted by Delft University of Technology. On this server, GeoServer 1.7.6 (with Java Development Kit environment) was pre-installed. The Web Administration Tool of this GeoServer entity is accessible, after user authorization, at: http://casagrande.otb.tudelft.nl:8088/GeoServer. The shapefiles and the metadata files with the data from Narew National Park have been copied into "data/park" directory of GeoServer installation on the web server.

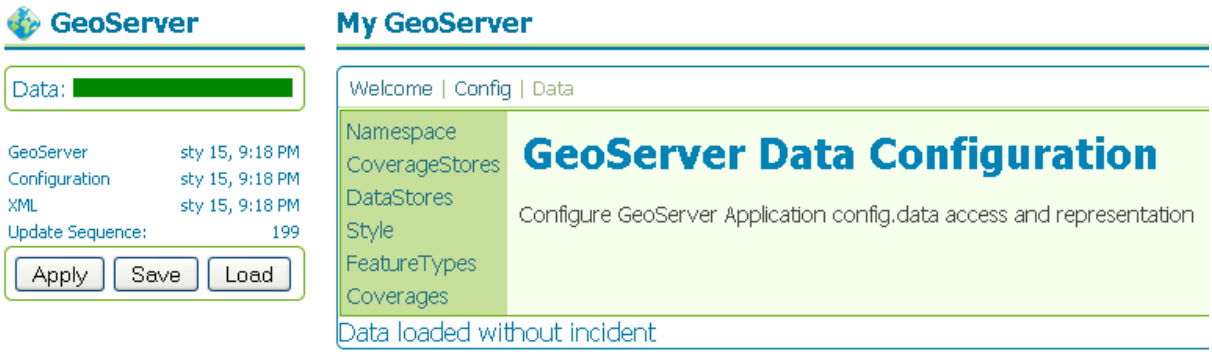


Fig.31 GeoServer Data Configuration Panel

The process started with loading the data into GeoServer and the configuration of data layers. All these operations were done in GeoServer Data Configuration panel (Data → Config) (Fig.31). First, in Namespace Configuration panel a new Namespace "park_new" has been created. A namespace is a kind of workspace for data stores which are representations of data files (shapefiles) in the GeoServer application. In the Feature Dataset Configuration panel four new Data Stores have been created based on the provided shapefiles: AdministrativeUnit, AquiferNode, PhysicalWaters.Waterbodies and ProtectedSites.

A step following creation of each new data store is feature type configuration in Feature Type Editor. In this panel (editor) the basic data layer elements are configurable. In GeoServer 1.7 feature types may be regarded as equivalent to data layers. In the Feature Type Editor, such properties of particular feature types can be configured as Name and Title, Spatial Reference System, Bounding Box, Keywords, Abstract, Metadata path, Styling, Caching, KML properties (Fig.32). The Feature Type definition and configuration has been made for all four Data Stores.

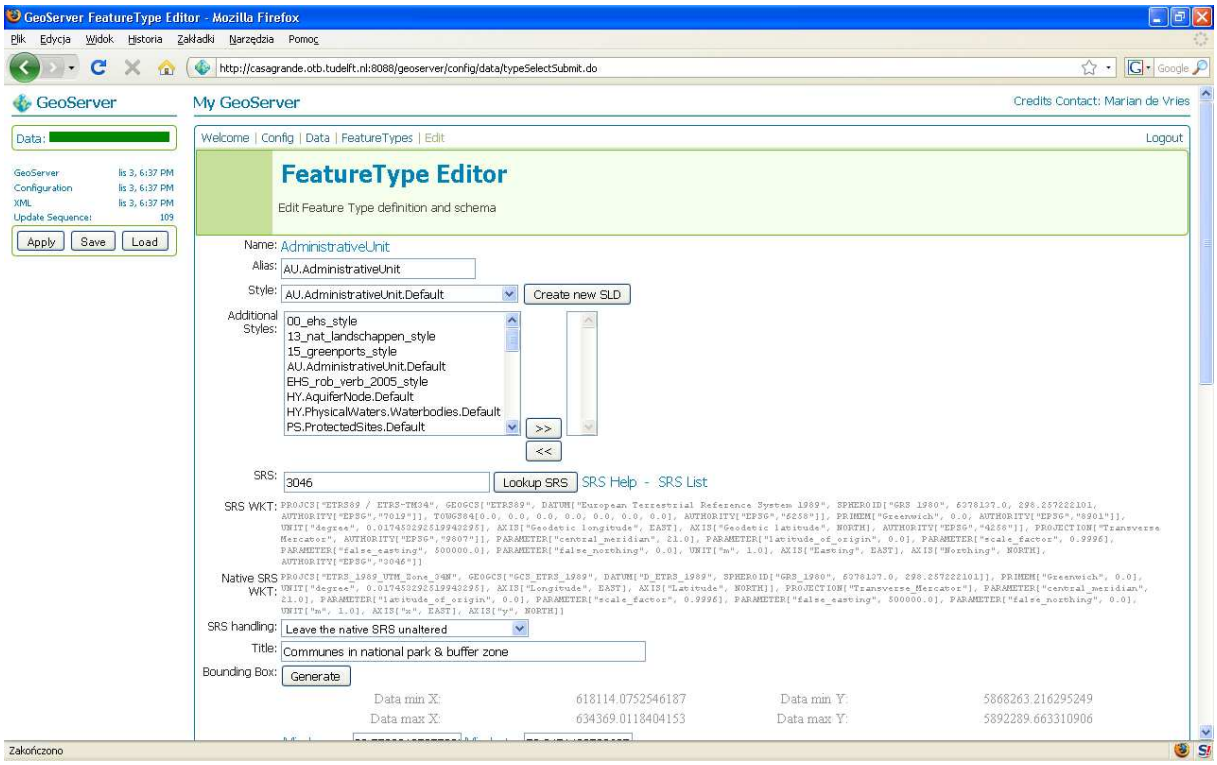


Fig.32 Feature Type Editor in GeoServer 1.7

In GeoServer it is possible to make a preview of chosen data layers. After the Data Stores are created and Feature Types configured, one can point to Demo panel → Map Preview. The Map Preview page will display each Feature Type that is enabled. The Map Preview provides a link for the display of each Feature Type in WMS form with embedded OpenLayers[6] interface (Fig.33). Other options of the Map Preview include exporting the data to KML to visualize it in Google Earth, generating GeoRSS feed to browse the data attributes, creating PDF and SVG files with simple images of the data.

Following the procedures described above, WMS and WFS services have been set up and configured in GeoServer 1.7.6 installed on the TU Delft web server. The whole procedure was limited to creating a new Namespace, creating Data Stores for particular shapefiles and configuring Feature Types for the Data Stores. Moreover, minor changes were applied in Web Map Server Configuration panel (Config → WMS) and Web Feature Server Configuration panel (Config → WFS). A preview of data layers was made with GeoServer's map preview but the final testing of the services was done with chosen GIS desktop applications (Quantum GIS and uDig) that are able to read WMS and WFS layers from GIS servers.

[6] OpenLayers is an open source JavaScript library that provides an interface for displaying map data in web client applications (web browsers). OpenLayers is able to load map data from many sources, including WMS, WFS, Google Maps, Virtual Earth, Yahoo! Maps, World Wind servers or ArcGIS Server. OpenLayers home page is: http://www.openlayers.org.

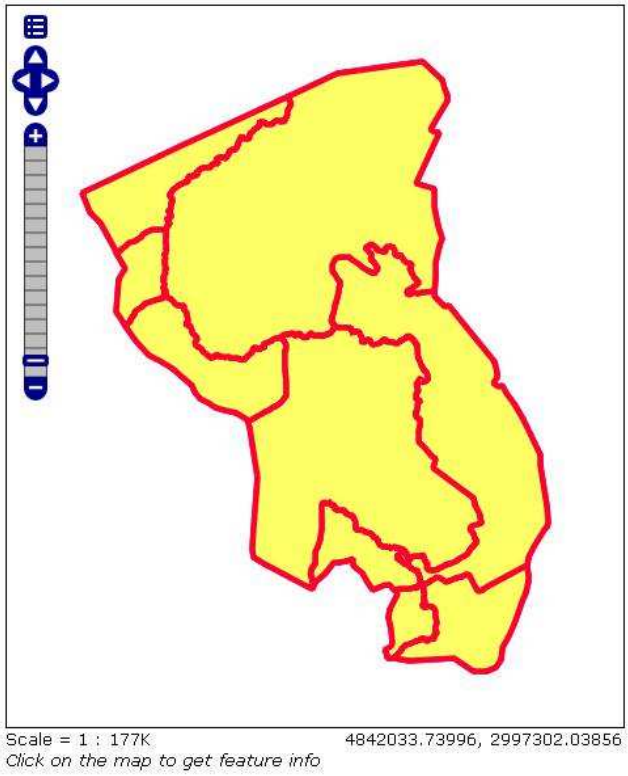


Fig.33 Map Preview in GeoServer 1.7 with embedded OpenLayers interface – WMS layer: AdministrativeUnit (communes in Narew National Park and its buffer zone)

5.2.3 Testing View and Download Services with Quantum GIS and uDig

Quantum GIS and uDig (open-source GIS applications) were used to check the availability of services. For the testing it was necessary to retrieve Get Capabilities documents from the server, load the data layers with the prototype data into these applications to check how they are being rendered and how the WMS/WFS operations are handled.

Quantum GIS, also known as QGIS (http://qgis.org), is an open-source desktop GIS application, that provides data viewing, editing and analysis capabilities. QGIS allows the use of data from various sources, including ESRI shapefiles and coverages, MapInfo files, PostGIS databases, GML, various raster formats, but also external sources of data such as Web Feature Servers and Web Map Servers. For instance, to add new WMS layers to a Project, one should choose "Add WMS Layer" option. The user has to specify the server connection (name and URL) and connect to the server. The available data layers are presented from the GetCapabilities XML document of the Web Map Server (Fig.34). One can choose the desired layers and add them to the QGIS project (GetMap operation of WMS). The maps are clickable. When the user clicks on a map, attribute information about certain feature is given (GetFeatureInfo operation of WMS) (Fig.35).

In the case of this prototype, the URL of WMS GetCapabilities document is: http://casagrande.otb.tudelft.nl:8088/GeoServer/wms?

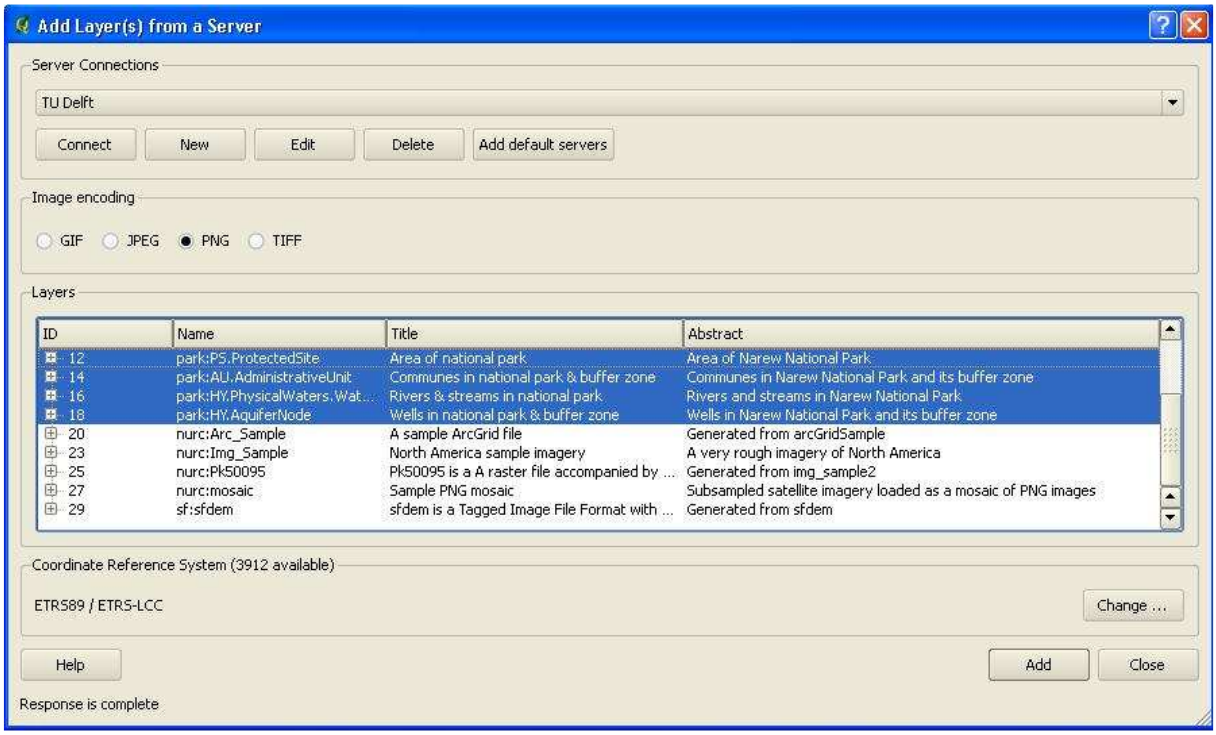


Fig.34 Adding WMS Layers with data from Narew National Park in Quantum GIS (list of data layers available from the GetCapabilities of Web Map Server)

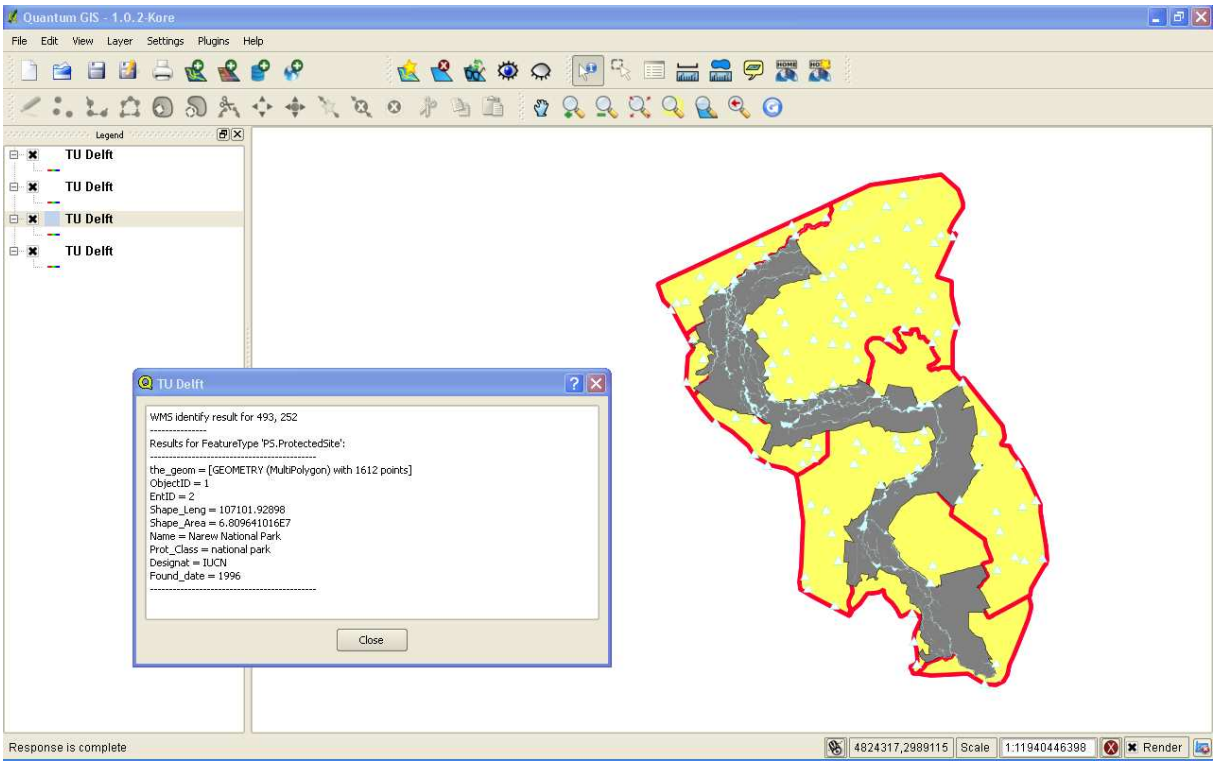


Fig.35 WMS Layers with data from Narew National Park in Quantum GIS (GetMap operation) with INSPIRE default SLD styling applied + information about the 'Narew National Park' feature from PS.ProtectedSite layer (GetFeatureInfo operation)

UDig (homepage: http://udig.refractions.net) is an open-source GIS software application written in Java and developed by Canadian consulting company Refractions Research. It is able to read ESRI Shapefiles, PostGIS databases and many other data sources, including WMS and WFS. For instance, to add a new WFS layer to a Project, one should choose Add Data from the Layer menu, select 'Web Feature Server' and provide URL of the WFS to retrieve information from the GetCapabilities document. The list of available resources (datasets) is provided. The user can select the desired layers (Fig.36).

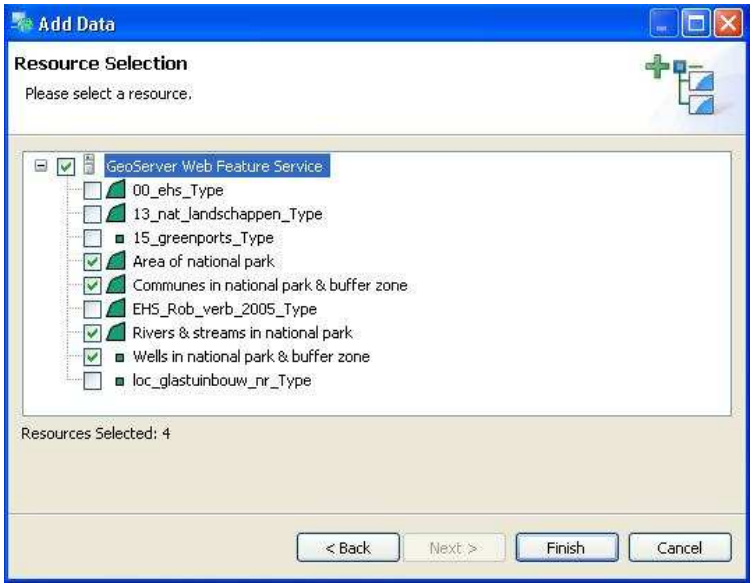


Fig.36 Adding WFS data layers with data from Narew National Park to a map in uDig

The layers are added to a map in the current project (GetFeature operation of WFS). The map layers are presented in a default portrayal style defined in uDig. The reason is that WFS streams "raw GIS data" and portrayal rules are not defined by WFS specification. In uDig, the user can click on a chosen object on WFS map data layer to retrieve attribute information about this object (Fig.37). This is possible since GetFeature operation of WFS streams whole data features, including both geometry and attribute information. It is also possible to make a DescribeFeatureType request to get more detailed information about the schema for a particular FeatureType in a form of XSD schema file. The response returns the FeatureType's property names, types, and restrictions.

In the case of this prototype, the URL of WFS GetCapabilities document is: http://casagrande.otb.tudelft.nl:8088/GeoServer/wfs?

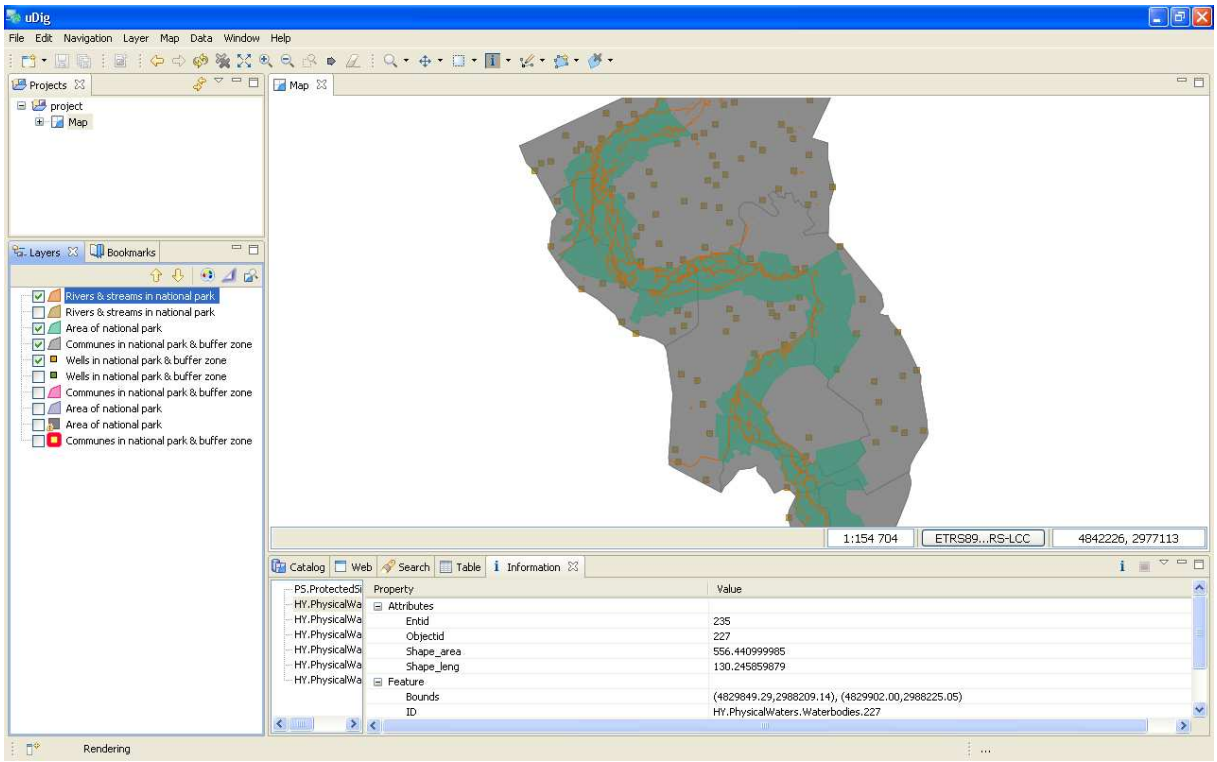


Fig.37 Spatial data from Narew National Park visualized in uDig as WFS map data layers (not using INSPIRE default styling)

5.3 Prototype evaluation

This section aims to provide a list of elements of 'INSPIRE-compliance' implemented or recognized when setting up the prototype. It is also described how these requirements and recommendations were handled or shall be handled.

When setting up the prototype, it has been recognized that GeoServer already implements the majority of requirements for INSPIRE View and Download Services with its WMS and WFS profiles (see: sub-sections 5.3.1, 5.3.2). However, some settings have been applied in the configuration of GeoServer and data layers to make the services more compliant with INSPIRE guidelines (see: sub-section 5.3.3). Moreover, some necessary changes have been recognized but not applied, due to limited scope of this research or the limitations of GeoServer (see: sub-section 5.3.4).

The findings of the prototype evaluation are summarized in Table 9 at the end of this section (corresponding to the Table 8 from section 4.7 with the synthesis of INSPIRE guidelines).

5.3.1 View Service handling in GeoServer

The WMS (Web Map Service) served by GeoServer 1.7 offers the following capabilities required or recommended by INSPIRE View Service:

- **Get Service Metadata operation (required), implemented by GetCapabilities operation of WMS,** that provides service metadata, including a list of available WMS

data layers on the server. GeoServer serves a full GetCapabilities response for WMS. Values for several parameters of GetCapabilities need to be defined in GeoServer's Web Map Server configuration panel. These parameters include: Title, Abstract, Keyword List, Online Resource, Fees, Access Constraints. Furthermore, Contact Information is defined in the Server Configuration panel in GeoServer. The required Layer Metadata are mostly defined in the Feature Type Editor for particular layers (Title, Name, Abstract, Keyword List, Unique Resource Identifier, Geographic Bounding Box, Coordinate Reference Systems, Styles).[7]

- **Get Map operation (required), implemented by GetMap operation of WMS,** that returns a map – a georeferenced image with defined spatial reference system (SRS) and bounding box. GeoServer allows for definition of all mandatory parameters of GetMap operation. However, several parameters need to have INSPIRE-compliant values configured (e.g. harmonized Layer names, default portrayal Styles, recommended CRS's).

- **Get Feature Info operation (recommended - optional), implemented by GetFeatureInfo operation of WMS,** that returns attribute information about particular features on a map.

- **Support for GIF and PNG output formats.** At least: Portable Network Graphics format (PNG; MIME type "image/png") and the GIF (Graphics Interchange Format) without LZW compression (MIME type "image/gif") shall be supported by the View service. (Technical Guidance to implement INSPIRE View Services, v. 2.0).

- **Support of HTTP GET Method for WMS operations. GeoServer offers the capabilities of the 'Standard Profile' of INSPIRE View Service**.
  "As stated in the ISO 19128:2005(E) standard support for the GET method is mandatory, NS DT recommends the use of the GET method for the view service operations. In order to make provisions for the SOAP framework, the NS DT recommends the use of the POST method once a decision is taken on the use of the SOAP protocol" (…) The following profiles are recommended for an INSPIRE-compliant View service implementation :
  - Basic profile: support of GET method for the "Get Service Metadata", "Get Map" and "Link View Service"
  - **Standard profile: basic profile and support of the GetFeatureInfo operation through the GET method**
  - SOAP Profile: basic profile plus support of the SOAP/POST method for the three mandatory View service operations
  - Advanced SOAP Profile: SOAP profile plus support of the GetFeatureInfo operation through the SOAP/POST method.

  (…) It is worth noting that ISO 19128:2005(E) standard only support HTTP as distributed computing platform type. It is mandatory to advertise the HTTP GET method according to the ISO standard." (Technical Guidance to implement INSPIRE View Services, v. 2.0).
  Note: SOAP Profile and Advanced SOAP Profile is not supported by the prototype. Link View Service Operation is also not supported with GeoServer.

[7] Note: the Layer Metadata defined through the Feature Type Editor of GeoServer does not follow the INSPIRE profile. The INSPIRE-compliant metadata has been provided separately in XML files (see: sub-section 5.2.1).

5.3.2 Download Service handling in GeoServer

The WFS (Web Feature Service) served by GeoServer 1.7 fulfills the basic capabilities required or recommended by INSPIRE Download Service. WFS is a simpler case of service than WMS. For instance, it does not require definition of portrayal rules. The purpose of WFS is the download of raw GIS data instead of map images.

- INSPIRE Download Service can be of two types. One is 'direct access download service' with Filter Encoding (FE) query capabilities, usually working on data from a spatial database. The other, much simplier type of Download Service is a 'non-direct access download service' (for pre-defined data sets or parts of data sets). A pre-defined dataset or a pre-defined part of a dataset represent conceptually a file stored in a dataset repository, and can be downloaded as a complete unity with no possibility to change content, whether encoding, the CRS of the coordinates, etc. (unless a Transformation Service is used). Such dataset should have a metadata record and be discovered using an INSPIRE conformant discovery service. The metadata should contain a URL link whereby the dataset or part of dataset can be immediately downloaded by a simple HTTP-protocol request (Draft Implementing Rules for INSPIRE Download Services, v.3.0). Pre-defined data set download services and direct access download service may serve different purposes. MSs should be encouraged to implement both types for a given data set. **The case of this prototype is a 'non-direct access download service' (for pre-defined data sets or parts of data sets).** Direct access download service was not tested due to limited scope of this research but primarily due to the nature of the input data used (file-based and not available through a database management system).

- GeoServer 1.7 is a reference implementation of WFS 1.1.0. and WFS 1.0.0. GeoServer supports all WFS operations including Transaction. **WFS in GeoServer implements also the operations required by the 'non-direct access download service', as in case of this prototype:**
    - **Get Download Service Metadata (required) is implemented by GetCapabilities operation of WFS.** This operation provides necessary information about the service to a user (service provider, spatial objects available, access constraints …) and describes service capabilities to enable client application to use the service (list of supported operations).
    - **Get Spatial Objects (required) is implemented by GetFeature operation of WFS.** This operation issues a GET-command in HTTP protocol with the URL to the dataset as parameter, initiates and completes the download.
    - **Describe Spatial Object Types (optional) is implemented by DescribeFeatureType operation of WFS.** The operation returns the description of the complete set of spatial object types contained in the data set or part of data set.

  As stated before **GeoServer supports all operations of WFS 1.1.0 and 1.0.0. Furthermore, it accepts filters encoded in Filter Encoding specification v.1.0 and v.1.1**. **Therefore GeoServer shall be able to support all operations of the 'direct access download service'.** However this type of the download service was not directly tested with the prototype.

  Note: Link Download Service operation is not supported with GeoServer.

- As stated in the Draft Implementing Rules for INSPIRE Download Services (v.3.0), "The Download Services shall support at least one of the encodings defined by the corresponding specification of the INSPIRE themes, if applicable." "Unless specific encodings are specified by the Implementing Rule on interoperability of data sets and services or technical guidance accompanying this, the pre-defined data set or pre-defined part of data set shall be encoded in GML as described by ISO 19136" (Draft Technical Guidance for INSPIRE Download Services, v.2.0). The encoding of data required in all Data Specifications (version 3.0) for INSPIRE Annex 1 data themes is, at the moment of writing: GML 3.0, version 3.2.1. Reference to the specification of the format: ISO 19136:2007. Character set: UTF-8. GeoServer 1.7 (also GeoServer 2.0) supports the GML 3.0 format. **WFS 1.1.0 returns GML 3.1.1 as the default GML format. Unfortunately the output format of the WFS returned from GeoServer 1.7 is not fully compliant with the INSPIRE requirements as the GML 3.2.1 is not supported.**

5.3.3 Configuration modifications for INSPIRE services

Several modifications needed to be made in the configuration of the services and the data to make them compliant to INSPIRE. These modifications are applicable both to the WMS (View Service) and WFS (Download Service), apart from portrayal (styling) which is applicable only to WMS. **The following modifications have been applied in the phase of data preparation or by configuring the GeoServer's settings:**

- **The datasets belong to the themes corresponding to the themes covered by the INSPIRE Directive Annexes** (Annex 1: Administrative Units, Hydrography, Protected Sites). However the spatial object types and associated attributes shall be compliant with the INSPIRE Implementing Rules on Interoperability of Spatial Data Sets and Services (2009). This condition has not been met in this prototype due to limited scope of this research and limitations in the source data resulting from the data capture conditions. For a real INSPIRE-compliant service, the data should be adjusted to the INSPIRE model (see: sub-section 5.2.1).

- **One of the coordinate reference systems recommended by INSPIRE has been applied.** In ArcMap the data has been reprojected to ETRS 1989 UTM Zone 34 N. In the standardized nomenclature of CRS' used by the International Association of Oil and Gas Producers (OGP) (formerly: European Petroleum Survey Group); http://www.epsg.org), this CRS is known as **ETRS89 / ETRS-TM34 (EPSG:3046).** In GeoServer's Feature Type Editor the SRS:3046 has been set as default for all data stores. For the INSPIRE View Service "it is mandatory to use geographical coordinate system based on ETRS89 in continental Europe." (Technical Guidance to implement INSPIRE View Services, v. 2.0) List of the Coordinate Reference Systems in which the layers may be available is defined in the INSPIRE Specification on Coordinate Reference Systems – Guidelines (version 3.0). "In the case of download service of a pre-defined data set or predefined part of data set, the operation shall return spatial objects in at least one of the CRS's defined by the Implementing Rule the Annex 1 theme coordinate reference systems." (Draft Technical Guidance for INSPIRE Download Services, v.2.0).

- **Harmonized data layer names** (defined by Feature Type Name in GeoServer) have been defined for machine-to-machine communication, used in the GetMap request of WMS and GetFeature request of WFS. Harmonized names of data layers are given by Data Specification Implementing Rules for particular INSPIRE themes. Based on the recommendations of Data Specifications, the following naming of Feature Types (data layers) have been used:
    - AU.AdministrativeUnit
    - PS.ProtectedSite
    - HY.PhysicalWaters.Waterbodies
    - HY.AquiferNode.

- **Styling used in WMS follows the recommendations of particular Data Specifications for default portrayal styles.**
  "A style shall be composed of a title and a Unique Identifier. While there is no requirement in the Directive about portrayal, in order to guarantee that maps are presented consistently from the different MS some rules are then necessary. (…) A very minimum default style must be defined for INSPIRE themes (…): this is the "INSPIRE:DEFAULT" style name. (…)When an "harmonized" style is defined across Europe for a spatial object type , then this style becomes the default style, encoded in SE 1.1 or later. (…)Its name is still "INSPIRE:DEFAULT". Its content reflects the harmonized name of the layer. (…)Waiting these "harmonized" styles, and if providers do not want to use the too poor "INSPIRE:DEFAULT" style, they may use their available national or thematic styles (for example : IGNF:TRANSPORTNETWORKS.ROADS)" (Technical Guidance to implement INSPIRE View Services, v. 2.0).
  In this prototype, the following INSPIRE:DEFAULT styles have been applied to particular Feature Types (all defined as Styled Layer Descriptor (SLD) styling in XML):
    - AU.AdministrativeUnit → In this case, a composition of two styles (for two different classes) has been used to show both the area fill and the boundaries: AU.AdministrativeUnit.Default (area) and AU.AdministrativeBoundary.Default (boundary). The administrative unit is rendered using a yellow (#FFFF66) fill. The administrative boundary is rendered using a red (#FF0033) line of 4 pixel stroke width.
    - HY.AquiferNode → HY.AquiferNode style has been used (the style for 'Vanishing Points'). The well represented in this case by 'Vanishing Point' is rendered using blue (#33FFFF) triangle with white (#FFFFFF) fill.
    - HY.PhysicalWaters.Waterbodies → HY.PhysicalWaters.Waterbodies.Default style has been used (the style for 'Watercourses' – polygons). The superficial watercourse is depicted by filled blue light polygons (#CCFFFF) without border.
    - PS.ProtectedSite → PS.ProtectedSite style has been used for the area of national park. The polygon of national park (protected site) is rendered using a 50% grey (#808080) fill and a solid black outline with a stroke width of 1 pixel.

- **INSPIRE-compliant metadata** (compliant with ISO 19115 and ISO/TC 19139 encoding) has been created for the spatial data sets with the use of INSPIRE Metadata Editor, available from the INSPIRE Community Geoportal (http://www.inspire-geoportal.eu/InspireEditor) (see: sub-section 5.2.1). The XML files with metadata have been placed on the web server. In the GeoServer's Feature Type Editor links have been provided for each Feature Type to the corresponding metadata file.

"According to *Article 11* of the Directive, metadata for the INSPIRE services shall be available.
a) The metadata of a View Service must be available :
- through the service Capabilities, as defined in the WMS Standard ISO19128:2005,
- through the "Discover Metadata" operation of the Discovery service.
b) Metadata of the datasets represented in the layers of the View Service are available :
- through Unique Resource Identifer corresponding to a "Discover Metadata" operation of the Discovery service. Generally, this URI is found in the coupledResource of the View service metadata." (Technical Guidance to implement INSPIRE View Services, v. 2.0). "Download services shall be described by service metadata and be discovered using a Discovery service" (Draft Implementing Rules for INSPIRE Download Services, v.3.0). **In case of this prototype, the View Service metadata is available through the GetCapabilities operation of WMS. The Download Service metadata is available through the GetCapabilities operation of WFS.** This prototype is not linked to any external Discovery Service. However the **dataset level metadata has been made available in XML files accessible via URL** (as defined in Feature Type Editor for each Feature Type) (for the metadata URL's see: sub-section 5.2.1).

5.3.4 Additional aspects of INSPIRE services

Several other categories of requirements/recommendations have been recognized that shall be fulfilled by INSPIRE-compliant web services but were not dealt with when setting up this prototype. This is because of the limited scope of this research and because of the limitations of GeoServer application. These requirement/recommendations are related to the following themes:

- **SOAP framework for INSPIRE web services.** The Technical Guidelines for particular types of INSPIRE services (in this prototype: View Service and Download Service) permit for use of HTTP GET and HTTP POST encodings for the requests and responses of services. The relevant ISO and OGC standards for GI web services still rely on HTTP GET and HTTP POST encodings, although new versions of these specifications are now complemented with SOAP annexes. The recommendation of INSPIRE is to develop profiles of these services compliant with SOAP and WS-I specifications. SOAP-based, OGC-compliant web services are still in the phase of prototyping and testing, however they should become de facto standard in the future (see: section 4.1).

  This prototype implements a simple ('standard') profile of INSPIRE View and Download Services based on HTTP GET protocol. GeoServer is not a compliant implementation of SOAP-based services. As yet, there are no plans officially announced to support SOAP with GeoServer (see: GeoServer Road Map: http://geoserver.org/display/GEOS/Roadmap+Ideas)

- **Multilingualism.** The rules shall be developed for dealing with multilingual issues in INSPIRE Network Services. There is not yet a standard way to deal with multilingualism when using ISO or OGC standards specification to implement INSPIRE Network Services. According to Implementing Rules, the View Service and Download Service must provide a way for a client application to specify a language when issuing requests. Several elements are language dependent: the service

capabilities (result of the GetCapabilities operation), the attribute information of the datasets, the dataset metadata, the textual information on maps or in map legends, the service exceptions. The XSD Schemas in Annex B of Technical Guidance to implement INSPIRE View Services, v. 2.0 and Draft Technical Guidance for INSPIRE Download Services, v.2.0 ('Capabilities extension for multilingualism') define the XSD Types that are needed to provide additional information on multilingual aspects. This information has to be provided in a capabilities documents that is returned by an INSPIRE View Service or an INSPIRE Download Service.

This prototype implemented in GeoServer uses English as a default language for all information provided.

- **Rights Management.** Member States may allow restricted access to spatial data sets and services, and/or licence, and/or require payment from, the public authorities or institutions and bodies of the Community that use these spatial data sets and services. Security, protection and rights management aspects shall be as transparent as possible for service users. The functionality and display format shall be compatible with digital right managements and restriction of access and use as envisioned in the INSPIRE directive. When access to a service is restricted, then the following elements shall be given as a part of Get Service Metadata (GetCapabilities) request:
    - Access constraints - type of constraints for accessing the view service
    - Fees - information about pricing/licensing

  (Draft Implementing Rules for INSPIRE View Services (v.3.0), Draft Implementing Rules for INSPIRE Download Services (v.3.0)). Extensive information about the Rights Management framework for INSPIRE Network Services is given in the INSPIRE Network Services Architecture (v. 3.0) document (Section 7.2 and Annex B).

  This prototype does not assume existence of specific fees or access constraints for the services offered.

- **Quality of Services.** Quality of Service (QoS) requirements are introduced for network services. These requirements define quality criteria, associated measures, acceptable values of measures and quality testing conditions. Quality of Service includes mandatory categories: Performance, Capacity, Availability, and recommended categories: Security, Reliability and Compliance. The definitions of QoS criteria for INSPIRE Network Services are defined in the INSPIRE Network Services Architecture, v.3.0. Quality of Services requirements for INSPIRE Network Services are defined in the following documents:
    - 'INSPIRE Discovery and View Services Regulation': Commission Regulation (EC) No 976/2009 of 19 October 2009 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards the network services
    - Draft Commission Regulation amending Regulation (EC) No 976/2009 as regards download services and transformation services
    - Implementing Rules for particular services (Draft Implementing Rules for INSPIRE View Services, v.3.0; Draft Implementing Rules for INSPIRE Download Services, v.3.0…)
    - Technical Guidance for particular services (Technical Guidance to implement INSPIRE View Services, v. 2.0…).

This prototype has not been tested against QoS requirements. The reason is that for many of the QoS elements, they should be tested with the services working in an operational environment, that requires concurrent access to the services from many machines (e.g. Capacity testing) or testing processes that last for a longer period of time (Availability testing). As regards the response times (Performance parameter) in a "single user" setting, they are in accordance with the QoS requirements (see: section 4.5)

- **Discovery Service capabilities.** Discovery Service is an important type of services in the INSPIRE infrastructure. Download and View Services have also linkages with the Discovery Service. Both the service metadata and metadata for particular datasets offered by this services, shall be available through the "Discover Metadata" operation of a relevant Discovery Service. Furthermore, **Discovery Service is expected to serve the "Link Download Service" and "Link View Service" operations required by the Implementation Rules for these services.** These operations shall provide all information about the Public Authority's or Third Party's Download/View service compliant with INSPIRE, enabling a Member State Download Service to get resources from the Public Authority's or Third Party's Download Service and to collate it with other resources. The downloading/viewing capabilities are still to be maintained at the Public Authority or the Third party location. (Draft Implementing Rules for INSPIRE Download Services, v.3.0; Technical Guidance to implement INSPIRE View Services, v. 2.0) Specific rules for the implementation of these operations by the Discovery Service are not yet given. However, it is recommended to implement it for Download Service by uploading the appropriate metadata to the INSPIRE network using PublishMetadata function of an INSPIRE compliant discovery service (Draft Technical Guidance for INSPIRE Download Services, v.2.0). The same rules may apply to the implementation of this operation for the View Service (Technical Guidance to implement INSPIRE View Services, version 2.0).

  Due to the limited scope of the research, this prototype does not implement a Discovery Service instance. It also does not provide a linkage with external Discovery Service. This topic calls for further investigation, also in the context of recommended SOAP framework for INSPIRE services.

Table 9 is a synthesis of the prototype evaluation that serves to provide information which requirements of INSPIRE identified in table 8 (section 4.7) have been fulfilled by the prototype set up in GeoServer.

	requirements	**Download Service**	**View Service**	**Fulfilled with the prototype?**
1	Support of GET method	M	M	Yes
2	Support of SOAP/POST methods	O	O	No
3	Implementation of ISO 19128 (WMS) standard	n.a.	M	Yes/Partly[I]
4	Implementation of OGC 'Styled Layer Descriptor for WMS' and 'Symbology Encoding' standards	n.a.	O	Yes/Partly[II]
5	Implementation of ISO/DIS 19142 (WFS) and ISO/DIS 19143 (FE)	M/C	n.a.	Yes/Partly[III]
6	Get Service Metadata operation	M	M	Yes
7	Get Map operation	n.a.	M	Yes

8	Get Feature Info operation	n.a.	O	Yes
9	Get Spatial Objects operation	M	n.a.	Yes
10	Describe Spatial Object Types operation	C	n.a.	Yes
11	Define Query operation	C	n.a.	No[IV]
12	Link Download/View Service operation	M	M	No[V]
13	Output format: GML 3.2.1 (ISO 19136)	M	O	No[VI]
14	Output formats: PNG, JPEG	O	M	Yes
15	INSPIRE-compliant (harmonized) dataset and layer names	M	M	Yes
16	Coordinate reference systems (compliant with ETRS89/ITRS)	M	M	Yes
17	Temporal data dimension	C	C	No[VII]
18	INSPIRE-default portrayal rules	n.a.	M	Yes
19	Multilingual elements	M	M	No[VIII]
20	Rights Management layer	O	O	No[IX]
21	Quality of services (performance, capacity, availability)	M	M	No[X]
22	INSPIRE-compliant data model	M	M	No
23	INSPIRE-compliant metadata (compliant with ISO 19115/19119, ISO/TS 19139)	M	M	Yes

M – mandatory; O – optional; C – conditional; n.a. – not applicable

Table 9 – INSPIRE requirements implemented with the prototype in GeoServer

[I] GeoServer implements WMS 1.1.1. INSPIRE View Service shall be implemented with ISO 19128 which relies on WMS 1.3.0.

[II] GeoServer implements Styled Layer Descriptor (SLD), v. 1.0 for styling definition in WMS, while INSPIRE View Service recommends the use of 'Styled Layer Descriptor profile of the Web Map Service' 1.1.0 and 'Symbology Encoding', v. 1.1.

[III] GeoServer implements WFS 1.0.0 and WFS 1.1.0. INSPIRE Download Service shall be implemented with ISO/DIS 19142 which relies on WFS 2.0. ISO/DIS 19143 (Filter Encoding) is implemented in GeoServer, however not applicable in case of this prototype (download service for predefined datasets).

[IV] 'Define Query' operation is implemented with WFS in GeoServer, however not applicable in case of this prototype (download service for predefined datasets).

[V] 'Link Download Service' and 'Link View Service' operations shall be served through the operations of INSPIRE Discovery Service (not to be implemented with GeoServer).

[VI] GML version 3.0 is supported as a default output format of WFS 1.1.0 in GeoServer.

[VII] Temporal aspects of data are not applicable in case of this prototype.

[VIII] Multilingual aspects of services were not considered within this prototype. All the information provided is served in English. In ISO 19128, language related parameters remain undefined for request and response (however, the OWS Common Standards Working Group is working on expanding the multilingual abilities).

[IX] This prototype does not assume existence of a Rights Management layer and specific fees or access constraints for the services offered. However, information on such constraints may be defined in GeoServer and attached to the GetCapabilities documents of WMS/WFS.

[IX] This prototype has not been tested against Quality of Service (QoS) requirements.

5.4 Findings and recommendations for GeoServer

This prototype implemented an instance of WMS and WFS OGC web services with GeoServer application. WMS is the base specification for INSPIRE View Service. WFS is the base specification for INSPIRE Download Service. The prototype has proved that GeoServer fulfills the majority of requirements for View/Download Services through the WMS/WFS functionalities. The compliance with INSPIRE guidelines relies also on the configuration of the settings of services in GeoServer. The prototype has been implemented with GeoServer 1.7, however GeoServer 2.0 ('beta' version at the moment of writing) provides very similar functionality and capabilities as regards handling the WMS and WFS services.[8]

The current versions of GeoServer (up to GeoServer 2.0) are capable to provide WFS versions 1.0.0 and 1.1.0 and WMS version 1.1.1 A problem with strict compliance of the View Service results from the fact that its implementation shall be based on 'ISO 19128:2005: Geographic information — Web map server interface' standard, which relies on 'OGC Web Map Service (WMS), version 1.3.0' specification. WMS 1.3 introduced some changes which are not exactly compatible with the previous WMS versions. The one change in WMS 1.3 is that all references to Styled Layer Descriptor (SLD), v.1.0 support has been removed from its specifications. It has been replaced by the following OGC specifications: 'Styled Layer Descriptor profile of the Web Map Service' (v.1.1.0) and 'Symbology Encoding Implementation Specification' (v.1.1). The other change is a different way in which WMS 1.3 deals with handling axis order for several SRS's. Finally, WMS 1.3 offers extended support for HTTP POST encoding of request messages in XML documents (see also: http://mapserver.org/development/rfc/ms-rfc-30.html).

Similarly, the implementation of the Download Service shall be based on 'ISO/DIS 19142 – Web Feature Service' standard, which relies on 'OGC Web Feature Service (WFS), version 2.0' specification. While WMS 1.3 is already a published standard by OGC, WFS 2.0 is, at the moment of writing still a draft (in the process of completion). It is defined within ISO but there are no products yet available compliant with this standard.

GeoServer has not as yet (February 2010) implemented neither WMS 1.3 nor WFS 2.0. Therefore WFS 1.0.0./1.1.0 and WMS 1.1.1 need to be used as interim solutions. According to the OpenGeo (GI division of TOPP – The Open Planning Project; http://opengeo.org/services/coredevelopment/geoserver/wms13) and the GeoServer website (http://geoserver.org/display/GEOS/Roadmap+Ideas), the needed infrastructure for GeoServer is already present but the bindings need to be built and the WMS 1.3 will have to pass the CITE compliance tests. The OGC Compliance and Interoperability Testing Initiative (CITE) provides automatic tests to validate the WMS 1.3.0 implementation (http://cite.opengeospatial.org/test_engine/wms/1.3.0). WFS 2.0 shall be also implemented in future in GeoServer, however the CITE tests for WFS 2.0 are not yet available. In addition it would be advisable to implement Symbology Encoding 1.1 (the successor to SLD) in GeoServer, as it is more in line with WMS 1.3 and the INSPIRE guidelines.

It has to be noted that GeoServer is only an example of software that can be used to set up spatial data services on the Web. It has been chosen for this prototype due to its popularity, good documentation and WFS/WMS support it offers. GeoServer is also a good example of

[8] The major improvements in GeoServer 2.0 include: new Web Administration user interface, application schema support for handling complex features in WFS ('app-schema' plug-in), new security extensions. More information about the current and future improvements in GeoServer can be found at: http://geoserver.org/display/GEOS/Roadmap+Ideas.

open-source software project. Prototypes and tests of INSPIRE-compliant web services made with other web mapping applications (e.g. UMN MapServer) could bring different results. This is, however, out of scope of this research.

Furthermore, the major concern about the implementation of INSPIRE-compliant Network Services is currently how to implement the ISO/OGC-based web services within the recommended SOAP framework. This is not currently possible with the widely available web mapping applications and spatial data servers, such as GeoServer. However, OGC has issued several discussion papers to discover the feasibility and usefulness of enabling SOAP communication in OGC services (see also: section 4.1). Furthermore annexes are provided to the new versions of ISO/OGC service specifications as regards the use of SOAP. A pilot project for prototyping and testing such services is conducted in the Netherlands by Geonovum (http://www.geonovum.nl) – an organization responsible as the National Spatial Data Infrastructure (NSDI) executive committee in this country. Within the integrated project of European Union 'ORCHESTRA – Open Architecture and Spatial Data Infrastructure for Risk Management' (http://www.eu-orchestra.org), initiated in September of 2004, the topic of the use of SOAP/WSDL bindings in geo-information services has been also investigated. Results of the 'ORCHESTRA' surveys provided input for the INSPIRE SOAP framework documentation.

6. Compliance testing of INSPIRE Network Services (View and Download Service)

In chapter 4, the basic requirements for the INSPIRE-compliant web services have been identified. Chapter 5 presented the development and evaluation of a prototype of INSPIRE-compliant web services. Thus, the INSPIRE guidelines have been investigated both from the theoretical and practical point of view. The third step in this analysis is a study on compliance testing. It seems very relevant not only to know what are the requirements for INSPIRE-compliant web services and how can they be implemented, but also how to test compliance to these requirements.

The structure of this chapter is as follows. It starts with an introduction to the topic of testing of software applications and compliance testing (section 6.1). The discussion follows to the understanding of 'compliance' of web services in the context of INSPIRE (section 6.2). Next, a brief review of relevant testing methodologies and standards is presented in the context of INSPIRE Network Services (section 6.3). For the practical part (section 6.4), one testing method (OGC test suite for WMS) is chosen. The compliance testing is discussed with reference to the tests performed on GeoServer, which was the software application used to set up the prototype web services for this research (see: chapter 5). Finally, an evaluation of current test strategies and tools is made and recommendations are provided for the methodology of compliance testing of INSPIRE Network Services (in particular: View and Download Services) (section 6.5).

6.1 Software testing and compliance testing

Software testing is a process that aims to verify if a software application (software component or system – a collection of software components) fulfills specified requirements. It is a topic of technological research. It is 'technological', since a technological approach is involved, including experiments, mathematics, logics, tools (supportive applications), measurements etc. It is also a 'research' since it is an organized form of information retrieval (Stapp L., 2007).

The software testing encompasses: checking for errors in software applications (in order to fix them afterwards), checking for compliance with other applications (components, systems) and checking for compliance with formal requirements (e.g. legal regulations). Testing is helpful in taking the decision about releasing the product on the market (risk assessment). Moreover, testing and error fixing minimizes the costs of technical support services.

Testing is a process which consists of several phases including test planning (time, costs, resources), creating test documentation, creating testing environment, performing tests, adding patches, performing re-tests, test evaluation (analysis of results), preparing test report. Fig.38 presents one of the possible schemas of the software testing process (in a form of software testing life cycle).

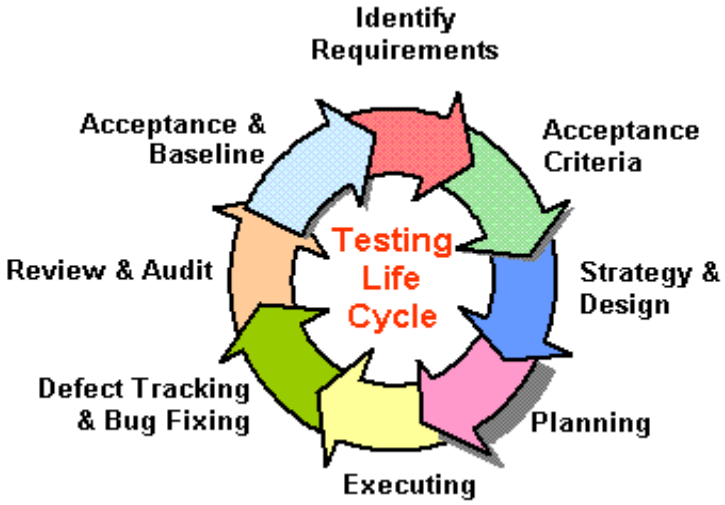


Fig.38 Software Testing Life Cycle
(http://thepcweb.com/wp-content/uploads/2008/08/testing-life-cycle.gif)

There are very different types of tests which use different strategies, e.g. module tests, system tests, integration tests, regressive tests, code review tests. The types of tests considered in this chapter are, in general, requirement based tests, or, in other words, compliance/conformance tests, that is: tests designed to check compliance with requirement specifications (for a system or for certain modules of a system). Requirements are tested in relation to specific functions and functionalities of the tested application. The compliance tests can be also automatic, semi-automatic or manual. For this research the issue of automation of compliance tests for INSPIRE services has been also discussed (see: sections 6.4, 6.5).

Following the definition by International Software Testing Qualification Board (ISTQB), 'compliance testing' is 'the process of testing to determine the compliance of the component or system', where 'compliance' is defined as 'the capability of the software product to adhere to standards, conventions or regulations in laws and similar prescriptions' (ISO 9126). (http://www.astqb.org/educational-resources/glossary.php)

Referring to the compliance testing in the field of geographic information, 'ISO 19105:2000 – Geographic Information – Conformance and testing' document (see: sub-section 6.3.2) states that: "The objective of standardization in the field of digital geographic information cannot be completely achieved unless data and systems can be tested to determine whether they conform to the relevant geographic information standards."

6.2 'Compliance' in the context of INSPIRE Network Services

The most straightforward way to define what is meant by compliance in the context of INSPIRE Network Services, is to quote the INSPIRE Network Architecture (v. 3.0) document: "The compliance of an INSPIRE service is the quality aspect of the web service in conformance with the rules, the law, compliance with standards, and the established service level agreement."
"The compliance criterion defines whether the service is compliant with INSPIRE Implementing Rules. The compliance is checked based on the following sub-criteria:

- the service version,
- existence of the mandatory operations,

- correct handling of the mandatory parameters of operations,
- correct format and versions (when applicable) of the results returned by the mandatory operations,
- compliance with INSPIRE data models for themes defined by the directive annexes."

(INSPIRE Network Architecture, v. 3.0)

The definition given above brings much clarity about what is meant by INSPIRE-compliance of services. However as yet there are no methods formally specified for testing of compliance of web services to the INSPIRE requirements. For this reason, various documentation on GI compliance testing has been inspected and particular strategies and tools for testing investigated. The purpose is to identify standards and projects that can be a guideline for creating the methodology of INSPIRE Network Services compliance testing.

6.3 Strategies and tools for compliance testing

6.3.1 INSPIRE documentation

INSPIRE documentation shall provide not only abstract specifications and technical guidelines for the implementation of compliant data, services and metadata, but also specify relevant methods of compliance testing.
At the moment of writing (February 2010), the state of INSPIRE documentation is the following:

- Abstract Test Suites (ATS) shall be available for the Data Specifications for Data themes from Annex I of the INSPIRE Directive and, in the future, for Annex II and III Data Themes. In some of the Data Specifications, version 2.0 (e.g. Protected Sites, Hydrography) very draft ATS's can be found (Annex A). These ATS's enumerate different elements of the data compliance that shall be tested (e.g. model and structure of the data, UML models, GML application schemas, Coordinate Reference Systems, metadata). However these draft ATS's have been removed in version 3.0 of the Data Specifications.[9]
- A common abstract test suite for INSPIRE-compliant data is in the phase of development (draft document: 'Conformance and abstract test suite in conformance with the ISO 19105 and the INSPIRE conceptual modelling framework'). In the version 3.0 of the Data Specifications a note can be found that 'A common abstract test suite including detailed instructions on how to test each requirement will be added at a later stage.'
- A set of documents is available including:
    - Data State of Play. Compliance testing and interoperability checking. (2007)
    - Metadata State of Play. Compliance testing and interoperability checking. (2007)
    - Services State of Play. Compliance testing and interoperability checking. (2007)

  Regarding the 'Services State of Play', the main aim of this document was identification and assessment of software solutions suitable for testing of functional behavior and performance of the services. However it does not propose any specific test suites for the INSPIRE Network Services. The document mainly evaluates the

[9] As an example of ATS for the specific spatial data theme, the ATS from the annex to the 'ISO/CD 19152 Geographic Information: Land Administration Domain Model' can be referred to.

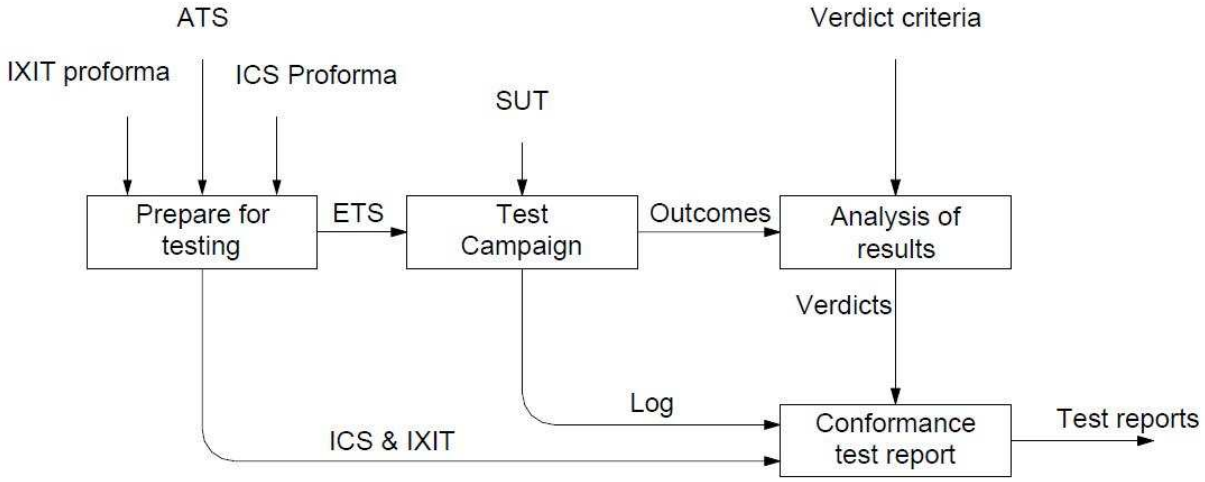
available (in 2007) test software solutions in the context of Service Oriented Architecture (SOA).

- There is no existing abstract test suite for INSPIRE Network Services, neither in particular Network Services Implementing Rules / Technical Guidance, nor as a separate document.

6.3.2. ISO 19105 / 19119

As regards the compliance testing of geographic information, the relevant standard from ISO/TC 211 is 'ISO 19105:2000 Geographic Information – Conformance and testing'. As can be read in the document about its scope: "This international standard specifies the framework, concepts, and methodology for testing and criteria to be achieved to claim conformance to the family of ISO geographic information standards. It provides a framework for specifying abstract test suites (ATS) and for defining the procedures to be followed during conformance testing. Conformance may be claimed for data or software product or service or by specifications including any profile or functional standard."

ISO 19105 sets the rules for conformance/compliance testing related to geographic information on a very abstract level (Fig.39). Testing by means of test methods which are specific to particular applications or systems is outside the scope of this standard. It does also not provide specific rules for compliance testing of web services. However, the concepts and methodology provided in this standard may be helpful in designing the methodology for testing of network services. For instance: it identifies relevant phases of conformance testing process, it describes different approaches to compliance testing (falsification/verification tests, automated/manual tests), it describes the purpose and method for structuring of abstract test suites.



ATS – Abstract Test Suite, ETS – Executable Test Suite, ICS – Implementation Conformance Statement, IXIT – Implementation eXtra Information for Testing, SUT – System Under Test

Fig.39 ISO 19105 Conformance assessment process overview
(ISO 19105:2000 Geographic Information – Conformance and testing)

Whereas the ISO 19105 defines the framework, concepts and methodology for conformance and testing for ISO 19100 series standards, the 'ISO 19119:2005 Geographic Information – Services' standard has as its scope:

- To identify and define the architecture patterns for service interfaces used for geographic information.
- To present a geographic services taxonomy and a list of example geographic services placed in the services taxonomy.
- To prescribe how to create a platform-neutral service specification, and how to derive platform-specific service specifications that are conformant with this specification.
- To provides guidelines for the selection and specification of geographic services from both platform-neutral and platform-specific perspectives.

In the Annex A of the ISO 19119 standard, an abstract test suite can be found defining the methodology of conformance testing of geographic services in relation to the two modules: service architecture test module and service specification test module. Service architecture test module includes definitions of the tests for: geographic services types definition, service chain, service chaining patterns, simple service architecture. Service specification test module includes definitions of the tests for: platform-neutral service specifications, platform-specific service specifications, platform-specific service implementations. Any specification, including a profile or functional standard that claims conformance with ISO 19119 shall pass all of the corresponding requirements described in the relevant abstract test module. Despite the abstract level of the proposed testing methodology, the concepts provided in this test suite may be relevant for the methodology of testing of INSPIRE network services.

6.3.3. OGC Compliance Testing Program

Open Geospatial Consortium (OGC) carries out its own compliance testing program. The purpose of this program is to provide methodology and tools for testing for compliance of applications to the OGC specifications. The Consortium introduced OGC Compliance Testing Language (CTL), which is an XML grammar for documenting and scripting suites of tests for verifying that an implementation of a specification complies with the specification. A suite of CTL files is typically installed in a compliance test engine, which executes the scripts and determines whether the implementation being tested passes or fails. The CTL files can also be used to generate user documentation for the tests in the suite (Compliance Test Language (CTL) Discussion Paper [OGC 06-126]).

An overview of this testing program is given in the OpenGIS Compliance Testing Program document [OGC 03-085r2]. The document defines the approach, including policies and procedures that OGC uses in testing software implementations for compliance to its Implementation Specifications. Some information is very specific to the OGC compliance testing program (responsible parties, formal testing procedures, fees and costs, certification). However, part of the information (documentation guidelines, test suite policies) can be relevant to other compliance testing programs, such as the INSPIRE Network Services compliance testing.

Compliance & Interoperability Testing & Evaluation (CITE) is an ongoing activity of the OGC that develops tests for OGC standards, and makes those tests available for online testing on the following website: http://cite.opengeospatial.org. The available test suites and test engines may be used as a reference for creating testing framework for other projects where geographic information and services are involved, in particular for the INSPIRE project. In the case of this thesis research and the case study, the most relevant are the tests that could be used as a reference for creating the methodology for compliance testing of INSPIRE View and Download Services. The corresponding standards are OGC Web Feature Service (WFS)

for INSPIRE Download Service and OGC Web Map Service (WMS) for INSPIRE View Service. The testing methodology for OGC WMS has been investigated more in details. Section 6.4 describes the process and the outcome of performing the CITE compliance test for WMS on GeoServer software instance. In the Table 10 in this section it is indicated which elements of the View and Download Services can be tested with CITE tests for WMS/WFS.

6.3.4. Geonovum

Geonovum (www.geonovum.nl) is the National Spatial Data Infrastructure (NSDI) executive committee in the Netherlands. The organization was founded in spring 2007 and devotes itself to providing better access to geo-information in the public sector. It is a successor of the Dutch Council for Real Estate Information (RAVI). Geonovum develops and manages the geo-standards necessary to implement this goal. The tasks focus in particular on developing and controlling standards, making up-to-date geo-information accessible, developing knowledge and giving advice to the Council for Geo-information on technology and implementation aspects. Geonovum does not carry out all its tasks itself but calls in third-party help where needed. Within the scope of activities of Geonovum are the projects focused on implementation of the INSPIRE Directive in the Netherlands. However, the organization is also involved in the projects leading to the improvement of the INSPIRE infrastructure on the European level.

Geonovum is responsible for the development of the Dutch National GeoRegistry (NGR). One of the components of the NGR is a Catalogue Service for the Web (CSW) on Dutch metadata. As part of the INSPIRE programme, Geonovum is conducting a conformance test on conformance of the NGR to the INSPIRE Discovery Services guidelines. The CSW of the NGR is tested on being compliant with the OGC CSW 2.0.2. AP ISO 1.0 and with the INSPIRE guidelines for Discovery Services, by using an abstract test suite, 'TEAM' test engine, test scripts written in Compliance Test Language (CTL), test data and documentation. The source code of the test engine comes from GDI-DE (Geodateninfrastruktur Deutschland), which is the German SDI (http://www.gdi-de.org/de_neu/test/navl_test.html) (Report: INSPIRE Discovery Service and Dutch NGR, 2010). The experiences from the Geonovum's project could be possibly used in the future in the development of testing environment for other INSPIRE Network Services, including View and Download Service.

Geonovum is also conducting work on implementation of the client side of the INSPIRE View Services. Furthermore, the work has started with a testbed that should deliver a View Service conforming to INSPIRE Technical Guidelines. The testbed is being performed in cooperation with Atos Origin (IT company). The expected results of this testbed will include a working environment, consisting of services connected to the Dutch national e-government infrastructure.

6.4 Compliance testing – practical example (OGC test suite for WMS)

One testing methodology has been chosen for the practical example of compliance testing. As no INSPIRE test suites for network services exist up till the moment of writing (February 2010), the tests have been performed according to the OGC test suites for web services (Web Map Service). The tests have been performed on GeoServer 1.7 which is a software application used to set up the prototype web services for this thesis research (see: chapter 5).

GeoServer 1.7 is a compliant implementation of WMS 1.1.1 with SLD 1.0 styling. Therefore, the following OGC (CITE) test have been performed: CITE test for Web Map Service (WMS) 1.1.1, available at: http://cite.opengeospatial.org/test_engine/wms/1.1.1. This test engine is designed to test implementations of the Web Map Service 1.1.1 servers.

The purpose of this practical part was to try out how do the OGC test engines work, to evaluate the tests in practice and to derive conclusions for INSPIRE-compliance testing recommendations (see: section 6.5).

OGC automated testing environment is based on 'TEAM' test engine (Test, Evaluation and Measurement Engine), available at: http://cite.opengeospatial.org/test_engine. The test engine is a software product that run scripts (a script interpreter). A test script is an XML file that describes a request to send to the server, and an expected response from the server. Test scripts are often referred to as simply tests. OGC maintains test scripts for several types of services. These are official tests required for compliance certification. As mentioned before, for this thesis research the CITE test for Web Map Service (WMS) 1.1.1 has been chosen.

Tests are run for specific web services and against specific servers. Each run of the test against a specific server is called a test session. A test session is hosted to check if a server (software component running the services) is a compliant implementation of the OGC specifications. A test session saves the server and test information along with a record of which tests have passed or failed. In case of this thesis research, the server used for running the tests was GeoServer 1.7 hosted at: http://casagrande.geo.tudelft.nl:8088/GeoServer (web server of the Delft University of Technology).

OGC CITE tests use specific test data. Compliance tests are much more predictable when standardized data is used. Appropriate test data has to be installed on the server. The engine may be able to run some of the tests on different data to compare the answers (results), but most of the tests depend on the dataset, so a much larger set of tests will be executed when the dataset is properly implemented. The service will not pass certification testing if this step is skipped.

For the test performed in this research, the Web Map Service 1.1.1 Compliance Test Suite Data Set has been used (available at: http://cite.opengeospatial.org/teamengine/wms-1.1.1-r1/data/data-wms-1.1.1.zip). The spatial data from Narew National Park used for the prototyping, was not used for this test since it does not adhere to the 'OpenGIS Simple Features Specification for SQL' standard and also because the test script uses own specific data to check the correctness of results.

Testing process for particular services consisted of the following steps:

1. Preparation
2. Creating an account
3. Creating a test session
4. Executing test
5. Examining test results.

The steps of testing will be described in this manner – from the preparation phase to the evaluation phase.

1. Preparation

It had to be verified if a service is running on a supported port number. In case of the TU Delft server (http://casagrande.geo.tudelft.nl:8088/GeoServer), GeoServer is running on the port number 8080, which is a default port number assumed by the test engine.

The test datasets had to be loaded into the service. In this case, the test data for WMS 1.1.1 was connected to GeoServer. In GeoServer 1.7 a new Namespace "test_data" was created. Within this Namespace, new Feature Data Set (DataStore) was created of a type "Directory of spatial files". The Feature Data Set is "wms111" with the test data for WMS 1.1.1. For this Feature Data Set, URL have been provided to the location of the test data on the TU Delft server in the GeoServer's Feature Data Set Configuration panel.

The majority of the CITE standard dataset is based on the Conformance Test Guidelines for OpenGIS Simple Features Specification for SQL, Revision 1.0. This set of features makes up a map of a fictional location called Blue Lake. (Fig.40). The files are available as GML files, MapInfo files and ESRI Shapefiles. In case of this test, the shapefiles have been loaded into GeoServer.

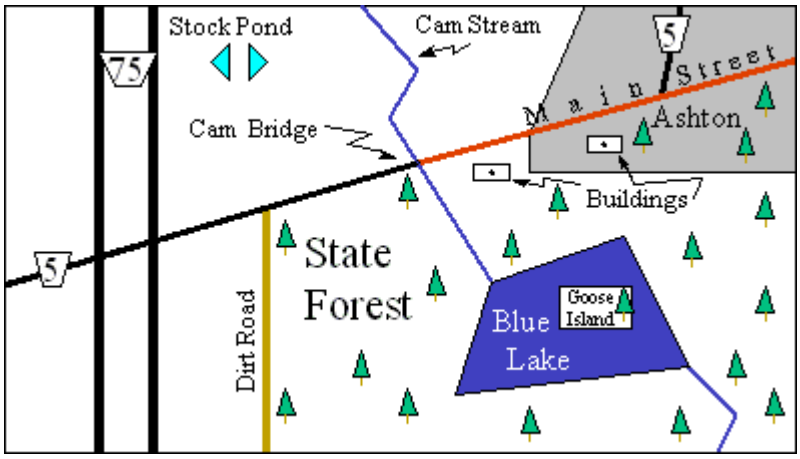


Fig.40 Blue Lake Vicinity Map – test dataset features for the OGC Web Map Service 1.1.1 Compliance Test

2. Creating an account

A new user account had to be created for the testing. The account registration is made at the test engine web page (http://cite.opengeospatial.org/teamengine). After the user name, password and other relevant details are given, the account is created and the user is able to log in to the testing environment.

3. Creating a test session

A new test session had to be created for each run of a test script upon a specific service. A test session ("s0001" session) was created for WMS 1.1.1. Appropriate test suite and and configuration information were selected at the TEAM engine web page.

The Web Map Service 1.1.1 test scripts are designed to test WMS implementations based on the WMS 1.1.1 specification. Not all of the tests available for particular specification are applicable to all servers. The number of tests actually executed during a test session depends on the capabilities advertised in the capabilities URL of the service. The URL to the GetCapabilities request from the WMS on the TU Delft server was given in the TEAM engine configuration panel: http://casagrande.geo.tudelft.nl:8088/GeoServer/wms?request=getCapabilities.

Certification is available for servers that implement either the 'basic' profile or the 'queryable' profile. In order to be certified, the server must implement the requirements for the specific profile. In case of this test session it was chosen to test if all requirements for the 'queryable' profile are met.

Finally, some optional tests are available for the WMS 1.1.1 specification. The remaining tests are not required for specification, but may prove informative or be useful as a debugging aid. These include: recommendation support tests, GML FeatureInfo tests, fees and access constraints tests. For this test session these optional tests have not been chosen due to limited scope of this research.

4. Executing test

The test was run against all required test assertions for WMS 1.1.1.
The following basic elements were tested:

- Basic service elements
  - version numbering and negotiation
  - request parameter rules (parameter ordering and case)
- GetCapabilities operation
  - request parameters
  - GetCapabilities response (general service metadata, capability metadata, layer properties, layer Attributes)
  - output formats
- GetMap operation
  - request parameters
- GetFeatureInfo operation
  - request parameters.

For the details of the tested elements see Annex D of this thesis.

An execution log was automatically created for the test session. For each test assertion, a separate XML log file was also generated. The results of the session were saved on the server, but also available for download on a local machine.

5. Examining test results

The test results are available in a form of a log listing information obtained by running the test. It shows both the HTTP headers and the body of the response received from the server for each request. If any variables are set by the test, their values are listed. If the test failed, there will be an Errors section showing the result value that was expected, the actual value received, any other informative messages, if available.

In total 3983 behaviors (test elements) were tested. The result of the test was 'passed' for 3549 behaviors and 'failed' for 434 behaviors (almost all of the tests that failed, are the tests

for specific spatial reference systems which are not supported by the service). In total, the WMS was claimed to be valid based on the test results. That means that Geosever 1.7 is a compliant implementation of WMS 1.1.1 specification. The test log file will not be shown in here due to its length (the most numerous test assertions are in this case request/response tests for particular spatial reference systems that can be requested by GetMap operation). An extract of the test log file is included in Annex E.

Apart from the OGC test suite for WMS, also the OGC test suites for WFS have been revised (http://cite.opengeospatial.org/test_engine/wfs). The inspection of the content of the test suites for WMS/WFS was used to develop a table (Table 10) which lists the elements of INSPIRE View and Download Services that could be tested with the use of automated CITE tests. The other elements need to be inspected manually or inspected with different test suites until a more comprehensive testing environment for the INSPIRE Network Services is developed. Table 10 corresponds to the Table 8 (section 4.7) listing the requirements for INSPIRE View and Download Services, and to the Table 9 (section 5.3) listing the requirements of INSPIRE that were implemented with the prototype in GeoServer.

	requirements	**Download Service**	**View Service**	**Fulfilled with the prototype?**	**Can be tested with CITE?**
1	Support of GET method	M	M	Yes	Yes
2	Support of SOAP/POST methods	O	O	No	No
3	Implementation of ISO 19128 (WMS)	n.a.	M	Yes/Partly	Yes
4	Implementation of OGC 'SLD for WMS' and 'Symbology Encoding'	n.a.	O	Yes/Partly	No
5	Implementation of ISO/DIS 19142 (WFS) and ISO/DIS 19143 (FE)	M/C	n.a.	Yes/Partly	Yes
6	Get Service Metadata operation	M	M	Yes	Yes
7	Get Map operation	n.a.	M	Yes	Yes
8	Get Feature Info operation	n.a.	O	Yes	Yes
9	Get Spatial Objects operation	M	n.a.	Yes	Yes
10	Describe Spatial Object Types operation	C	n.a.	Yes	Yes
11	Define Query operation	C	n.a.	No	Yes
12	Link Download/View Service operation	M	M	No	No
13	Output format: GML 3.2.1 (ISO 19136)	M	O	Yes	Yes/Partly[I]
14	Output formats: PNG, JPEG	O	M	Yes	Yes
15	INSPIRE-compliant (harmonized) dataset and layer names	M	M	Yes	No
16	Coordinate reference systems (compliant with ETRS89/ITRS)	M	M	Yes	Yes
17	Temporal data dimension	C	C	No	No
18	INSPIRE-default portrayal rules	n.a.	M	Yes	No
19	Multilingual elements	M	M	No	No
20	Rights Management layer	O	O	No	Yes/Partly[II]
21	Quality of services (performance, capacity, availability)	M	M	No	No[III]
22	INSPIRE-compliant data model	M	M	No	No[IV]
23	INSPIRE-compliant metadata (ISO 19115/19119, ISO/TS 19139)	M	M	Yes	No[V]

M – mandatory; O – optional; C – conditional; n.a. – not applicable

Table 9 – Elements of View and Download Services testable with CITE tests for WMS and WFS

[I] Output format of the WFS can be tested, however a full test for GML 3.1.1 compliance and validation is not within the scope of the CITE tests. Also, the validation test for GML 3.2.1 (as required by INSPIRE) is not yet within the scope of the CITE tests. The GML 2.1.2 test engine (http://cite.opengeospatial.org/test_engine/gml/2.1.2) supports the validation of GML 2.1.2 schemas and instance documents.

[II] Optional fees and access constraints tests are available.

[III] Elements of the quality of services need to be tested with different types of tests (benchmark tests for performance, capacity, availability) and preferably in an operational environment.

[IV] For testing of the data compliance to the INSPIRE model, specific Abstract Test Suites (ATS) for spatial data shall be referred to (see also: sub-section 6.3.1). At least two types of tests are needed: tests for data model/application schema validation and tests for the compliance of the data against the required data model/application schema.

[V] Full validation of the INSPIRE-compliant metadata is out of scope of the CITE tests. Metadata files encoded in XML can be validated for compliance with the use of INSPIRE Metadata Editor (see also: sub-section 5.2.1).

6.5 Recommendations for INSPIRE-compliance testing

As mentioned before, there is no established methodology for compliance testing of INSPIRE Network Services. It is necessary to elaborate the Abstract Test Suites (ATS's) for the INSPIRE services. It would be also recommended to prepare Executable Test Suites (ETS's) – collection of the test cases executable by a program for automated testing of the compliant services. The INSPIRE Network Architecture (v.3.0) document roughly defines what is meant by compliance of INSPIRE web services (see: section 6.2). Some core elements of the abstract framework for GI compliance testing are provided by ISO standards, in particular 'ISO 19105:2000 – Geographic Information – Conformance and testing' and 'ISO 19119:2005 Geographic Information – Services' (see: sub-section 6.3.2), some others can be derived from particular INSPIRE documents (see: sub-section 6.3.1).

Nevertheless, the most relevant source of methodology for the automated compliance testing of INSPIRE Network Services are the test suites for conformance testing of OGC web services (see: sub-section 6.3.3). These test suites are a part of the OGC compliance testing program known as CITE (Compliance & Interoperability Testing and Evaluation). The OGC test suites are particularly relevant in the context of INSPIRE-compliance testing of web services since the Technical Guidance documents for INSPIRE Network Services are based in a vast part on the OGC web services specifications (and their corresponding ISO implementations), namely:

- INSPIRE View Services shall be implemented based on the OGC Web Map Service – WMS 1.3 (ISO 19128).
- INSPIRE Download Services shall be implemented based on simple HTTP file download protocol, OGC Web Feature Service – WFS 2.0 (ISO/DIS 19142) with Filter Encoding (ISO/DIS 19143) capabilities, in future also on the OGC Web Coverage Service (WCS), depending on the characteristics of data.
- INSPIRE Discovery Services shall be implemented based on the OGC Catalog Service with the ISO Application Profile (OGC CS-W 2.0 ISO AP).
- INSPIRE Transformation Services include file format transformations, language transformations, geometric transformations and schema transformations. Most of them shall be implemented based on functions of the OGC Web Processing Service (WPS), including the OGC Web Coordinate Transformation Service (WCTS) as an

Application Profile of the OGC WPS Implementation Specification for the coordinate transformations.

- INSPIRE Invoke Service – base specifications are not yet specified, however BPEL (Business Process Execution Language) from OASIS is advised to be used for the web services orchestration, in combination with the OGC Web Processing Service (WPS) interface.

In general, INSPIRE makes use of existing OGC specifications (and their corresponding ISO implementations) for web services with some INSPIRE-specific extensions for particular aspects of these web services (WMS, WFS, CS-W etc.).

Taking into account the above, it is advisable for the future test suites for INSPIRE Network Services to be based on the test suites for their corresponding OGC web services. This remark applies to the structure of the test suites, terminologies, testing methodology, and elements subject to testing. The elements subject to testing shall include: service version numbering and negotiation, request parameter rules, mandatory (and optional) operations, handling of parameters of operations, output formats of the operations. For the SOAP-based services, the elements subject to testing would be similar, however a different test engine would need to be used.

The data and metadata models used by the services shall be subject to compliance testing but this is within the scope of work of other INSPIRE Drafting Teams (Data Specifications DT and Metadata DT). A part of the compliance testing program for the spatial data are the tests for GML/XML validation. However, before the data is checked for compliance with the GML application schema/data model, the schema/model itself has to be validated. Elements of Quality of Services, such as performance, capacity, availability, shall be tested with benchmarks tests and preferably in an environment ensuring continuous operability and concurrent access to the services. A methodology for testing of the multilingual elements of services shall also be developed.

It should not be forgotten, that in the future the INSPIRE Network Services will make use of the SOA framework for web services, including all the relevant standards. The challenge is to set up the network services based on the OGC specifications but operating on SOA-based protocols (SOAP-based counterparts of the RESTful services). This is also the challenge for compliance testing program since it will have to make use both of the OGC CITE testing methodologies and of the methodologies for testing of SOA-based web services (see also: Services State of Play. Compliance testing and interoperability checking. (2007)).

7. Summary

The summary of the research consists of three parts. Section 7.1 includes the research overview (objectives, phasing, role of the case study). Section 7.2 includes the actual research evaluation – conclusions based on the outcome of the research, recommendations for the INSPIRE documentation and services. Section 7.3 includes open issues for future research work (extended research).

7.1 Research overview

The major objective of this research was to answer the question **"What is the quality of the guidelines for implementation of INSPIRE-compliant web services?"**. All the analyses in the theoretical and practical parts of the research were performed in the search for an answer to this central question and relevant sub-questions (see also: section 1.2 'Research objectives').

The first sub-objective was to identify what is meant by 'compliance' in the context of INSPIRE Network Services, as well as in the context of spatial data and metadata which are used as an input to all INSPIRE services. In particular, the objective was to identify, based on the INSPIRE documentation, the specific guidelines for INSPIRE-compliant web services, with emphasis on View and Download Services.

The second sub-objective, was to evaluate the quality of these guidelines in the sense of completeness, clarity and consistency.

The third sub-objective was to identify the guidelines for compliance testing of INSPIRE Network Services, providing assessment of these guidelines and further recommendations.

The fourth sub-objective was to evaluate the feasibility of implementation of INSPIRE-compliant web services, taking into account the current state of play of INSPIRE guidelines and the current state of relevant technologies.

The research that was done can be conceptually divided into three phases:

- theoretical part (chapters 2,3,4) – study on relevant concepts, methodologies and technologies; identification of the documentation/specifications with guidelines for implementation of INSPIRE-compliant web services;
- practical part 1 – prototyping (chapter 5) – implementation of a prototype of web services according to the INSPIRE guidelines (based on OGC-compliant GeoServer application); primary assessment of the feasibility of implementation of INSPIRE-compliant web services;
- practical part 2 – compliance testing (chapter 6) – theoretical study on compliance testing of GI web services, followed by a practical OGC compliance test execution on the GeoServer instance; recommendations for compliance testing of INSPIRE network services.

The case study chosen for this research were the GI web services for protected sites / national parks with a particular case of Narew National Park located in Poland. The web services for protected sites are a very good example of GI network services useful for varied user groups (see: section 3.3). However, the major role of the case study was to support the evaluation of

the central research question and the sub-questions and to validate the proposed technical solutions (setting up the prototype and compliance testing). The results of this research shall be generic – applicable not only to Narew National Park or other national parks but to different kinds of GI web services, which claim to be INSPIRE-compliant.

7.2 Conclusions and recommendations

This chapter aims to provide final conclusions and recommendations of the research based on the experience gained in the previous phases. It provides the final assessment of the guidelines and of the feasibility of implementation of INSPIRE-compliant web services.

The conclusions and recommendations of this research are discussed in relation to the four sub-objectives given. Conclusions of the research are presented together with the recommendations. The main research goal was to evaluate:

- what already has been done within INSPIRE to provide the guidelines for implementation of INSPIRE-compliant services and how this problem was tackled – what is the quality of these guidelines (conclusions), and
- what is still to be done within INSPIRE, in the sense of new documentation but also technical environment and support, to improve the feasibility of implementation of INSPIRE-compliant web services (recommendations).

These questions will be answered in this section, in relation to the four sub-objectives of the research, and as a summary, in relation to the main research objective.

The first sub-objective was to identify the meaning of 'compliance' in the context of INSPIRE Network Services and identify the specific guidelines for these services.

Based on the INSPIRE documentation, the following general compliance elements of the web services have been identified:

- the service version,
- existence of the mandatory operations,
- correct handling of the mandatory parameters of operations,
- correct format and versions (when applicable) of the results returned by the mandatory operations,
- compliance with INSPIRE data models for themes defined by the directive annexes.

The synthesis of the elements of INSPIRE-compliant web services can be found in section 4.7 (Table 8 on p.66). The list of mandatory requirements for View and Download services presented in Table 8 provides the answer to the first sub-objective of this thesis: when a web service implements the mandatory requirements, it would be fair to state that this web service is 'compliant' to the INSPIRE implementing rules. More specific information on the INSPIRE guidelines can be found in sections 4.1-4.6 and in Annex B of this thesis.

The second sub-objective was to evaluate the quality of these guidelines in the sense of completeness, clarity and consistency.

The review of the INSPIRE documentation done during this research revealed that these documents have been prepared in an effort to be comprehensive, specific and clear enough to provide a framework for implementation of INSPIRE-compliant services, data and metadata. This is assessed based on the fact that the *INSPIRE documents include specific requirements*

(mandatory) and recommendations (optional) as regards all the relevant aspects of services: technical architecture, mandatory operations and parameters of operations, output formats, reference systems, quality of services, multilingual aspects, rights management, spatial data and metadata. Furthermore, the core of INSPIRE guidelines is based on well-established international standards, especially those coming from International Organization for Standardization (ISO) and Open Geospatial Consortium (OGC). The documents are well structured (often following document structuring set out in ISO and OGC standards), balanced and written in an understandable manner.

The current scope of the INSPIRE documentation is, however, limited due to the fact that the process of drafting of the INSPIRE guidance documents has not been completed yet. The status of work on the various INSPIRE Network Services is different – the most advanced for the Discovery and View Services, less advanced for the Download and Transformation Services and almost no work done for Invoke Services (preliminary surveys).

After investigating the INSPIRE documentation in details, it can be stated that the technical architecture, functionality of services (operations and parameters of operations), reference systems and output formats have been thoroughly elaborated. The documentation provides a clear guidance for implementation and the relevant OGC and ISO standards might be referred to further details in most cases. However, there are some shortcomings also in this issue. *The definition of SOAP bindings and WSDL descriptions is only present in relevant documentation, as yet, for the Discovery and View Services. The strict definition of some optional operations and their parameters is lacking (e.g. Get Feature Info operation of the View Service is not described in details).* Such shortcomings in the guidelines may still obstruct the implementation of the compliant services.

The problem of the consistency of the guidelines is also present. For instance, a clear mechanism shall be established for the Member States for linking their services and data to the European infrastructure (e.g. clear definition of Link View / Download Service functions implementation), as *a harmonized interpretation of the link operation across all services is lacking.* Another example are the harmonized layer names for the INSPIRE View Service. In this case, the *Technical Guidance document for the View Services recommends a different approach to the naming in relation to the approach proposed in particular Data Specifications.* If more examples of such contradictions are found, the topic shall be further investigated, since the consistency of the guidelines is crucial for their implementation.

Apart from the technical aspects of services, *more work is also needed on setting the guidelines for dealing with other issues such as multilingual aspects* (dealing with language parameters of services) *and rights management* (access and security rights – standards/protocols, policies, registries, certification). A common approach to these issues is needed since they are of especially high importance for the data and service sharing on the EU-level.

Another issue are the *Quality of Service (QoS) requirements which need to be more precise in the technical guidance documents* and relevant benchmark tests shall be executed. In particular, reference tests and regulations for the reliability and security aspects of the quality of services have to be prepared. More strict already guidelines are available for such aspects of the quality as performance, capacity and availability, but still the practical tests of these elements of quality need to be performed in operational environments.

The third sub-objective was to identify and evaluate the guidelines for compliance testing of INSPIRE Network Services, providing further recommendations for the compliance testing methodology.

This topic calls for particular attention in the nearest future, *as the specific guidelines for the testing of compliance of INSPIRE Network Services are not present at the moment of writing* (February 2010). Such guidelines shall be elaborated based on the experience of INSPIRE Drafting Teams (in particular: DT 'Network Services') and experts in software testing. The testing environment would need to include a test engine, scripts, test suites, test data, instructions. The possibility of automation of the testing processes should be considered to the extent reasonably possible.

The recommendation of this research is to use the OGC compliance testing environment (CITE – Compliance & Interoperability Testing & Evaluation) as the reference framework for INSPIRE compliance testing. The OGC tests are especially suitable as the reference since the core technical specifications for implementation of the particular INSPIRE Network Services are the OGC web services specifications (see: section 6.6).

Table 10 in section 6.6 (p.101) shows which of the INSPIRE requirements for View and Download services could be tested using the CITE methodology, and which ones could not be tested this way. The overall conclusion that can be drawn from this list is that the *OGC tests would need to be extended with INSPIRE-specific extensions (e.g. for harmonized layer names, reference systems, multilingual elements)*. The principles set out for the geographic information by ISO/TC 211 (in particular in 'ISO 19105 – Conformance and testing' and 'ISO 19119 – Services') are also relevant for the development of the testing methodology of INSPIRE services on a more abstract level.

The development of compliance testing programs for spatial data and metadata is a separate topic and within the scope of Drafting Teams on 'Data Specifications' and 'Metadata'.

The fourth sub-objective of the research was to evaluate the feasibility of implementation of INSPIRE-compliant web services, taking into account the current state of play of INSPIRE guidelines and the current state of relevant technologies.

Unfortunately the review of existing 'INSPIRE-compliant' technologies cannot be done in full due to limited scope of this research. One particular software application (GeoServer 1.7) has been chosen for a review and testing as a compliant implementation of OGC web services (WMS and WFS). Prototype web services set up with GeoServer have been evaluated for compliance with the INSPIRE guidelines for View and Download Services (see: chapter 5). One of the main problems with the compliance of WMS and WFS in GeoServer to the INSPIRE Network Services definitions is that GeoServer does not support as yet the most current versions of the ISO/OGC specifications as required by INSPIRE (see: section 5.4). Table 9 in section 5.3 (pp.88-89) lists the INSPIRE requirements that could be implemented in the prototype using GeoServer 1.7, and the ones that could not be complied to yet.

The evaluation of the prototype services against the INSPIRE requirements allows to state that it is relatively straightforward to set up INSPIRE-compliant web services based on HTTP GET and HTTP POST bindings, as these protocols are supported by the relevant OGC web services and their use has been envisioned in particular OGC specifications (for WMS, WFS, CS-W and others). However, the *functionality of the OGC web services needs to be extended*

with INSPIRE-specific extensions or constraints (regarding: handling mandatory/optional parameters of operations, multilingual aspects of the services, rights management etc.). The requirements and recommendations for these extensions can be found in Technical Guidance documents for particular types of INSPIRE Network Services. The versioning of OGC web services is also important since INSPIRE recommends the use of the latest versions of specifications, e.g. WMS 1.3, WFS 2.0 (see: section 5.4).

The implementation of INSPIRE-compliant web services based on the technical standards for web services set out as the 'SOA-stack' (Service Oriented Architecture) is more complicated than for the HTTP GET/POST-based services. At the moment of writing, there are no technical solutions (development tools) widely available to establish OGC-compliant services based on the SOA protocols (SOAP, WSDL, UDDI etc.). Pilot projects for the establishment of such services have begun. One of them is conducted by the Dutch NSDI executive committee – Geonovum. The integrated EU project ORCHESTRA is another project that investigates the topic of the use of SOAP/WSDL bindings in geo-information services, also in the INSPIRE context. The OGC teams are also working on the documentation and pilot projects for the use of WSDL/SOAP protocols within OGC web services (see also: sections 4.1, 5.4).

This topic is very important for INSPIRE since almost all INSPIRE Network Services have OGC standards as their reference specifications (see: section 6.6). Simultaneously, *SOAP is considered as the default communication protocol and binding technology for the INSPIRE services in future* and the relevant implementation documentation has already been issued for the Discovery and View Services (see: section 4.1). *The application of SOAP protocol*, instead of relying only on HTTP GET/POST bindings, *will allow a full integration with the Web Services Architecture and with the current development environments.* Moreover, the definition of a common SOAP header *will allow INSPIRE Network Services to support requirements from "horizontal services" (rights management, e-commerce).* The topic needs particular attention in the future – both at the side of preparation of relevant documentation and subsequent technical implementation. *The development of the conformance testing program for SOAP-based INSPIRE-compliant services is another challenge for the future.*

Another requirement for the INSPIRE-conformant web services is that the spatial data and metadata are provided compliant with the data models required by INSPIRE. At the moment it is possible for the spatial data corresponding to the Annex 1 of the INSPIRE Directive. Harmonized data models for INSPIRE Annex 2 and 3 data themes have not been proposed yet (the implementing rules for these data themes shall be submitted for opinion of the INSPIRE committee until 15 May 2012). Nevertheless, it is not always needed that the source data are fully INSPIRE-compliant. This shall apply to the raw spatial data available for download through a INSPIRE Download Service. However a Download Service, View Service or Discovery Service may be also chained with a Transformation Service which transforms the spatial data (or metadata) "on the fly" to the INSPIRE-compliant data model or format.

As it can be concluded from all the above, and in relation to the **main research question**, the quality of the guidelines for implementation of INSPIRE-compliant web services is good, as the guidelines refer to all relevant aspects of network services and rely on established standards, in particular ISO/OGC standards. However the main problem is of the completeness of these rules since the process of drafting of INSPIRE documents is still ongoing. Some inconsistencies and contradictions can be found in the documentation as well.

These elements should be improved in the further amendments of the documents. Moreover, a compliance testing methodology for INSPIRE services is lacking and shall be elaborated.

The feasibility in the near future of the implementation of web services that are completely compliant to INSPIRE implementing rules has also to do with the broader context, such as the existence of already partly compliant software products or the level of compliance of the existing spatial data resources in the Member States with the INSPIRE data models. The process of the adoption of legislation and implementing rules for INSPIRE and the process of implementation of INSPIRE-compliant solutions in practice shall be seen as two that go parallel. The adoption of INSPIRE guidelines shall stimulate the implementation of the compliant solutions as an ongoing process of building the infrastructure from the state level to the EU-level. The making of spatial data and services INSPIRE-compliant cannot be overlooked since it is a legal obligation for the Member States of the European Union, but has also an immense practical significance in terms of improving the technical and organizational dimensions of interoperability of geographic information in Europe.

7.3 Future work

The research had it limited scope, also due to the limited time schedule, however it would be possible to introduce the following new research elements in case of a more in-depth approach:

- detailed research on the assessment of the quality of the guidelines to implement INSPIRE-compliant data (not only services)
- real transformation of the spatial data to the INSPIRE-compliant model for the prototype of INSPIRE services (e.g. with the use of data mapping tools from ESDIN project; see: section 5.2.1)
- setting up a prototype of direct access Download Service with query capabilities (with data retrieved from a database management system with spatial extension, e.g. PosgreSQL/PostGIS)
- setting up a prototype of Discovery Service (e.g. with the use of GeoNetwork application)
- setting up a prototype of Transformation Service (e.g. for coordinate transformations)
- setting up prototype services using different software tools (e.g. GeoServer, MapServer, ArcIMS) in order to compare the feasibility of implementation of INSPIRE-compliant web services with different applications
- development of a prototype of network services relying on the 'SOAP-stack' protocols (SOAP, WSDL, UDDI etc.)
- Quality of Service testing and evaluation (performance, capacity tests etc.)
- preparation of complete Abstract Test Suites (ATS's) for compliance testing of INSPIRE Network Services (in case of a more advanced research: also preparation of testing environments).

All these elements are open issues in the future work on the topic of INSPIRE-compliant web services, and could be further investigated with new research projects.

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Geonovum www.geonovum.nl
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GRISI project ("Geomatic Regional Operation Society Initiative") http://www.grisi.org
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Institute for Environmental Security http://www.envirosecurity.org
International Association of Oil and Gas Producers (OGP) (formerly: European Petroleum Survey Group) http://www.epsg.org
International Organization for Standardization http://www.iso.org
Java Sun Developers Network http://developers.sun.com
Karkonosze National Park http://www.kpnmab.pl
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OpenGeo – geospatial division of TOPP (The Open Planning Project) http://opengeo.org
Open Geospatial Consortium (OGC) http://www.opengeospatial.org
OpenLayers http://www.openlayers.org
ORCHESTRA – Open Architecture and Spatial Data Infrastructure for Risk Management http://www.eu-orchestra.org
OSGeo – Open Source Geospatial Foundation http://www.osgeo.org
Polish National Geoportal http://www.geoportal.gov.pl
Quantum GIS (QGIS) http://qgis.org
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Annex A

Web Services for protected areas (examples)

The purpose of this Annex is to present several interesting examples of projects for web services/geoportals for protected areas (in particular national parks). A few examples of diverse projects will be shown. The software components applied and the standards used for the data and services will be mentioned as well. A link will be provided to one of the projects which makes an attempt to be compliant with the standards provided by INSPIRE (GRISI project).

Example 1: Florida's Wetland Web-GIS and Geodatabase

One of the projects which is very well documented on the Web is the project for Florida's Wetland Web-GIS and Geodatabase. The objective of the project was to develop an interactive web-based tool to integrate and visualize geographic data and information for Florida's wetlands providing map and data services to users (Mathiyalagan V. *et. al.*, 2005). The services of the project are available through the website http://giswetlands.ifas.ufl.edu.

The unit responsible for the thematic content of the services and the adopted methodology is Wetland Biogeochemistry Laboratory, Soil and Water Science Department, University of Florida. For this project 2130 geo-referenced point observations of 78 different soil physical, chemical, and biological attributes collected in Florida's wetlands starting from 1987 have been standardized and integrated. Additional GIS data layers include geology, land use, county boundaries.

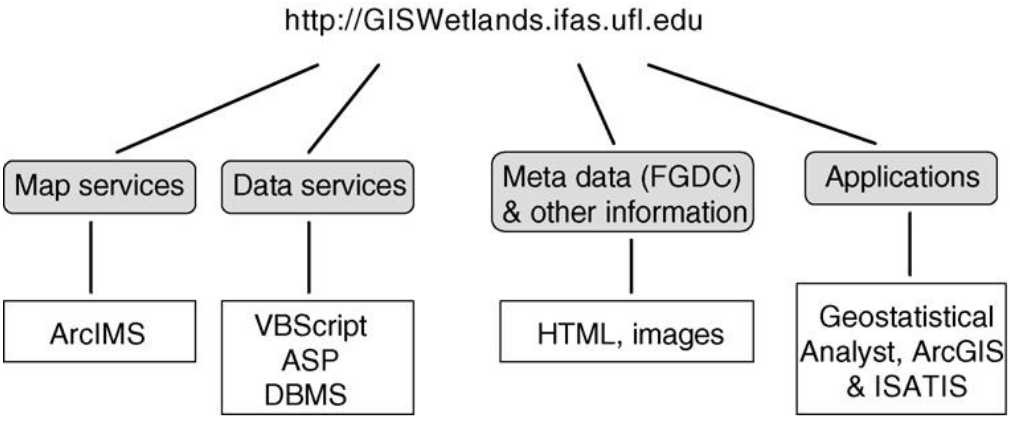

Fig. I Architecture of the Florida Wetland WebGIS and Geodatabase
(Mathiyalagan V. *et. al.*, 2005)

The WebGIS application (Fig.I, II) was created with ArcIMS software. This is a commercial web mapping software from ESRI. The functionality of application was extended with Microsoft Access database, Java, Visual Basic and Active Server Pages. The users of the map service (http://srvgis.ifas.ufl.edu/website/wbl2002/viewer.htm) are equipped with query,

selection and navigation functions. They can run SQL-based queries and select data basing on geographic location, projection, time period, depth of sample, vegetation type, and soil property. The data is available for download and can be combined with other environmental data for the Greater Everglades ecosystem. The metadata service is available as well. The Florida's Wetland Web-GIS is a very good example of a project of WebGIS with a sound scientific background and provides a centralized repository of environmental datasets that support the documentation of the quality of the ecosystem.

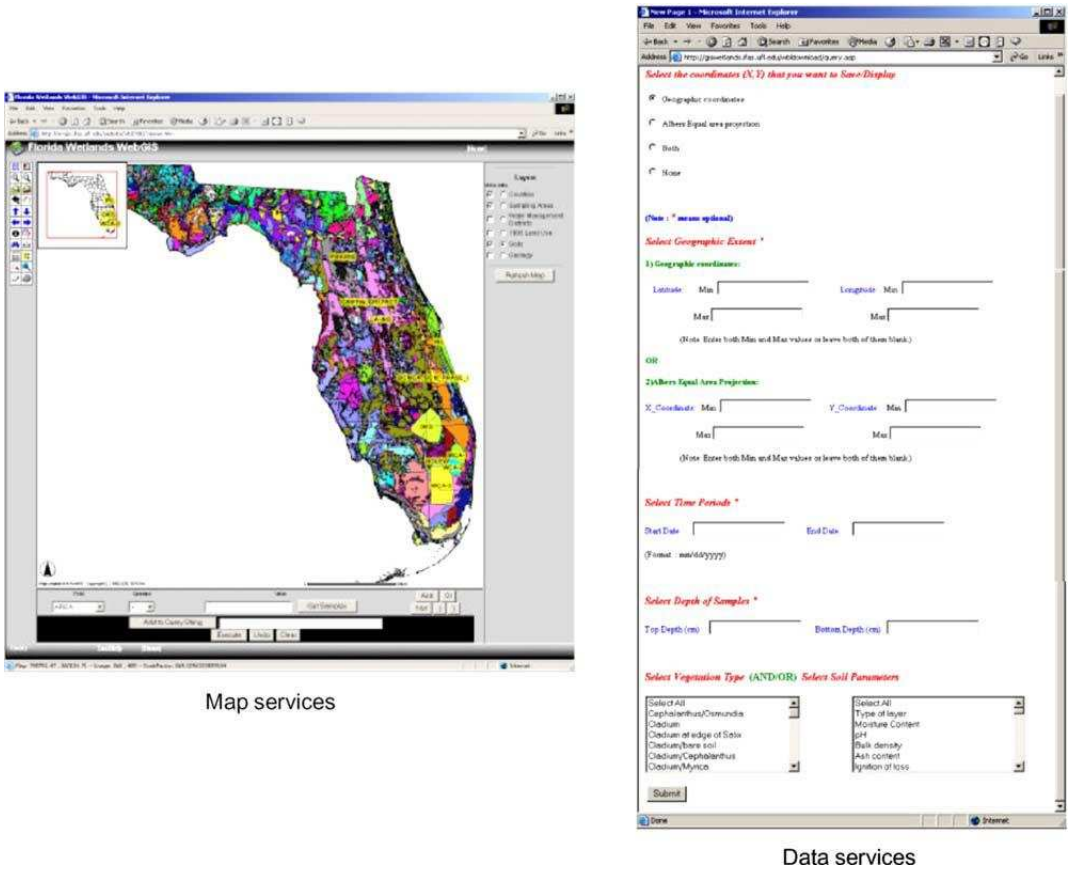

Fig. II Florida Wetland WebGIS implemented in ArcIMS
(Mathiyalagan V. *et. al.*, 2005)

Example 2: Swiss National Park geoportal

An example of a project from Europe aimed especially at tourists is the geoportal of the Swiss National Park (Schmid Ch., 2006). The core element of the WebGIS is an interactive map module, available from the website of the park (http://www.nationalpark.ch) and directly at: http://195.65.102.71/Website/IKD/viewer.htm **(**Fig.III**)**. The map module serves as useful source of information for visitors. Tourists can discover both natural values of the park (e.g. flora and fauna), as well as elements of infrastructure (e.g. availability of hiking trails). The map module was designed to provide the users with rich thematic content and in the same time with high level of interactivity and simple operability. The WebGIS application is based on Geomedia WebMap Professional – a commercial web mapping software (map server) from Integraph. GIS data used is stored in Microsoft Access databases and file systems. Interactive maps are made available to the user in SVG format (Fig.IV). Data comes from

various sources – internal GIS database of Swiss National Park, Federal Office of Topography ('swisstopo'), cadastral survey, project "HABITALP" documenting alpine habitats diversity, land use and land cover. A metadata catalogue is available as well.

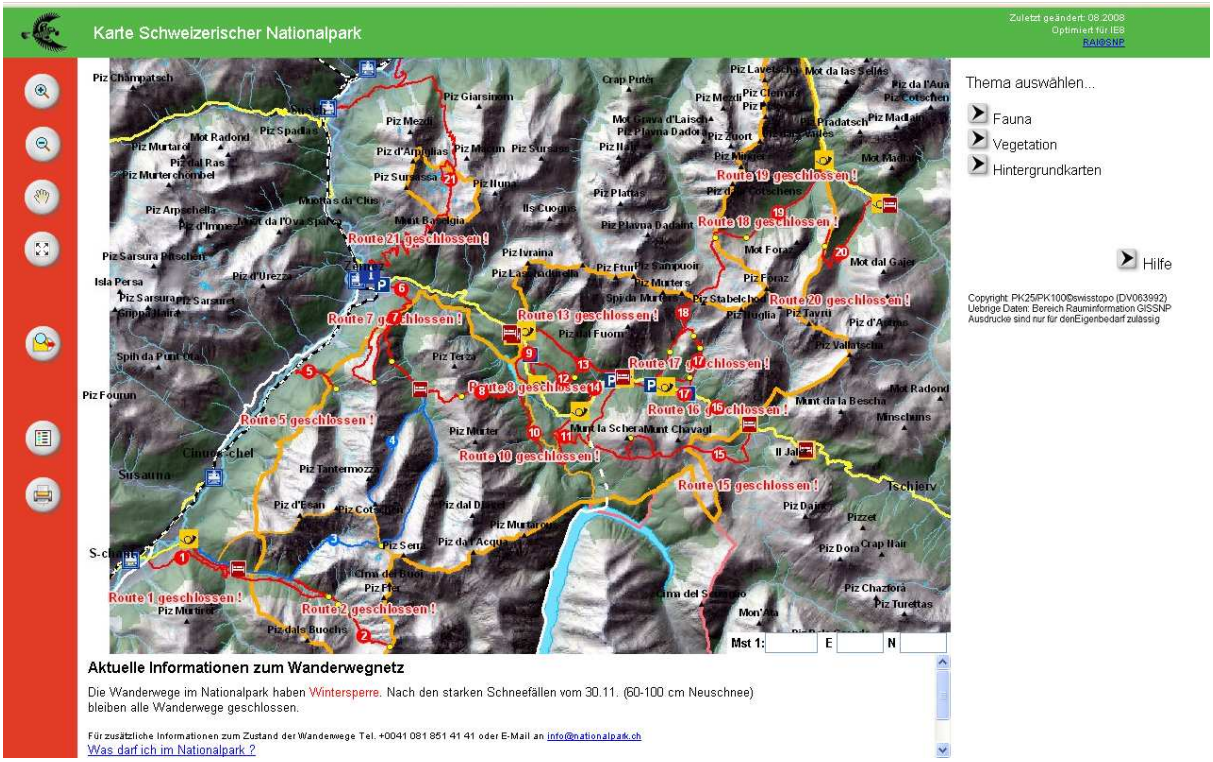

Fig. III Swiss National Park geoportal – map module view (http://195.65.102.71/Website/IKD/viewer.htm)

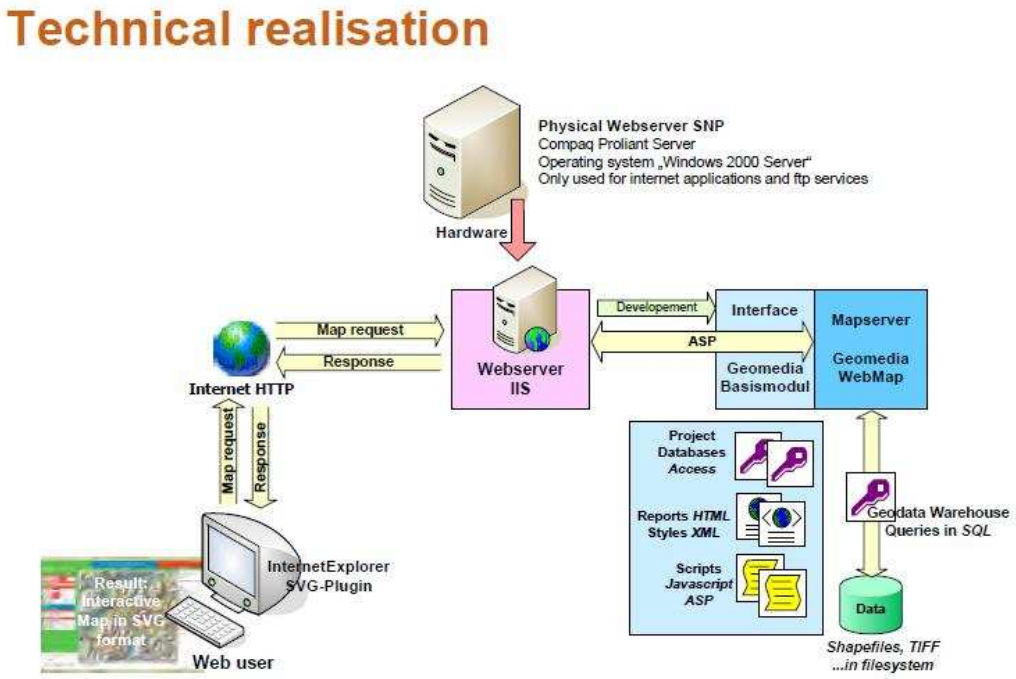

Fig. IV Swiss National Park geoportal – technical realization (Schmid Ch., 2006)

Example 3: WebGIS for Krkonoše/Karkonosze national parks

A WebGIS for Krkonoše/Karkonosze national parks is a result of long-term cooperation of managements of these two protected areas and is a good example of a geoportal developed in a cross-border project. Krkonošský Národní Park is located in Czech Republic and Karkonoski Park Narodowy in Poland. This is a border mountainous region of very high natural and landscape values, with trails available for walking and hiking, cross-country skiing and alpine skiing in resorts in the neighborhood. The cooperation between two parks in creation of a common Geographic Information System started in 1999 with the project "PHARE preparation for Natura 2000". The next project, also financed from the PHARE fund of the European Union, was the **"**GIS for Krkonoše/Karkonosze" (2005) aimed at integration of geographic databases and creation of a common WebGIS for both parks. (http://www.kpnmab.pl/pl/gis-w-karkonoskim-parku-narodowym,136)

The geoportal offers a map view service (Fig.V) and a metadata catalogue, both accessible through the website http://mapy.krnap.cz. The functionality of the map services includes, apart from the browsing functions, also measurements on a map, queries about objects and simple editing functions (for registered users). The metadata catalogue is compliant with basic ISO standards for metadata (ISO 19115, ISO19139) and is integrated with the map application to search for data for a specific area. Open source software has been used to develop the web services: PostgreSQL database management system, PHP scripting language, UMN MapServer, Apache HTTP Web Server, Linux Red Hat operating system (Fajfr Z. *et. al.*, 2006). Three language versions are offered for the interface and majority of data: Czech, English and Polish.

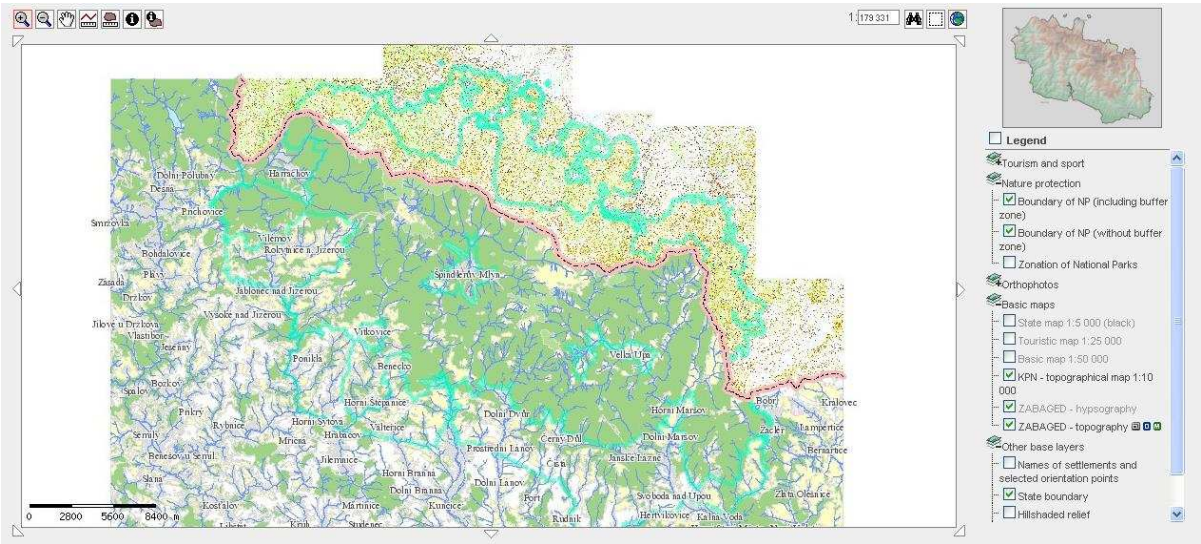

Fig. V Krkonoše/Karkonosze National Parks map view service (http://mapy.krnap.cz)

Krkonošský Národní Park and Karkonoski Park Narodowy participated together in the project SISTEMaPARC (Spatial Information Systems for Transnational and Environmental Management of Protected Areas and Regions in CADSES [Central, Adriatic, Danubian and South-Eastern European Space]) realized in 2004-2006 within the EU INTERREG IIIB Programme. The project aimed to foster sustainable regional management and development of cross-border national park regions by improving or establishing geo-spatial information pools

and TransEuropean exchange of communication concerning homogenised documentation, management and development of these regions. (Csaplovics E., Wagenknecht S., 2006). Involved in the project were four cross-border national park regions: Saxon-Bohemian Switzerland (Germany / Czech Republic), Lake Neusiedler / Fertö-Hanság (Austria / Hungary), Triglav National Park / Parco naturale delle Prealpi Giulie (Slovenia/Italy) and Karkonosze (Poland/Czech Republic). One of the results of involvement of both parks from the Krkonoše/Karkonosze region in the SISTEMaPARC project was creation of methodology for transformation between different spatial reference systems (Polish, Czech, German).

Example 4: GRISI/GISST project – geoportal for Majella National Park

Another international project supported with the funds of European Union was GRISI ("Geomatic Regional Operation Society Initiative. Regional Framework Operation INTERREG IIIC. Geomatics for Regional Development") realized in 2005-2008 (http://www.grisi.org). The aim of GRISI was to demonstrate how the use of geographic information and geoportals can help European regions in improving governance, economic development, identity promotion and cooperation with other European territories (GRISI, 2008). Project partners of GRISI (diverse local and regional communities) came from 4 European regions (Midi-Pyrénées, Navarra, Abruzzo and Latvia).

The GRISI partners have decided to adopt INSPIRE as technological and methodological framework for GRISI actions. The local geoportals of the project GRISI were formed as nodes in the framework of INSPIRE, accepting in all the effects (information, metadata, services, interoperability, etc.) the approach of what was still at that time a proposal for a Directive and the first implementation documents. INSPIRE not only constituted a homogeneous methodological frame, but also a substantial added value of the project GRISI. The main elements of INSPIRE-compliance include metadata profiles based on ISO19115 and Dublin Core standards and INSPIRE recommendations, as well as OGC-compliant web services to explore and use data and metadata.

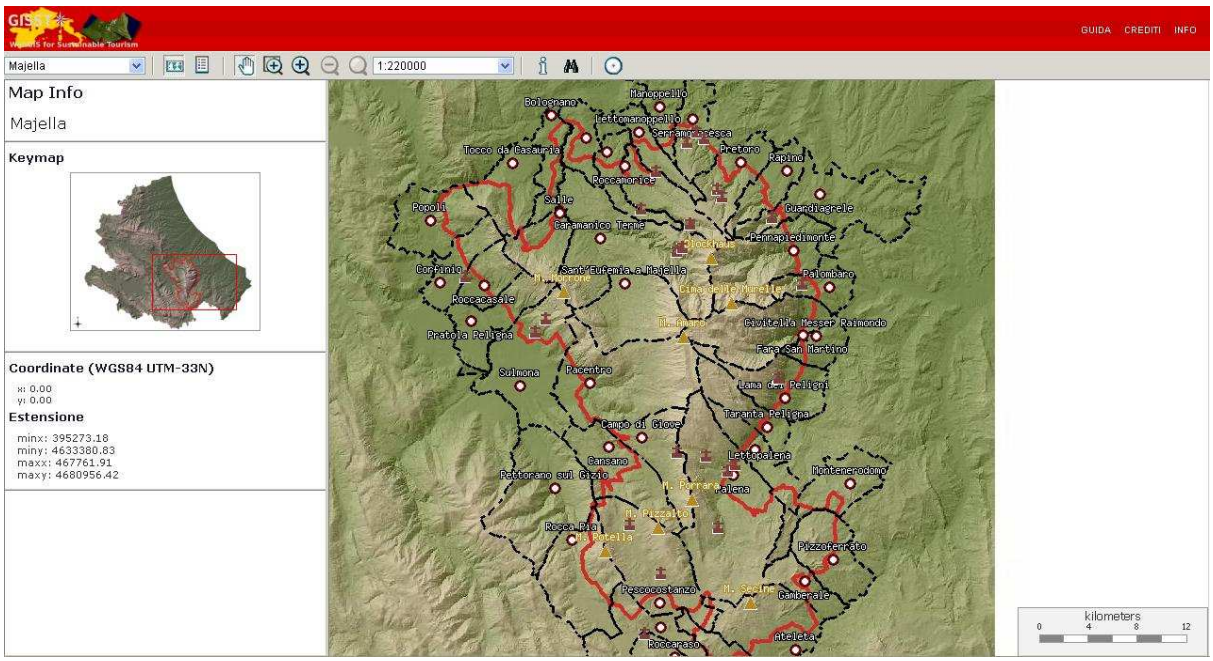

Fig. VI Majella National Park map view service (GISST project)
(http://www.gisst.eu/mappe)

One of the local sub-projects of GRISI was "GISST – WebGIS for Sustainable Tourism" (http://www.gisst.eu), for which the leading partner was Majella National Park (Parco Nazionale della Majella) from Italy. In the framework of GISST a tourism information system and geoportal have been developed. The geoportal is accessible through the website http://www.parcomajella.it/cartografia.asp and directly at http://www.gisst.eu/mappe (Fig.VI). The primary purpose of the geoportal is tourism data searching. The mapping application includes a Web Map Service following the OGC specifications. A geographic data catalogue is integrated with the map viewer. Through the map viewer several data layers are accessible, including ortophotomaps, Digital Terrain Model and tourist information.

It has been recognized in the context of GRISI project that the application of INSPIRE framework brought relevant benefits:
- INSPIRE frame makes possible consistent deployment of local and regional SDIs, despite the different starting points.
- INSPIRE facilitates communication among different European stakeholders working with geographical information
- INSPIRE allows a quick advance in the development and use of territorial information.
- INSPIRE encourages interregional cooperation related to the management of geographical information (Cabello M., Valentin A., 2008).

Annex B

Requirements and compliance elements of the INSPIRE View and Download services (synthesis)

General compliance elements of the web services:

- the service version,
- existence of the mandatory operations,
- correct handling of the mandatory parameters of operations,
- correct format and versions (when applicable) of the results returned by the mandatory operations,
- compliance with INSPIRE data models for themes defined by the directive annexes.

(according to the 'INSPIRE Network Services Architecture')

Technical architecture

- The network services (web services) shall cooperate using the framework compliant with WS-I Basic Profile 1.2. XML v.1.0, SOAP v.1.1 and WSDL v.1.1 standards shall be used; to be superseded in foreseeable future by SOAP v.1.2 / WSDL v.2.0 (WS-I Basic Profile 2.0).
- SOAP with Document-Literal wrapped data encoding is to be the basic remote procedure calling and messaging protocol with HTTP/HTTPS as underlying protocols. Operation requests, responses and faults messages should be managed inside SOAP bodies.
- XML shall be used for serializing SOAP envelopes. A definition of the SOAP binding has to be added to the WSDL description of the service.
- Common SOAP header can be used as an extension for handling problems with security, download checksums, artifacts signatures, multilingualism metadata.
- MTOM (1.0) and XOP (1.0) encapsulated inside MIME messages are to be used for the transport of large volumes of binary data and for XML compression.
- The INSPIRE technical architecture for the web services based on the WS-I profile and SOAP protocol is defined in the 'INSPIRE Network Services SOAP Framework'
- The use of RESTful web services architecture relying on the HTTP GET and HTTP POST bindings is acceptable, however in future all INSPIRE Network Services shall migrate to the WS-I profile. Details on the implementation of the INSPIRE Network Services according to the HTTP GET, HTTP POST and SOAP profiles are given in the Technical Guidance documents for particular network services.

View Service

- View services should "make it possible, as a minimum, to display, navigate, zoom in/out, pan or overlay viewable spatial data sets and to display legend information and any relevant content of metadata." (*INSPIRE Directive)*
- The View Service shall provide the following operations: Get Service Metadata, Get Map, Get Feature Information (optional).
- The required operation request and response parameters for the abovementioned operations shall be available.
- The rules for the following View Service elements shall be also complied to: nature of the metadata, coordinate reference systems, temporal data dimension, three-dimensional data, output formats, datasets and layers, styling, legend availability and handling, useful scale range, multilingualism, rights management.
- The details of the abovementioned requirements on an abstract level can be found in 'The INSPIRE Discovery and View Services Regulation' and also in 'Draft Implementing Rules for View Services, v.3.0' (IR3).
- Instructions to implement a View Service service according to the current technology and existing standards have been given in a separate document: 'Technical Guidance for implementation of INSPIRE View Services, v.2.0' (TG).
- According to the TG, the base specification of the INSPIRE Discovery Service is the 'ISO 19128:2005: Geographic information — Web map server interface'. Required extensions to the profile of ISO 19128:2005 have been defined in the Technical Guidance document (TG).

- Two other OGC standards for portraying geographic information are associated with the ISO 19128:2005, and are supplementary specifications for the implementation of INSPIRE View Services: 'OGC Styled Layer Descriptor Profile of the Web Map Service Implementation Specification (05-078r4)' and 'OGC Symbology Encoding Implementation Specification (05-077r4)'.
- As stated in the ISO 19128:2005 standard support for the GET method is mandatory, the use of the GET method is recommended for the view service operations. In order to make provisions for the SOAP framework, the use of the POST method is recommended once a decision is taken on the use of the SOAP protocol, this decision shall be recorded in further amendments of the Technical Guidance for implementation of INSPIRE View Services .
- The following profiles are recommended for an INSPIRE-compliant View service implementation :
  - Basic profile : support of GET method for the "Get Service Metadata", "Get Map" and "Link View Service" ;
  - Standard profile : basic profile and support of the GetFeatureInfo operation through the GET method ;
  - SOAP profile : basic profile plus support of the SOAP/POST method for the three mandatory View service operations ;
  - Advanced SOAP profile : SOAP profile plus support of the GetFeatureInfo operation through the SOAP/POST method.
- 'SOAP Primer for INSPIRE Discovery and View Services' demonstrates the use of the proposed INSPIRE SOAP Framework for the INSPIRE Discovery and View services.

Download Service

- Download Services should "enable copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly" (*INSPIRE Directive).*
- Download Services may be of two types: download services for pre-defined datasets or pre-defined parts of datasets and direct access download services including a query capability.
- Download Services shall implement five functions: Get Download Service Metadata, Get Spatial Objects, Describe Spatial Object Types, Define Query, and Link Download Service. Define Query function is only applicable to the direct access Download Services. Describe Spatial Object Types function is mandatory for the direct access download services and optional for the download services for pre-defined datasets or parts of datasets. All other functions are mandatory in both cases.
- The required operation request and response parameters for the abovementioned operations shall be available.
- The rules for the following Download Service elements shall be also complied to: nature of the metadata, coordinate reference systems, temporal data dimension, download output format, multingualism, geo rights management.
- The basic documents defining the requirements and recommendations for INSPIRE Download Services are: Draft Implementing Rules for INSPIRE Download Services (v.3.0, 2009) (abstract level guidelines) and Draft Technical Guidance for INSPIRE Download Services, (v.2.0, 2009) (technical implementation guidelines). Furthermore, the 'Draft Commission Regulation amending Regulation (EC) No 976/2009 as regards download services and transformation services' has been published.
- It is recommended to implement the direct access download services using the Web Feature Service, (WFS), as specified in ISO/DIS 19142, and with the query capabilities based on Filter Encoding (FE) standard, as specified in ISO/DIS 19143.
- WFS and FE have the capability of serving all download service requirements for the data corresponding to the Annex I themes of the INSPIRE Directive. If later data specifications relating to Annex II or Annex III themes should require additional functionality, like those covered by the OGC Web Coverage Service (WCS), extensions to the Technical Guidance document will be given.
- An implementation of Download services using WFS, shall conform to WFS conformance classes according to the Draft Technical Guidance for INSPIRE Download Services (v.2.0). In the Technical Guidance document several conformance classess are defined using HTTP GET, HTTP POST and SOAP bindings.
- In the case of download services for pre-defined datasets, simple HTTP protocol can be used for data download (HTTPS for secure connection) and GML 3.2.1 for data encoding.

Quality of services

- Performance: Response time to a Get Map request (View Service, 470 kB image) – max. 5 seconds in normal situation. Response time to a Get Download Service Metadata operation – max. 10 seconds in normal situation. Response time for sending the initial response for the Get Spatial Data Set operation and for the Get Spatial Object operation, and for a query consisting exclusively of a bounding box – max. 30 seconds in normal situation. A sustained response shall be maintained greater than 0.5 Megabytes per second or greater than 500 Spatial Objects per second. Response time for sending the initial response for the Describe Spatial Data Set operation and for the Describe Spatial Object Type operation – max. 10 seconds in normal situation. A sustained response shall be maintained greater than 0.5 Megabytes per second or greater than 500 descriptions of Spatial Objects per second.
- Capacity: the minimum number of served simultaneous requests to a View Service shall be 20 per second. The minimum number of served simultaneous requests to a Download Service shall be 10 requests per second.
- Availability: the probability of a Network Service to be available shall be 99% of the time.

Rights Management

- The key functionality of the rights management layer shall be implemented based on the 'OGC Abstract Specification - Topic 18 - Geospatial Digital Rights Management Reference Model (GeoDRM RM)'. This standard specifies a policy and technology neutral framework for the electronic licensing of spatial data and services.
- Technically, a RightsManagementKey attached to the SOAP header of the communication is required to support the rights management in the INSPIRE services infrastructure. INSPIRE service requests (possibly extended with further data such as license or identity information coded in the RightsManagementKey) can be passed through rights management functionalities of particular web services.

General compliance elements of the spatial data:

- the model and the structure of the datasets compliant with the data specification (existence of GIS layers, attribute tables, feature classes and attribute classes, relationships, domains; multiplicity/cardinality of relationships)
- the conceptual structure of the data model compliant with the UML model of the application schemas
- feature types semantically conforming to the definitions provided in the corresponding feature type catalogue
- GML application schemas compliant with the schemas encodings defined in the data specifications
- a valid, unique identifier for each component (element/feature)
- use of the values of attributes consistent with the defined data types, domain values, enumerations, code lists etc.
- completeness: mandatory attributes should be populated with valid values for each element/feature
- positional accuracy, geometric relationships, topological consistency
- required accuracy of the attribute values; correctness of the thematic classification
- temporal accuracy/data currency: the dataset should be the most up to date available
- use of the proper coordinate reference systems, map projections, temporal reference systems
- compliance with the requirements on data capture, maintenance, transfer, transformation, portrayal
- all constraints specified for the datasets should be met
- possibly all elements corresponding to the particular INSPIRE data theme in the area covered by the dataset should be included
- the metadata should conform to the requirements of the section of the data specifications defining the dataset-level metadata

(according to the 'Conformance and abstract test suite in conformance with the ISO 19105 and the INSPIRE conceptual modelling framework' (draft document) and the Data Specifications for INSPIRE Annex I themes)

- default spatial data encoding standard: ISO 19136:2007 – Geographic Information Markup Language; additional or alternative encoding rules may be specified for particular application schemas
- Specific rules for the data compliance can be found in the Data Specifications for particular INSPIRE data themes.

General compliance elements of metadata:

- Completeness – inclusion of all metadata elements that are mandatory or mandatory under the conditions specified.
- Maximum occurance - metadata element should occur no more than the number of times specified (maximum cardinality).
- Data type - metadata elements within a subject metadata set should use the specified data types.
- Domain - all provided metadata elements within a subject metadata set should fall within the specified domain.

(according to the: 'Conformance and abstract test suite in conformance with the ISO 19105 and the INSPIRE conceptual modelling framework' (draft document))

- The dataset metadata should conform to the ISO 19115 Geographic information-Metadata standard and shall be technically implemented in accordance with the ISO/CD TS 19139 Geographic information-Metadata-XML schema implementation. The services metadata should conform to the ISO 19119 Geographic Information – Services standard. Nevertheless, the conformance of a metadata set to the ISO 19115 Core does not guarantee the conformance to INSPIRE. In the same time, the use of the INSPIRE Metadata Implementing Rules guidelines to create the metadata ensures that the metadata is not in conflict with ISO 19115. However, full conformance to ISO 19115 implies the provision of additional metadata elements which are not required by INSPIRE.
- The details of the profile of INSPIRE-compliant metadata, including the obligatory and optional metadata components, can be derived from the document on 'INSPIRE Metadata Implementing Rules'.

Annex C

Sample INSPIRE-compliant XML metadata record

AdministrativeUnit_metadata.xml
(extract: pages 1-3 out of 6)


```
  <?xml version="1.0" encoding="UTF-8" ?>
- <gmd:MD_Metadata xsi:schemaLocation="http://www.isotc211.org/2005/gmd
      http://schemas.opengis.net/iso/19139/20060504/gmd/gmd.xsd"
      xmlns:gmd="http://www.isotc211.org/2005/gmd" xmlns:gco="http://www.isotc211.org/2005/gco"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:gml="http://www.opengis.net/gml"
      xmlns:xlink="http://www.w3.org/1999/xlink">
- <gmd:fileIdentifier>
  <gco:CharacterString>3ac80b7b-e8cc-4b91-bfc2-38966a2cfd89</gco:CharacterString>
    </gmd:fileIdentifier>
- <gmd:language>
  <gmd:LanguageCode
      codeList="http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/Codelis
      t/ML_gmxCodelists.xml#LanguageCode" codeListValue="eng">eng</gmd:LanguageCode>
    </gmd:language>
- <gmd:hierarchyLevel>
  <gmd:MD_ScopeCode
      codeList="http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/Codelis
      t/ML_gmxCodelists.xml#MD_ScopeCode" codeListValue="dataset">dataset</gmd:MD_ScopeCode>
    </gmd:hierarchyLevel>
- <gmd:contact>
- <gmd:CI_ResponsibleParty>
- <gmd:organisationName>
  <gco:CharacterString>GIMA</gco:CharacterString>
    </gmd:organisationName>
- <gmd:contactInfo>
- <gmd:CI_Contact>
- <gmd:address>
- <gmd:CI_Address>
- <gmd:electronicMailAddress>
  <gco:CharacterString>sudra19804@itc.nl</gco:CharacterString>
    </gmd:electronicMailAddress>
    </gmd:CI_Address>
    </gmd:address>
    </gmd:CI_Contact>
    </gmd:contactInfo>
- <gmd:role>
  <gmd:CI_RoleCode
      codeList="http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/Codelis
      t/ML_gmxCodelists.xml#CI_RoleCode"
      codeListValue="pointOfContact">pointOfContact</gmd:CI_RoleCode>
    </gmd:role>
    </gmd:CI_ResponsibleParty>
    </gmd:contact>
- <gmd:dateStamp>
  <gco:Date>2009-10-19</gco:Date>
    </gmd:dateStamp>
- <gmd:metadataStandardName>
  <gco:CharacterString>ISO19115</gco:CharacterString>
    </gmd:metadataStandardName>
```

- <gmd:metadataStandardVersion>
<gco:CharacterString>**2003/Cor.1:2006**</gco:CharacterString>
</gmd:metadataStandardVersion>
- <gmd:identificationInfo>
- <gmd:MD_DataIdentification>
- <gmd:citation>
- <gmd:CI_Citation>
- <gmd:title>
<gco:CharacterString>**AU.AdministrativeUnit**</gco:CharacterString>
</gmd:title>
- <gmd:date>
- <gmd:CI_Date>
- <gmd:date>
<gco:Date>**2009-10-18**</gco:Date>
</gmd:date>
- <gmd:dateType>
<gmd:CI_DateTypeCode
codeList="**http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/Codelist/ML_gmxCodelists.xml#CI_DateTypeCode**" codeListValue="**creation**">**creation**</gmd:CI_DateTypeCode>
</gmd:dateType>
</gmd:CI_Date>
</gmd:date>
- <gmd:identifier>
- <gmd:RS_Identifier>
- <gmd:code>
<gco:CharacterString>**AU.AdministrativeUnit.shp**</gco:CharacterString>
</gmd:code>
- <gmd:codeSpace>
<gco:CharacterString>**http://www.opengeospatial.net/Sample_Data**</gco:CharacterString>
</gmd:codeSpace>
</gmd:RS_Identifier>
</gmd:identifier>
</gmd:CI_Citation>
</gmd:citation>
- <gmd:abstract>
<gco:CharacterString>**Communes in Narew National Park and its buffer zone (Poland)**</gco:CharacterString>
</gmd:abstract>
- <gmd:pointOfContact>
- <gmd:CI_ResponsibleParty>
- <gmd:organisationName>
<gco:CharacterString>**GIMA**</gco:CharacterString>
</gmd:organisationName>
- <gmd:contactInfo>
- <gmd:CI_Contact>
- <gmd:address>
- <gmd:CI_Address>
- <gmd:electronicMailAddress>
<gco:CharacterString>**sudra19804@itc.nl**</gco:CharacterString>
</gmd:electronicMailAddress>
</gmd:CI_Address>
</gmd:address>
</gmd:CI_Contact>
</gmd:contactInfo>
- <gmd:role>
<gmd:CI_RoleCode
codeList="**http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/Codelist/ML_gmxCodelists.xml#CI_RoleCode**"
codeListValue="**pointOfContact**">**pointOfContact**</gmd:CI_RoleCode>
</gmd:role>
</gmd:CI_ResponsibleParty>

```
      </gmd:pointOfContact>
- <gmd:descriptiveKeywords>
- <gmd:MD_Keywords>
- <gmd:keyword>
  <gco:CharacterString>Administrative units</gco:CharacterString>
      </gmd:keyword>
- <gmd:thesaurusName>
- <gmd:CI_Citation>
- <gmd:title>
  <gco:CharacterString>GEMET - INSPIRE themes, version 1.0</gco:CharacterString>
      </gmd:title>
- <gmd:date>
- <gmd:CI_Date>
- <gmd:date>
  <gco:Date>2008-06-01</gco:Date>
      </gmd:date>
- <gmd:dateType>
  <gmd:CI_DateTypeCode
        codeList="http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/Codelist/ML_gmxCodelists.xml#CI_DateTypeCode"
        codeListValue="publication">publication</gmd:CI_DateTypeCode>
      </gmd:dateType>
      </gmd:CI_Date>
      </gmd:date>
      </gmd:CI_Citation>
      </gmd:thesaurusName>
      </gmd:MD_Keywords>
      </gmd:descriptiveKeywords>
- <gmd:descriptiveKeywords>
- <gmd:MD_Keywords>
- <gmd:keyword>
  <gco:CharacterString>administration</gco:CharacterString>
      </gmd:keyword>
- <gmd:keyword>
  <gco:CharacterString>municipality</gco:CharacterString>
      </gmd:keyword>
- <gmd:keyword>
  <gco:CharacterString>boundary layer</gco:CharacterString>
      </gmd:keyword>
- <gmd:thesaurusName>
- <gmd:CI_Citation>
- <gmd:title>
  <gco:CharacterString>GEMET - Concepts, version 2.3</gco:CharacterString>
      </gmd:title>
- <gmd:date>
- <gmd:CI_Date>
- <gmd:date>
  <gco:Date>2009-07-13</gco:Date>
      </gmd:date>
- <gmd:dateType>
  <gmd:CI_DateTypeCode
        codeList="http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/Codelist/ML_gmxCodelists.xml#CI_DateTypeCode"
        codeListValue="publication">publication</gmd:CI_DateTypeCode>
      </gmd:dateType>
      </gmd:CI_Date>
      </gmd:date>
      </gmd:CI_Citation>
      </gmd:thesaurusName>
      </gmd:MD_Keywords>
```

Annex D

OGC CITE test for WMS 1.1.1 – basic test elements

Annex E

OGC CITE test for WMS 1.1.1 – extract from the result log file

(pages 1-3 out of 266)

Testing suite wms:main_wms...
  Testing wms:wms_main (s0001)...
    Assertion: This WMS is valid
    Testing wms:basic_elements-param_rules-order_and_case-3 (s0001/d207e766_1)...
      Assertion: When a GetCapabilities request contains a parameter which is not defined by the spec, the result is valid.
    Test wms:basic_elements-param_rules-order_and_case-3 Passed
    Testing wms:basic_elements-version-negotiation-2 (s0001/d207e804_1)...
      Assertion: When a GetCapabilities request is made for a supported version, then the response is the requested version.
    Test wms:basic_elements-version-negotiation-2 Passed
    Testing wms:basic_elements-version-negotiation-4 (s0001/d207e811_1)...
      Assertion: When a GetCapabilities request is made for version 0.0.0, the response is between 0.0.0 and [[VAR_WMS_VERSION]], inclusive.
    Test wms:basic_elements-version-negotiation-4 Passed
    Testing wms:dims-declaring-3 (s0001/d207e828_1)...
      Assertion: All declarations for the time dimension use 'ISO8601' for units.
      VAR_LAYERS_WITH_NONSTANDARD_TIME_UNITS:
    Test wms:dims-declaring-3 Passed
    Testing wms:dims-declaring-4 (s0001/d207e835_1)...
      Assertion: All declarations for the elevation dimension use an EPSG vertical datum for units.
      VAR_LAYERS_WITH_NON_EPSG_VERTICAL_DATUM:
    Test wms:dims-declaring-4 Passed
    Testing wms:profiles-queryable-1 (s0001/d207e865_1)...
      Assertion: The server implements the CITE standard dataset in subsettable, resizable layers that support EPSG:4326.
java.io.FileNotFoundException: http://cite.opengeospatial.org/OGCTestData/wms/1.1.1/null.xml
    Test wms:profiles-queryable-1 Failed
    Testing wms:profiles-queryable-2 (s0001/d207e875_1)...
      Assertion: The server supports GetMap format image/gif and/or image/png.
java.io.FileNotFoundException: http://cite.opengeospatial.org/OGCTestData/wms/1.1.1/null.xml
    Test wms:profiles-queryable-2 Passed
    Testing wms:profiles-queryable-3 (s0001/d207e885_1)...
      Assertion: The server supports GetFeatureInfo requests and the CITE standard dataset layers containing polygons are queryable.
java.io.FileNotFoundException: http://cite.opengeospatial.org/OGCTestData/wms/1.1.1/null.xml
    Test wms:profiles-queryable-3 Failed
    Testing wms:wmsops-getcapabilities-output_formats-1 (s0001/d207e895_1)...
      Assertion: The application/vnd.ogc.se_xml exception format is listed in the capabilities document.
    Test wms:wmsops-getcapabilities-output_formats-1 Passed
    Testing wms:wmsops-getcapabilities-params-request-1 (s0001/d207e902_1)...
      Assertion: When REQUEST is "capabilities", then the response is capabilities XML.
    Test wms:wmsops-getcapabilities-params-request-1 Passed
    Testing wms:wmsops-getcapabilities-params-updatesequence-2 (s0001/d207e922_1)...
      Assertion: When a GetCapabilities request is made with an UPDATESEQUENCE parameter set to the current update sequence value, then the server returns a valid exception (code=CurrentUpdateSequence).
    Test wms:wmsops-getcapabilities-params-updatesequence-2 Passed
    Testing wms:wmsops-getcapabilities-params-updatesequence-5 (s0001/d207e958_1)...
      Assertion: When a GetCapabilities request is made with an UPDATESEQUENCE parameter set to a value lower than the current update sequence value, then the server returns capabilities XML.
    Test wms:wmsops-getcapabilities-params-updatesequence-5 Passed
    Testing wms:wmsops-getcapabilities-params-updatesequence-6 (s0001/d207e970_1)...

Assertion: When a GetCapabilities request is made with an UPDATESEQUENCE parameter set to a value higher than the current update sequence value, then the server returns an InvalidUpdateSequence exception.
Test wms:wmsops-getcapabilities-params-updatesequence-6 Passed
Testing wms:wmsops-getcapabilities-params-version-1 (s0001/d207e981_1)...
Assertion: When a GetCapabilities request is made for the version in test using WMTVER instead of VERSION, then the response is the requested version.
Test wms:wmsops-getcapabilities-params-version-1 Passed
Testing wms:wmsops-getcapabilities-params-version-2 (s0001/d207e988_1)...
Assertion: When a GetCapabilities request is made for a supported version other than [[VAR_WMS_VERSION]] using WMTVER instead of VERSION, then the version returned is the version requested.
VAR_VERSION_1: 1.1.1
VAR_OTHER_VERSION: 1.1.1
VAR_REQUEST_NAME: GetCapabilities
Test wms:wmsops-getcapabilities-params-version-2 Passed
Testing wms:wmsops-getcapabilities-params-version-3 (s0001/d207e995_1)...
Assertion: When a GetCapabilities request is made with VERSION set to [[VAR_WMS_VERSION]] and WMTVER set to 0.0.0 and VERSION precedes WMTVER, then the version returned is [[VAR_WMS_VERSION]].
Test wms:wmsops-getcapabilities-params-version-3 Passed
Testing wms:wmsops-getcapabilities-params-version-4 (s0001/d207e1002_1)...
Assertion: When a GetCapabilities request is made with VERSION set to [[VAR_WMS_VERSION]] and WMTVER set to 100.0.0 and VERSION precedes WMTVER, then the version returned is [[VAR_WMS_VERSION]].
Test wms:wmsops-getcapabilities-params-version-4 Passed
Testing wms:wmsops-getcapabilities-params-version-5 (s0001/d207e1009_1)...
Assertion: When a GetCapabilities request is made with VERSION set to [[VAR_WMS_VERSION]] and WMTVER set to 0.0.0 and WMTVER precedes VERSION, then the version returned is [[VAR_WMS_VERSION]].
Test wms:wmsops-getcapabilities-params-version-5 Passed
Testing wms:wmsops-getcapabilities-params-version-6 (s0001/d207e1016_1)...
Assertion: When a GetCapabilities request is made with VERSION set to [[VAR_WMS_VERSION]] and WMTVER set to 100.0.0 and WMTVER precedes VERSION, then the version returned is [[VAR_WMS_VERSION]].
Test wms:wmsops-getcapabilities-params-version-6 Passed
Testing wms:wmsops-getcapabilities-response-1 (s0001/d207e1024_1)...
Assertion: When a GetCapabilities request is made, then the content-type header of the response is application/vnd.ogc.wms_xml
Test wms:wmsops-getcapabilities-response-1 Passed
Testing wms:wmsops-getcapabilities-response-2 (s0001/d207e1031_1)...
Assertion: The response to a GetCapabilities request references a valid copy of the DTD in Annex A.1 at a fully-quallified and accessible location and validates with the DTD.
Test wms:wmsops-getcapabilities-response-2 Passed
Testing wms:wmsops-getcapabilities-response-capability_metadata-1 (s0001/d207e1038_1)...
Assertion: Each OnlineResource URL intended for HTTP Get requests in the capabilities document is a URL prefix
Test wms:wmsops-getcapabilities-response-capability_metadata-1 Passed
Testing wms:wmsops-getcapabilities-response-general_metadata-1 (s0001/d207e1055_1)...
Assertion: The Service Name element in the capabilities document has the value "OGC:WMS".
Test wms:wmsops-getcapabilities-response-general_metadata-1 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-bbox-1 (s0001/d207e1073_1)...
Assertion: For each of the layer elements in the capabilities document, each BoundingBox on the layer states a different SRS.
VAR_DUPLICATE_SRS_BBOXES:
VAR_LAYERS_WITH_DUPLICATE_SRS:
Test wms:wmsops-getcapabilities-response-layer_properties-bbox-1 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-dim_and_extent-1 (s0001/d207e1080_1)...
Assertion: There are no child Dimension elements in the capabilities document that use a name attribute that is defined in a parent layer.
VAR_REDEFINED_DIMS:

VAR_LAYERS_WITH_REDEFINED_DIMS:
Test wms:wmsops-getcapabilities-response-layer_properties-dim_and_extent-1 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-dim_and_extent-2 (s0001/d207e1087_1)...
Assertion: Each Extent element in the capabilities document uses a name that has been declared or inherited in a corresponding Dimension element.
VAR_EXTENTS_WITHOUT_DIMS:
VAR_LAYERS_WITH_EXTENTS_WITHOUT_DIMS:
Test wms:wmsops-getcapabilities-response-layer_properties-dim_and_extent-2 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-identifier_and_authorityurl-1 (s0001/d207e1094_1)...
Assertion: There are no child Layer elements in the capabilities document that define an AuthorityURL with the same name attribute as one inherited from a parent layer.
VAR_REDEFINED_AUTHORITY_URLS:
VAR_LAYERS_WITH_REDEFINED_AUTHORITY_URLS:
Test wms:wmsops-getcapabilities-response-layer_properties-identifier_and_authorityurl-1 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-identifier_and_authorityurl-2 (s0001/d207e1101_1)...
Assertion: There are no Layer elements in the capabilities document that declare an Identifier without also declaring or inheriting a corresponding AuthorityURL.
VAR_UNDEFINED_AUTHORITIES:
VAR_LAYERS_WITH_UNDEFINED_AUTHORITIES:
Test wms:wmsops-getcapabilities-response-layer_properties-identifier_and_authorityurl-2 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-latlonbbox-1 (s0001/d207e1108_1)...
Assertion: The root layer in the capabilities document has a LatLonBoundingBox.
Test wms:wmsops-getcapabilities-response-layer_properties-latlonbbox-1 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-latlonbbox-2 (s0001/d207e1116_1)...
Assertion: The minx, miny, maxx, and maxy attributes on each LatLonBoundingBox are expressed in decimal degrees.
VAR_LAYERS_WITH_INVALID_LAT_LON_BBOX:
Test wms:wmsops-getcapabilities-response-layer_properties-latlonbbox-2 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-srs-1 (s0001/d207e1123_1)...
Assertion: The root layer in the capabilities document has at least one SRS element.
Test wms:wmsops-getcapabilities-response-layer_properties-srs-1 Passed
Testing wms:wmsops-getcapabilities-response-layer_properties-style-1 (s0001/d207e1130_1)...
Assertion: There are no child layers in the capabilities document that redefine a Style with the same name as one inherited from one of its parents.
VAR_LAYERS_WITH_REDEFINED_STYLES:
VAR_REDEFINED_STYLES:
Test wms:wmsops-getcapabilities-response-layer_properties-style-1 Passed
Testing wms:wmsops-getmap-params-exceptions-1 (s0001/d207e1541_1)...
Assertion: When an exception is raised without specifying the EXCEPTIONS parameter, then the Content-type of the return header is application/vnd.ogc.se_xml.
Test wms:wmsops-getmap-params-exceptions-1 Passed
Testing wms:wmsops-getmap-params-exceptions-2 (s0001/d207e1550_1)...
Assertion: When an exception is raised and EXCEPTIONS=application/vnd.ogc.se_xml, then the Content-type of the return header is application/vnd.ogc.se_xml.
Test wms:wmsops-getmap-params-exceptions-2 Passed
Testing wms:wmsops-getmap-params-layers-5 (s0001/d207e1706_1)...
Assertion: When the layer in a GetMap request is invalid, then the response is an exception (code="LayerNotDefined").
Test wms:wmsops-getmap-params-layers-5 Passed
Testing wms:wmsops-getfeatureinfo-each-info_format (s0001/d207e2072_1)...
Assertion: For each advertised GetFeatureInfo format, when a GetFeatureInfo request is made with the INFO_FORMAT parameter set to the format, then the Content-type header returned is the same.
Test wms:wmsops-getfeatureinfo-each-info_format Passed
Testing wms:wmsops-getfeatureinfo-each-info_format (s0001/d207e2072_2)...
Assertion: For each advertised GetFeatureInfo format, when a GetFeatureInfo request is made with the INFO_FORMAT parameter set to the format, then the Content-type header returned is the same.
Test wms:wmsops-getfeatureinfo-each-info_format Passed
Testing wms:wmsops-getfeatureinfo-each-info_format (s0001/d207e2072_3)...