ADMINISTRAŢIA NAŢIONALĂ "APELE ROMÂNE"
INSTITUTUL NAŢIONAL DE HIDROLOGIE ŞI GOSPODĂRIRE A APELOR
Şos. Bucureşti - Ploieşti 97 E, Bucureşti, cod 013686, ROMÂNIA
Tel.: +40-21 - 3181115 Fax: +40-21-3181116 E-mail:relatii@hidro.ro

EAST AVERT Project

TECHNICAL REPORT

COMMON METHODOLOGY FOR PRFA AND HAZARD AND RISK MAPPING

2017

The prevention and protection against floods in the upper Siret and Prut River Basins, through the implementation of a modern monitoring system with automatic stations – EAST AVERT Project

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TECHNICAL REPORT

Part 1 - COMMON GIS SOFTWARE APPLICATION – GEODATABASE

Part 2 - COMMON COMPREHENSIVE GEO-DATABASE USING A COMMON GIS SOFTWARE APPLICATION

Coordinated by
Dr. Viorel CHENDES

Partner 4 - National Institute of Hydrology and Water Management, Romania

With the contribution of:

Lead Partner:	*Ministry of Environment, Romania*
Partner 2:	*Prut-Barlad Water Basin Administration, Romania*
Partner 3:	*Siret Water Basin Administration, Romania*
Partner 5:	*“Apele Moldovei” Agency, Republic of Moldova*
Partner 6:	*Dnister-Prut Basin Department of water resources, Ukraine*
Partner 7:	*Chernivtsi Regional Centre on Hydrometeorology, Ukraine*
Partner 8:	*State Scientific and Technical Centre for inter-sectorial&regional problems of the Environemental Safety and Resources Conservation “EcoResources”, Ukraine*

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CONTENT

Part 1

PART 2

PART 1

1. INTRODUCTION

Effective flood prevention and mitigation of transnational rivers requires cooperation between Romania, Ukraine and Republic of Moldova. Harmonization of spatial information is needed in Prut and Siret basins and the rivers must be conceived like a system which does not respect any border.

The objective is to create a common database necessary for mapping historical floods, for production of hazard and risk maps and for configuration of Dispatch and Cartographical applications. Thus, geodatabase structure was developed in order to be used for all mentioned project activities (Fig. 1.1).

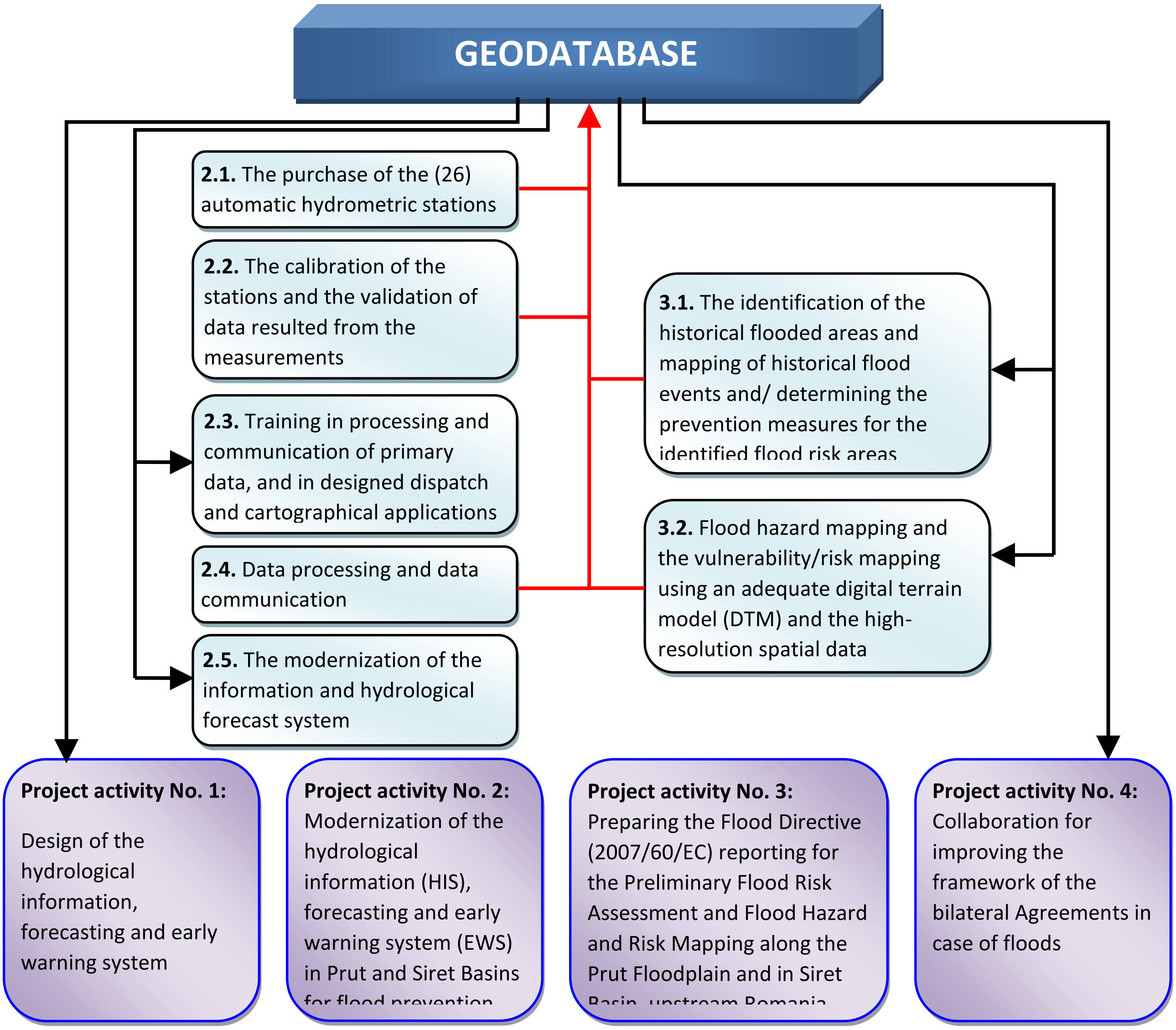


Fig. 1.1. **- Inputs and outputs of project activities in the geodatabase**

Spatial data harmonization is not only needed regarding the three nations, but also regarding different user groups who have both different expectations and uses from map content.

Data are the heart of flood forecasting and water modeling process. Inconsistencies or quality deficits may lead to bad results.

Database design is the process of producing a detailed data model of a database. The geodatabase combines "geo" (spatial data) with "database" (data repository) to create a central data repository for spatial data storage and management.

The geodatabase offers the ability to:

- store a rich collection of spatial data in a centralized location;
- apply rules and relationships to the data;
- define geospatial relational models (e.g., topologies);
- work within a multiuser access and editing environment;
- integrate spatial data with other IT databases;
- create custom features and behaviour.

The geodatabase supports different elements of GIS data, such as:

- geographic features;
- attribute data;
- satellite and aerial images (raster data);
- surface modeling or 3D data;
- GPS coordinates;
- survey measurements.

Establish the necessary geospatial data has to take into consideration conditional spatial variability of hydrological parameters determined by a series of climatic factors (precipitation, evaporation, snow cover, air temperature etc.) or non-climatic factors (geology, topography, soils, vegetation, human activities etc.).

Systematization of physical-geographical layers within a geodatabase, analysis and processing in a GIS environment, including spatial statistics, are meant to identify new causal relations and provide inputs for hydrological or hydraulic models. Also, historical information contained in the geodatabase has to be supported by a digital cartographic content (digital elevation model, hydrographic network, land use, catchments, meteorological and hydrometric gauging stations etc.).

In the past 20 years several studies have been conducted to incorporate processing and analysis of spatial data in hydrological modeling of river basins. These studies have different purposes and can be generally grouped into four categories (Melesse et al, 2003):

1. calculate the input parameters for hydrological models;
2. mapping hydrological variables;
3. representation of catchment area;
4. identification of hydrological response units.

Maidment (1993) identified different contributions of GIS in hydrology:

- analyse and hydrological assessment;
- estimation of hydrological parameters;
- coupling scattered spatial data and hydrological models;
- integration of GIS analysis and hydrological models into independent applications (HEC-RAS, HEC-HMS, MIKE, FLDVIEW etc.)

A scheme in which sparse systems are coupled is proposed by National Institute of Hydrology and Water Management (Stanciu et al, 2009) and is presented in the figure 1.2. This hydrologic system approach resides in a package of applications that are coupled through automatic or semi-automatic procedures, exchange of data between different components being aimed to analyse flood-prone areas. The scheme highlights the place GIS and spatial data occupy in this approach.

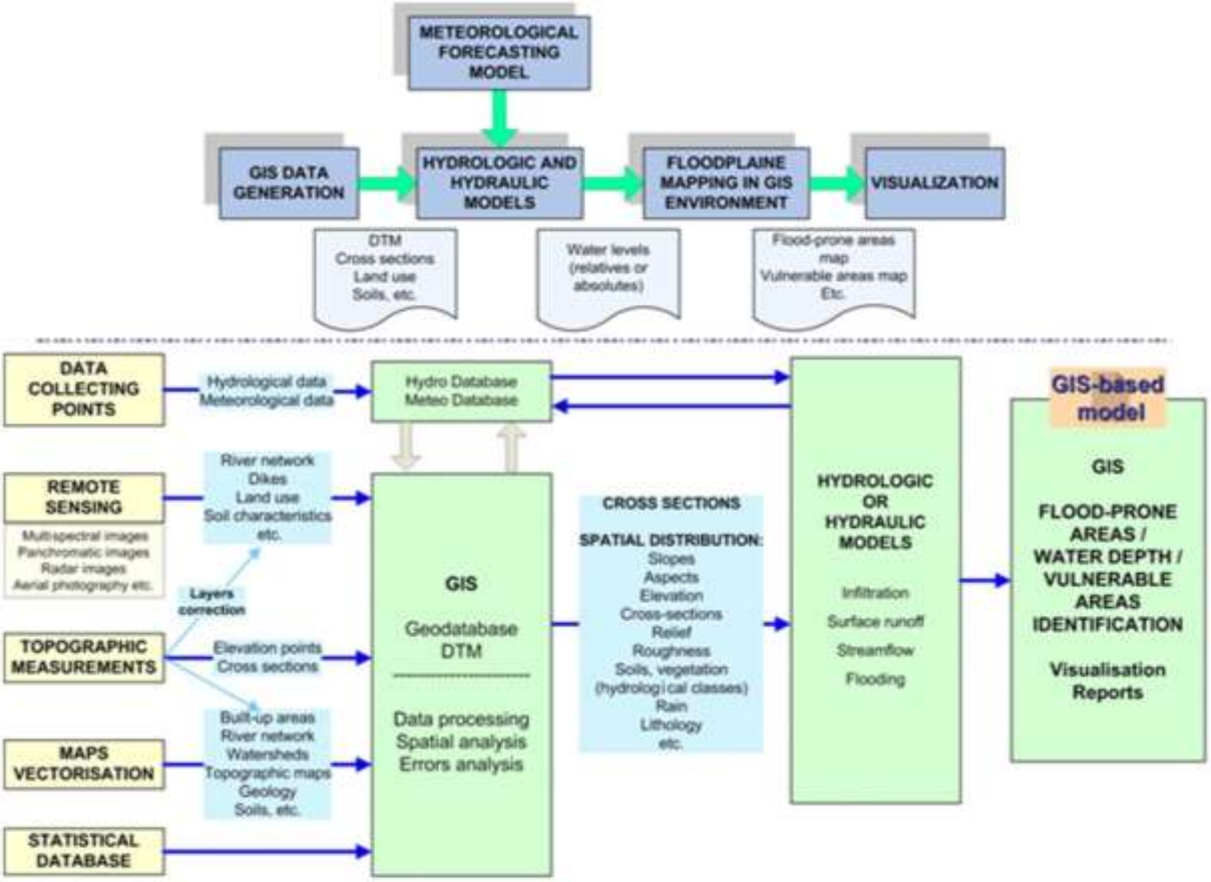


Fig. 1.2.- **Inputs in GIS-base model to analyse flood-prone areas**

Based on this scheme a geodatabase structure can be developed that satisfies both the requirements of spatial analysis of the hydrologic system components and of hydrological modeling. The main data sources to be included in a geodatabase are topographic and bathymetric measurements, different plans and georeferenced scanned maps, satellite images and orthophotos etc.

2. SPATIAL DATA HARMONIZATION

Before creating the geodatabase a table must be filled by all partners in order to know what data is already available, what data will be produced and some other usefull information. In table 2.1 are presented column headers that need to be filled for each layer or table that will be included in the geodatabase.

Table 2.1 **- Column headers to be filled for each layer, table or flood management plan**

LAYER	Quick Description of expectations	Data type (GIS, table, report etc.)	Owner institution	Provider for the project	Existing data (E) or to be produced (P)	Format	Scale / resolution	Receivable between experts (Y/N)	Public data access (Y/N)	Comments / Conditions to be obtained for project

In table 2.2 are presented the layers and tables that the geodatabase will contain and also the flood management plans accompanied by a brief description. The layers are divided into 4 main categories: historical floods, digital elevation models and orthophotos, general layers and layers for flood risk assessment. Layers used for flood risk assessment are split into 5 datasets: economic activities, socio-economic objectives, infrastructure, cultural assets and environment and pollutants.

Table 2.2 **- Short description of layers and tables within the geodatabase**

LAYER	Short description of expectations
Historical floods	
Historical Floods	Polygon representing the extent of flood at different probability of exceedance
Settlements affected by floods	Points representing settlements significant affected by historical floods
Satellite images for last historical events	Satellite images from floods occurred in july 2008 and july 2010
Multi-purposes data	
General Digital Elevation Model	SRTM, ASTER, EU-DEM or topographic maps 1:25k or 1:50k; expected resolution is 10-30 m; will be used for general maps, pre-modeling assessments etc.
Detailed Digital Elevation Model	→ based on LiDAR or orthophotos data → includes river channel measurements → maximum 3-5 m resolution → 1-2 m resolution an optimum resolution → used for hydraulic modeling → a common DEM between 3 countries
Ortophotos (aerial photograph) / multispectral satellite images	→ 0.5 m for orthophotos or 0.5-1 m for satellite images → RGB and georeferenced images

Modeling / Information System	
Hydrographic network	Prut and Siret rivers and the main tributaries
River Catchments	The River Catchments in Siret and Prut basins
Natural lakes	The lakes in the eligible counties
Hydrometric stations	Along the Prut and Siret River and lower stations on tributaries
Weather stations	Weather stations at the basin level
Pluviometric spots	Points with only precipitation measurements at the basin level
Dams	The dams in the eligible counties
Reservoirs	The reservoirs in the eligible counties
Small hydro plants	Small hydro plants in the eligible counties
Dikes	The dikes in the eligible counties
Polders	The polders in the eligible counties
Channels	Channels for irrigation or drainage in the eligible counties
Pumping stations	The pumping stations in the eligible counties
Intakes	The intakes in the eligible counties
Diversions	The diversions of the stream flow leaving the main channel
Shore defenses	Shore defenses in the eligible counties
Land marks	Geodetic points from national network
Elevation Points	Elevation Points from topographic maps, including toponyms (place name)
Other topographic points	Points measured during field campaign with high precision
Longitudinal profiles on dykes	Elevation points along dyke crest at a minimum 250 m distance
Cross-sections in the river channel	A minimum 500 m distance between cross-section or bathymetric tracks
Land Cover	Corinne Land Cover or FAO LULC type
Flood Risk	
Economic activities	
Main economic activities	Main economic activities - for example SEVESO or IPPC points
European Pollutant Release and Transfer Register (E-PRTR)	Main pollutant units
Gravel pits	Gravel pits in the flood-prone area and mapping area
Fishing ponds	Fishing ponds in the flood-prone area and mapping area
Health resort	Health resort in the flood-prone area and mapping area
Shopping complex	Shopping complex in the flood-prone area and mapping area
Other small economic activities	Manufactory, medical offices and pharmacies, hotels, restaurants etc.
Socio-economic objectives	
Counties (NUTS 3)	Eligible counties
Local Administrative Units (Municipalities or Communes)	Municipalities in the flood-prone area and mapping area

Settlements	The settlements in the eligible counties
Built-up areas	Polygon type delineating only built-up areas inside the settlements
Hospitals	Hospitals in the flood-prone area and mapping area
Schools	Universities, schools and kindergartens in the flood-prone area and mapping area
Town halls	Town halls in the flood-prone area and mapping area
Police offices	Police offices in the flood-prone area and mapping area
Water supply facilities (station)	Water supply facilities in the flood-prone area and mapping area
Wells	Wells in the flood-prone area and mapping area
Sewerage network	Sewerage network in the flood-prone area and mapping area
Other urban infrastructure	Other urban infrastructure in the flood-prone area and mapping area
Infrastructure	
Roads and streets	Non-urban roads, urban roads and rural roads
Railways	Railways in the flood-prone area and mapping area
Airports	Airports in the flood-prone area and mapping area
Railway station	Railway stations and halts
Bus Terminal	Bus terminals in the flood-prone area and mapping area
Bridges	Concrete bridges and wood footbridge
Parkings	Parkings in the flood-prone area and mapping area
Border crossing points	Border crossing points in the flood-prone area and mapping area
Culverts	Culverts in the flood-prone area and mapping area
Cultural assets	
Churches	Churches in the flood-prone area and mapping area
Monuments	Monuments in the flood-prone area and mapping area
Museums	Museums in the flood-prone area and mapping area
Cinemas, theaters and cultural centers	Cinemas, theaters and cultural centers in the mapping area
Environment and pollutants	
Abstraction for drinking water	Surface water or groundwater abstractions for drinking water
Birds - SPA	Special Protection Areas in the flood-prone area and mapping area
Habitats - SCI	Sites of Community Importance in the mapping area
Natural protected areas	Natural protected areas in the flood-prone area and mapping area
Local protected areas	Local protected areas in the flood-prone area and mapping area
Parks and recreational areas	Parks and recreational areas in mapping area

Urban waste water treatment	Urban waste water treatment in the mapping area
Livestock farms	Livestock farms in the flood-prone area and mapping area
Cemeteries	Cemeteries in the flood-prone area and mapping area
Other pollutant units	Other pollutant units in the flood-prone area and mapping area
Flood management Plans	
Emergency situation institutions	Emergency situation institutions in the flood-prone area and mapping area
Other public institutions involved in flood management	Other public institutions involved in flood management in the flood-prone area and mapping area
Buildings used for flood casualties	Buildings used for flood casualties in the flood-prone area and mapping area
Hydrologycal table data	
Flow hydrographs and peak flows for different probabilities of exceedance	Water discharge for 10%, 1% and 0,1% probabilities of exceedance must be analysed
Water levels	Water levels for 10%, 1% and 0,1% probabilities of exceedance must be analysed
Data on the Stanca-Costesti dam operating rules	Water discharge and levels for 10%, 1% and 0,1% probabilities of exceedance at Stanca-Costensti dam must be analysed
Significant floods, synthetic floods corresponding to peak flows with different probabilities of exceedance and synthetic floods of the appropriate scenarios necessary for the hazard maps computation	10%, 1% and 0,1% probabilities of exceedance must be analysed
Other significant hydrological and hydraulic data	Longitudinal and cross-sections for 10%, 1% and 0,1% probabilities of exceedance must be analysed

Each vector layer will have an attribute table where different information will be completed. The fields to be completed are not final for vector layers. In table 2.3 are some examples for each vector type: point, line and polygon.

***Table 2.3* – Column headers of 3 attribute table for all types of vector layers**

LAYER	Layer TYPE	Field name	Field type	Field description
Historical Floods	polygon	ID_HF	Text	Historical flood event code (it will include ISO code of the country, cadastral code/other code, year and month when the flood occured, eg. RO_12.01_2008.07)
		R_Name	Text	River name where the flood occured
		L_river	Double	Length of the river sector affected (km)

LAYER	Layer TYPE	Field name	Field type	Field description
		Source	Text	Source of flooding (e.g. fluvial, pluvial groundwater, sea water, artificial body water - bearing infrastructure, other)
		Mechanism	Text	Mechanism of flooding (e.g. natural exceedance, defence exceedance, defence or infrastructure/failure, blockage/restriction, other)
		Cha_flood	Text	Characteristics of flooding (e.g. flash flood, other rapid onset, medium onset flood, slow onset onset flood, snow melt flood, debris flow, high velocity flow, deep flood, other)
		Start_Date	Date	Start date
		Duration	Short Integer	Flood duration (days)
		Q_disch	Float	Peak discharge
		Prob	Float	Excedence probability of flood
		Precip	Double	Rainfall amount that generated the flood (hourly, daily or cumulated)
		Tributary	Text	Cadastral codes of the flood affected tributaries
Settlements / Local Administrative Units affected by floods	point	ID_set	Text	Settlement code at national level
		ID_HF	Text	Historical flood event code
		Casualties	Short Integer	Casualties (number)
		N_house	Short Integer	Number of affected householdes
		L_rail	Double	Length of affected railway (km)
		L_road	Double	Length of affected road (km)
		N_bridge	Short Integer	Number of affected bridges
		L_w_supply	Double	Length of water supply network affected (km)
		L_sewerage	Double	Length of sewerage network affected (km)
		A_affect	Double	Area of arable land affected (km2)
		Obj_affect	Short Integer	Socio Economical objectives affected (number)
Roads	line	ID_road	Text	Unique identifier of the road in the geodatabase
		N_Road	Text	Name of the road (e.g. E70 - European number 70)

LAYER	Layer TYPE	Field name	Field type	Field description
		Type	Text	Road type (e.g. Non-urban, urban or rural road)
		Sub_type	Text	For Non-urban roads (highway, Expressways, national and county roads), Urban roads (arterial, local street etc) and rural roads (village roads and another types)
		NrLanes	Short Integer	Total number of lanes on both directions

3. COMPOUND COORDINATE REFERENCE SYSTEM

Compound coordinate reference system means a coordinate reference system using two other independent coordinate reference systems, one for the horizontal component and one for the vertical component, to describe a position, in accordance with EN ISO 19111.

3.1. HORIZONTAL COORDINATE SYSTEM

For this project a geodatabase for Prut and Siret basins was designed. The geodatabase that was created contains multiple layers in ESRI file Geodatabase in UTM 35 projection in the ETRS89 datum.

For the common area of Romania, Ukraine and Republic of Moldova 3 horizontal coordinate systems can be used: 2 at the European level and 1 at the local level (Fig. 3.1). The proposed system is UTM 35 zone on GCS ETRS_1989.

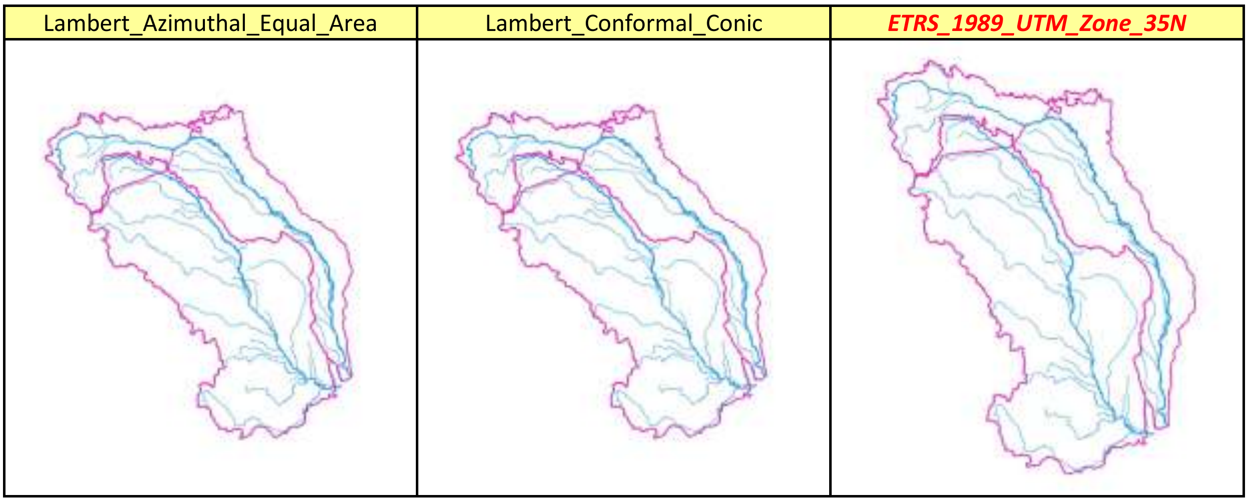


Fig. 3.1 **- Different coordinate systems suitable to be used in the project area**

The **Universal Transverse Mercator** (**UTM**) is a conformal projection which uses a 2-dimensional Cartesian coordinate system to give locations on the surface of the Earth. It is a horizontal position representation and is used to identify locations on the Earth independently of vertical position.

The UTM system divides the Earth between 80°S and 84°N latitude into 60 zones, each 6 of longitude in width and uses a secant transverse Mercator projection in each zone. Zone 1 covers longitude 180° to 174° W; zone numbering increases eastward to zone 60 that covers longitude 174 to 180 east.

The zones are then further subdivided into an eastern and western half by drawing a line, representing a transverse Mercator projection, down the middle of the zone. This line is known as the ‘central meridian’ and is the only line within the zone that can be drawn between the poles and be perpendicular to the equator (in other words, it is the new ‘equator’ for the projection and suffers the least amount of distortion). For this reason, vertical grid lines in the UTM system are oriented parallel to the central meridian. The central meridian is also used in setting up the origin for the grid system.

Universal Transverse Mercator projection exist both in spherical and ellipsoidal version.

The ETRS89 is a geodetic Cartesian reference frame, in which the Eurasian Plate as a whole is static. The development of ETRS89 is related to the global ITRS geodetic datum, in which the representation of the continental drift is balanced in such a way that the total apparent angular momentum of continental plates is about 0.

The ETRS89 reference system was adopted in 2003 by the European Commission and is recommended to be used by the EuroGeographics – the organization that unifies all the cadaster agencies across Europe. All European countries adopted the ETRS89 reference system and provide tools for transformations between ETRS89 and the national systems.

3.2. VERTICAL COORDINATE SYSTEM

Vertical datum is determined by the mean sea level, which is estimated at one or more tide gauge stations. The tide gauge stations of the national European height systems in Europe are located at Atlantic Ocean and different seas: Baltic Sea, North Sea, Mediterranean Sea and Black Sea. The differences between these sea levels can come up to several decimetres. They are caused by the various separations between the ocean surface and the geoid.

In Europe three different kinds of heights (normal heights, orthometric heights and normal-orthometric heights) are used. Examples for the use of orthometric heights are Belgium, Denmark, Italy and Switzerland. Today normal heights are used in France, Germany, Scandinavia and in most countries of Eastern Europe. In Austria and in countries of the former Yugoslavia normal-orthometric heights are used (Fig. 3.2).

Fig. 3.2 **- Kind of heights of national height systems in Europe**

The European Vertical Reference System (EVRS) is a kinematical height reference system. The EVRS definitions fulfil the following four conventions:

1. The vertical datum is defined as the equipotential surface for which the Earth gravity field potential is constant:

$W_0 = W_{0E} = \text{const.}$

and which is in the level of the Normaal Amsterdams Peil (NAP).

2. The unit of length of the EVRS is the meter (SI). The unit of time is second (SI). This scale is consistent with the TCG time coordinate for a geocentric local frame, in agreement with International Astronomical Union (IAU) and International Union of Geodesy and Geophysics (IUGG) resolutions (1991). This is obtained by appropriate relativistic modelling.
3. The height components are the differences between the potential ΔW_P of the Earth gravity field through the considered points *P,* and the potential W_P of the EVRS conventional zero level. The potential difference $-\Delta W_P$ is also designated as the geopotential number c_P

$-\Delta W_P = c_P = W_{0E} - W_P$

Normal heights are equivalent with geopotential numbers, provided that the reference gravity field is specified.

4. The EVRS is a zero tidal system, in agreement with the IAG Resolutions No. 9 and 16 adopted in Hamburg in 1983.

The European Vertical Reference Frame (EVRF2007) is defined in terms of geopotential. It is realized using geopotential numbers determined by levelling, or alternatively a geopotential model and 3-dimensional coordinates. None of these quantities depend on ellipsoidal reference, and therefore a reference ellipsoid is not part of the EVRS definitions. However, to convert the geopotential numbers to normal heights, a normal gravity field and geodetic latitude is required. The GRS80 normal gravity field is adopted for the purpose, evaluated at ETRS89 coordinates.

The objectives of EVRF2007 are:

- to fulfil the EU requirements for seamless, harmonised vertical data;
- to prepare recommendations to the European Commission for a future adoption of a common European Vertical Reference System to be proposed in the INSPIRE (Infrastructure for Spatial Information in Europe) Directive;
- to provide European users and producers of height information with a vertical reference system, which is based on up-to-date datasets and on advanced conventions for EVRS definition and realization.

Romania altimetry network, the Black Sea 1975 system, is a normal heights system with zero fundamental Constanta Military Chapel, representing annual average sea level.

Routes developed from this mark are found along the passageways, especially railways. These are combined in different orders networks, evidenced by good leveling marks embedded in solid supports.

A standard transformation parameters were computed by EVRF Computing Centre from Federal Agency for Cartography and Geodesy (BKG, Germany). These set of parameters realize the transformation of normal heights from Black Sea 1975 System to EVRF2007 (RO_CONST / NH to EVRF2007).

Transformation parameters were derived from 48 identical points (UELN nodal points) with a transformation RMS of 0.004 m, and residual deviation between -0.012 m and +0.013 m.

A general view of the EVRF2007 realization in comparison with national height reference systems can be seen on the fig. 3.3.

In 2009, NACLR finalized the coordinates transformation including a distorsion model from ETRS89 system to S42 (Krasovski ellipsoid) – Stereographic 1970 projection system and provided TransDatRo software and algorithm for the users.

Currently transformation of normal heights from Black Sea 1975 System to EVRF2007 are completed.

For Republic of Moldova and Ukraine, the Baltic Sea 1977 system altimetry network is a normal heights system with zero fundamental at Kronstadt.

Fig. 3.3 **- Mean differences between EVRF2007 and national height reference systems**

4. ADVANTAGES OF A GEODATABASE

In EastAvert project one ArcGIS Basic Single Use License with Spatial Analyst extension were bought and a number of 5 peoples were specialized with the goal to create *"Atlas – Flood Hazard and Risk Maps",* other internal applications and to increase institutional capacity. The courses which were held during the project were:

- Introduction to GIS;
- Editing Data with ArcGIS for Desktop;
- Essential Workflows;
- ArcGIS Online Subscriptions for Organizations: Publisher Workflows;
- Advanced Analyze in ArcGIS in hydrology domain;

We bought ArcGIS because we have previous knowledge regarding this software and because it gives us advanced editing tools and feature behavior in geodatabases (topologies) that allows us to create and maintain high-quality geographic data.

GIS specialists use geodatabase for many reasons. In our case we use a file geodatabase for single or small groups whether we are working with large or small datasets. Whether we are working on a single-use project or a project involving a small group with one or several editors, we considered using a file geodatabase rather than a personal geodatabase or a collection of shapefiles which both have a size limit of 2 GB, relative to 1 TB for feature class only. File geodatabases offers structural, performance and data management advantages compared to the other two formats.

One of the structural advantage of the file geodatabase is the fact that is stored as a system folder that contains binary files that store and manage geospatial data. It is available at all ArcGIS license levels and functions in the same fashion on Windows and UNIX operating systems. This storage system is based on relational principles and provides a simple, formal data model for storing and working with information in tables. The file geodatabase contains this files when seen in a browser: geographic data, attribute data, index files, lock files, signature files, and other files. Each feature class or table in the geodatabase is stored in two or more files.

Other structural advantage of the file geodatabase is the optimized performance. The data structure of a file geodatabase is optimized for performance and storage. Although individual feature classes can be as large as 1 terabyte (TB) in size and contain hundreds of millions of features, they still provide fast performance. File geodatabases significantly outperform shapefiles for operations involving attributes and allow scaling of dataset size limits way beyond those of shapefiles.

The most important structural advantage of file geodatabase is the fact that the size is limited only by available disk space. By default, individual tables and feature classes can be up to 1 TB. With the use of configuration keywords, this can be expanded to 256 TB.

Regarding the performance advantages there are a few that the file geodatabase is offering. Easy data migration between file geodatabases and personal geodatabases is one of them, because both are designed to be edited by a single user and do not support geodatabase versioning (only enterprise geodatabase permits versioning).

Also, file geodatabases do not lock down the whole geodatabase if a user is editing a feature class, which indicates improved editing model. An edit model similar to that used for shapefiles is deployed. This model supports a single data editor and many data viewers concurrently. Stand-alone feature classes, tables, and feature dataset contents can be edited by different editors simultaneously without the entire geodatabase being locked. If a feature class in a feature dataset is being edited, all feature classes in that feature dataset are unavailable for editing, but features may still be viewed and selected in ArcMap.

Other performance advantage is the raster storage in a file geodatabase which is a shared functionality from both the ArcSDE geodatabase and the personal geodatabase.

Managed raster data is stored in the same way as in an ArcSDE geodatabase, and unmanaged raster data is stored in the same way as in a personal geodatabase. Managed raster data is subdivided into small, manageable areas called tiles, stored as binary large objects (BLOBs) in the database. The tiling is automatic and invisible to end users. These tiles are indexed and pyramided for fast display performance. Pyramiding allows the geodatabase to fetch only data at the specified resolution or level required for display. Unmanaged rasters are maintained by users. Only the path to the location on the disk where the raster dataset is stored is maintained in the file geodatabase.

Regarding the data management advantage customizable storage configuration is one of them. When creating a dataset, applying optional configuration keywords to customize data storage is often used to improve storage efficiency and performance. In most cases, the defaults keyword is used and if the dataset exceeds 1 TB or is less than 4 GB the keywords must be changed.

File geodatabase allows updates to spatial index settings using simple data loader or append tool. Spatial indexes are used by ArcGIS to quickly locate features when you display, edit, or query data. An appropriate spatial index is important, especially when you are working with large datasets. While the spatial index of a personal geodatabase feature class uses a single grid size that cannot be modified, the spatial index of a file geodatabase feature class uses as many as three grid sizes, which can be modified. Additional grids allow feature classes with features of very different sizes to be queried more quickly. ArcGIS automatically rebuilds the spatial index at the end of some update operations to ensure the index and its grid sizes are optimal.

La last data management advantage is data compression. Vector data can be stored in a file geodatabase in a compressed, read-only format that reduces storage requirements. Compression reduces the geodatabase's overall footprint on disk without reducing the performance. Once compressed, display and query performance are comparable to uncompressed data. Compressed data is in a direct-access format, so there is no need to uncompress the data because ArcGIS can read it directly. Compression is ideally suited to mature datasets that do not require further editing. However, if required, a compressed dataset can always be uncompressed and returned to its original, read/write format. The compression method applied is lossless, so no information is lost. One of the most important factors affecting spatial data compression is the average number of vertices per feature. As a general rule, the fewer vertices/features, the greater the compression.

Table 4.1 **- File geodatabase parameters**

Property	**Settings**
File geodatabase size	Technically no limit
Table or feature class size	1 TB (default) 256 TB (with keyword)
Number of feature classes and tables	2,147,483,647
Number of fields in a table or feature class	65,534
Number of rows in a table or feature class	4,294,967,295
Geodatabase name length	Operating system limits for a folder name
Table or feature class name length	160 characters
Field name length	64 characters
Character field width	2,147,483,647

PART 2

5. STATE OF THE ART OF OTHER MAPPING PROJECTS

5.1.ELBE-ATLAS, ELLA - PROJECT

The Elbe atlas provides an overview of the flooding hazard in the catchment area of the River Elbe (scale 1:100,000). The Elbe atlas shows the areas endangered by flooding with a recurrence period of 100 years as well as a very extreme event. In order to illustrate the hazard level in particular behind the dykes as well, the situation is examined without taking the effects of the existing flood protection installations into account. The framework for action is to be defined through a cartographical presentation of the areas with the currently existing damage potential (damage risk maps) and the flooding areas (flood information maps). The necessary steps for flood prevention can thus be initiated by the responsible political and administrative bodies. For those who are affected in the immediate vicinity, the atlas serves as a reference work and basis for their own prevention measures and precautions.

The maps were produced within the INTERREG III B CADSES project ELLA and supported by funds of the German Federal Ministry of Transport, Building and Urban Affairs. The atlas is available at this link https://www.umwelt.sachsen.de/umwelt/wasser/2565.htm

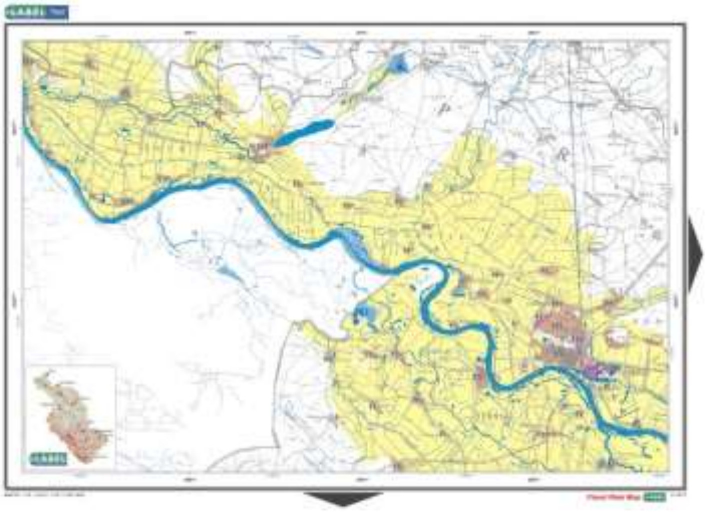


Fig. 5.1 **- Risk map from the Elbe Atlas**

The geodatabase for this project includes for flood hazard maps:

- areas potentially inundated by 100 year flood;
- areas potentially inundated by extreme floods;
- main levee (designed for 100 year flood);
- minor levee (designed for floods < 100 year).

For risk maps the possible affected land was divided in 4 land use classes: residential areas, agricultural and forestry areas, industrial and transportation areas and other areas.

Population exposed to extreme flooding was represented graphically in 3 classes as in the figure above: below 99 potentially affected inhabitants, between 100 – 999 and over 1000 (Fig. 5.1).

Other points of interest exposed to extreme flooding were considered industrial plant with damage potential, sewage treatment plant and natura 2000 habitat.

5.2.DANUBE ATLAS HAZARD AND RISK MAPS, DANUBE FLOODRISK PROJECT

During the past century flood protection along the Danube River has been generally conducted by constructing dykes, leading to a feeling of safety and, therefore, a decrease of flood awareness. The floods in 2002 in the upper reach of the Danube catchment as well as in 2006 and 2010 in the lower reach of the catchment have again highlighted the limits of implemented protection measures since overtopping or dyke failure occurred, highlighting that residual flood risk always remains despite all efforts (Fig. 5.2). The Danube Atlas represents areas exposed to flood hazard and the associated damage potentials and flood risk. Even though the terrain data are available at high resolution for almost all national river sectors (LiDAR data) and land survey information is at hand for cross sections, the atlas is printed in a scale of 1: 100 000.

Fig. 5.2 **– Cover page of Danube Atlas Hazard and Risk Maps**

The geodatabase for this project includes for flood hazard maps:

- water depth at HQ1000;
- flood extent for HQ1000 without depth information;
- flood extent for HQ100;
- dykes;
- rivers and lakes;
- woodland and parks;
- settlements;

For risk maps the possible affected land was divided in 4 land use classes with minimum 2 subclasses each according to value: residential/settlement, agricultural/forestry, industrial and other.

Population exposed to HQ1000 flooding was represented graphically in 4 classes: below 10 000 potentially affected inhabitants, between 10 000 – 50 000, between 50 000-100 000 and over 100 000.

Also major road, street, railway were considered and many points of interest as industrial site, wastewater, main train station, hospital, cultural heritage, airport etc.

6. DATABASE ACCORDING TO THE FLOODS DIRECTIVE

In order to satisfy Floods Directive requirements, collected data and information have to allow the identification of floods that occurred in the past and that have significant negative effects on human health, environment, cultural heritage and economic activity. To achieve this purpose, a relational database containing information from various documentary sources has to be created.

The reporting schemes, description of the codes and the attributes used, including data type, description of the relationships between the various elements, were developed at EU level and were the subject of Reference books for reporting within Directive. (*Maidens and Wolstrup, 2011; Atkins Danmark, 2011*).

The structure of this database was imposed by the technical specifications adopted according to the Floods Directive. The section for significant historical floods includes attribute regarding general information, source, mechanism, characteristics and consequences of flooding (Table 6.1).

Table 6.1 **- The attributes required by Flood Directive database and floods reporting schema**

Flood attribute	Code	Type/Sub-type	Description
General information about historical floods		Basin name	Name of the river basin
		Flood location code	Unique code for the flood location - up to 40 characters in total.
		Flood location name	Name of the locality, river basin, sub-basin and/or coastal area or other area associated with the flood
		Flood event code	Unique code for the flood event - up to 40 characters in total.
		Name of flood event	Relevant name of flood event; it will include the name of river, month and year
		Event onset date	Date of commencement of the flood
		Duration of the event	Time interval between the beginning and the end of the direct runoff
		Flood extent (kmp)	Extent of land inundated. Indicate the total area in km
		Length of the affected river sector (km)	Inundated length of river stretches in km
		Frequency	The statistical prediction of years between certain flood magnitude events
Source of flooding	A11	Fluvial	Flooding of land by waters originating from part of a natural drainage system, including natural or modified drainage channels. This source could include flooding from rivers, streams, drainage channels, mountain torrents and ephemeral watercourses, lakes and floods arising from snow melt.
	A12	Pluvial	Flooding of land directly from rainfall water falling on, or flowing over, the land. This source could include urban storm water, rural overland flow or excess water, or overland floods arising from snowmelt.
	A13	Groundwater	Flooding of land by waters from underground rising to above the land surface. This source could include rising groundwater and underground flow from elevated surface waters
	A14	Sea water	Flooding of land by water from the sea, estuaries or coastal lakes. This

Flood attribute	Code	Type/Sub-type	Description
			source could include flooding from the sea (e.g., extreme tidal level and / or storm surges) or arising from wave action or coastal tsunamis.
	A15	Artificial water – Bearing infrastructure	Flooding of land by water arising from artificial, water-bearing infrastructure or failure of such infrastructure. This source could include flooding arising from sewerage systems (including storm water, combined and foul sewers), water supply and wastewater treatment systems, artificial navigation canals and impoundments (e.g., dams and reservoirs).
	A16	Other	Flooding of land by water due to other sources, can include other tsunamis.
	A17	No data	No data available on the source of flooding
Mechanism of flooding	A21	Natural exceedance	Flooding of land by waters exceeding the capacity of their carrying channel or the level of adjacent lands
	A22	Defence exceedance	Flooding of land due to floodwaters overtopping flood defences
	A23	Defence or infrastructural failure	Flooding of land due to the failure of natural or artificial defences or infrastructure. This mechanism of flooding could include the breaching or collapse of a flood defence or retention structure, or the failure in operation of pumping equipment or gates
	A24	Blockage/Restriction	Flooding of land due to a natural or artificial blockage or restriction of a conveyance channel or system. This mechanism of flooding could include the blockage of sewerage systems or due to restrictive channel structures such as bridges or culverts or arising from ice jams or land slides.
	A25	Other	Flooding of land by water due to other mechanisms, for instance wind setup floods
	A26	No data available	No data available on the mechanism of flooding
Characteristics of flooding	A31	Flash flood	A flood that rises and falls quite rapidly with little or no advance warning, usually the result of intense rainfall over a relatively small area.
	A32	Snow melt flood	Flooding due to rapid snow melt, possibly in combination with rainfall or blockage due to ice jams.
	A33	Other rapid onset	A flood which develops quickly, other than a flash flood.
	A34	Medium onset flood	An onset of flooding, that occurs at a slower rate than a flash flood.
	A35	Slow onset flood	A flood which takes a longer time to develop.
	A36	Debris flow	A flood conveying a high degree of debris
	A37	High velocity flow	A flood where the floodwaters are flowing at a high velocity
	A38	Deep flood	A flood where the floodwaters are of significant depth
	A39	Other characteristics	No special characteristics
	A40	No data available	No data available on the characteristics of flooding
Consequences	B10	**Human health (Social aspects)**	
	B11	Human health	Adverse consequences to human health, either as immediate or consequential impacts, such as might arise from pollution or interruption of services related to water supply and treatment
		Number of victims	Human casualties

Flood attribute	**Code**	**Type/Sub-type**	**Description**
	B12	Community	Adverse consequences to the community, such as detrimental impacts on local governance and public administration, emergency response, education, health and social work facilities (such as hospitals)
	B13	Other	-
	B20	**Environment**	
	B21	Waterbody status	Adverse consequences ecological or chemical status of surface water bodies or chemical status of ground water bodies affected, as of concern under the WFD. Such consequences may arise from pollution from various sources (point and diffuse) or due to hydromorphological impacts of flooding
	B22	Protected area	Adverse consequences to protected areas or waterbodies such as those designated under the Birds and Habitats Directives, bathing waters or drinking water abstraction points
	B23	Pollution sources	Sources of potential pollution in the event of a flood, installations, or point or diffuse sources.
	B24	Other	Other potential adverse environmental impacts, such as those on soil, biodiversity, flora and fauna etc.
	B30	**Cultural heritage**	
	B31	Cultural assets	Adverse consequences to cultural heritage, which could include archaeological sites/monuments, architectural sites, museums, spiritual sites and buildings
	B32	Landscape	Adverse permanent or long-term consequences on cultural landscapes, that is cultural properties which represents the combined works of nature and man, such as relics of traditional landscapes, anchor locations or zones
	B33	Other	-
	B40	**Economic**	
	B41	Property	Adverse consequences to property, which could include homes
	B42	Infrastructure	Adverse consequences to infrastructural assets such as utilities, power generation, transport, storage and communication
	B43	Rural land use	Adverse consequences to uses of the land, such as agricultural activity (livestock, arable and horticulture), forestry, mineral extraction and fishing
	B44	Economic activity	Adverse consequences to sectors of economic activity, such as manufacturing, construction, retail, services and other sources of employment
	B45	Other	-

Areas with significant potential flood risk are mapped based on the available information about historical floods. For these areas, another database with similar attributes with the first was created at the European level.

European level database within 2007/60/EC Directive has a relatively high degree of complexity, requiring the allocation of a significant range to populate it (Fig. 6.1).

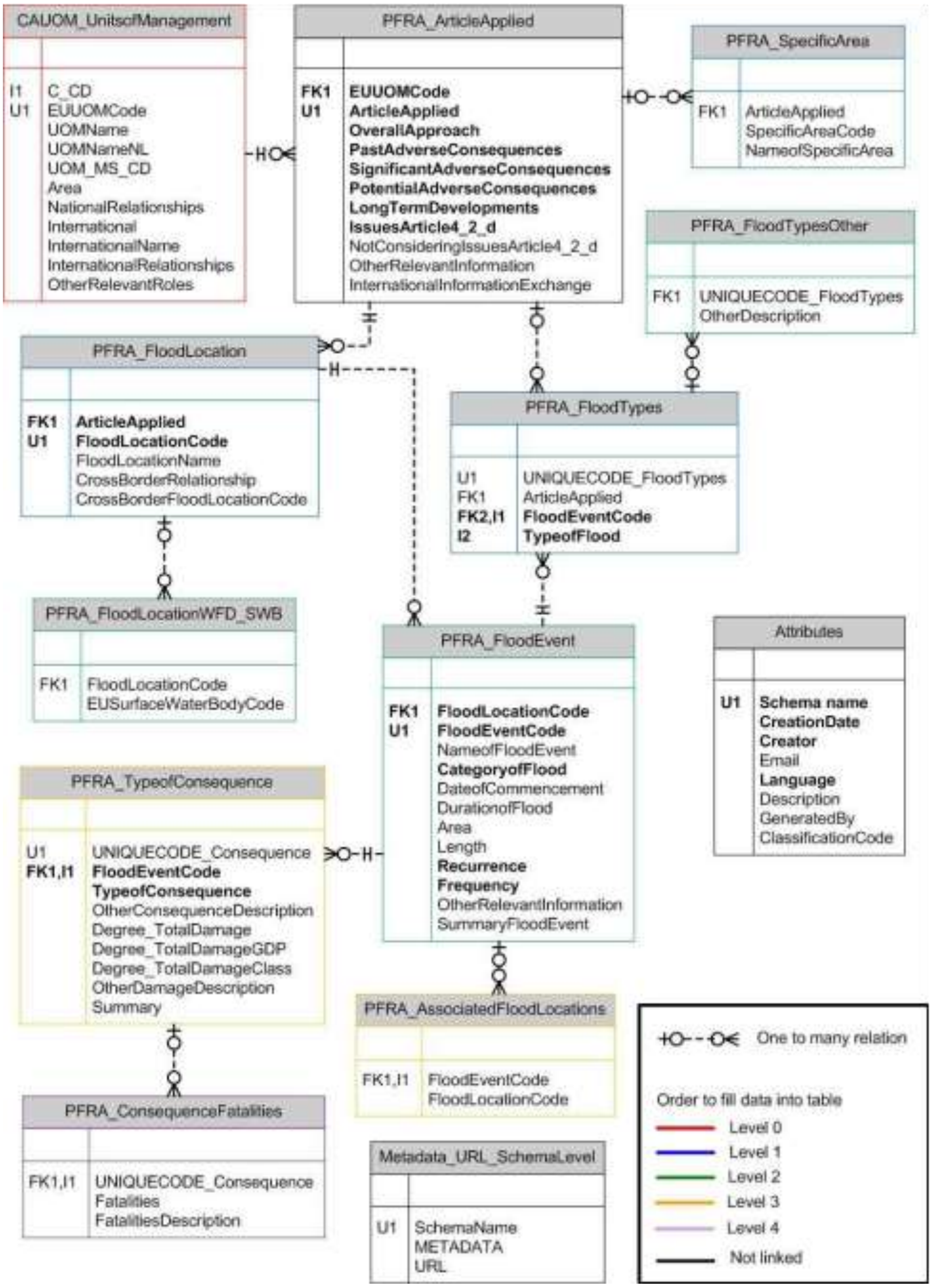


***Fig. 6.1.* - Linking tabular information specific to Preliminary Flood Risk Assessment**

7. EASTAVERT GEODATABASE

EastAvert project is an important contribution to the implementation to the EU policy - Flood Directive and INSPIRE Directive. The results of Flood Directive are disseminated to the public at the address below but Prut River hazard and risk maps were not ready at that time (Fig. 7.1).

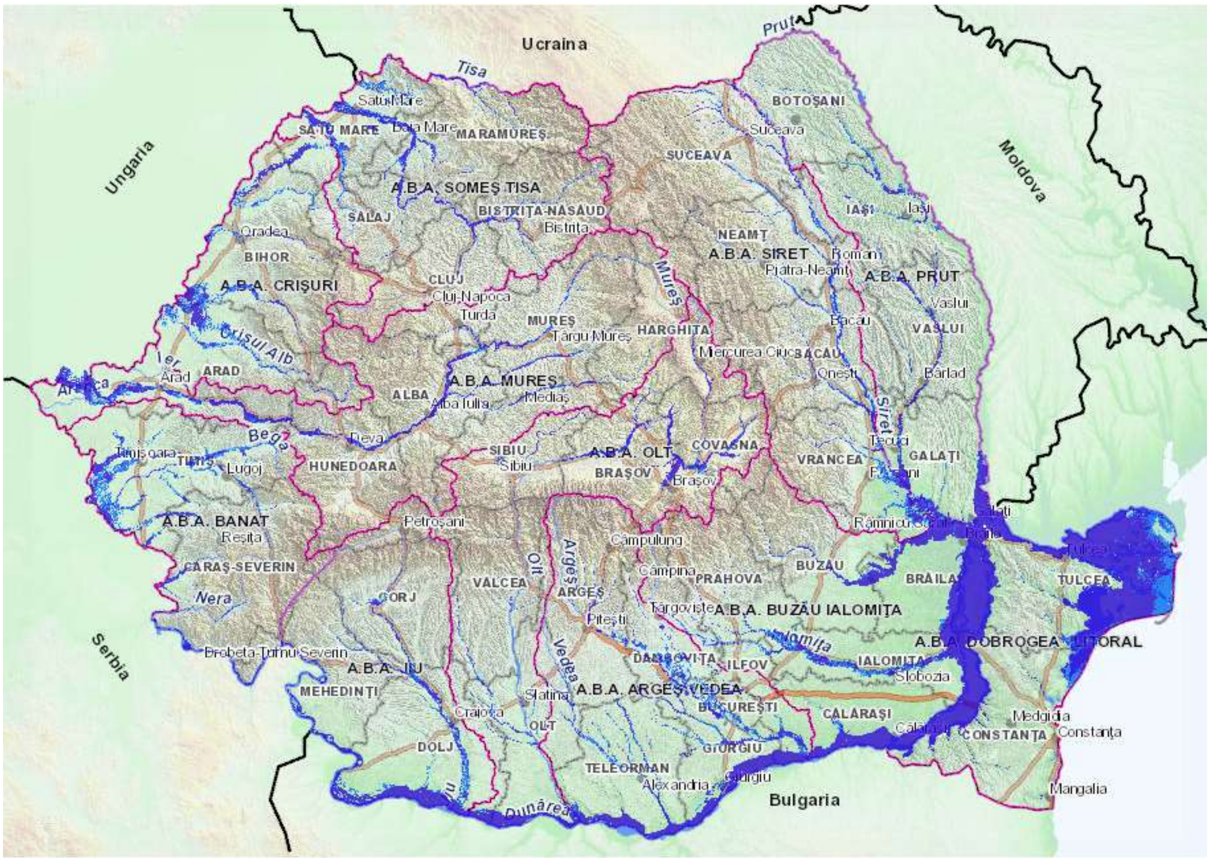


***Fig. 7.1* - Romanian Hazard and Risk Maps** http://gis2.rowater.ro:8989/flood/

Earth’s increasingly complex environmental challenges demand increasingly sophisticated solutions. Geographic information system (GIS) technology is one solution to humanity’s need to better manage, protect and preserve our environment.

GIS helps the public learn about the restoration efforts and promotes data sharing among those working on the restoration. “There is no doubt that visual information is always easier to interpret than text or numbers. […] This can help the public to understand without specialized knowledge. Therefore, we can show the current situations and problematic points intuitively by using maps as part of the public education.” *Masami Kaneko*

GIS has the merit of presenting an overall picture efficiently, it has chosen as a tool to aggregate scientific data systematically related to floods.

Siret is one of the major rivers of Romania, both by discharge (250mc/s) and by area (largest river basin in the country - 42890 kmp inside Romania, 44811 kmp totally). Main tributaries of the Siret river, also with the highest discharges are on the right side of it

(Suceava, Moldova, Bistrita, Neagra, Bistricioara, Bicaz, Tarcau, Cracau, Trotus, Slanic, Oituz, Casin, Tazlau, Buzau), while the main tributary on the left side is Barlad, resulting an obvious asymmetry between the two sides of the main river.

Inside Prut river catchment, although Prut river lengh is considerable (742 km inside Romania), its tributaries are fewer with much lower discharges compared to Siret (Baseu and Jijia, with Sitna and Bahlui).

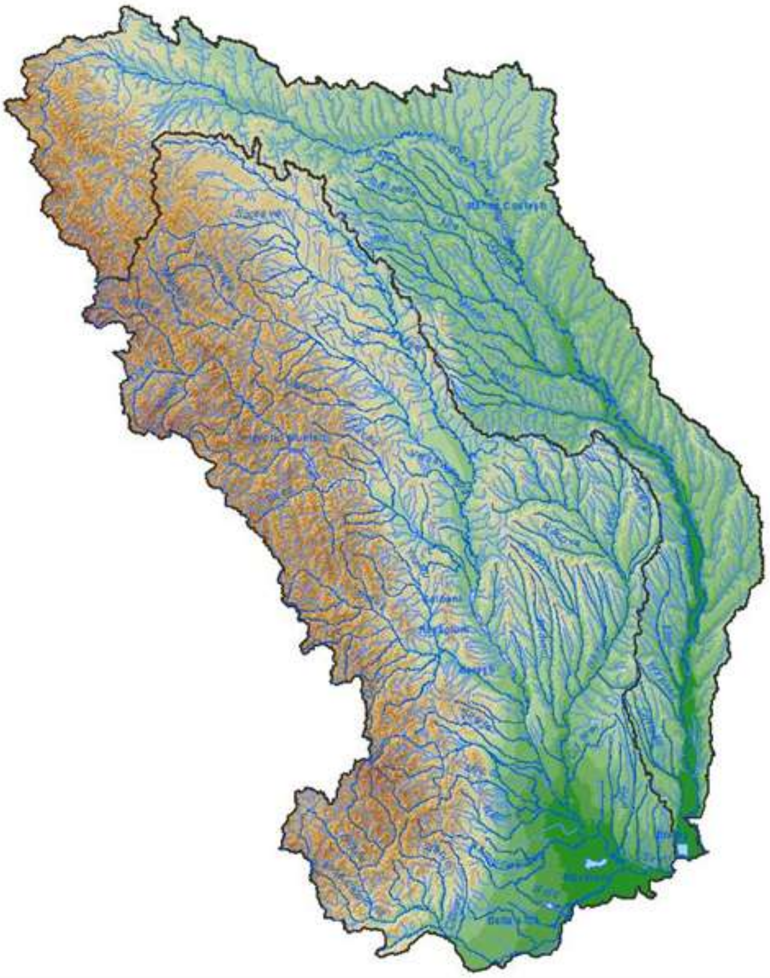


Fig. 7.2 **- Catchement areas of the Siret and Prut rivers**

GIS spatial data updating is necessary for mapping historical floods, for production of hazard and risk maps and configuration of Dispatch and Cartographical applications.

Thus, the starting point was the verification and correction of the existing layers inside geospatial data. First step in flood analysis is a better representation of the hydrological network in Prut and Siret catchment areas.

Verification and correction of the shapefile "rivers" was made considering topographic maps (1:25000), hydrological maps and satellite images.

After this step, it was necessary the delineation of the rivers catchments, using the same materials as above (for Romania). The rivers in Moldova and Ukraine and their catchments were determined based on a digital terrain model using an ArcGIS extension, named ArcHydro (Fig.7.3).

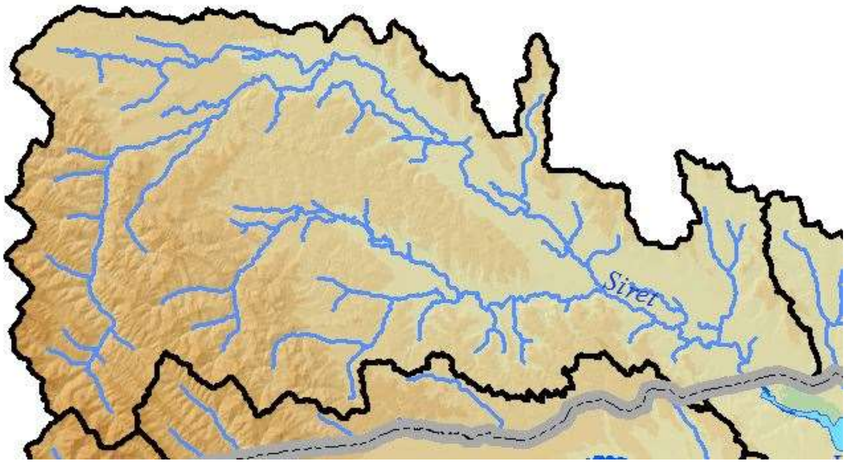


Fig.7.3 **- Hydrological network and catchment area using ArcHydro extension**

Fig. 7.4 **- Drainage network in the study area**

Next step was to determine the observations points, in the hydrometric gauging stations (HGS) on the main rivers (Prut and Siret) and closing HGS on the tributaries in Ukraine and Republic of Moldova, totaling 24 points – 16 in Ukraine and 8 in Republic of Moldova (Table 7.1). These were correlated with HGS in Romania, verified in earlier stage, resulting a final shape "HGS" with 49 records. Their position was updated according the latest data available (Fig. 7.6). Also, longitudinal profiles along the two main rivers were made (in the graphic below - Fig. 7.5 - there is an example for Prut river).

***Table 7.1* - Hydrometric gauging stations**

Nr	River	HGS	Country
1	Prut	Oroftiana	Romania
2	Prut	Radauti-Prut	Romania
3	Prut	Stanca (Aval)	Romania
4	Prut	Ungheni	Romania
5	Prut	Prisacani	Romania
6	Prut	Dranceni	Romania
7	Prut	Falciu	Romania
8	Prut	Oancea	Romania
9	Prut	Sivita	Romania
10	Baseu	Stefanesti	Romania
11	Jijia	Chiperesti	Romania
12	Elan	Murgeni	Romania
13	Horincea	Ganesti	Romania
14	Siret	Siret	Romania
15	Siret	Zvoristea	Romania
16	Siret	Hutani	Romania
17	Siret	Lespezi	Romania
18	Rapas	Dragesti	Romania
19	Siret	N.Balcescu	Romania
20	Siret	Dragesti	Romania
21	Suceava	Itcani	Romania
22	Volovat	Manoleasa	Romania
23	Somuzul Mare	Dolhesti	Romania
24	Moldova	Roman	Romania
25	Vl.Neagra	Secuieni	Romania
26	Sirausi	Prut	Moldova
27	Ungheni	Prut	Moldova
28	Balasinesti	Vilia	Moldova
29	Trinca	Draghiste	Moldova
30	Cajba	Caldarusa	Moldova
31	Pirlisa	Delia	Moldova
32	Costesti	Prut	Moldova
33	Barladeni	Ciuhur	Moldova
34	Tatariv	Prut	Ukraine
35	Yaremche	Prut	Ukraine
36	Kolomya	Prut	Ukraine
37	Vorokhta	Prut	Ukraine
38	Chernivtsi	Prut	Ukraine
39	Yaremche Zhonka	Zhonka	Ukraine
40	Dora	Kamyanka	Ukraine
41	Lyubkivtsi	Chornyava	Ukraine
42	Usteriky	Cheremosh	Ukraine
43	Kuty	Cheremosh	Ukraine

Nr	River	HGS	Country
44	Yablunytsya	Bily Cheremosh	Ukraine
45	Verkhovyna	Chorny Cheremosh	Ukraine
46	Putyla	Putyla	Ukraine
47	Storozhynets	Siret	Ukraine
48	Verhny Yaseniv	Veretyn	Ukraine
49	Iltsi	Iltsya	Ukraine

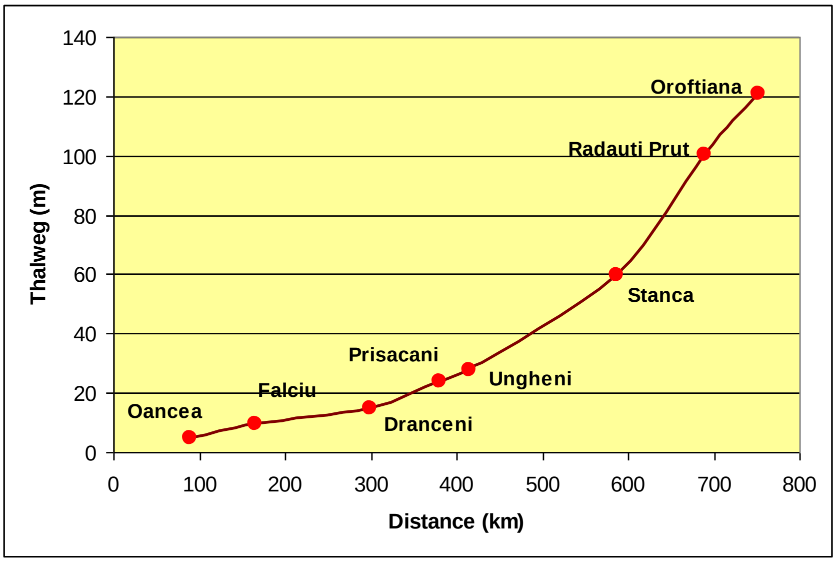


Fig. 7.5 - **Longitudinal profile along Prut river**

Fig. 7.6 - **HGS positions**

Further, drainage basins for the HGS on Prut and Siret rivers and also for their tibutaries in Ukraine were determined in the HGS sections, based on DTM and using ArcHydro extension, then they was correlated with drainage basins for Romanian HGS (Fig. 7.7).

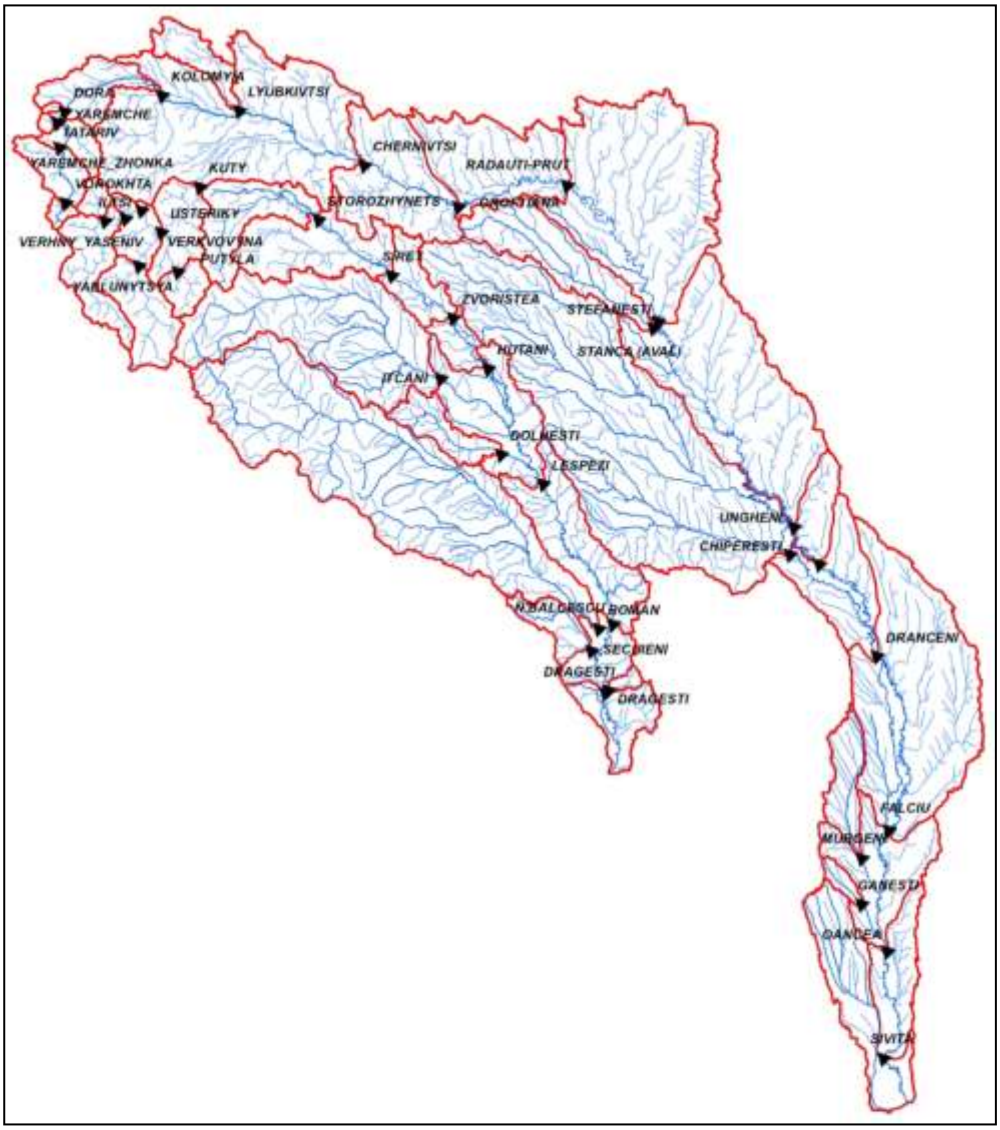


Fig. 7.7 - **HGS positions (Romania and Ukraine)and their catchment areas**

Also, morphometric parameters (surface, medium elevation, slope) were determined for drainage basins in Ukraine, further they will be correlated with parameters from Romania and Republic of Moldova (Table 7.2).

Table 7.2 - **Morphometric parameters for drainage basins**

Nr	HGS	River	Surface (km^2)	Mean elevation (m)	Slope (1000)
1	Storozhynets	Siret	695,44	579,43	142,12
2	Yablunytsya	Bily Cheremosh	554,46	1157,85	322,90
3	Iltsi	Iltsya	105,42	1033,09	304,27

4	Verkhovyna	Chorny Cheremosh	670,38	1180,39	321,13
5	Verhny_Yaseniv	Veretyn	7,35	869,04	307,71
6	Usteriky	Cheremosh	1508,30	1105,53	318,87
7	Putyla	Putyla	208,12	953,08	267,33
8	Kuty	Cheremosh	2170,51	1015,16	308,71
9	Vorokhta	Prut	62,98	1296,27	302,34
10	Tatariv	Prut	363,39	1047,15	269,87
11	Yaremche_Zhonka	Zhonka	28,74	926,12	317,69
12	Yaremche	Prut	596,58	995,83	279,03
13	Dora	Kamyanka	18,22	833,23	329,60
14	Kolomyia	Prut	1094,75	794,86	220,19
15	Lyubkivtsi	Chornyava	321,89	306,97	48,09
16	Chernivtsi	Prut	6873,14	631,45	177,58

Next, a flood-prone area was created inside the study zone on the main rivers (Prut and Siret), by raising the ground level with 15 m. The resulting polygon was overlaid on "administrative territorial units" layer, this intersection highlighting the ATU who are potentially affected by floods (Fig. 7.8).

Damage evaluation was determined proportionally to the flooded area of each ATU and is approximate.

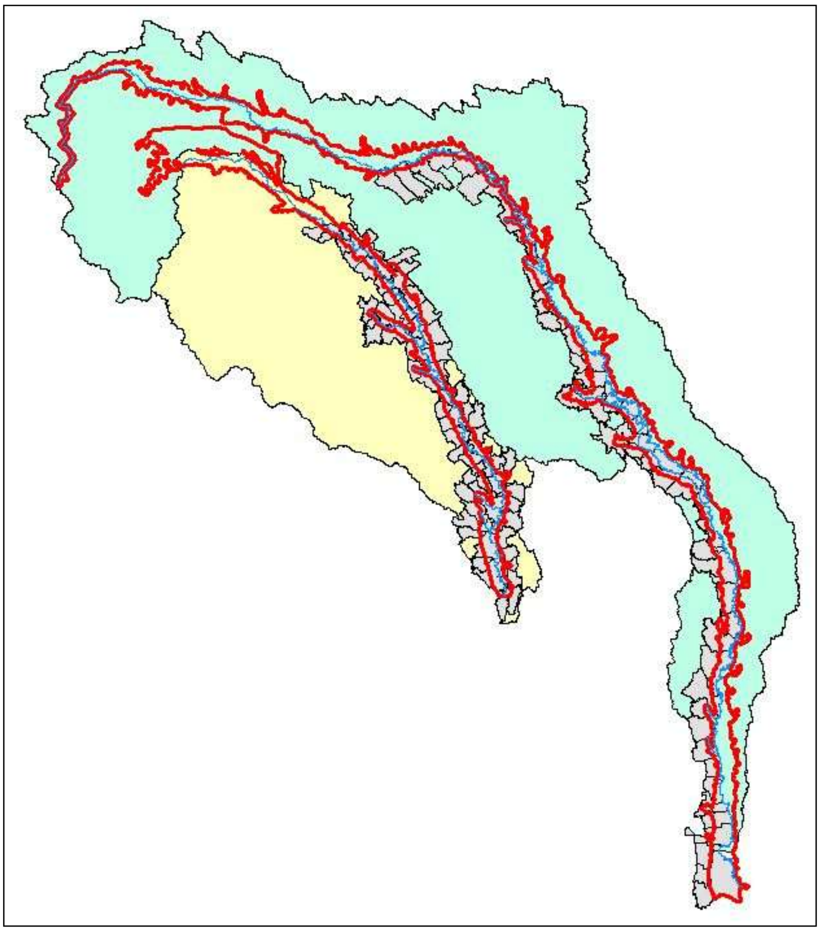


Fig. 7.8 **- Flood prone area and potentially affected ATU on Siret and Prut rivers**

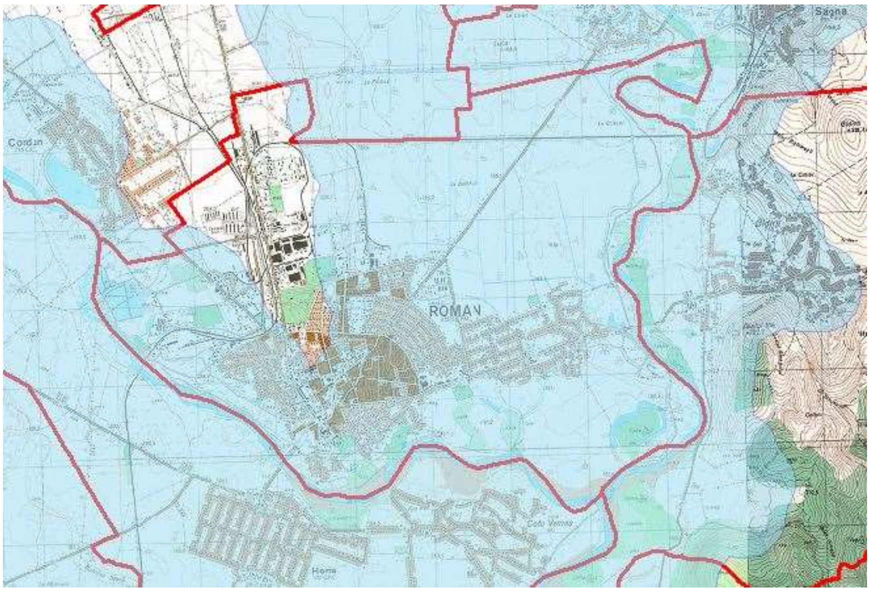


***Fig. 7.9* - Flooded area in Roman city**

To achieve hazard and risk maps of the area of interest in the project, we needed a digital terrain model to give us a fair representation of the terrain.

Existing DTM for Prut Water Branch is divided into tiles of 500m x 500m with 0.5 m x 0.5 m cell, tiff format.

For the whole territory are approximately 81000 DTM tiles. For the study area, based on created flood prone area 15 m raising the ground level polygon were selected 13393 tiles. The tiles were stitched in a mosaic using the "Raster catalog" ArcToolbox module (Fig. 7.10).

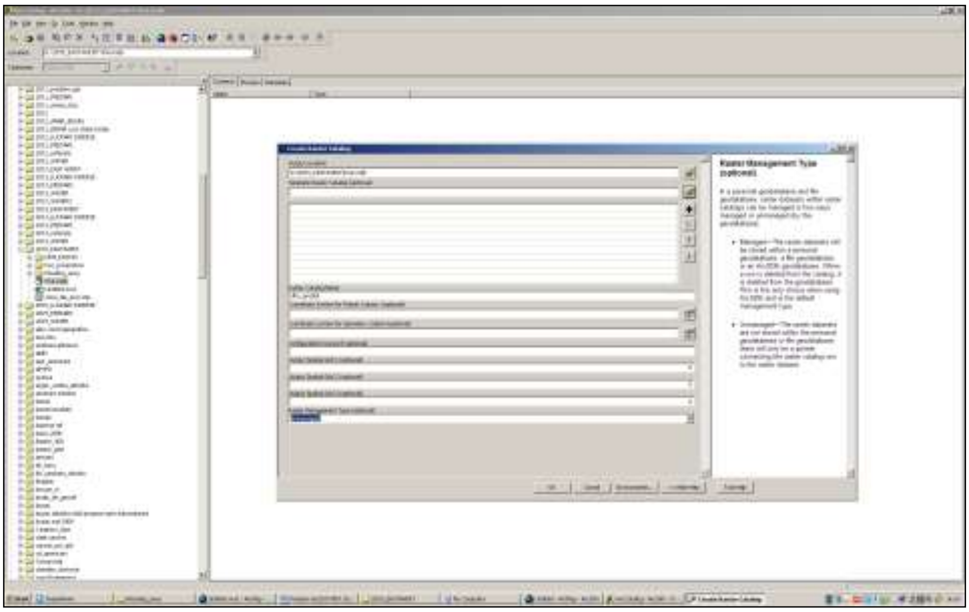


***Fig. 7.10* - Making digital terrain model using ArcToolbox, "Raster catalog" module**

After checking the resulted DTM, we met the following types of errors: negative values in the model, areas where grid cells have no values assigned, called "nodata" zones (Fig. 7.11), wrong referenced tile (Fig. 7.12).

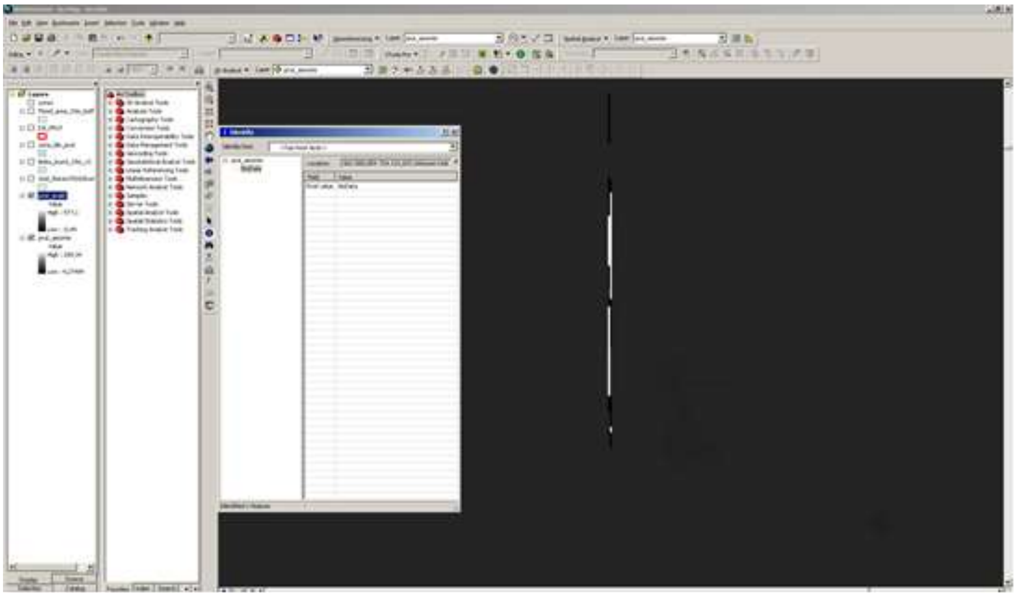


Fig. 7.11 - **Grid cells have no values assigned ("nodata" areas)**

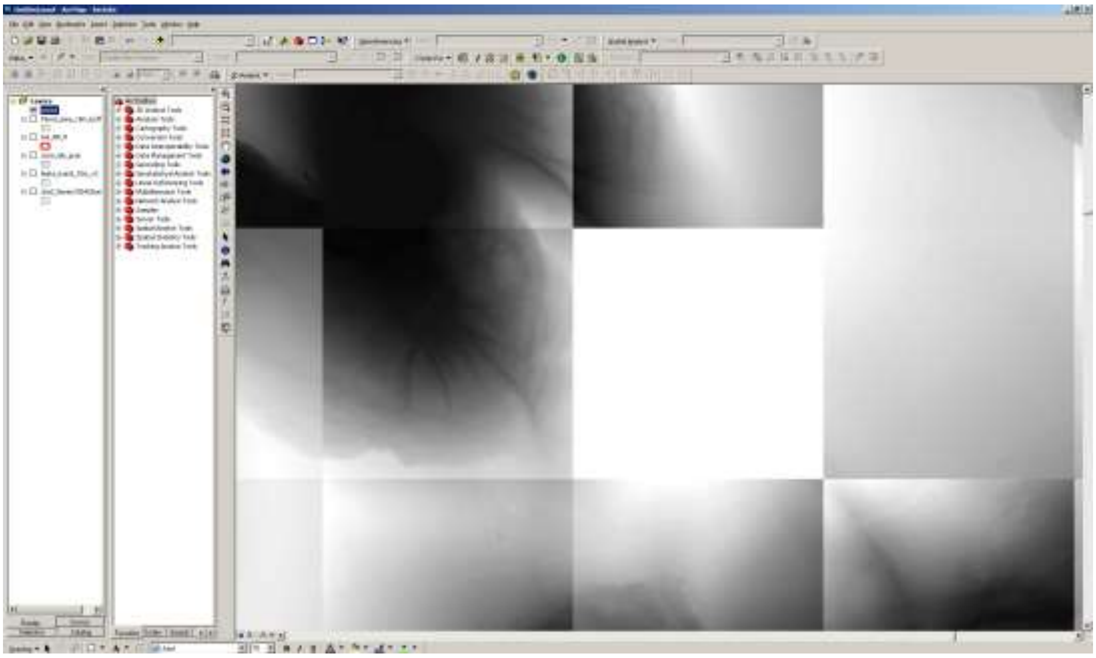
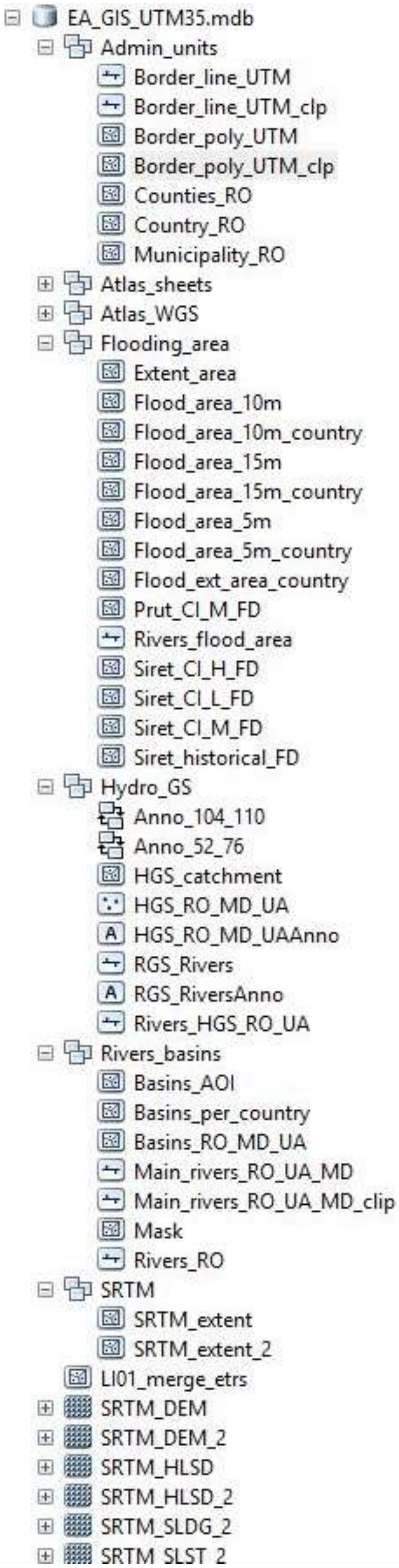


Fig. 7.12 - **Wrong referenced tile**

After DTM error correction, considering the size of the resulted digital terrain model, were derived two other terrain models with 2mx2m and 5mx5m cell respectively. The models were divided into 4 zones, so depending on the analysis or modeling the computing time will be minimized.

One of the first structure of database for EastAvert project had a structure which was thought to be completed by all three countries.

Here is the initial structure of the database (Fig. 7.13).



- EA_GIS_UTM35.mdb
  - Admin_units
    - Border_line_UTM
    - Border_line_UTM_clp
    - Border_poly_UTM
    - Border_poly_UTM_clp
    - Counties_RO
    - Country_RO
    - Municipality_RO
  - Atlas_sheets
  - Atlas_WGS
  - Flooding_area
    - Extent_area
    - Flood_area_10m
    - Flood_area_10m_country
    - Flood_area_15m
    - Flood_area_15m_country
    - Flood_area_5m
    - Flood_area_5m_country
    - Flood_ext_area_country
    - Prut_CI_M_FD
    - Rivers_flood_area
    - Siret_CI_H_FD
    - Siret_CI_L_FD
    - Siret_CI_M_FD
    - Siret_historical_FD
  - Hydro_GS
    - Anno_104_110
    - Anno_52_76
    - HGS_catchment
    - HGS_RO_MD_UA
    - HGS_RO_MD_UAAnno
    - RGS_Rivers
    - RGS_RiversAnno
    - Rivers_HGS_RO_UA
  - Rivers_basins
    - Basins_AOI
    - Basins_per_country
    - Basins_RO_MD_UA
    - Main_rivers_RO_UA_MD
    - Main_rivers_RO_UA_MD_clip
    - Mask
    - Rivers_RO
  - SRTM
    - SRTM_extent
    - SRTM_extent_2
  - LI01_merge_etrs
  - SRTM_DEM
  - SRTM_DEM_2
  - SRTM_HLSD
  - SRTM_HLSD_2
  - SRTM_SLDG_2
  - SRTM_SLST_2

***Fig. 7.13* – Initial structure of geodatabase for EastAvert project**

The field's name of all feature classes were in English like in the example below and we created a kind of metadata for all files (Table 7.3). The attribute table was thought to be pretty complex for all files.

For hydrometric gauging stations (HGS) a structure of attributes has been established (Table 7.3). During the project, the information for stations of all 3 countries will be fill-up (at the moment only for Romania the information are completed).

***Table 7.3* - Structure of attributes for HGS**

SHAPE ENG	Field type	Field length	Field description
Shape	Geometry		Point geometry
ID_HGS	Long Integer	9	Unique ID
HGS_NAME	Text	35	Name of HGS
HGS_NAME_S	Text	35	Name of HGS - lowercase
R_NAME	Text	24	River name
START_Y	Long Integer	9	Year of starting HGS recorded data in database
START_Y_2	Long Integer	9	Year of HGS establishment
END_Y	Long Integer	9	Year of measurements stopping
GAPDATA_Y	Text	27	Years with no data
DIST_CONFL	Double		Distance from confluence
BAS_AREA	Double		River basin surface
BAS_MEAN_E	Double		River basin elevation
BAS_SLOPE	Double		River basin slope
VERT_RS	Text	15	Elevation System Reference
LNDMK_NAME	Text	25	Name or code of landmark
LNDMK_ELEV	Double		Landmark elevation
H0_STAFF_G	Double		"0" stage point elevation
H0_GRAPH_G	Double		"0" graphic point elevation
WAR_LEV1	Long Integer	9	Warning level 1 - attention
WAR_LEV2	Long Integer	9	Warning level 2 - flood
WAR_LEV3	Long Integer	9	Warning level 3 - danger
MAX_FLOW	Double		Maximum recorded peak flow
MAX_FL_LEV	Double		Corresponding level of maximum recorded peak flow
DATE_MAX_F	Text	16	Data of maximum recorded peak flow
MAX_LEVEL	Double		Maximum recorded peak level
MAX_LEV_FL	Double		Corresponding flow of maximum recorded peak level
DATE_MAX_L	Text	16	Data of maximum recorded peak level
PROB_EX_10	Double		10% exceedance probability of flow
PROB_EX_1	Double		1% exceedance probability of flow
PROB_EX_01	Double		0.1% exceedance probability of flow
AUTO_HGS	Text	5	Automate station - x for yes
FORECAST	Text	5	Forecasting use - x for yes
SED	Text	5	Sediment load measurements - x for yes
PRECIP	Text	5	Precipitation measurements - x for yes
ALT_GPS	Double		GPS elevation near stage of HGS
WM_SYSTEM	Text	25	Water Management System (or County)
REGW_BRNCH	Text	26	Water Basin Administration
LAT_DMS	Double		GPS latitude - decimal degree
LONG_DMS	Double		GPS longitude - decimal degree
Country	Text	6	Country

8. PLANNING THE LAYOUT

The Atlas was published on A3 layout and we had to size each map element relative to its importance for the map purpose. Think about the logic of the position of each element relative to other elements was also a challenge like position of legend which covered the flood extent.

The Atlas was created using Data Driven Pages tool. Data Driven Pages allow to quickly and easily create a series of layout pages from a single map document. In this case we used 4 map documents with 2 different documents for portrait and landscape orientation.

Each orientation had 2 different documents which gave us the freedom to find the best position for the legend. In this case moving from left to right was enough (Fig. 8.1).

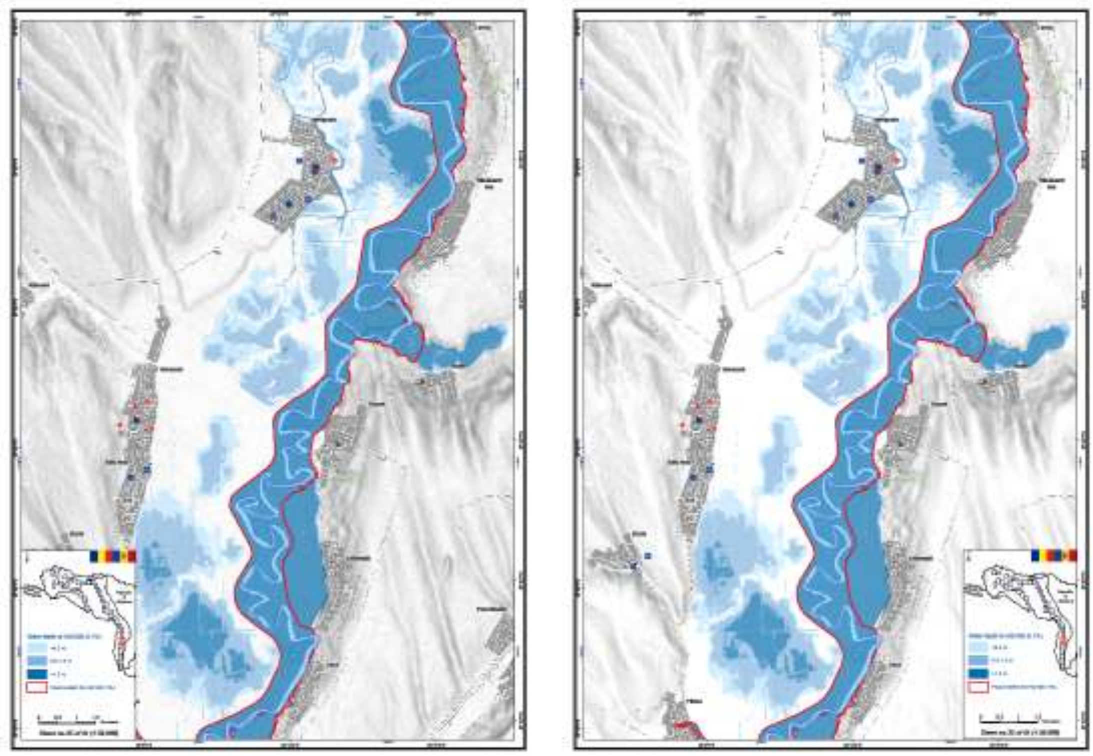


Fig. 8.1 **– Legend covering or not the flood band**

Data Driven Pages tool requires a feature layer, or index layer, which divides the map into sections based on each index feature in the layer and generates one page per index feature. We created a regular grid of 46 polygons of equal era using the fishnet tool. We kept only the polygons that intersected the 0.1% flood extent that we centered better afterwards. Each polygon was number starting upstream Prut river. This number was used as dynamic text in the legend and represented sheet name. Using dynamic text allows important information on the page layout to change dynamically as one goes from one page to another keeping the same frame.

A single layout defines the map composition for each data-driven page. Only dynamic parts of the layout change with each page. Static elements stay the same. Any changes made to static elements of the layout will be reflected on each page of the map series.

All dynamic elements used:

- Geographic extent of the map
- Map scale
- Scale bar
- Scale text (1:50 000)
- Dynamic text (page name, page number and 5 flags)

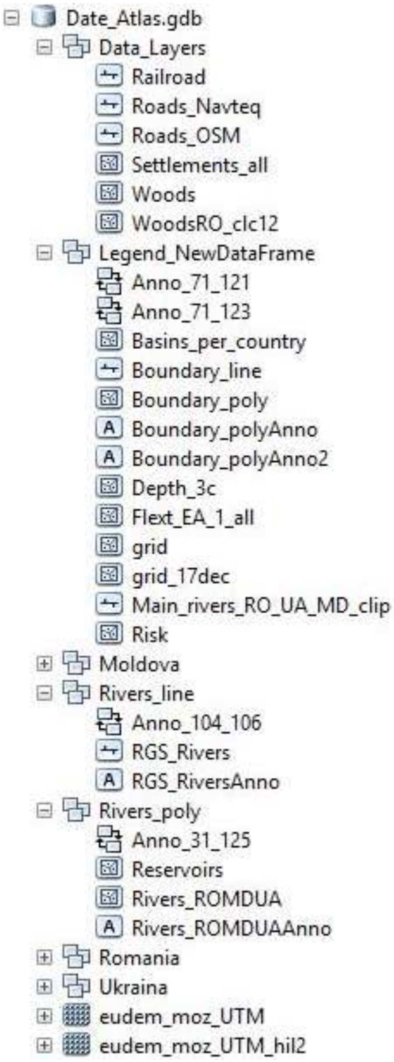
Static elements used:

- Size and orientation of layout page
- Size and position of data frames
- Static text
- Neatline

A powerful tool commonly used with Data Driven Pages is the dynamic overview map created using Extent indicators. Extent indicators are a way to show the extent of one data frame within another data frame. They automatically update whenever the extent of an associated data frame (main map or locator map) changes. In our case the main map is the map showing the flood extent and the locator map is displayed in the legend and each index polygon is red outlined by default.

9. COMPLETING THE DATABASE

The final database for the Atlas has a different structure (Fig. 9.1).



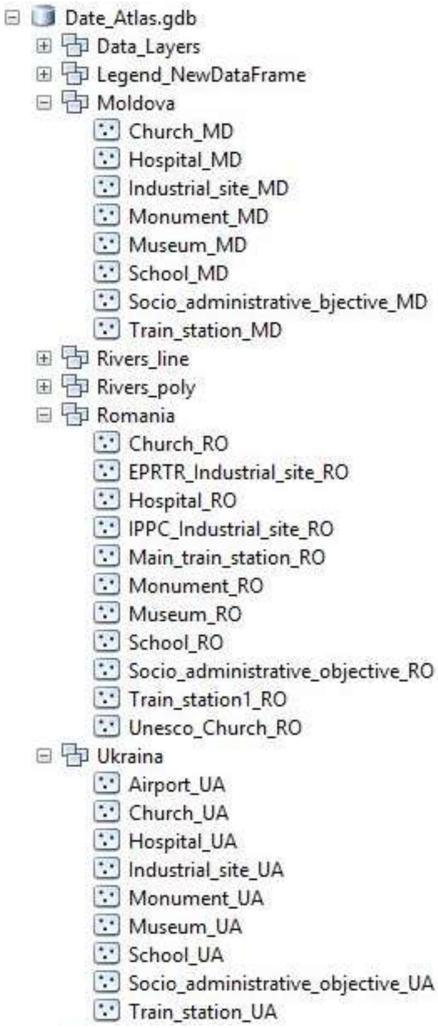
- Date_Atlas.gdb
  - Data_Layers
    - Railroad
    - Roads_Navteq
    - Roads_OSM
    - Settlements_all
    - Woods
    - WoodsRO_clc12
  - Legend_NewDataFrame
    - Anno_71_121
    - Anno_71_123
    - Basins_per_country
    - Boundary_line
    - Boundary_poly
    - Boundary_polyAnno
    - Boundary_polyAnno2
    - Depth_3c
    - Flext_EA_1_all
    - grid
    - grid_17dec
    - Main_rivers_RO_UA_MD_clip
    - Risk
  - Moldova
  - Rivers_line
    - Anno_104_106
    - RGS_Rivers
    - RGS_RiversAnno
  - Rivers_poly
    - Anno_31_125
    - Reservoirs
    - Rivers_ROMDUA
    - Rivers_ROMDUAAnno
  - Romania
  - Ukraina
  - eudem_moz_UTM
  - eudem_moz_UTM_hil2

Fig. 9.1 **– Final structure of the EastAvert geodatabase**

The basemap of the Atlas is a greyscale shaded relief image which has been created using a hillshade dataset derived from the reprojected ETRS-LAEA version of EU-DEM. EU-DEM is the digital elevation model over Europe, a realization of the Copernicus programme, managed by the European Commission. EU-DEM is a hybrid product based on SRTM and ASTER GDEM data fused by a weighted averaging approach and it has been generated as a contiguous dataset divided into 1 degree by 1 degree tiles, corresponding to the SRTM naming convention.

The spatial reference system is geographic, lat/lon with horizontal datum ETRS89, ellipsoid GRS80 and vertical datum EVRS2000 with geoid EGG08. These tiles have then been aggregated into 5°x5°.

The points of interest have almost the same structure for all the countries (Fig. 9.2).



- Date_Atlas.gdb
  - Data_Layers
  - Legend_NewDataFrame
  - Moldova
    - Church_MD
    - Hospital_MD
    - Industrial_site_MD
    - Monument_MD
    - Museum_MD
    - School_MD
    - Socio_administrative_bjective_MD
    - Train_station_MD
  - Rivers_line
  - Rivers_poly
  - Romania
    - Church_RO
    - EPRTR_Industrial_site_RO
    - Hospital_RO
    - IPPC_Industrial_site_RO
    - Main_train_station_RO
    - Monument_RO
    - Museum_RO
    - School_RO
    - Socio_administrative_objective_RO
    - Train_station1_RO
    - Unesco_Church_RO
  - Ukraina
    - Airport_UA
    - Church_UA
    - Hospital_UA
    - Industrial_site_UA
    - Monument_UA
    - Museum_UA
    - School_UA
    - Socio_administrative_objective_UA
    - Train_station_UA

Fig. 9.2 **– Points of interest for all countries**

The points of interest were selected from different data sources and only some of them can be potentially flooded (ones between the brackets) in case of floods with 1000 years return period (HQ0.1%).

Table 9.1 **– Points of interest selected and potentially affected**

	RO	**MD**	**UA**
Churches	1206	47	535 (104)
Schools	4004 (10)	29	765 (92)
Hospitals	1811 (2)	25	622 (58)
Train stations	437	13 (2)	45 (1)
Industrial sites	157 (4)	24	101 (34)
Monuments	130	12	19 (3)
Museums	91	4 (1)	74 (4)
Socio-administrative objectives	1777 (3)	25	119 (24)
Airports			1

10. SOURCE OF DATA

10.1 NAVTEQ

The printing rights for the area of interest was the acquisition made during the project because the standard license has been acquired for the first reporting of the Flood Directive. Navteq is an American Chicago-based provider of geographic information system (GIS) data founded in 1985 and a major provider of base electronic navigable maps.

NAVTEQ's comprehensive data build process ensured the highest quality data available for routing and mapping applications at the time of purchase. The Standard product includes the following layers:

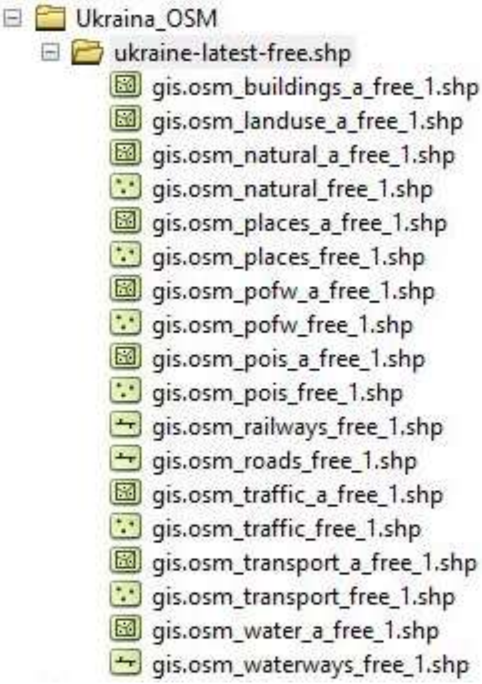
- Major and Secondary Highways;
- Interstate and Secondary Highway Shields;
- Railroads;
- Zones contains zone information (where applicable), for navigable lines and polylines in the Streets layer;
- Administrative Area Boundaries;
- Country boundary;
- Islands;
- Waterway Polygons and Segments include Rivers, Water Channels, Lakes, and Bays/Harbours;
- Building/Landmarks;
- Land Use Features which contains polygons that represent various land usage features found within a detailed coverage area. These include Airports, Cemeteries, Hospitals, Industrial Complexes, Military Bases, Parks, National Monuments, Public Use Areas, Shopping Centers, Sports Complexes, Undefined Traffic Areas, University/Colleges and Woodlands;
- Streets;
- Metadata;
- 16 Points of Interest (POIs) layers (Restaurants, Shopping, Parks and Recreation, Historical Monuments, Museums, Hospitals, Transportation Hubs, Financial Institutions, Business Facilities, Community Service Centers, Educational Institutions etc.).

From this data we selected the roads and some points of interest: cultural objectives (churches, museums, monuments), social objectives (schools, hospitals, police, city halls, airports), economic objectives (train station, factories) etc.

10.2 OPEN STREET MAP

The information covering Ukraine were not enough so had to supplement the data with Open Street Map Data. OpenStreetMap (OSM) was created in 2004, it was inspired by the success of Wikipedia and is considered a prominent example of volunteered geographic information. Thus, OSM is a collaborative project to create a free editable map of the world.

We downloaded the data for all three countries in shapefile format. Raw data after download had this structure in the picture below (Fig. 10.1).



```
⊟ Ukraina_OSM
    ⊟ ukraine-latest-free.shp
        gis.osm_buildings_a_free_1.shp
        gis.osm_landuse_a_free_1.shp
        gis.osm_natural_a_free_1.shp
        gis.osm_natural_free_1.shp
        gis.osm_places_a_free_1.shp
        gis.osm_places_free_1.shp
        gis.osm_pofw_a_free_1.shp
        gis.osm_pofw_free_1.shp
        gis.osm_pois_a_free_1.shp
        gis.osm_pois_free_1.shp
        gis.osm_railways_free_1.shp
        gis.osm_roads_free_1.shp
        gis.osm_traffic_a_free_1.shp
        gis.osm_traffic_free_1.shp
        gis.osm_transport_a_free_1.shp
        gis.osm_transport_free_1.shp
        gis.osm_water_a_free_1.shp
        gis.osm_waterways_free_1.shp
```

***Fig. 10.1* – Open Street Map structure**

From this data we selected the roads and some points of interest: cultural objectives (churches, museums, monuments), social objectives (schools, hospitals, police, city halls, airports), economic objectives (train station, factories) etc. Unfortunately the roads have not aligned perfectly with the roads from the Navteq database and we had to eliminate the roads that intersected on a certain radius.

11. VALIDATION AND MOSAICING OF DATA

The first step in harmonizing the data was to mosaic depth raster data and reclassify in 3 water depth classes:

< 0.5 meters
0.5 – 1.5 meters
> 1.5 meters

Then raster data was transformed to vector data keeping the 3 classes and the edge of the polygons will conform to the input raster's cell edges (no simplify polygons). Because of this procedure the hazard flood bands became very big in size so we had to reduce the number of vertices. To do this we have chosen the steps below (Fig. 11.1).

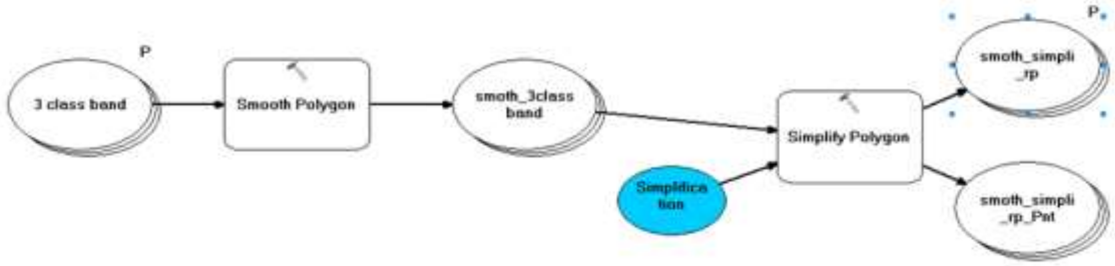


Fig. 11.1 **– Smooth of 3 classes flood band**

For risk maps we used Corine Land Cover 2006 layer, but a modified version. We added 6 classes. This classes were added using different shapefiles (Built-up area and settlements extent, road and rail networks, natural lakes and reservoirs, watercourses, dump sites). We also added 3 new columns representing risk class corresponding to water depth (Tabel 11.1).

Corine Land Cover classes were ranked in 4 classes for each water depth class:

0 – insignificant residual risk
1 – low risk
2 – medium risk
3 – high risk

It was difficult to harmonize the land use for all three countries because Corine Land Cover exist only in Romania even newer versions and because this new classes were hard to add.

***Tabel 11.1* – Corine Land Cover 2006 – 6 new classes**

CLC CODE	Existing CLC classes	New classes	**Risk class corresponding to the water depth**		
			Low <0,5	**Medium 0,5-1,5**	**High >1,5**
112A	Discontinuous urban fabric	Agricultural and other land on the outskirts of the village	**0**	**1**	**2**
122N	Road and rail networks and associated land	Highways, European and national roads	**3**	**3**	**3**
122J		County roads	**2**	**3**	**3**
122C		Municipal roads	**2**	**2**	**3**
122S		Streets	**2**	**3**	**3**
512P	Water bodies	Fish ponds	**0**	**2**	**2**

The table above was modified and transformed in info format in order to use it in model builder and ArcGIS (Fig. 11.2).

***Fig. 11.2* – Risk model builder**

The first step of this model builder is to clip the Corine Land Cover after 3 class hazard band. Second step is the union of 3 class hazard band with the output of the first step (Corine Land Cover cut after hazard band). Third step is converting the output of the second step from multipart to single part. Fourth step is concatenating the Corine Land Cover Code with the 3 class water depth in the field COMB_ADLU. Fifth step was joining the output of the fourth step with this table using COMB_ADLU field and CODCOMB field. The last step is dissolving the output from the fifth step after CLS_RISK field (Fig. 11.3).

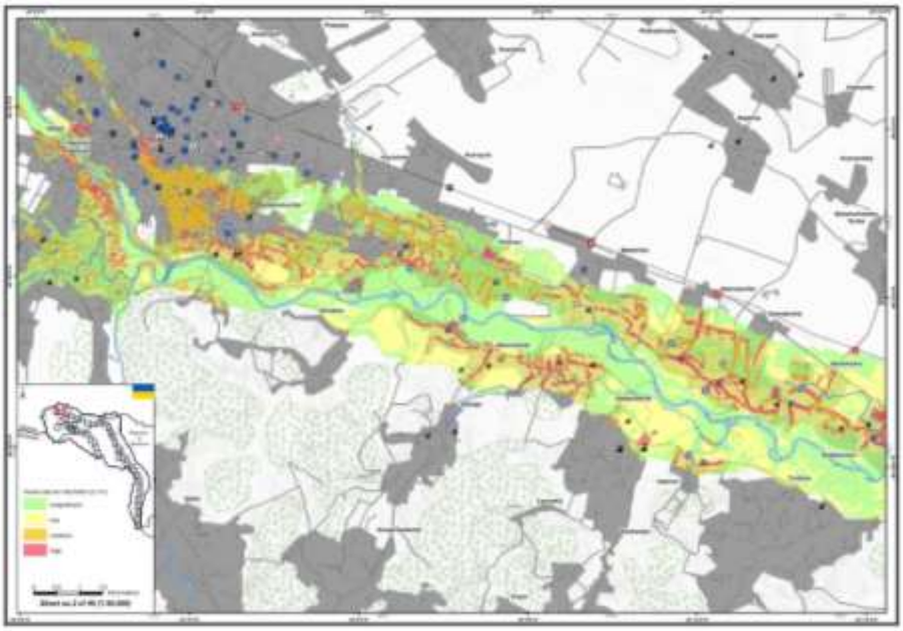


Fig. 11.3 **– Risk map**

At the end for each settlement the population density was calculated (inhabitants per square meter). The hazard band was intersected with settlements polygons, containing information about population density, in order to get the potentially affected population (affected area x density).

For the extent to which the population is affected, it was taking in consideration both the potentially affected population and proportion of affected population of the total population of each settlement.

Before beginning the risk analysis the geospatial data was topologically corrected. In geodatabases, topology is the arrangement that defines how point, line, and polygon features share coincident geometry. The geodatabase includes a topological data model using an open storage format for simple features (feature classes of points, lines, and polygons), topology rules, and topologically integrated coordinates among features with shared geometry. The data model includes the ability to define the integrity rules and topological behavior of the feature classes that participate in a topology.

That means in particular, that vector layers must not intersect or overlap where it would logically make no sense, e.g.:

- Hazard and Risk layers must not have gaps or have overlaps;
- The outline of the 100-year-flood must not exceed the outline of the 1000-year-flood;
- Roads and railways from Navteq must not intersect with roads from OSM etc.

At the end the Atlas was exported in .pdf format. PDF is the only export format that supports multiple pages in a single document and we used it based on selected index features depending on the orientation of the document. Fortunately, the publisher has requested this format too.