

## **EXTENDING THE FINNISH FLOOD INFORMATION SYSTEM TO INCLUDE FLOOD RISK MAPPING**

MIKKO SANE, ATTE VIRTANEN, RIIKKA REPO

*Finnish Environment Institute, P.O. Box 140 00251 Helsinki, Finland*

The sound flood risk management needs more and more effective information systems. In addition to flood risk management planning, the past floods in Finland have proved that up-to-date risk information is essential in emergencies. Therefore in addition to the water system forecasts and flood warnings, the information on potential exposed elements and flood damages are playing a significant role in maintaining an overview of the national flood situation. The national flood information system of Finland, established in 2006 and extended since 2010, brings together the essential information on floods under a single user interface. The extensions include flood information that serves the EU Floods Directive, as well as, national requirements. In this paper we introduce the new parts and information types of the system. It is written both from a substance and a technical point of view. The main focus is on flood risk mapping: how to manage risk information in the system and how the information can be used in applications.

### **INTRODUCTION**

Last two years were eventful years in terms of floods in Finland. Several serious floods occurred causing considerable damage and emergencies. Floods caused by heavy rain in October 2012, by melting snow and ice jams in April 2013 and due to frazil ice in January 2014.

Finnish Environment Institute (SYKE) was playing a significant role in maintaining an overview of the national flood situation. SYKE manages the Watershed Simulation and Forecasting System (WSFS) [1], which produces real-time hydrological maps and forecasts and form the basis of flood warnings for more than 600 locations covering the whole country.

A new Flood Centre, run jointly by SYKE and the Finnish Meteorological Institute (FMI), was launched in the beginning of 2014 [2]. The Flood Centre provides many services and products to the local authorities, e.g. forecasts, warnings, remote sensing and ad hoc flood maps. Close co-operation with the Regional Centres for Economic Development, Transport and the Environment (ELY Centres), municipalities, rescue services and others is working well.

One of the new services launched by the Flood Centre is a public flood map service. The service includes the flood maps required also by the EU Floods Directive (2007/60/EC). It is based on the national flood information system developed in SYKE [3]. Originally, the system was designed for flood risk management planning purposes only but now it has been used also operationally in flood situations.

Many different kinds of environmental information systems are also developed and maintained in SYKE. They are developed using a common set of software libraries and specified software architecture. These together form the Hertta framework. The current version

of the framework is web based and relies on the Microsoft .NET framework, the C# programming language and Microsoft SQL Server databases. The map service is based on ESRI's ArcGIS Server technology.

The flood information system has been developed in three stages since 2006 when it was taken into use. Originally, the system contained point and polygon based flood related information: water level and discharge scenarios, flood hazard and historic flood maps [4], hydrological flood observations, and recommended building site levels. All the data also include extensive metadata. The first version of the system was implemented according to the previous Hertta framework and was programmed using Visual Basic 6.0.

The flood information system is developed and maintained at a national level in SYKE. The information is mostly saved into the system by the ELY Centres' personnel involved in flood risk management. Lately, it has also been made possible for external users, e.g. for contractors to use the system during the contract.

### DEVELOPMENT OF THE SYSTEM FOR PRELIMINARY FLOOD RISK ASSESSMENT

The EU Floods Directive and the national legislation for its implementation (2010/620 and 2010/659) [2] includes three steps: preliminary flood risk assessment, flood mapping and flood risk management planning (Figure 1). Firstly, areas of potential significant flood risk (APSFRs) were identified for whole member states on the grounds of preliminary flood risk assessment (PFRA). The assessment is based on existing information, or data that could be derived from it, such as experiential flood information, hydrological records and different kinds of geographic data [5, 6]. Past floods, potential future flood events (scenarios) and APSFRs with information about the flood types and adverse consequences are reported to the European commission (EC).

The risk of fluvial and sea water flooding in Finland was assessed by ELY Centres in 2011. After public hearing, the Ministry of Agriculture and Forestry named the areas of significant flood risk. The risk was assessed as significant in 21 areas. 17 are alongside inland water bodies, and 4 are on the coast. The greatest risk of fluvial flooding was assessed to be in the City of Pori. More than 20 000 citizens are living within the flood-prone area. In addition, municipalities assessed the risk of pluvial flooding in urban area but no significant areas were named [2].

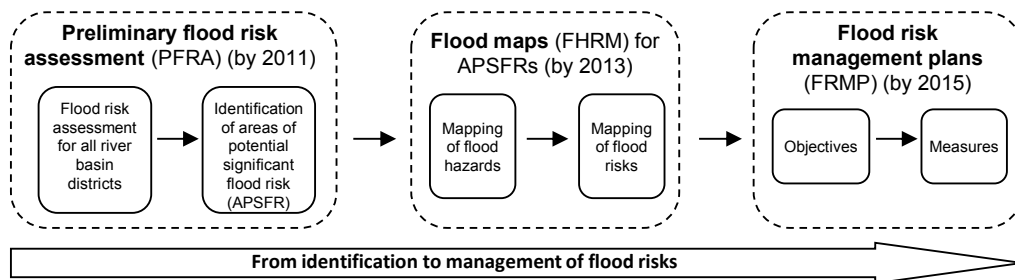


Figure 1. The flood risk management process according to the Floods Directive. The review and EU reporting should be made after each step every six years.

The database of a second stage of development was designed to include information needed for APSFR and PFRA reporting requirements. However, the national requirements were at top priority, e.g. before this stage it was not possible to save comprehensive information about past floods to the system, including adverse consequences and a description of the flood. The

database for the second stage of the system is presented in figure 2. Past and future flood events (PFRA) are saved under a location, which consists of river basins and which also can be restricted to water bodies. A flood risk area (APSFR) also includes a polygon [4].

A common entity set “flood data” was designed for the common information of past and future flood events and flood risk areas. Therefore, the database structure of possible and occurred damages, as well as, flood types could be reused for all these three flood information types. The adverse consequences are defined by either damage or damage indicator entities. Damage entities are main classes, which are related to codes (enumerations) needed for EU reporting, while damage indicators are describing damages at a lower level using indicator values, e.g. people affected, euros and number of buildings which are difficult to evacuate. Eventually, the EU reports were generated quite effortlessly from the created database.

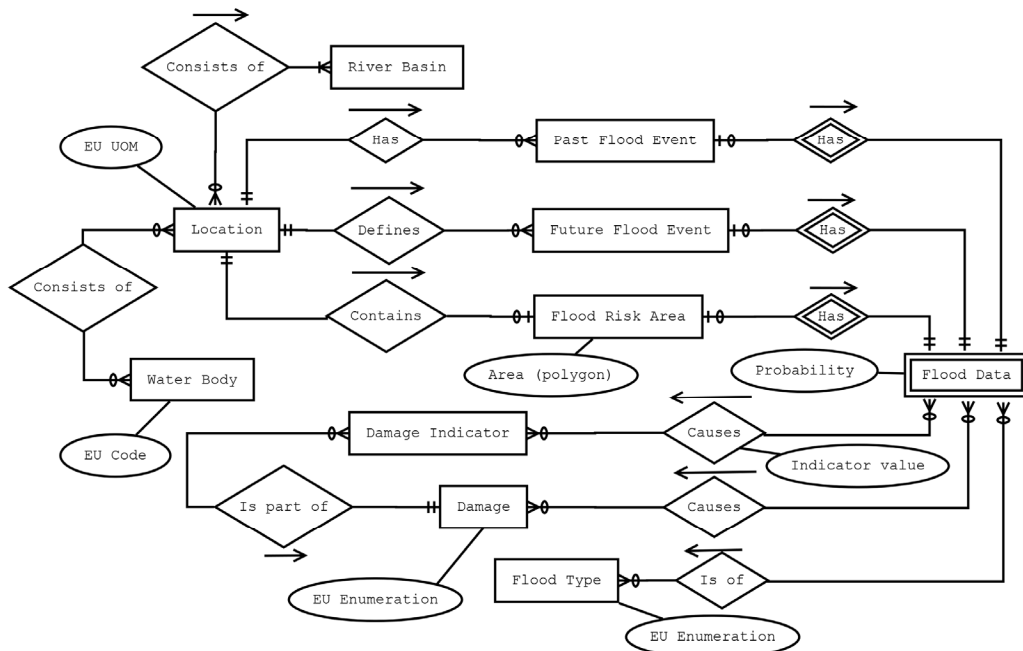


Figure 2. A simplified ER model of the second extension of the flood information system with Crow’s feet notation and arrows for the direction of the relation-verbs. Only selected, EU reporting related attributes are shown in the figure.

## DEVELOPMENT OF THE SYSTEM FOR FLOOD RISK MAPS

Flood hazard maps and flood risk maps (FHRM) were prepared for the areas of potential significant flood risk. The flood hazard map illustrates inundation and water depth with certain likelihood. The flood risk map presents the potential adverse consequences associated with floods with certain likelihood e.g. in terms of the indicative number of inhabitants potentially affected and the installations, which might cause accidental pollution in case of flooding [7]. Information about the adverse consequences for each APSFR and scenario, as well as, hyperlinks to the national flood maps were to be reported to the EU.

The following so called basic scenarios (open water conditions) were reported to the commission: probabilities 1/50a (flood insurance compensation criteria), 1/100a (mostly the lowest building site level) and 1/1000a (the same probability as used in PFRA, taking into account the climate change). Nationally there is also available some other basic scenarios

(MHQ/MHW, 1/5a, 1/10a, 1/20a, 1/250a). Additionally, some so called special scenarios, e.g. floods caused by ice or combined fluvial and sea water floods, were reported in certain areas where the APSFR is based on these flood types. These special scenarios are stored to the geodatabase as single layers instead of the basic scenario layers covering the whole country. All the flood maps were prepared as detailed scale based on the digital elevation model produced by laser scanning [8].

The information needed for flood risk maps is for the most part available in national GIS databases, such as the Population Register Centre's building and dwelling register (BDR), the Environmental Administrator's pollution control and loading database, and other GIS-data. Locally obtained information has also been added to the risk map.

ELY Centres or consultants have saved the exposed elements to the flood information system as points using a map based user interface and the above-mentioned data. Exposed elements are categorized to several types, which are shown as red symbols on the map service (Figure 5). The update process is continuous. Each of the exposed elements has been connected to the original data entity, if available, in accordance to the INSPIRE Directive (2007/2/EC). Therefore, polygon and line shaped objects can also be present in the future using the original geometry.

Some new GIS-data products were developed in this third stage of the project. The indicative number of inhabitants affected, required also in the Floods Directive, is visualised using 250 x 250 m risk squares (Figure 5). The squares are calculated for each flood scenario using the building-points of the BDR register within the flood hazard zone. In addition, different kinds of information related to the each square are presented in the attribute table, e.g. inhabitants affected, number of buildings classified by the purpose of use and floor area. Affected roads presented also in the flood map service are produced for each scenario using the intersection between the road network of Finland (Digiroad) and flood hazard zones.

The third development stage of the flood information system was designed to include information required by the FHRM reporting. In addition, national requirements of flood risk maps [2] were taken into account. The database and the user interface implementation for flood hazard maps was completely renewed for the third stage. The renewed part was designed to ease the flood hazard maps publishing process, by making it possible for update users to save metadata of the mappings themselves leaving only the work of publishing of GIS-data to SYKE.

The modelled area (location) is defined by a polygon (Figure 3). It contains the mappings which have been made for this location. A mapping includes flood scenarios, which in turn have an own future flood event, designed in the second stage. The flood scenario includes the flood hazard zone polygon, which will be defined as in the INSPIRE NZ specification [9].

A mapping contains the above mentioned coordinate based exposed elements. Adverse consequence for the exposed element is defined by the exposed element type selected, e.g. if a user have selected museum this means adverse consequence cultural heritage. Damage and damage indicator, as well as, future flood event entities are reused from the previous stage of development.

The system was implemented so, that when a user adds or edits an exposed element, the level of hazard, through the water depth at that point for each scenario, is automatically selected from the GIS-data. The user can then change the level of hazard at a certain scenario if necessary. Also other kinds of hazards can be selected, such as surrounded by flood.

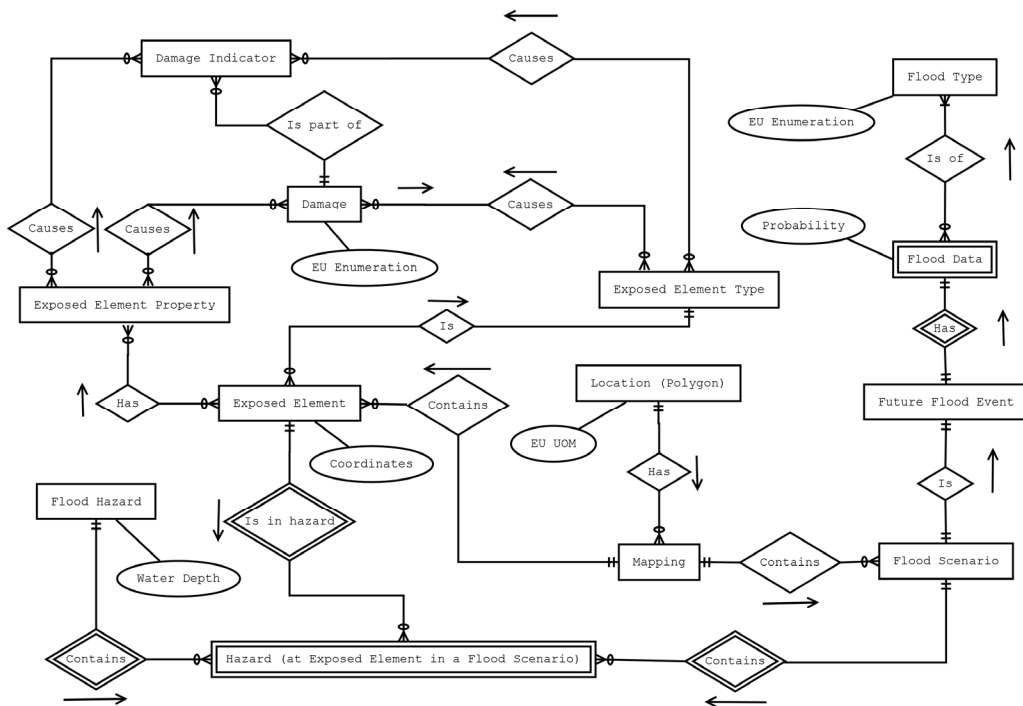


Figure 3. A simplified ER model of the third extension of the flood information system (with Crow's feet notation and arrows for the direction of the verbs). Only selected, EU reporting related attributes are shown in the figure.

## ARCHITECTURE AND TECHNOLOGY USED IN THE FLOOD INFORMATION SYSTEM

The architecture of the new flood information system parts is presented in figure 4. The Hertha architecture defines the core of the architecture, which consists of the flood information system database, a backend server and a front end server. The system is used by a restricted user group with an internet browser. The database contains flood information system specific data. Other databases, within the same database instance, are also used through database views. The database technology used is Microsoft SQL Server.

The backend server applications are hosted in a Microsoft Windows Process Activation Services (WAS) host. It contains the code for SQL commands, object relational mappings (ORM) using Entity Framework (EF) and the web service operations. The front end server application is programmed using ASP .NET Web Forms technologies. Although Web Forms is considered somewhat outdated because of its strongly server based user interaction, it has proven to be well suited for rapid development of database system user interfaces, as user interface components can quite effortlessly be reused.

The flood risk mapping user interface application utilizes Latitude's Geocortex Essentials Silverlight Viewer, through which basic map functionality, e.g. legend, zoom and selection, can be implemented effortlessly. For the customized functionality an own Geocortex Viewer module was implemented, through which, exposed elements could be saved, edited and moved. The flood risk mapping user interface application uses dynamic (for the special scenarios) and static (for the basic scenarios) map service layers of ESRI's ArcGIS Server to show spatial data.

For dynamic layers an own catalog library for Geocortex Essentials was implemented. SYKE also has its own Geocortex catalog library for Hertta systems, through which general map layers can be added.

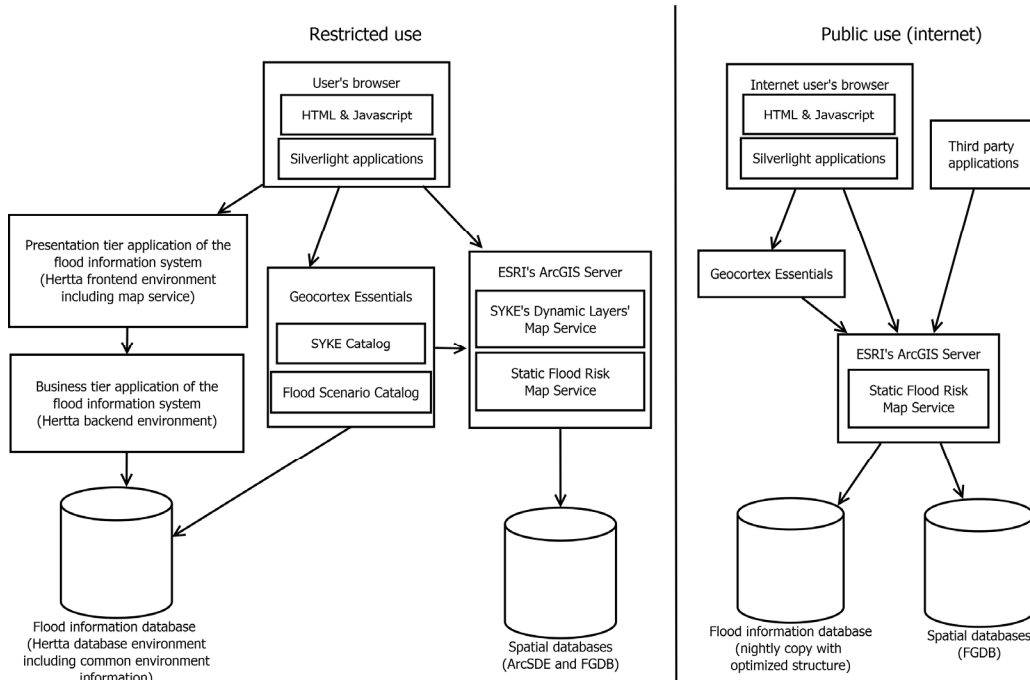


Figure 4. The architecture of the flood information system based on the new Hertta architecture. The arrows are pointing from the client to the operations' supplier. In addition, the background map series (raster) is used through the WMTS interface of the National Land Survey of Finland.

The APSFR and PFRA XML EU reports [10] were generated from the database of the flood information system using SQL procedures. For the FHRM reporting the XML generation from the database was made using the Map Force tool from the Altova Mission Kit. This improved the maintenance of the reporting code, which will need altering for the next cycle of the EU reporting. Database views were used to simplify the mapping made in Map Force. C# code was eventually generated from the Map Force mapping. Therefore, the reporting code could be published as a .NET web service application using the operational database. Thus, the XML reports could be inspected at real time while possible, for instance input mistakes are corrected in the operational database through the flood information system's user interface.

Finnish environmental administration maintains, develops and distributes data from spatial information systems. The majority of information, including the flood maps, are available free of charge through the OIVA service ([www.ymparisto.fi/oiva](http://www.ymparisto.fi/oiva)). General descriptions on different datasets can be viewed in the metadata portal [4]. GIS data can be downloaded from service as nationwide packages, or data on a given area can be retrieved using the LAPIO map user interface. Also map service interfaces (REST and WMS) are available for free use. In addition, flood maps, covering for approximately a hundred different areas, are viewable in the public flood map service ([www.ymparisto.fi/tulvakartat](http://www.ymparisto.fi/tulvakartat)). Anyone can design a customised service using the free data or interfaces. An example of this is a user interface, where water level forecasts are combined to flood risk maps ([www.environment.fi/waterforecast](http://www.environment.fi/waterforecast)).

**Flood hazard and risk map, location of the observation station and a simplified water level forecast**

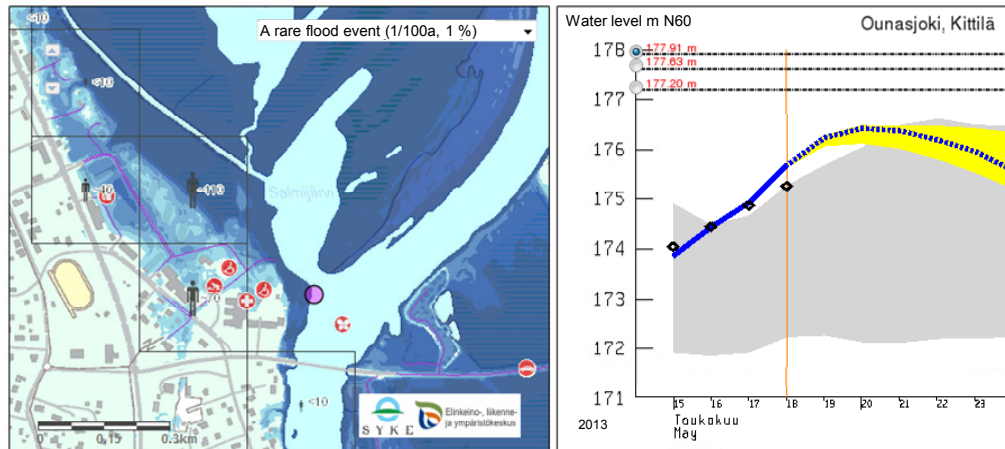


Figure 5. An application using the flood information system data: Integrated flood risk map and water level forecast for an observation station. Mean forecast is marked with a blue line. Observed values are marked as points. Variation of the observed values is shaded in grey and variation of the forecast in yellow. The user can choose the water level related to the flood map on the right hand side and the flood risk map is updated automatically.

## DISCUSSION AND CONCLUSION

The idea of a common strict in-house framework for information systems ease their maintenance, because the solutions made for individual systems are similar to other systems and are therefore easily understood by other developers using the framework. A disadvantage of an in-house framework can be that it can restrict the possibilities of the systems if no further development of the framework components is allowed.

Geocortex Essentials is well suited for creating restricted map based applications, which are created using Latitude's tools without programming. A software library, which implements the Geocortex catalog interface can easily be made, but creating own user interface components for Geocortex Essentials Silverlight Viewer have, at least at the moment, proven quite difficult as the API is not well documented for programmers.

ArcGIS REST API's dynamic layers are convenient, because they make it easier to update and publish GIS-data, but can only be called, if the client has identification knowledge about these layers. Static layers can be cataloged by the API, but they, however, seem to have a restriction that the layer IDs are generated according to the layer order, and therefore, the new layers have to be added last to the layers list for the IDs to remain unchanged.

In addition to functional requirements, it is good to consider separately the lifetime of the different parts of the developed system and also the maintenance needs of these. For example because of its longer lifetime, it might be recommended to design the database as a whole, at least roughly, before starting any user interface implementation.

Developing the information system, we have noticed, that reusing the data structure of earlier implemented parts is in some cases not recommended, as the database structure can grow very large and therefore it can become hard to comprehend and expensive to maintain.

Earlier all the flood maps were available as static PDF-files at our website. More recently the internet based flood maps service is replacing these PDF-maps. The map service is always up to date, the user can zoom and combine different kinds of layers on the map. However, the capacity of the server must be scaled to be sufficient. Use of scalable cloud services could be

considered for this kind of requirements, where the service load is usually very low but with strong peaks at flood events. In addition, it is important to have a recovery plan for the system.

The development of the flood information system has improved the productivity of the administration in several ways. Firstly, the EU reporting cycle every couple of years can now be done automatically from the operational database. The exposed elements contained in the database are effective to maintain through the user interface. Secondly, because contractors now can use the system, it is not anymore needed to import and export GIS-data between the parties. Municipalities can also now save e.g. information about the past floods to the system. Thirdly, when all the flood related information is freely available and easily accessible, thanks also to the INSPIRE-directive, there are better possibilities to improve public awareness and communication about the flood risks.

Developing the system is still continuing. The next step is to create possibilities to save flood risk management plans (FRMP) to the system. FRMP of fluvial floods should be established for those river basins that include at least one APSFR. Finally, measures for the prevention and mitigation of floods will be reported to the EU. However, the flood risk management planning cycle is a continuous process. In this way we can continuously improve prevention, protection and preparedness for the floods.

## ACKNOWLEDGEMENTS

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## REFERENCES

- [1] Finnish Environment Institute SYKE, “Watershed simulation and forecasting system (WSFS) -brochure”, (2013). Available at <http://www.syke.fi/en-US/Publications/Brochures>.
- [2] Finnish Environment Institute SYKE, “Flood risk management planning in Finland”, (referenced 3/31/2014). [http://www.environment.fi/en-US/Waters\\_and\\_sea/Floods](http://www.environment.fi/en-US/Waters_and_sea/Floods).
- [3] Dubrovin, T., Keskisarja, V., Sane, M. and Silander, J., “Flood Management in Finland - Introduction of a New Information System”, *Proc. 7th International Conference on Hydroinformatics*, Nice, France, Vol. 1, (2006), pp. 139-146.
- [4] Finnish Environment Institute SYKE, “Metadata portal, data systems and spatial data”, (referenced 3/31/2014). <http://metatieto.ymparisto.fi:8080/geoportal>.
- [5] Sane, M. & Huokuna, M. 2008. “Procedure for Identifying Automatically Possible Flood Risk Areas”, *EU, Working Group F, Thematic Workshop on Flood Mapping*, Dublin, (2008).
- [6] ELY Centre of Lapland, “The PFRA in Tana River basin”, (2011). Available at <http://goo.gl/SU0N0L>.
- [7] Alho, P., Sane M., Huokuna, M., Käyhkö, J., Lotsari, E. & Lehtiö, L., “*Guidelines for flood risk mapping*”, Finnish Environment Institute, (2008). Extended English summary is available at <https://helda.helsinki.fi/handle/10138/41688>.
- [8] National Land Survey of Finland, “Laser scanning data”, (referenced 3/31/2014). <http://www.maanmittauslaitos.fi/en/maps-5>.
- [9] European Commission, “INSPIRE Data Specification on Natural Risk Zones – Technical Guidelines”, (2013). Available at <http://inspire.ec.europa.eu/index.cfm/pageid/2>.
- [10] European Commission, “Floods Directive reporting resources”, (2014). <http://icm.eionet.europa.eu/schemas/dir200760ec/resources>.