BORIS

Cross **BO**rder **RIS**k assessment for increased prevention and preparedness in Europe

D2.2

Data availability and needs for large scale and cross-border risk assessment, obstacles and solutions

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1 SUMMARY

Cross border risk assessment for increased prevention and preparedness in Europe - BORIS project (GA. 101004882), sponsored by Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO), focuses on improving disaster preparedness and prevention in cross border areas. One of the crucial steps needed to develop the harmonised methodology for cross border and multi-risk assessment is to identify the data availability and data sources together with the legal framework and data protection rules applicable in each partner country.

Deliverable 2.2 provides detailed information on data availability and needs for large scale and cross-border risk assessment, together with specific obstacles and possible solutions. Each project beneficiary provided information on the use and availability of various data used for the seismic and flood risk assessment in partner countries: Slovenia, Italy, Austria, Turkey, and Montenegro. Further, a detailed description of the specific national seismic and flood risk assessment methodologies, including the presentation of the methodological approaches for defining the seismic/flood hazard and vulnerability/exposure elements, is provided.

In Slovenia, two different approaches to seismic risk assessment were used, the National Disaster Risk Assessment and the seismic stress test of the building stock in Slovenia. The seismic stress test of the building stock in Slovenia uses a probabilistic approach for seismic risk assessment, where the risk is calculated by following the conventional seismic risk integral consistent with probabilistic seismic hazard analysis (PSHA). In addition, seismic risk assessment can be performed based on a selected return period or a scenario, defined by the magnitude and hypocentral location. However, the later approach was not used by the Civil Protection Unit, but by the Ministry of the environment and spatial planning. On the other hand, the flood risk assessment in the Republic of Slovenia is based on EU Floods Directive. As a part of the first cycle of implementation of the EU Floods Directive, the Republic of Slovenia prepared and adopted a Preliminary Flood Risk Assessment, prepared an initial selection of the areas of significant flood impact for which detailed flood hazard maps have been prepared. The second cycle of the EU Floods Directive implementation was followed by the verification and possible amendment of flood hazard maps and flood risk maps for an updated set of Areas of Potentially Significant Flood Risk (APSFR). The flood hazard assessment in Slovenia follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. 10-, 100-, and 500-year flood return periods are considered in delineating the flood hazard classes. The flood hazard data are freely publicly available and can be viewed online (e.g., e-vode web portal). The methodology for flood vulnerability/exposure assessment and further flood risk assessment is based on the classification of the damage potential related to exposed damage elements located in areas exposed to flood hazard. In order to assess the flood vulnerability/exposure, several clusters of flood impact indicators and exposure elements (e.g., people's health, social infrastructure, cultural heritage, environment, economic activities, infrastructure) were defined. It was necessary to make considerable modifications to some of the available databases from different sources in terms of the selected spatial processing unit, which defined the suitable resolution of the basic data. The flood damage potential and subsequent flood risk in Slovenia was defined at 75 x 75 m raster cells resolution.

In Italy, the official Italian seismic hazard model is based on the Italian seismic hazard map (MPS04) adopted at the national level. Hazard maps were realized for nine different return periods (2500, 1000, 475, 200, 140, 100, 72, 50 and 30 years). The exposure database is derived from census data provided by the Italian National Institute of Statistics (ISTAT). The vulnerability model is defined by considering five vulnerability classes, many building typologies and six different fragility models. The impact indicators that can be estimated based on the existing vulnerability model and exposure data are: the number of collapsed buildings, usable buildings, unusable buildings in the short/long term homeless, victims, injured and direct/indirect economic losses. The seismic risk is calculated following a PSHA-based risk assessment approach. In addition, the return period-based and the scenario-based risk assessment can be performed. In the case of the flood risk assessment, the methodological approaches followed the EU Floods Directive. For each Unit of Management (UoM), a hydrological district containing one or more river basins, a database is available showing the flood polygons for all three probability scenarios (30-, 100-, and 300-year flood return periods). Generally, the flood hazard data are freely available for some UoM and can be viewed online. In the current version of the methodology for the preparation of Flood Risk maps, the quantification of the risk was expressed in relative terms, i.e. the risk of an exposed element assumes a gradation between 0 and 1, where 0 and 1 are respectively the cases of no risk or maximum risk of the exposed item whereas vulnerability equal to 1 for all the exposed elements. In relation to the macro-categories of exposed elements, the flood risk has been defined by overlaying the exposure elements data and flood hazard data related to 3 categories based on the defined flood return periods.

As for Austria, the seismic risk is mainly outlined through a seismic hazard map. There are currently two valid maps, one from 1994, which is still the basis for the national seismic building code of the Austria Standard Institute and the seismic hazard current ÖNORM 1998-1 hazard map, which outlines the seismic zones and the “effective” ground acceleration in m/s^2. Austria’s new seismic hazard map was presented in May 2020, showing the maximum horizontal ground acceleration corresponding to the return period of 475 years. The concept of vulnerability is considered via the European Macroseismic Scale EMS-98, which expresses differences in the way that buildings respond to earthquake shaking. However, there is no vulnerability model in use in Austria that assigns buildings to vulnerability classes on a nationwide basis. Detailed seismic risk assessments or vulnerability analyses have therefore not been yet carried out. On the other hand, flood hazard assessment has a long tradition. It follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. In 2014, a guideline was developed, which defines a uniform standard throughout Austria. In all, 30-, 100-, and 300-year flood return periods are considered in the hydraulic modelling. Because of a long tradition of the flood hazard assessment in Austria, flood hazard maps are publicly available on several web portals (WISA, Web-GIS Tools on federal level, HORA risk map). To assess the flood exposure, the following flood impact indicators and exposure elements (people’s health, cultural heritage, environment, economic activities) were used for assessing the flood exposure and further defining the APSFR. Regarding damage and event documentation data, a variety of regional and national databases and instruments exists in Austria that provide long time data series. For assessing the flood risk, the potential flood inundation area are intersected with the information on (people, environment, cultural heritage and industry). The number of potentially affected people, as the most important flood risk indicator, is aggregated on the basis of grid cells size of 125 × 125 meters.

The current Earthquake Hazard Map of Turkey was prepared by using PSHA methodology. Besides, AFAD-RED (Rapid Earthquake Damage and Loss Estimation System) is utilized for scenario-based risk assessment studies. Regarding the seismic vulnerability assessment, the structural damage is estimated by utilizing fragility curves defined for four damage states (slight, moderate, extensive and complete). Since the available building and population database contains only the number of buildings and population in each neighborhood/village in Turkey, the fragility curves that are average for all buildings are considered. As for National Disaster Risk Assessment Report of Turkey related to the seismic risk, the following impact indicators are used: number of fatalities, number of severely injured/ill, lack of fulfilment of basic needs, number of people who need to be evacuated, total economic impacts, impacts for nature and environment, disruptions to every day's life, loss of cultural heritage and loss of reputation. As for the flood risk assessment, Turkey has started to implement and transpose the EU Floods Directive and works for preparation of flood hazard maps, flood risk maps and flood risk management plans for river basins in 2013. Flood hazard assessment follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. Flood hazard is assessed for 5-, 10-,50-, 100-, and 500-years flood return periods. The main exposure elements considered in the flood vulnerability assessment are people's health, social infrastructure, cultural heritage, environment and economic activities. As for the flood risk assessment, 5 flood risk classes were defined (very low, low, medium, high, very high) by overlaying the flood polygons and the presence of exposure elements.

In Montenegro, a deterministic scenario approach is used for seismic risk assessment. The seismic hazard is obtained by the probabilistic seismic hazard analysis (PSHA). Since systematized data on the exposure model for buildings in Montenegro are not available, the SERA exposure model for Montenegro is used. The impact indicators that are included in the existing vulnerability models are: the number and net floor area of collapsed dwellings and unusable dwellings, the number of homeless people, injured people and fatalities, the length of the damaged roads, direct and indirect economic losses. The classification of buildings to vulnerability classes is done based on expert judgement and available census data related to the year of construction. The seismic risk is assessed at the national level and is expressed in terms of four risk classes: low, moderate, high and very high, depending on the calculated impacts on people, economy and environment, and society. Concerning the flood risk assessment, EU Flood Directive has been fully transposed into the Montenegrin legislative system. Current national legislation anticipates preparing a preliminary flood risk assessment and identification of APSFR. On the national level, rules for the preparation of flood hazard maps have been developed where 10-, 100-, and 500-year flood return periods are considered in delineating the flood hazard classes. Vulnerability classes are not defined numerically, only presented in a descriptive manner for each of the scenarios. The impact indicators used to describe different vulnerability elements are potential casualties, severely injured/ hospitalized/ threatened, endangered people basic needs, number of people to be evacuated, total economic impact, environmental impact, disrupted everyday life and loss of cultural heritage. Further, four levels of flood risk are identified (very high, high, moderate and low). Due to the fact that the implementation of the Floods Directive is at an early stage, Montenegro requested a transitional period for full implementation of the Floods Directive and preparation of Flood Risk Management Plans until the end of 2024.

2 DATA SOURCES AND DATA AVAILABILITY FOR RISK ASSESSMENT IN PARTNER COUNTRIES

2.1 Slovenia

2.1.1 Seismic risk assessment data

In Slovenia, two different approaches to seismic risk assessment were used; the National Disaster Risk Assessment (GRS, 2018; GRS, 2020) and the seismic stress test of the building stock in Slovenia (Dolšek et al., 2020). Both approaches are presented in Deliverable 2.1 (BORIS, 2021). However, in this report, only the seismic stress test (Dolšek et al., 2020) is considered since it is based on probabilistic models that allow for a more direct comparison of data and results with other partner countries.

The seismic stress test of the building stock in Slovenia uses a probabilistic approach for seismic risk assessment, where the risk is calculated by following the conventional seismic risk integral consistent with probabilistic seismic hazard analysis (PSHA). The seismic risk of each building from the building stock is first estimated. For this purpose, two risk indicators are used: the probability of reaching the complete damage state on the HAZUS damage scale and the expected annual losses. The estimated risk is then compared to risk boundaries that correspond to grades from A to G, indicating whether the building's seismic risk is acceptable in the short term and the long term (Babič and Dolšek, 2019).

2.1.1.1 Seismic hazard assessment data

A probabilistic seismic hazard assessment was performed for the seismic stress test of the building stock in Slovenia. Two different seismotectonic models were used, i.e. the official seismic hazard model in the Republic of Slovenia (Lapajne et al., 2003) and the SHARE seismic hazard model (Giardini et al., 2014; Woessner et al. 2015) (ESHM13 and ESHM2020). In the calculation of risk, the weights of 1/3 and 2/3 were applied to these models, respectively. The official seismic hazard model uses the Sabetta and Pugliese (1996) ground-motion model, whereas the ESHM13 model uses several ground-motion models which are selected for each individual case using a logic tree. The input models used in the seismic hazard assessment can also be used for further hazard analyses in the frame of the BORIS project.

Input parameters and results of the hazard assessment are summarized in Tables 2.1 and 2.2. The official seismic hazard maps of Slovenia for rock sites and return periods of 475, 1000 and 10,000 years are publicly accessible on the page of the Slovenian Environment Agency (ARSO). The seismic hazard models ESHM13 is publicly available and provided by the European Facilities for Earthquake Hazard and Risk (EFEHR), while the model ESHM2020 is not yet publicly available, but will probably soon be. In addition, databases of the Institute of Structural Engineering, Earthquake Engineering and Construction IT (IKPIR) contain results of some hazard analyses that are not publicly available on the ARSO or EFEHR platforms but use the input data from those two institutions. IKPIR databases also contain the soil factors estimated for locations of buildings based on the local geological characteristics.

Table 2.1: Data available for seismic hazard assessment.

Seismotectonic model	Regional ground-motion model	Soil effects	Possible types of hazard analysis	Data source	Data accessibility
From the official seismic hazard model in Slovenia (ARSO), from ESHM13, from ESHM2020	From ESHM2020	Soil class defined for some locations, not all. Geological characteristics determined for some locations, not all.	Return period-based (for any return period), scenario-based (for any magnitude and hypocentral location)	Slovenian environment agency (ARSO), EFEHR, Digital geological map.	ESHM13 and ESHM2020 models publicly available, ARSO model - restricted access, digital geological map.

Table 2.2: Comparison of seismic hazard assessment at national level (results of past analysis).

Type of hazard analysis	Intensity parameter	Return periods	Spatial scale	Soil effects	Data source	Data accessibility
Return period-based	PGA	All return periods	Entire country (smoothed based on 5 x 5 km mesh)	Considered by applying the values of the soil factor (location-specific)	Slovenian Environment Agency (ARSO), IKPIR (University of Ljubljana)	Publicly accessible hazard on rock for return periods of 475, 1000 and 10000 years. Soil factors not publicly available.

2.1.1.2 Seismic vulnerability/exposure assessment data and the availability of impact indicators

Parameters of the existing vulnerability analyses and exposure data are presented in Table 2.3. From the presented vulnerability model and exposure data, several impact indicators were already estimated in Dolšek et al. (2020) and Babič et al. (2021), i.e. direct economic losses, fatalities, expected number of buildings in different damage states. The direct economic losses for each designated damage state were calculated as a percentage of the reconstruction cost related to that damage state by assuming the replacement cost of 1250 EUR / m^2 of the net floor area (inclusive of VAT) and by considering the net floor areas of buildings from the Real Estate Register. The reconstruction cost ratios related to the designated damage states were obtained from HAZUS (FEMA, 2015), while the replacement cost was estimated from an online platform for the valuation of new construction (PEG, 2020) and by considering the ratio between the replacement cost and the cost of new construction equal to 13.5 %. However, the damage-to-impact model for the number of fatalities considered that a death event can occur only in the case of the building's collapse and that the latter occurs with a certain probability conditional to the damage state. The conditional collapse probabilities were obtained from HAZUS (FEMA, 2015). It was assumed that the number of fatalities in a collapsed building is equal to 10 % of all people inside the building.

It should be noted that the vulnerability model and exposure data allow for the estimation of other impact indicators, such as the number of dwellings in different damage states. Moreover, by including additional models for connecting damage and consequences, more impact indicators could be estimated, e.g. the number of displaced (homeless) people, the number of injured people, etc.

The exposure data about buildings and population was obtained from the Real Estate Register (REN) and the Central Population Register (CRP). REN contains building-specific information, e.g. the location of a building, the year of construction, the occupancy class, the net floor area, the predominant material of the load-bearing structure, the building value based on real estate mass appraisal procedure, the number of storeys, and the building height, whereas CRP provides the average number of people per housing unit in each municipality. The Real Estate Register is publicly accessible. However, gathering of the information from this register can be cumbersome if the data is needed at a large scale as the information can publicly be obtained only for each building separately. On the other hand, the Central Population Register has restricted access. Personal data from this register may be obtained only by state authorities and other users to perform prescribed tasks, to manage databases or to conduct statistical, socio-economic and other surveys.

Table 2.3: Parameters of the existing vulnerability analyses and exposure data.

Vulnerability classes	**Damage scale**	**Intensity measure (IM)**	**Available exposure data type**	**Data for buildings/dwellings**	**Exposure data spatial scale**
20 building typologies. Continuous fragility curves. Stochastically defined fragility curves for each building typology	HAZUS	PGA	Buildings and dwellings (publicly available), population (not publicly available)	Buildings: Number of storeys, predominant material of the load-bearing structure (structural type not reported), year of construction, net usable surface area, etc.	Building-specific information, entire country included

2.1.1.3 Data adaptations and modifications for seismic risk assessment

The seismic stress test uses a probabilistic risk assessment, where the risk is calculated by following the conventional seismic risk integral consistent with probabilistic seismic hazard analysis (PSHA). The uncertainties in seismic hazard and building stock vulnerability are taken into account. The seismic risk of each building from the building stock is estimated from the probability of reaching the complete damage state on the HAZUS damage scale and the expected annual losses. The estimated risk of each building is then compared to risk boundaries that correspond to grades from A to G, indicating if the building's seismic risk is acceptable in the short-term or in the long-term (Babič and Dolšek, 2019). The convolution of hazard, vulnerability and exposure as well as the risk-based grading is carried out for each building separately. The grades are then aggregated at the level of the building stock, where the result is given as the number of buildings in each risk class, also considering the uncertainties related to building-specific risk assessment. The building stock can refer to the national or municipality level.

2.1.2 Flood risk assessment data

The EU Floods Directive, adopted and enforced in 2007, provided the basis for establishing a framework for flood risk assessment in Slovenia with the aim of reducing the harmful effects of floods on human health, economic activity, cultural heritage and the environment. As a part of the first cycle of implementation of the EU Floods Directive, the Republic of Slovenia prepared and adopted a Preliminary Flood Risk Assessment, prepared initial selection of the areas of significant flood impact for which detailed flood hazard maps have been prepared. Based on the initial analysis of flood impact indicators and exposure elements, preliminary flood risk maps (i.e. Preliminary Flood Risk Assessment) have been made at a scale 1:50.000 as a basis for further preparation of preliminary Flood Risk Reduction Plan.

In 2016, the second cycle of implementation of the EU Floods Directive began. The first activity that needed to be performed was to review and update the Preliminary Flood Risk Assessment, and, additionally, to incorporate the possible impact of climate change on flood risk. The second cycle of implementation of the EU Floods Directive was followed by the verification and possible amendment of flood hazard maps and flood risk maps for an updated set of Areas of Potentially Significant Flood Risk (finished by the end of 2019) and preparation of an update of the Flood Risk Reduction Plan (to be done by the end of 2021). In scope of the activities, the upgraded methodology for preliminary flood risk assessment was prepared (IzVRS, 2018). The upgraded methodology is based on the first methodology, which was proposed in 2012 (IzVRS, 2012). In 2016, the second cycle of implementation of the EU Floods Directive began. The first activity that needed to be performed was to review and update the Preliminary Flood Risk Assessment, and, additionally, to incorporate the possible impact of climate change on flood risk. The second cycle of implementation of the EU Floods Directive was followed by the verification and possible amendment of flood hazard maps and flood risk maps for an updated set of areas of significant flood impact (finished by the end of 2019) and preparation of an update of the Flood Risk Reduction Plan (to be done by the end of 2021). In scope of the activities, the upgraded methodology for preliminary flood risk assessment was prepared (IzVRS, 2018). The upgraded methodology is based on the first methodology, which was proposed in 2012 (IzVRS, 2012).

The methodology represents the expert bases for determining the Areas of Potentially Significant Flood Risk (APSFR) and for preparing the upgraded Flood Risk Assessment of the Republic of Slovenia. The methodology is based on the classification of the damage potential located in those areas that are exposed to flood hazard. The main purpose of the upgraded methodology was to more consistently classify flood risk areas in Slovenia according to the potential extent of the damage potential. Based on this classification, other expert bases of the Preliminary Flood Risk Assessment could be upgraded, as well as general, multi-sectoral knowledge and overview of flood risk in the APSFR at the national level was improved through involvement of different ministries.

2.1.2.1 Flood hazard assessment data

In order to implement the EU Floods Directive in Slovenian legislation, two legislative documents were adopted: the Rules on the methodology for determining areas endangered by floods and related erosion of inland waters and the sea, as well as on the method of classifying land into endangered classes (Rules, 2007), and the Regulation on conditions and restrictions for carrying out activities and interventions in areas at risk of floods and associated inland and sea erosion (Decree, 2008). The flood hazard assessment in Slovenia follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. In all, 10-, 100-, and 500-year flood return periods are considered in the calculations. Below we provide a short overview of the main input data used for flood hazard assessment.

(a) Topography: LIDAR scanning of Slovenia from the period 2014-2015. The data required for this purpose has been obtained by collecting the high-density terrain elevation data (5-10 point per m^2) by using the LiDAR earth's surface laser scanning technique. One of the aims of the project was to provide high quality information for production of flood hazard maps, simulation of flood propagation and other spatial planning activities. For site-specific flood studies, additional geodetic surveys of stream channel cross sections and floodplains are performed.

(b) Hydrology: Statistical analysis of recorded precipitation and measured discharges for rain gauges and water stations in scope of the state hydrometeorological monitoring system operated by ARSO. Additional site-specific hydrological studies are performed for locations, where other hydrological data are not available.

(c) Hydraulics: Hydrological and hydraulic studies for particular areas using hydro-dynamical modelling software, generally combination of 1D/2D models (e.g. Hec-Ras, Mike Flood, Flo-2D). Data on land use (detailed land use classification by the Ministry of Agriculture, Forestry and Food) is usually used for defining the hydraulic roughness characteristics in the floodplain areas.

Definition and representation of flood hazard

Table 2.4 summarizes the basic components of the methodology used for flood hazard assessment in Slovenia and some basic metadata about the flood hazard assessment data layers. Table 2.5 provides an overview of the detailed criteria used for determining the flood hazard classes.

Table 2.4: Comparison of flood hazard assessment at national level (fluvial flooding).

Intensity parameter	Return periods (Q_x)	Scenario considered	Spatial scale	Source of each data layer
discharge (Q), water level (G), water velocity (v), product of water velocity and water depth (where v > 1 m/s at Q100)	10 years, 100 years, 500 years	Four hazard classes: low, medium, high, other	Flood hazard maps in 1: 5.000 scale (preferred)	Ministry of the Environment and Spatial Planning

Table 2.5: Comparison of criteria for determination of flood hazard classes (fluvial flooding).

High	Medium	Low	Other
At discharge Q100 or water level G100, water depth ≥ 1.5 m OR water depth water velocity ≥ 1.5m²/s	At discharge Q_{100} or water level G_{100}, 1.5m > water depth ≥ 0.5 m OR 1.5m²/s > water depth· water velocity ≥ 0.5 m²/s OR where at discharge Q_{10} or water level G_{10}, water depth > 0m.	at discharge Q_{100} or water level G_{100}, water depth < 0.5 m OR water depth · water velocity < 0.5m²/s	at discharge Q500 water depth ≥ 0 m OR where flooding occurs due to extraordinary natural or man-made events

The flood hazard information are publicly available on the web portal called "eVode" (http://evode.arso.gov.si/) using a web GIS viewer called "Atlas Voda", the first publicly accessible viewer based in the state computer cloud, and in alliance with the EU INSPIRE Directive (2007).

2.1.2.2 Flood vulnerability/exposure assessment data

The methodology for flood vulnerability/exposure assessment and further flood risk assessment is based on the classification of the damage potential related to exposed damage elements located in areas exposed to flood hazard. In order to assess the flood vulnerability/exposure, flood impact indicators and exposure elements were defined.

In scope of the methodology implementation, it was necessary to modify some of the available databases from different sources in terms of the selected spatial processing unit, which defined the appropriate resolution of the basic data. In addition to the mentioned data layers, data from public databases were obtained with regard to the basic six types of impact indicators, then the possibilities of their intended use were studied and proposals for modifications were made. Impact indicators are defined on the basis of available spatial and statistical data, which are briefly summarized in the following paragraphs. Generally, most of the data layers used in the flood vulnerability/exposure assessment have limited data access; the data accessibility is restricted following the national data protection rules.

Impact indicators and the corresponding exposure elements

The following paragraphs summarize the main characteristics of the impact indicators used for assessing the flood vulnerability/exposure and further delineation of APSFR.

(a) People's health: Vulnerability is related to the data on the location and density of permanent and temporary population. The layer is obtained from the Ministry of the Interior and contains point data on the number of people who permanently or temporarily reside at a given location.

(b) Human health: Vulnerability is related to the data on the location and density of permanent and temporary population. The layer is obtained from the Ministry of the Interior and contains point data on the number of people who permanently or temporarily reside at a given location.

(c) Social infrastructure: The impact indicator was created due to the awareness that general building and infrastructure data cannot be directly implemented for the most vulnerable infrastructure types during floods. Therefore, social infrastructure impact indicator was considered. The following elements of the social infrastructure were considered in this data layer: firefighters, hospitals and health centers, homes for the elderly, visually impaired and disabled, schools and educational institutions. Data were obtained from the Slovenian Business Register and analyzed on the basis of the Standard Statistical Classification of Economic Activities.

(d) Cultural heritage: Cultural heritage data is represented by two layers: the register of cultural heritage and a common layer which includes libraries, archives, museums and cultural centers. Layers of cultural heritage are obtained from the State register of cultural heritage by the Ministry of Culture. The impact element is further classified according to vulnerability assessments related to importance, namely state, municipal and other.

(e) Environment: This impact indicator was defined by including data describing several exposure elements: large-scale pollution facilities (according to IED, SEVESO and IPPC directive), industrial and municipal landfill areas, wastewater treatment plants; areas under environmental or other protection status (NATURA 2000, areas of special natural importance), and water protection areas at state and local level. Based on the potential impact of the exposure elements in view of flood vulnerability/exposure, special attention was given to assigning the weights.

(f) Economic activities: Due to wide variety of different economic activities and their variable vulnerability/exposure to floods, a set of the following exposure elements was suggested based on the classification of the activities from the Slovenian Business Register: (a) Health and care services, (b) Other economic activities, (c) Agriculture, hunting, fishing and forestry, (d) Mining, (e) Food, (f) Textile footwear paper, (g) Manufacturing industry, (h) Infrastructure, construction, trade, catering, and (i) Public administration.

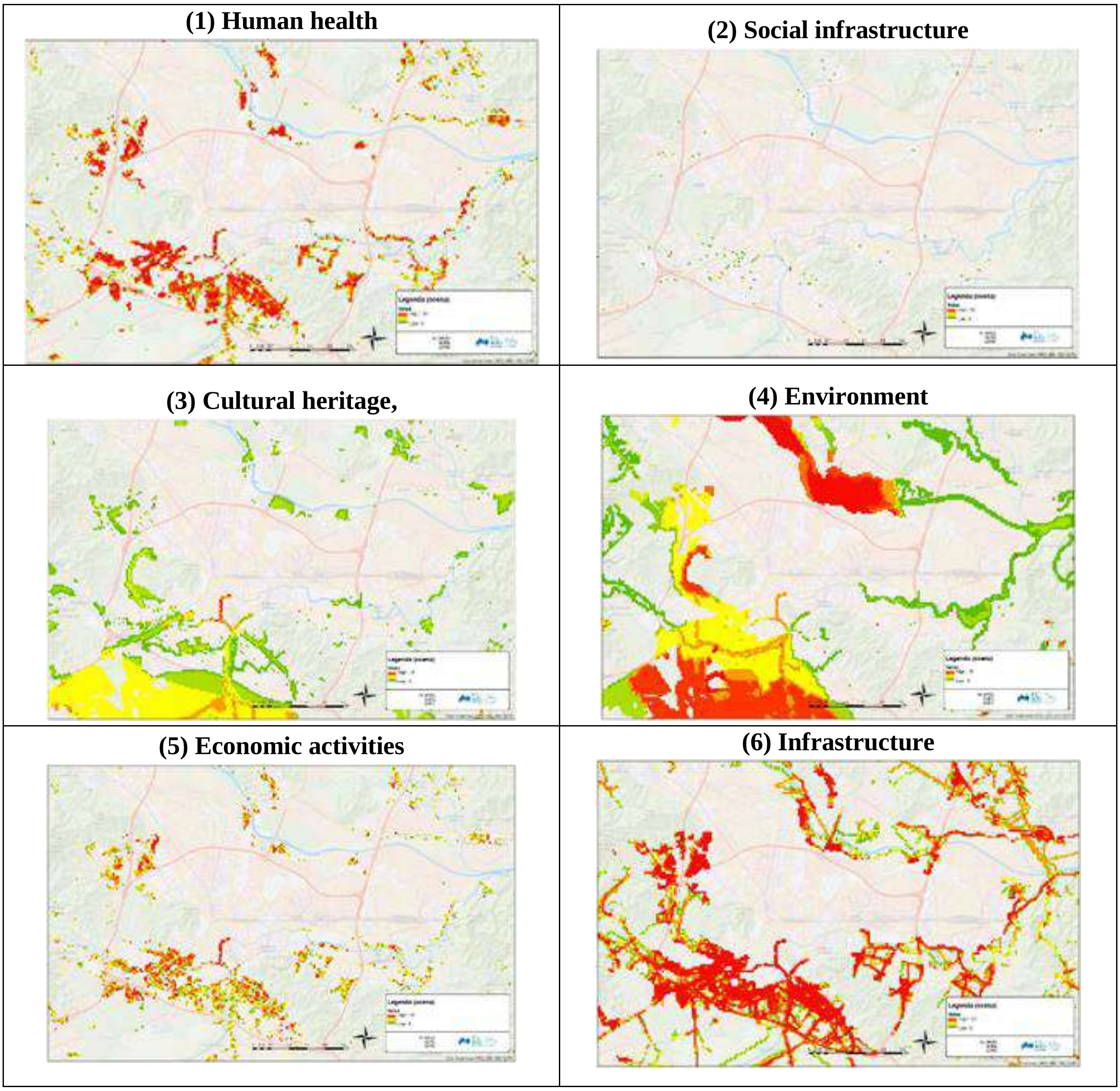


Figure 2.1: Detailed display of the impact indicators in the urban area of the City of Ljubljana (IzVRS, 2018).

(g) Infrastructure: The following types of facilities are defined as the infrastructure indicator: railways, roads, water supply, sewerage, gas and electricity (subgroups). For the infrastructure indicator, data are obtained from the Register of economic public infrastructure with a short description of the facility (classification by criteria). Based on this classification, a weight value (from 1 to 5) was assigned. A value of 5 expressed the highest and 1 the lowest vulnerability. Estimates for railways and roads were given according to the type and importance of the infrastructure. For other infrastructure elements (water supply, sewerage, gas and electricity), the assessment was determined according to the type of element and how vulnerable the element is, when subjected to a flood event. Figure 2.1 shows an overview of the potential flood damage related to impact indicators in the urban area of the City of Ljubljana.

2.1.2.3 Data adaptations and modifications for flood risk assessment

Floods do not cause direct harm to society in the areas that are not exposed to flood hazard. The assessed flood hazard potential is the set of designed flood events with particular return period and characteristics of the designed flood intensity parameters (e.g. water depth, flow velocity, etc.). By combining/overlaying the flood hazard classes with the presence of impact indicators, the flood risk classes were defined. The flood damage potential and subsequent flood risk in Slovenia was defined at 75 x 75 m raster cells resolution. In order to make the flood risk calculations at the pre-defined 75 m raster grid, several generalization, homogenization and reclassification procedures had to be performed. Due to a wide variety of impact indicators and exposure elements, the analysis of the flood damage potential was grouped into 4 layers. For each individual layer of exposure elements, it was necessary to determine more or less homogeneous groups of elements and to evaluate them. The combination of the vulnerability assessment values determines the size of the damage potential of an individual impact indicator which is shown for each type of impact indicator damage potential on the state maps at the scale of 1: 250,000. In Figure 2.2 we show an example of the flood risk assessment for the urban area of the City of Ljubljana, one of the most critical APSFR in Slovenia.

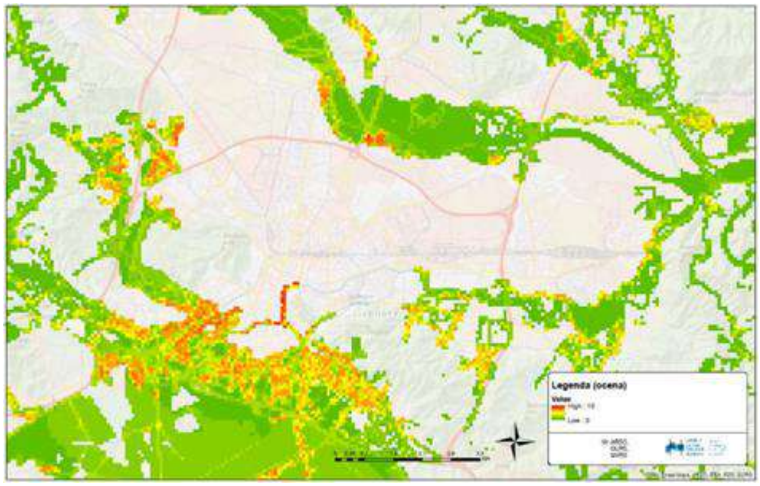


Figure 2.2: Detailed display of the flood risk in the urban area of the City of Ljubljana (IZVRS, 2018).

Related to the flood risk assessment for the operational purposes of the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief (ACPDR), the flood risk was evaluated at the municipal level. Based on the determined level and the flood risk class, the basic flood protection and rescue plan will be determined within the APSFR areas in the scope of the obligations from protection and rescue planning at the municipality level. For the verification of the model used for classification of municipalities based on the potential flood risk, data from the application called AJDA were used. The AJDA web-platform (http://ajda.sos112.si/ajda) is intended for electronic centralized capture and processing of applications of victims in natural disasters who report damage to property (land, current agricultural production and facilities), agricultural crops, and the economy. The platform is operated by the ACPDR, the damage data are collected following the methodology for damage estimation (Decree, 2003).

2.2 Italy

2.2.1 Seismic risk assessment data

The seismic risk results from the convolution of hazard, exposure and vulnerability. The unconditional risk (herein also denoted as time-based risk) is related to a specific observation time window (To), the conditional risk (herein also denoted as return period-based or event-based risk) is related to an event with a certain return period (Tr), the scenario-based assessment can be calculated adopting as input a shakemap or magnitude and hypocentral location. In Italy the official Italian hazard model (Stucchi et al., 2004; 2011) is based on the Italian seismic hazard map (MPS04) developed by Istituto Nazionale di Geofisca e Vulcanologia (INGV) and adopted at the national level with a Civil Protection Ordinance (OPCM 3519/2006). This map is freely publicly available. The exposure database is derived from census data provided by the Italian National Institute of Statistics (ISTAT). Currently, the 2011 census database, which provides information about buildings, dwellings and population, is the most recent database available. It is not publicly accessible in the unbundled format. Finally, vulnerability is expressed with lognormal fragility curves that describe the behavior of classes of buildings as a function of PGA and in terms of probability of reaching a level of damage. Numerous fragility curves can be found in the literature. In particular, there are research units of ReLUIS (Network of university laboratories for seismic engineering) and EUCENTRE (European Centre for Training and Research in Earthquake Engineering), engaged by the Italian Department of Civil Protection, that since 2018 are working specifically to develop and improve nationally valid fragility curves for masonry and reinforced concrete buildings (Dolce et al., 2021; Zuccaro et al., 2021; Lagomarsino et al., 2021; Donà et al., 2021; Rosti et al., 2021a; Rosti et al., 2021b; Borzi et al., 2021a).

2.2.1.1 Seismic hazard assessment data

The seismic hazard in Italy is obtained by the probabilistic seismic hazard analysis (PSHA). The results of the PSHA model in terms of maps showing the value of peak ground acceleration (PGA) and spectral acceleration (Sa) corresponding to an exceedance probability in a given period of time or, equally, to an assigned return period. Nine different hazard maps of Italy were realized by INGV for nine different return periods (2500, 1000, 475, 200, 140, 100, 72, 50 and 30 years) or probabilities of exceedance in 50 years (2%, 5%, 10%, 22%, 30%, 39%, 50%, 63% and 81%). Data on hazard are available for a net of 5'', corresponding to about 5 km at this latitude. The seismic hazard map (MPS04) is elaborated on rock. In order to take into account the lithostratigraphy, the amplification map by Mori et al. (2020) is available (Figure 2.3). This map gives for a grid of points (25 metres by 25 metres) the Vs30 value that can be elaborate and provide the % of soil A, B, etc. in each municipality or in each census section.

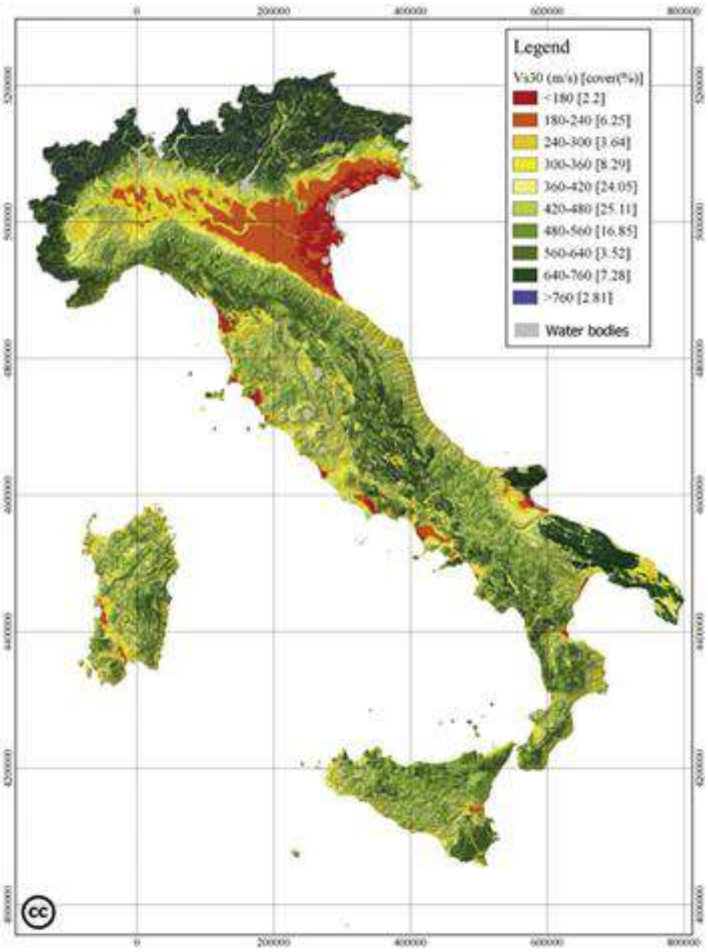


Figure 2.3: The Vs30 map for Italy (Mori et al. 2020).

In Table 2.6 below, the following data are summarized: the seismotectonic model used in Italy, how to consider the soil effects, the possible types of hazard analysis and the data source. The Italian hazard model (MPS04) and the soil amplification map selected (Mori et al. 2020) are publicly accessible.

Table 2.6: Data available for seismic hazard assessment.

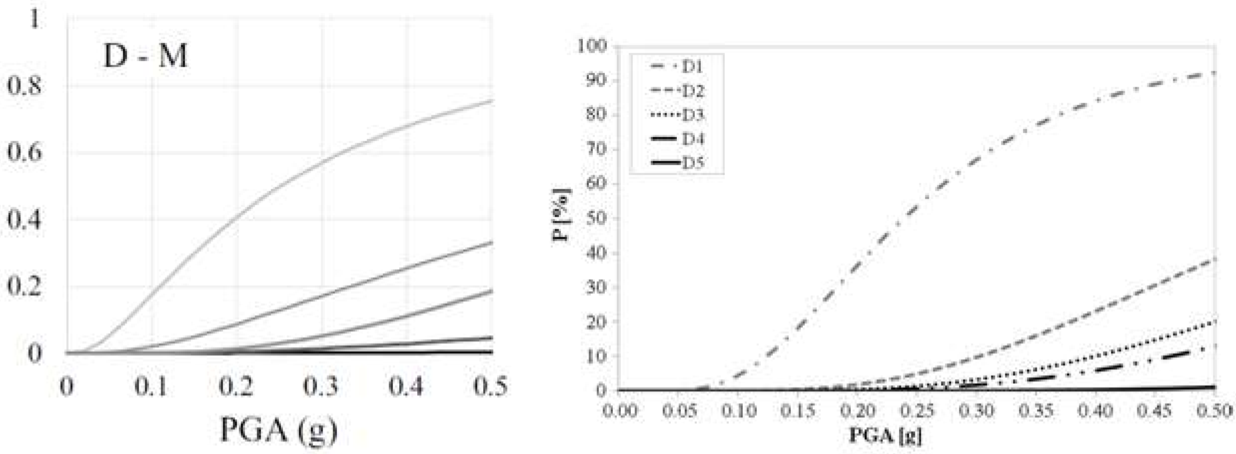
Seismotectonic model	Soil effects	Possible types of hazard analysis	Data source
From the official seismic hazard model in Italy (MPS04) made by INGV	The amplification map is a grid of point that gives the Vs30 for each point. We can elaborate it and provide the % of soil A, B, etc. in each municipality or in each census section	Return period-based (for any return period), scenario-based (for any magnitude and hypocentral location)	National Institute of Geophysics and Volcanology (INGV), Mori et al. (2020)

2.2.1.2 Seismic vulnerability/exposure assessment data and the availability of impact indicators

In the Table 2.7 below the available results of the existing vulnerability analyses are summarized, in particular: the building typologies taken into account, the vulnerability classes identified, the fragility models available, the damage scale used and the intensity measure considered. In Figure 2.4 an example of two models is reported: on the left the fragility curves proposed by Rosti et al. (2021b) derived by an empirical model, on the right those proposed by Borzi et al. (2021a) calculated with an analytical approach. Both sets of curves refer to reinforced concrete buildings seismically designed (vulnerability class D) and high-rise buildings (corresponding to 3-4 storeys in Rosti et al. (2021b) and 4 storeys in Borzi et al. (2021a)).

Table 2.7: Data available for vulnerability assessment.

Building typologies	Vulnerability classes	Fragility model	Damage scale	Intensity measure (IM)
Residential buildings in masonry and reinforced concrete, divided into construction periods and classes of height.	Five vulnerability classes are considered: A, B, C1, C2, D. The building typologies can be grouped into vulnerability classes by an exposure model. Fragility curves (Empirical, Analytical, Hybrid) are defined for each class	6 fragility models are available in terms of lognormal function, 4 for masonry and 2 for reinforced concrete (Zuccaro et al., 2021; Lagomarsino et al., 2021; Donà et al., 2021; Rosti et al., 2021a; Rosti et al., 2021b; Borzi et al., 2021a)	EMS98 scale (Grünthal 1998), which is composed of five damage levels, i.e. light damage D1, moderate damage D2, extensive damage D3, complete damage D4, and collapse D5	PGA



(a) (b)

Figure 2.4: Fragility curves for vulnerability classes D (reinforced concrete buildings seismically designed) and high buildings for: a) Rosti et al. (2021b) and b) Borzi et al. (2021a).

In the table below the available exposure data are summarized, in particular: the type of data and the scale to which the composition of the building stock is available. By now, only the exposure for municipality is available. An attempt to reduce the scale to the census sections can be made, but it is not clear if that is going to be possible.

Table 2.8: Data available for exposure assessment.

Available exposure data type	**Data for buildings/dwellings**	**Exposure data spatial scale**
Buildings, dwellings, population	Number of storeys, material, year of construction, surface area	Non-aggregate data at municipality level

Table 2.9: Method for passing from damage levels to impact indicators in the Italian National Risk Assessment (NRA) (Borzi et al., 2021b; Dolce et al., 2021)

.Damage level	Usable (%)	Not usable (short time span) %	Not usable (long time span) %	Collapsed (%)
D1	100	0	0	0
D2	60	40	0	0
D3	0	40	60	0
D4	0	0	100	0
D5	0	0	0	100

The impact indicators that can be estimated based on the existing vulnerability models and exposure data are: collapsed buildings, usable buildings, unusable buildings in the short term and in the long term, homeless, victims, injured, direct/indirect economic losses. In Table 2.9 a possible method for passing from damage levels (from D1 to D5) to impact indicators (usable, unusable and collapsed buildings) is shown. The suggested method was adopted in the Italian NRA (Borzi et al., 2021b; Dolce et al., 2021). The values involve, for example, that 60% of the buildings with D3 damage and all buildings with D4 damage have to be considered not usable in long time span.

Regarding the source of the data and its accessibility:

- **Hazard data**: the seismic hazard map (MPS04) by INGV and the Vs30 map by Mori et al. (2020) are publicly accessible;
- **Fragility models**: the fragility models selected are published in the literature;
- **Exposure data**: the most recent exposure data come from ISTAT 2011. The aggregate data are publicly accessible but not usable for the risk assessment. The non-aggregate data are not public; for their use, authorization must be requested from the Italian Department of Civil Protection (DPC).

The exposure data from ISTAT 2001 is also available. A brief comparison between ISTAT 2001 and ISTAT 2011 data, reported in Figure 2.5, shows that from 2001 to 2011 the number of buildings and the population have sensibly increased (+8.6% for buildings and +4.0% for population) while the number of dwellings has decreased (-11.8%). The differences observed led to the use of the most recent database, i.e. ISTAT 2011.

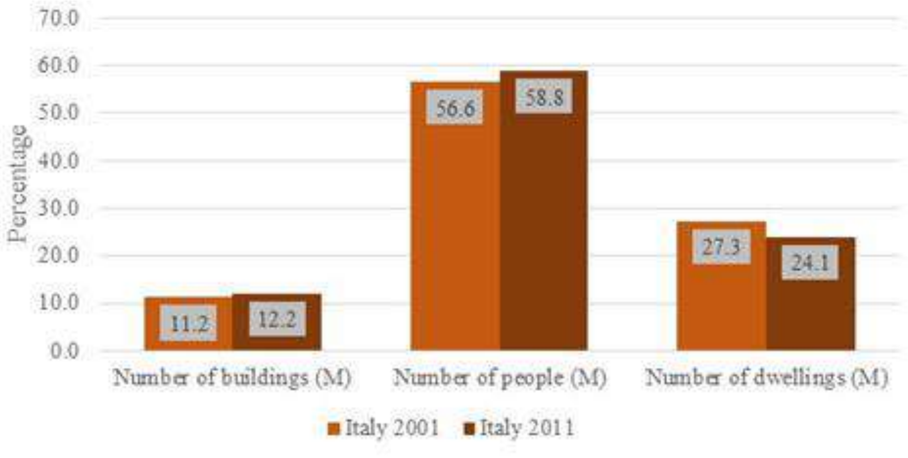


Figure 2.5: Comparison between ISTAT 2001 and ISTAT 2011 for all buildings, people and dwellings in Italy (Borzi et al. 2021b).

2.2.1.3 Data adaptations and modifications for seismic risk assessment

The seismic risk can be calculated following probabilistic seismic hazard assessment PSHA-based risk approach. The unconditional risk assessment can be performed with reference to a specific observation time windows (e.g. one-year or fifty-year). Moreover, the conditional risk assessment can be performed with reference to earthquakes with a selected return period. Finally, the scenario-based assessment can be calculated adopting as input a shakemap or magnitude and hypocentral location. Seismic risk is evaluated in terms of expected damage for the residential building stock and associated consequences (direct economic losses and impact quantities such as unusable buildings, homeless and casualties). In the table below a summary of the calculation model adopted for the seismic risk definition in Italy is reported.

Table 2.10: Data available for seismic risk.

Calculation of risk	Risk classes	Spatial scale
Convolution of hazard, fragility and exposure for each typology and then aggregated	The risk is expressed in terms of number of buildings/dwellings into a certain class that reach the level of damage considered. Using impact models, you can move from damage levels to impact indicators.	In this moment, we have the exposure for municipality so the result can be given for municipality. We can try to obtain the exposure for the census sections; in this case the result will be for census sections

2.2.2 Flood risk assessment data

The main information about the methodological approaches followed for flood risk assessment are reported in D2.1 and are related to the application of the EU Floods Directive. The EU Floods Directive (FD) (2007/60/EC) requires each Member State (MS) to assess its territory for significant risk from flooding, to map the flood extent, identify the potential adverse consequences of future floods for human health, the environment, cultural heritage and economic activity in these areas, and to take adequate and coordinated measures to reduce this flood risk. The Directive 2007/60/EC related to the assessment and management of flood risks (Floods Directive), was implemented in Italy with Legislative Decree 49/2010, with the aims to establish a reference framework for flood risk assessment and management. The main purpose is to reduce the potential negative consequences on: 1) human health; 2) economic activities; 3) environment; 4) cultural heritage.

The Legislative Decree 49/2010 includes in the category of protected areas to be considered for the purposes of potential pollution all the categories of protected areas that for the Italian legislation implementing the Water Framework Directive are listed in attachment 9 to the third part of Legislative Decree no. Lgs. 152/2006 reports below:

- areas designated for the abstraction of water intended for human consumption (art. 7 Water Framework Directive 2000/60/EC - Waters used for the abstraction of drinking water);
- areas designated for the protection of economically significant aquatic species;
- water bodies intended for recreational purposes, including areas designated as bathing water pursuant to Directive 76/160/EEC;
- sensitive areas with respect to nutrients, including those designated as vulnerable areas under Directive 91/676 / EEC (Nitrates Directive) and areas designated as sensitive areas under Directive 91/271/EEC (Urban Reflu Directive);
- areas designated for the protection of habitat species, in which it is standard to maintain the status of the waters that are important for their protection, the relevant sites of the 2000 network established by Directive 92/43/EEC (Habitats Directive) and Directive 79/409/EEC (Birds Directive).

The FD considers the risk maps as maps of the elements at risk (one for each of the 3 probability scenarios). Legislative Decree 49/2010, taking up the criteria established in the DPCM of 29 September 1998, notes that the risk mapping also provides for a representation in terms of risk classes (R1 - moderate, R2 - medium, R3 - high, R4 - very high), able to synthetically damage, through a single map, the way in which the hazard (P1, P2, P3) and the potential combine within floodable areas.

2.2.2.1 Flood hazard assessment data

For what concerns flood hazard assessment, for each Unit of Management (UoM), that is an hydrological district containing one or mor river basin, a vector file (shapefile with related metadata) is availabe showing the polygons of the flooded areas (including the riverbed in them) for all three probability scenarios and two xml files containing: For further details we refer to Deliverable 2.1.

These data available upon request to the UoM that are in charge of preparing the data, models, maps and evaluation related to the EU Floods Directive. Here we report the example and choices made for the UoM "Distretto delle Alpi Orientali" (Eastern Alps District), that is the most relevant for the BORIS project. For this UoM flood hazard maps contain the boundaries of the geographical areas that could be flooded according to three probability scenarios chosen within the:

- P1 extreme events - low hazard (return period T=300 years);
- P2 - average hazard (return period T=100 years);
- P3 - high danger (return period T=30 years).

In addition to the extent of the flood, the hazard maps show, for each scenario, the elevation (height with respect to the mean sea) or depth of the flood (height with respect to the ground) and, where appropriate, the flow velocity. For coastal areas, the FD note that where there is an adequate level of protection from the sea, the perimeter of floodable areas can be limited to the low probability scenario only.

In the following we report the links to access the flood maps through a shared viewer made available by the hydrographic District of the Eastern Alps, the layers produced at the level of the 10 Units of Management (UoM), are shared on a specific web GIS portal in the form of WMS services that refer to the three probability scenarios and concern in particular the water bodies investigated under the Floods Directive 2007/60 / EC belonging to those designated under the WFD Directive 2000/60 / EC. The following table shows the links for accessing the viewer set up for each UoM and the connected WMS service.

Table 2.11: Example of Unit of Management for which are developed flood hazard and risk maps available for Italy.

Code – Unit of Management	**Unit of Management**	**Link WebGIS (Portal)**	**WMS service**
ITI017	Lemene	https://webgis1.alpiorientali.it/flexviewers/200760/ITI017/	LINK
ITI026	Fissero, Tartaro, Canalbianco	https://webgis1.alpiorientali.it/flexviewers/200760/ITI026/	LINK
ITN001	Adige	https://webgis1.alpiorientali.it/flexviewers/200760/ITN001/	LINK
ITN003	Brenta-Bacchiglione	https://webgis1.alpiorientali.it/flexviewers/200760/ITN003/	LINK
ITN004	Isonzo	https://webgis1.alpiorientali.it/flexviewers/200760/ITN004/	LINK
ITN006	Livenza	https://webgis1.alpiorientali.it/flexviewers/200760/ITN006/	LINK
ITN007	Piave	https://webgis1.alpiorientali.it/flexviewers/200760/ITN007/	LINK
ITN009	Tagliamento	https://webgis1.alpiorientali.it/flexviewers/200760/ITN009/	LINK
ITR051	Regionale Veneto	https://webgis1.alpiorientali.it/flexviewers/200760/ITR051/	LINK
ITR061	Regionale Friuli Venezia Giulia	https://webgis1.alpiorientali.it/flexviewers/200760/ITR061/	LINK

Input datasets used for flood hazard assessment:

The assessment of the flood hazard was conducted based on specific dataset as:

(a) Topography: LIDAR maps of 2011 acquistion campaign. The data required for this purpose has been obtained by collecting the high-density terrain elevation data (1m resolution) by using the LiDAR earth's surface laser scanning technique.

(b) Hydrology: Statistical analysis of decades record of precipitation and water flow registered by the Italian rain gauge and hydrometer network (different spatial resolution along the time, from 30 minutes to 5minutes) within a civil protection framework with the goal of hydrometeorological monitoring.

(c) Hydraulics: Hydrological modelling adopting a hydro-dynamical 2D software. Data on land use (detailed land use classification by the Ministry of Agriculture, Forestry and Food) is usually used for defining the hydraulic roughness characteristics in the floodplain areas.

Representation and definition of flood hazard

For each UoM identified, the portal created translates into an assisted GIS tool, capable of guiding the user in an intuitive and facilitated way through specific tools such as: zoom (punctual or in the form of an area selection), pan, print the view or export it in PDF format, management of legend layers, search for information through guided queries, display of attribute tables.

Table 2.12: Comparison of flood hazard assessment at national level (fluvial flooding).

Intensity parameter	Return periods (Qx)	Scenario considered	Spatial scale	Data type	Projection	Data accessibility	Source of each data layer
water level [m], water velocity [m/s]	30 years, 100 years, 300 years	three hazard classes: low, medium, high	Flood hazard maps 1:25.000	vector SHP	EPSG: 3035	Legal framework (publicly available/restricted), data protection rules	Ministry of Environment - Hydrological Districts (Unit of Management)

The maps are represented by layers reporting for each area subject to flood hazard the following information:

- water height layers: 0–0,5 m; 0,50–1,00 m; 1,00–2,00 m; > 2,00 m;
- water velocity layer: 0–0.5 m/s; 0.5–1 m/s; > 1 m/s.

Figure 2.6 shows an example the flood extension and water depth map for Tr=100 years.

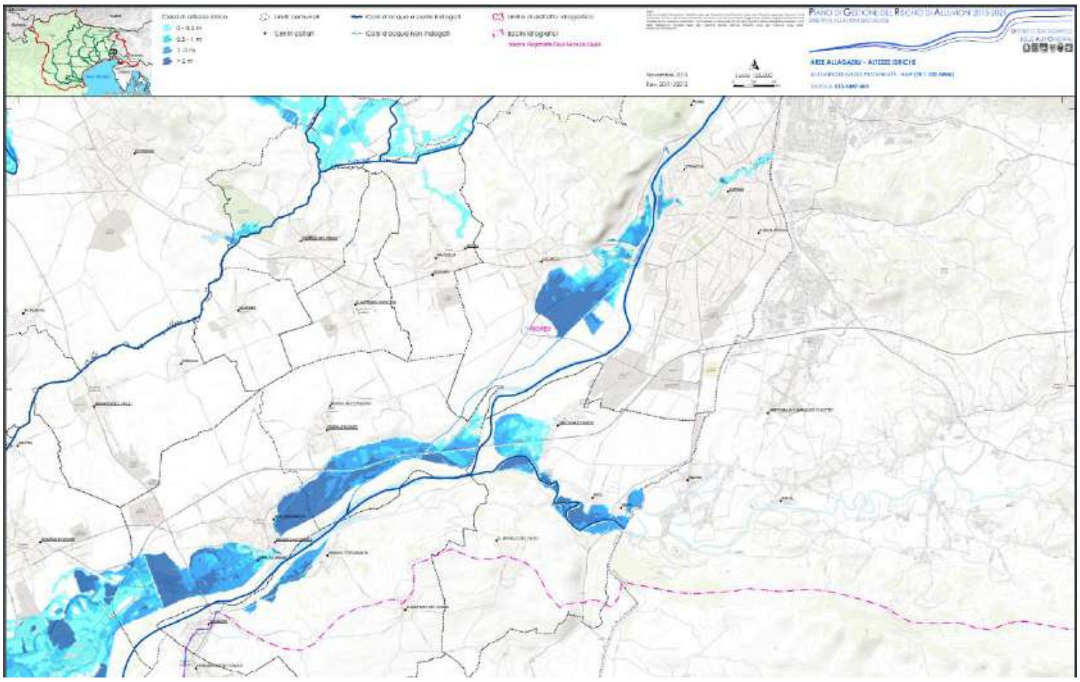


Figure 2.6: Example the flood extension and water depth map for Tr=100 years.

2.2.2.2 Flood vulnerability/exposure assessment data

In the actual version of the Flood Risk maps officially available and prepared in the framework of the EU Floods Directive are considered:

(a) Vulnerability. For what concerns vulnerability the actual version of the EU Floods Directive data prepared at Italian level considers Vulnerability equal to 1 for all the exposed elements.

(b) Exposure. In the activities carried out for the implementation of the Floods Directive, the quantification of the risk was expressed in relative terms, i.e. the risk of an exposed element assumes a gradation between 0 and 1, where 0 and 1 are respectively the cases of no risk or maximum risk of the exposed item.

This referred to the three macro-categories of exposed elements:

- **population** (Article 6-5.a of 2007/60 / EC and of Legislative Decree no. 49 of 23.02.2010);
- **economic activities** (art.6-5.b of 2007/60 / EC): buildings, agriculture, natural and semi-natural environments (art.6-5.d of Legislative Decree no. 49), infrastructures and strategic structures (Article 6-5.b of Legislative Decree 23.02.2010);

- **environmental** and **cultural-**archaeological **heritage** (Article 6-5.c of Legislative Decree No. 49), including among them, the facilities referred to in Annex I of Legislative Decree No. 59 of 18.2.2005 and the protected areas of referred to in attachment 9 of Legislative Decree 152 of 2006.

All these data are publicly available but accessible upon request.

2.2.2.3 Data adaptations and modifications for flood risk assessment

Within the Eastern Alps District, the data acquired as a result of the three scenarios provided for by the FD were processed in terms of intensity, vulnerability and exposure (potential damage) and consequently risk function according to the specific procedures developed.

In relation to the macro-categories of exposed elements identified the specific risk (Rp - population, Re – economic activities and Ra – environment and cultural heritage) have been defined by overlaying in GIS format the exposure maps related to the 3 categories with the flood scenario available for the different return period. To formulate an overall evaluation in terms of "total risk" (R), for each area has been performed a combination of the three risk components, as reported below, using three different weights for the three risk components:

$$R = \frac{p_p \cdot R_p + p_E \cdot R_E + p_A \cdot R_A}{p_p + p_E + p_A}$$

Were R is a combination of the specific risk (Rp - population, Re – economic activities and Ra – environment and cultural heritage) and p_p, p_E and p_A are the weights that have been selected for population (p_p), economic activities (p_E) and environmental and cultural heritage (p_A). Specifically, the selected weights are p_p=10, p_E=1 and p_A=1. Within the Eastern Alps District, the impact of the floods was assessed on a municipal scale. This choice is a consequence of the data or databases currently available in the survey area. Information on exposure was mainly referred to land use, while vulnerability was linked only to susceptibility.

The "total risk" in order to establish its class (**moderate, medium, high, very high**), has been categorized according to the ranges of numerical membership, as illustrated in the following table:

- R1 (moderate or zero risk): social, economic, assets and environmental damages are negligible or nil.
- R2 (medium risk): presence of minor damage to buildings, infrastructure and environmental heritage that does not affect the safety of people, the usability of buildings and the functionality of economic activities;
- R3 (high risk): presence of possible problems for the safety of people, functional damage to buildings and infrastructures, the interruption of socio-economic activities and damage related to assets and environmental;

- R4 (very high risk): losses of life and serious injuries to people are possible, relevant damages to buildings, infrastructures and environmental heritage, as well as the destruction of socio-economic activities can also be observed.

In Figure 2.7 an example of final flood risk map is shown corresponding to the flood hazard map reported in the previous section. In these maps, together with the risk classes (Moderate-green, Medium -yellow, High-orange, Very High - red) are indicated the exposed elements considered (population, economic and industrial activities, cultural and environmental heritage).

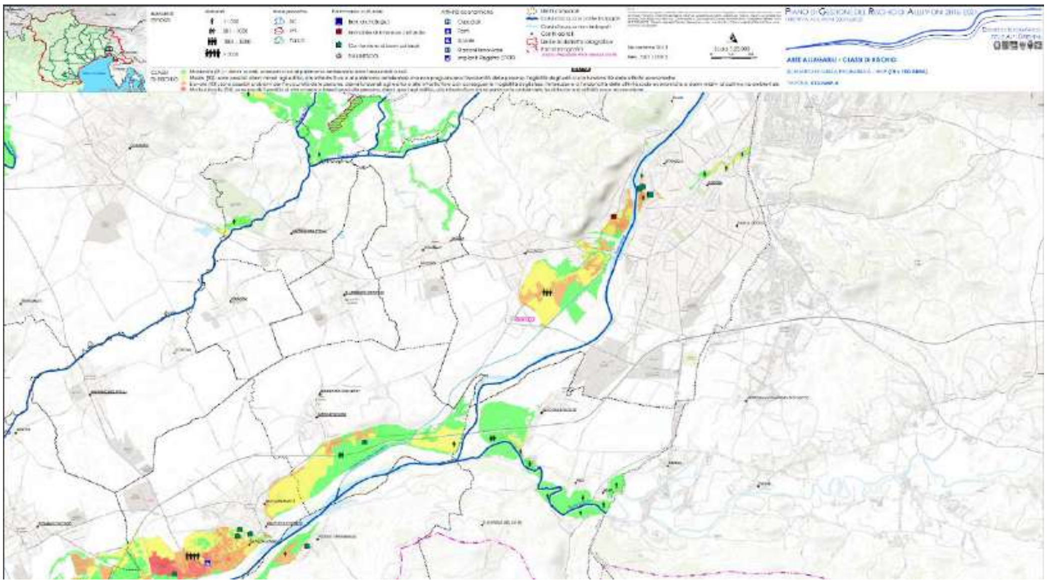


Figure 2.7: Example of the flood risk map.

2.3 Austria

2.3.1 Seismic risk assessment data

In Austria, the seismic risk is mainly outlined through a seismic hazard map by the Central Institute for Meteorology and Geodynamics (ZAMG). There are currently two valid maps, one from 1994, which is still the basis for the national seismic building code of the Austria Standard Institute, and an updated hazard map from 2020. The seismic hazard map of Austria that is included in the current ÖNORM 1998-1 outlines the seismic zones and the "effective" ground acceleration in m/s^2 (which is 70% of the maximum ground acceleration). A new building code is currently being drafted. The new seismic hazard map for Austria (Weginger et al., 2020), was presented in May 2020, showing the maximum horizontal ground acceleration with an exceedance probability of 10% in 50 years corresponding to the return period of 475 years (calculated for rock, Vs30=800m/s).

2.3.1.1 Seismic hazard assessment data

The results of the updated datasets and advanced models for seismic hazard assessment were presented in 2020 in a new hazard map after 25 years. The improvements in the Probabilistic Seismic Hazard Assessment (PSHA) are based on expanded and updated catalog data with improved depths, source-mechanisms, and moment magnitudes. The Earthquake catalog includes data from the year 1000 to 2018 which are composed of different sources: historical earthquake research (primary data obtained until the year 1900), macroseismic data obtained after the year 1900 and data obtained after the year 2004 from the digital network. Locally adapted ground motion prediction models (GMPM) were developed by applying a least square adjustment according to the local measurements (PGA, PGV, PSA, Intensity). The final selection of the used regional and global GMPMs was carried out by using statistical parameters, like Log-Likelihood and Euclidean Distance Range. The Magnitude-Frequency-Distributions were calculated by verified methods, like Weichert and Bayesian Penalized Maximum Likelihood and the maximum magnitudes were calculated by the EPRI-Approach. The PSHA approach combines a model of seismic zones (area sources), which is composed of zones and superzones, a zone-free model (smoothed seismicity) and a model with geological fault zones. A logic tree function was used to merge the models and the GMPM. The calculations were carried out with the Openquake software framework. The results (maps with ground motions with 10, 5, and 2 percent probability of exceedance (PE) in 50 years) were compared with the current norm and the results of neighboring countries. Furthermore, the uniform hazard spectra were compared with the new Eurocode draft (Weginger et al., 2020; Glade et al., 2020).

Table 2.13: Data available for seismic hazard assessment.

Seismotectonic model	Regional ground-motion model	Soil effects	Possible types of hazard analysis	Data source	Data accessibility
From the official seismic hazard model in Austria carried out by the ZAMG	From the official seismic hazard model / maps in Austria carried out by the ZAMG	Hazard on rock. There is no local Soil amplification map.	Return period-based	ZAMG - Central Institute for Meteorology and Geodynamics Austria	Maps publicly available. Underlying data via ZAMG

Table 2.14: Comparison of seismic hazard assessment at national level (results of past analysis).

Type of hazard analysis	Intensity parameter	Return periods	Spatial scale	Soil effects	Data source	Data accessibility
Return period-based	PGA	475 years	Entire country,	The hazard on rock.	ZAMG - Central Institute for Meteorology and Geodynamics Austria	Publicly accessible hazard on rock for the return period of 475 years

2.3.1.2 Seismic vulnerability/exposure assessment data and the availability of impact indicators

Detailed risk assessments or vulnerability analyses for earthquakes have not been carried out in Austria until now, as there are no fragility curves, vulnerability maps, or damage maps available. There is a European risk project ongoing that also includes Austria (https://eu-risk.eucentre.it/seismic-risk/). The concept of vulnerability is considered via the European Macroseismic Scale EMS-98 (Grünthal, 1998), which expresses differences in the way that buildings respond to earthquake shaking. However, there is no vulnerability model in use in Austria that assigns buildings to vulnerability classes on a nationwide basis.

Table 2.15: Parameters of the existing vulnerability analyses and exposure data.

Vulnerability classes	Damage scale	Intensity measure (IM)	Available exposure data type (buildings, dwellings, population)	Data for buildings/dwellings	Exposure data spatial scale
no	EMS 98	PGA	Buildings and dwellings population,	Buildings (construction period; predominant construction method and dominant material ([ ] (not specified), [M] Brick construction, [B] Reinforced concrete frame, [S] Steel skeleton, [H], Wood frame construction); number of floors and number of cellar floors available	Building-specific information, entire country included. (i) number of buildings and (ii) dwellings per municipality (iii) number of persons per census track; and number of primary residences,

2.3.1.3 Data adaptations and modifications for seismic risk assessment

There is currently no comprehensive risk analysis on earthquakes in Austria. However, the Earthquake Service of ZAMG develops (real time) shake maps to provide the disaster and civil protection authorities with detailed information of earthquake effects shortly after an earthquake event.

2.3.2 Flood risk assessment data

The legal framework for Austrian flood risk management can be found in both federal and provincial law and is based on the requirements of EU law and, in particular, the Water Framework Directive and the Floods Directive (FD). The implementation of the FD is especially valuable for strategic planning on the national level, which is then linked to existing and well-proven mechanisms of detailed planning and funding (Neuhold, 2016). In detail, the FD prescribes the following contents for the risk maps: (1) designation of the number of inhabitants affected, (2) type of economic activities in the potentially affected areas, (3) installations according to Annex I of Directive 96/61/EC, and (4) further information deemed useful by the Member States (European Commission, 2007). These requirements were implemented into national legislation through § 55k of the Austrian Water Act, version of 2011.

At the national level, different laws, regulations, and guidelines define the responsibilities of the ministries Federal Ministry of Agriculture, Regions and Tourism - BMLRT (with the departments BWV and WLV) and Federal Ministry of the Interior (more details in D2.1). The provincial laws on spatial planning and disaster management as also the building regulations, implemented and controlled by the districts and provincial governments, allocate further competences in flood risk management. The division of competencies means that different bodies collect and manage data, although in recent years, a focus has been given to collaborative databases and open data. From a very local point of view, Austrian municipalities play a key role in flood risk management initiatives, e.g. in zoning, building permits and through the volunteer fire brigade. (BMLRT, 2018)

The implementation of the FD was performed by the following three main steps: the APSFRs were designated, the hazard and risk maps were developed or enhanced by 2019, and the nationwide flood risk management plan was adapted. The elaborated flood hazard maps (1:25,000) show the extent of the flood, the water depth, the flow velocity, and risk indicators for 30-, 100- and 300-year flood events (high/medium/ low probability). The Austrian national flood risk management plan, in line with the FD, is the superordinate planning instrument since 2015 and revised every six years. In 2020 a 2nd flood risk management plan was drafted and refined by all federal states from a regional and local perspective. After a public participation phase, the comments are currently integrated, and the final version will be completed by December 2021 (BMLRT, 2018). At the regional level, a River Basin and Risk Management Concept (GE-RM) serves to coordinate possible measures in a catchment area or longer water body sections to identify potential synergies and to avoid conflicts. At the local level hazard zone plans with further details are created for torrent catchments and APSFRs. The implementation of the EU Floods Directive (maps and detailed information) is visualized to the public through the web portal Water Information System Austria (WISA).

The data used in flood hazard and risk assessments are partly publicly available. An essential open data principle states that no data may be published that allows conclusions to be drawn about individual natural persons. In terms of national visibility and transparency, data.gv.at, as a central "Austria" catalogue, is to record the metadata of the decentralised data catalogues of the administration in Austria and keep them accessible. An essential basis for data.gv.at is the cooperation agreement between the federal government, cities, federal states and municipalities - with the agreement to plan, implement, operate and further develop a joint portal. The geodata portal created based on the INSPIRE EU Directive is also linked to this portal.

2.3.2.1 Flood hazard assessment data

The flood hazard assessment in Austria follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. In 2014 a guideline was developed, which defines a uniform standard throughout Austria. In all, 30-, 100-, and 300-year flood return periods are considered in the calculations. Since flood hazard assessments have a long tradition in Austria, a multitude of existing data (hazard zone plans, HORA maps) and experiences was combined within the hazard assessments. The summary below gives an overview of the main input dataset used for flood hazard assessment. Flood hazard maps are publicly available on the following web portals: a) “WISA” – Water Information System Austria, b) via all Web-GIS Tools provided by every federal state, c) HORA risk map. Open access data is provided in different portals (for example, Open Data Austria, Inspire Geodatabase Austria, eHyd Austria, eBod Austria).

Input datasets used for flood hazard assessment:

(a) Topography: The digital terrain models used to calculate flood hazards are mainly based on Laser Scan data (DTM 1 x 1 m resolution, LIDAR scanning, Airborne Laserscan) combined with information derived from terrestrial river profile surveys. Where such detailed data has not been available, terrain models with a resolution of 10 x 10 meters were used (which is available for the whole territory, open access). Infrastructure and buildings have been considered by the DTM and the use of suitable roughness coefficients. Furthermore, existing flood defences were considered. For the pilot region in Styria, the original data is used for planning purposes in a point cloud with 4 points/m² below 2000 m above sea level and 2 points/m² above 2000 m above sea level.

(b) Hydrology: The eHYD web portal (Data of the Hydrology of Austria) provides current data from about 700 precipitation, runoff and groundwater measuring stations in Austria (https://ehyd.gv.at). For flood hazard assessments hydrological studies, trend analysis of historical data of hydrological and meteorological observations are used. Within small or unobserved catchments, additional site-specific hydrological studies are carried out.

(c) Hydraulics: Hydraulic studies, based on Hydrological modelling results, using hydrodynamical modelling software, generally combination of 1D/2D models (e.g. Hydro-AS 2D, Hec-Ras, Mike Flood, Flo-2D) are standard. A combination of detailed data on land use, sensitivity analyses, photographs and site inspections are usually used for defining the hydraulic roughness characteristics. IF available, past events are used for calibration and validation.

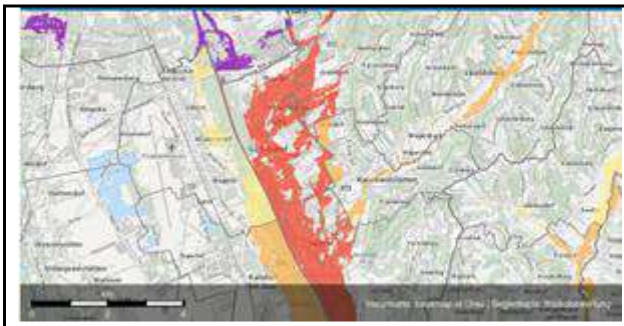
(d) Information on Past Events: Datasets of Austrian event documentation cadasters are used to calibrate and validate the results of the assessments.

Definition and representation of flood hazard:

Although the overall structure for the representation of flood hazard and risk is defined by the FD, the individual Member States are given flexibility in the composition and visualisation of the maps. An Austrian assessment of target group-specific visualisation of flood hazards and flood risk have revealed that maps at scales ranging from 1:10,000 to 1:15,000 offer the opportunity to observe individual risk situations and, at the same time, to provide an overview of an area (Heintz et al. 2012; Wenk et al. 2018). Austrian flood hazard maps record those areas which, including typical characteristics of the respective catchment area (bedload, wooden debris, morphological processes), may be flooded under scenarios of a flood of:

- low probability (expected recurrence interval of 300 years or failure of protective of protection systems - extreme event)
- medium probability (expected return interval at least 100 years) and
- high probability (expected return interval 30 years).

For these scenarios, flood hazard maps contain information on: Extent of flooded areas, water depths and flow velocities. Figure 2.8 gives an example of the different flood hazard and risk maps that are provided via the WISA Web Portal (Water information system Austria ©BMLRT).

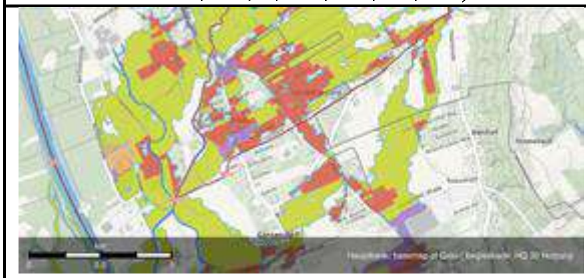


(a) The overview map for the **preliminary risk assessment** (APSFR) illustrates the potentially affected persons per municipality in calculated inundation areas (number of people: purple = very high, red = high, orange = moderate, yellow = low)

(b) The **hazard map flood extension** outlines the extent of the flooding based on different flood scenarios. These are based on simulations of different runoff values and flood characteristics.

(c) The **hazard maps (process characteristics)** show **flow depth and flow velocity** for all three scenarios. Flow velocity is area-based with class boundaries <0,6 m/s; 0,6-2 m/s; >2 m/s. Water depths are shown with class boundaries of <0,6 m; 0,6 -1,5 m; >1,5 m).

(d) **Risk maps (impact on people and infrastructure)** show the number of potentially affected persons per raster and the potentially affected infrastructure (e.g. train station, schools, hospitals, industry) for all three scenarios.



(e) **Risk maps (impact on land use)** show six different forms of land and settlement use within the floodplains.

(f) **Risk map (impact on protected areas)** outlines five different types of protected areas within the floodplain.

Figure 2.8: Example of different flood hazard and risk maps that are provided via the WISA Web Portal.

Table 2.16 summarizes the basic components of the methodology used for flood hazard assessment in Austria and some basic metadata about the flood hazard assessment data layers. For each scenario, process characteristics such as water depth and flow velocity can be identified. In the flood hazard maps, a distinction is made between three water depth classes. To be able to assess the hazard situation and to act accordingly in the event of an incident, a consideration combined with the local flow velocity is expedient and is illustrated by additional graphics and explanations in the WISA Web-Portal. Table 2.17 provides an overview of the detailed classification. However, Austria also provides flood hazard zone plans - used as experts' opinion for spatial planning - for most APSFRs and torrent catchments considering medium scenarios (100 years). The two main zones (red and yellow) outline areas where the combination of water depth [m] and flow velocity [m/s] exceeds certain limits and criteria. These zones are completed by additional information zones, as for example for residual risk.

Table 2.16: Comparison of flood hazard assessment at national level (fluvial flooding).

Intensity parameter	**Return periods (Qx)**	**Scenario considered**	**Spatial scale**	**Data type**	**Projection**	**Data accessibility**	**Source of each data layer**
water level [m], flow velocity [m/s], flood extension, product of water velocity and water depth	30 years, 100 years, 300 years	high (30 years), medium (100 years), low (300 years= extreme event), no (likelihood of occurrence)	Flood hazard maps in 1:25 000, in some cases 1: 5.000 or more detailed	vector SHP	EPSG: 3035	Legal framework (publicly available/restricted), data protection rules. All hazard and risk maps publicly available in WISA and Web GIS portals of federal states. BMLRT in charge of underlying data. Some data (flood extension) is open access data (inspire)	Ministry of Agriculture, Regions and Tourism (BMLRT)

Table 2.17: Classification of process characteristics

Characteristics	**High**	**Medium**	**Low**
Water depth	>1,5 m	0,6-1,5 m	<0,6 m
Flow velocity	>2 m/s	0,6-2 m/s	<0,6 m/s

2.3.2.2 Flood vulnerability/exposure assessment data

To assess the flood exposure, according to the FD, flood impact indicators and exposure elements were defined and Table 2.18 provides an overview of the used data. The following paragraphs summarize the main characteristics of impact indicators (People's health, Cultural heritage, Environment, Economic activities) used for assessing the flood exposure and further defining the Areas of Potential Significant Flood Risk APSFR. Regarding damage and event documentation data, a variety of regional and national databases and instruments exists in Austria that provide long time series. Referring to these circumstances the ongoing CESARE Project, as a follow up of past initiatives and by including various stakeholders, aims to develop a national event and loss database that enables a centralized access to harmonized event and loss information.

Table 2.18: Overview of the data used in flood vulnerability/exposure assessment.

Impact indicators	Exposure elements	Data layers used in assessment	Data type	Spatial scale	Source of each data layer
Main impact indicators (APSFR): 1) Peoples health, 2) Environment, 3) Cultural heritage, 4) Economic activities	a) Population (>100, 76–100, 51–75, 26–50, 1–25, no affected persons) per raster cell (census track data used) b) Land use (settlement-related uses, agriculture, forestry and grassland, Water, transport infrastructure) c) Protected areas (Water conservation area, UNESCO World Heritage Site, NATURA 2000 area, National Park), d) Infrastructure (contaminated site, Industry, Swimming water, Railway station, hospitals, Schools, kindergarten, senior residence)	(a) StatAT Population Register and future development (census track 2001), b) land use cadastre and corine dataset d) official and private data	Excel (a), Vector ShP: (b), (c), (d)	risk maps: raster grid 125 x 125 m, 1:25000	Ministry of Agriculture, Regions and Tourism (BMLRT), Federal Ministry Digital and Economic Affairs (BEV), Statistic Austria Institute

For the preliminary risk assessment, floodplains were overlaid with a total of 20 different protected assets, considering the effectiveness of existing flood protection structures up to the design event, where available (EC,2014). For these protected assets, data from public administrations were mainly used, but also data from public and private service providers. The flood risk was determined by overlapping these risk indicators or criteria with the flooded areas and presented in non-monetary terms. The evaluation of the individual risk indicators was carried out in 5 risk classes (no, low, moderate, high, very high risk) for each watercourse section in the federal reporting watercourse network (BGN). For each watercourse sub-section, the risk assessments of the individual objects of protection were combined to form an overall risk, with the highest individual risk in each case determining the overall risk (BMLFUW, 2015).

(a) Risk to human health: The risk to human health has been determined in Austria based on impacted inhabitants, categorized into four categories: up to 50 inhabitants impacted, 51 – 500, 501 – 5,000 and above 5,000. The database for this is the data of the official Austrian statistics Institute (February 2013), which lists all registered inhabitants per building. Based on the flooded area, the number of people impacted has then been calculated per scenario.

(b) Risk to economic activity: The risk to economic activity was determined and depicted in two different ways for a) area-wise usages (like agriculture), and b) punctual and linear for critical infrastructure. Area-wise economic activities at risk were determined by using CORINE Landcover information from 2006 and NAVTEQ data in urban areas (complemented in most cases by more detailed information from the federal states), simplified into five categories (which are depicted on the maps: living quarters; industry and craft; usages "related to the settlement"; agriculture, forestry and "other grassland"; and water bodies). In the risk maps, the flooded areas (according to the low / medium / high probability events) were then colored differently, i.e. according to the usage determined. Critical infrastructure at risk was depicted on the risk maps independent of the location within or outside of a potentially flooded area. Punctual infrastructure was depicted using a symbol, linear infrastructure by marking the whole course of the road or railway tracks across the map. The depicted infrastructures are Railway lines of the categories A and B1 (Austrian railways and preliminary FR assessment), Railway stations of the categories A and B1 (Austrian railways and preliminary FR assessment), Highways ("Autobahnen" and "Schnellstraßen") (ASFINAG road network), Hospitals (data from GÖG), and senior citizen´s residences (reported data from the federal states), Schools and kindergartens (reported data from the federal states, Airports (data from Environment Agency), Harbours (data from viadonau). (EC,2014)

(c) Risk to Installations covered by the requirements of the Industrial Emissions Directive (IED) or previously under the IPPC Directive: Sites posing high or medium risk are classified as significant and were depicted on the maps. As with punctual critical infrastructures, the sites classified as being at risk or posing a risk in the case of flooding are depicted on the risk maps independently of the location within or outside of a potentially flooded area. This methodology was employed in the Danube and Rhine RB; in the Elbe RBD, no hazard and risk maps have been produced (no APSFRs designated). (EC,2014)

(d) Risk to WFD protected areas: The protected areas at risk are depicted in the risk maps in three different ways using three different signatures: Natura 2000 areas and Austrian National Parks are depicted as a single category "Natura 2000 / National Parks". Considered are only those of the areas situated within a potentially flooded area (considering the low /medium / high probability scenarios). Protected areas according to the WFD are depicted as a single, not distinguishing between the objective of the protection. Considered are only those of the areas situated within a potentially flooded area. The only exception to this are bathing waters, which are depicted with a punctual symbol on the risk maps independently of the location within or outside of a potentially flooded area. (EC,2014)

(e) Other consequences considered are **cultural heritage sites** (UNESCO Cultural Heritage sites) in all three probability scenarios. Other cultural assets, like churches, theatres, museums, and historical buildings, are not depicted, as there is no comprehensive information available on the federal level. Additionally, areas in which floods may carry a high amount of material/debris (mostly torrent catchments, i.e. alpine creeks with irregular course and heavy current) were marked on the maps by linear markings lining the course of the water body. (EC,2014)

2.3.2.3 Data adaptations and modifications for flood risk assessment

In Austria, the potential flood inundation area of three scenarios (HQ30, 100, 300) are intersected with the information on (people, environment, cultural heritage and industry and displayed as risk maps (as explained in detail in the paragraph above). The number of potentially affected persons, i.e. those with a primary or secondary residence or workplace in the area, are aggregated on the basis of grid cells visualised in a yellow-red scale displayed using a raster with a size of 125 x 125 meters (see Figure 2.8 (d) above). The predominant use of the areas, for example, for housing or as agricultural land, is also assigned (Neuhold, 2016; BMLRT, 2018). This is the current approach Austria has chosen to outline local hotspots as basis for the potentially affected population, the Civil Protection and Disaster Relief authorities and first responders. Austria further puts a strong focus on risk communication, awareness raising and regional assessments and has therefore developed further information material for this purpose Further data and information layers as for example, land use plans and local development concepts, information on historical and cultural assets, essential infrastructure and strategic structures are available through the Web-GIS Portal of every federal.

2.4 Turkey

2.4.1 Seismic risk assessment data

The current Earthquake Hazard Map of Turkey (AFAD, 2018) was prepared by using probabilistic seismic hazard analysis methodology and published in the Official Gazette on March 18, 2018. Besides, AFAD-RED (Rapid Earthquake Damage and Loss Estimation System) is utilized for scenario-based risk assessment studies. AFAD-RED has been developed by AFAD Earthquake Department in collaboration with scientists with the aim of estimating potential losses of an earthquake occurring in Turkey and also for earthquake scenarios. AFAD-RED estimates potential structural damage (slight, moderate, extensive and complete), the number of casualties, the need for temporary shelter service and serviceability of critical facilities (i.e. schools, hospitals, governorship buildings etc.), transportation systems (i.e. bridges, highways, railways etc.) and lifeline systems (i.e. gas, petroleum, water and waste water lines). AFAD-RED also produces maps for seismic intensity, peak ground acceleration, peak ground velocity etc. AFAD-RED uses several databases of different institutions such as administrative information (country, province, district and neighborhood boundaries), information on population, buildings, critical facilities, transportation systems, lifeline systems, geology (active faults), USGS Vs30 map data, Vs30 information from AFAD acceleration stations and so on. The data are not publicly accessible. AFAD-RED is compatible with Disaster Management and Decision Support System of Turkey (AYDES). Provincial AFAD directorates can easily integrate AFAD-RED outputs to their studies from AYDES.

2.4.1.1 Seismic hazard assessment data

The current Earthquake Hazard Map of Turkey (AFAD, 2018) is a product of "Revision of Turkish Seismic Hazard Map" project supported by the National Earthquake Research Program of AFAD. The project implemented state-of-art knowledge in probabilistic seismic hazard assessment (PSHA) and took into account the recent studies on basic components of seismic hazard calculations (i.e. seismic sources, earthquake catalogues, ground motion prediction equations etc.). The active fault database (Emre et al., 2013; 2018) that comprises the interpretation of seismotectonic features in terms of geological, geophysical, seismological and geodetic information (Duman et al., 2018) as well as the instrumental earthquake catalogue (Kadirioğlu et al., 2018), and historical earthquakes catalogue (pre-1900) information, which is compiled from the studies by Stucchi et al. (2013), Zare et al. (2014) and Albini et al. (2014), are the main inputs for the delineation of seismic sources in the project (Akkar et al., 2018). Two independent seismic source models, area sources (Şeşetyan et al., 2018) and fault sources, complemented with a smoothed seismicity model to account for background seismic activity (Demircioğlu et al., 2018), were used in the project. A strong motion database, which includes recordings from Turkey as well as Italy, Greece and Western United States resembling similar shallow crustal seismicity, was compiled. The candidate ground-motion prediction models (GMPMs) were tested and ranked under this database via a series of data-driven statistical goodness-of-fit methods. Also, PSHA sensitivity analyses were performed over some selected regions that are representatives of high, moderate and low seismicity. Since strong motion data recorded in Turkey is deficient for subduction regions, the GMPMs used in EMME (Earthquake Model of the Middle East) project were implemented for these regions. Table 2.19a shows the final set of GMPMs used in "Revision of Turkish Seismic Hazard Map" project. Seismic hazard computations were carried out using both area source model and fault+smoothed seismicity model. Results obtained from these two seismic source models were combined by assigning equal weight to each model (i.e. 0.5 for area source model and 0.5 for fault+smoothed seismicity model). Seismic hazard maps were produced in terms of different ground-motion intensity measures (peak ground acceleration-PGA, peak ground velocity-PGV, 5%-damped pseudo-spectral accelerations at 0.2 sec and 1.0 sec periods-S_S and S_1) for different return periods (43, 72, 475 and 2475 years). The computed ground-motion intensity measures (IMs) are for a generic rock site (Vs30 = 760 m/s) and their horizontal component definition is geometric mean. Current Earthquake Hazard Map of Turkey and the data including PGA, PGV, S_S and S_1 values for different return periods at grid points with spacing of 0.1° x 0.1° in latitude and longitude were published in the Official Gazette on March 18, 2018. A GIS-based interactive web application, which enables to view and query earthquake hazard maps prepared based on this data, was developed. It can be accessed through e-Government system of Turkey.

Table 2.19a: Data and models used in seismic hazard assessment in Turkey (the case of earthquake hazard maps of Turkey).

<table>
<tr><th></th><th>Seismotectonic model</th><th colspan="2">Ground-motion model</th><th>Soil effects</th><th>Possible types of hazard analysis</th><th>Data source</th><th>Data accessibility</th></tr>
<tr><td rowspan="7">Earthquake Hazard Maps of Turkey</td><td rowspan="7">It was created with different data sets that are listed below (Duman et al., 2018):
• The active faults (Emre et al., 2013)
• Instrumental earthquake catalogue (Kadirioğlu et al., 2018)
• Historical earthquake catalogue (Stucchi et al., 2013; Zare et al., 2014; Albini et al., 2014)
• Crustal thickness (Arslan, 2012)</td><td colspan="2">PGA, S_S and S_1</td><td rowspan="7">Earthquake Hazard Maps of Turkey were prepared considering soil condition Vs30=760 m/s and doesn't include the hazards caused by local soil conditions like liquefaction, ground amplific., subsidence, etc.</td><td rowspan="7">Probab. seismic hazard analyses were carried out.</td><td rowspan="7">It is summarized in "Seismotec. Model" column.</td><td rowspan="7">The digital data on only the instrumental catalogue are publicly accessible. Kadirioğlu et al. (2018) published this data as suppl. material.</td></tr>
<tr><td>Shallow active crustal regions</td><td>• Akkar et al. (2014)
• Chiou and Youngs (2008)
• Akkar and Çağnan (2010)
• Zhao et al. (2006)</td></tr>
<tr><td>Subduction zones</td><td>• Zhao et al. (2006)
• Atkinson and Boore (2003)
• Youngs et al. (1997)
• Lin and Lee (2008)</td></tr>
<tr><td colspan="2">PGV</td></tr>
<tr><td>Shallow active crustal regions</td><td>• Akkar et al. (2014)
• Chiou and Youngs (2008)
• Akkar and Çağnan (2010)</td></tr>
<tr><td>Subduction zones</td><td>• Megawati and Pan (2010)-interface
• Garcia et al. (2005) – inslab</td></tr>
</table>

As mentioned in Section 2.4.1, AFAD-RED is utilized for scenario-based risk assessment studies. In AFAD-RED, earthquake scenarios are developed by manual data entry. In other words, the parameters of the scenario earthquakes (i.e. epicentral coordinates, magnitude, depth, average dip, rupture length etc.) are provided by the users. Within the scope of the Disaster Response Plan of Turkey (TAMP) and Provincial Disaster Risk Reduction Plans (İRAP), earthquake scenarios are developed and the parameters of scenario earthquakes are defined by considering past earthquakes and active fault map of Turkey (Emre et al., 2013) database. AFAD-RED estimates PGA, PGV, S_S and S_1 values and produces maps. The ground-motion prediction models defined at the current version of AFAD-RED are given in Table 2.19b. AFAD-RED enables to use more than one GMPM with weights assigned by the user. It estimates IMs at Vs30 = 760 m/s and then soil amplification is applied through the Vs30 database.

Table 2.19b: Data and models used in seismic hazard assessment in Turkey (the case of AFAD-RED).

	Seismotectonic model	**Ground-motion model**	**Soil effects**	**Possible types of hazard analysis**	**Data source**	**Data accessibility**
AFAD-RED	• Parameters of the scenario earthquakes are defined by the users. • Within the scope of TAMP and İRAP, the parameters of scenario earthquakes are defined by considering the followings: - The active faults (Emre et al., 2013) - Instrumental earthquake catalogue (Kadirioğlu et al., 2018; AFAD Earthquake Catalogue) - Historical earthquake catalogue (AFAD Earthquake Catalogue)	• NGA Boore and Atkinson (2008) • NGA Campbell and Bozorgnia (2008) • NGA Abrahamson and Silva (2008) • NGA-West2 Boore, Stewart, Seyhan and Atkinson, BSSA14 (2014) • NGA-West2 Campbell and Bozorgnia, CB14 (2014) • NGA-West2 Abrahamson, Silva and Kamai, ASK14 (2014) • NGA-West2 Chiou and Youngs, CY14 (2014) • NGA-West2 Idriss, I14 (2014) • Akkar and Çağnan (2010) • Akkar, Sandıkkaya and Bommer (2014) • Çeken, Beyhan and Gülkan (2008) • Kalkan and Gülkan (2004) • Boore et al. (1997) • Sadigh et al. (1997) • Ambraseys et al. (1996)	Ground motion prediction models are used to estimate ground motion parameters. at Vs30 = 760 m/s and then soil amplific. is applied through the Vs30 database.	Scenario-based seismic hazard assess. are carried out.	Data source on faults and earthquake catalogues are summar. in "Seismotec. Model" column. For Vs30 database, AFAD-RED considers the following: • USGS Vs30 map data • Vs30 inform. from AFAD accel. stations	The digital data on the instrumental catalog (1900-2012) are publicly accessible and published by Kadirioğlu et al. (2018) as supplementary material. The data on instrumental (2013-2021) and historical earthquake catalogs (pre-1900) are publicly accessible on AFAD web-site (deprem.afad.gov.tr). Vs30 information for AFAD acceleration stations are publicly accessible on Turkish Accelerometric Database and Analysis System (tadas.afad.gov.tr)

Table 2.20 summarizes the results of seismic hazard assessments obtained from AFAD-RED as well as Earthquake Hazard Maps of Turkey.

Table 2.20: Seismic hazard assessments in Turkey.

	Type of hazard analysis	Intensity parameter	Return periods	Spatial scale	Soil effects	Data source	Data accessibility
Earthquake Hazard Maps of Turkey	Probabilistic seismic hazard analyses were carried out.	PGA, PGV, S_S, S_1	43, 72, 475, 2475 years	Entire Country	Earthquake Hazard Maps of Turkey were prepared considering soil condition Vs30 =760 m/s and doesn't include the hazards caused by local soil conditions like liquefaction, ground amplification, subsidence, etc.	AFAD	Publicly accessible. (Data with spacing of 0.1° x 0.1° in latitude and longitude were published in the Official Gazette on March 18, 2018. Earthquake Hazard Maps of Turkey, which were prepared based on this data, can be viewed and queried through a GIS-based interactive web application. It can be accessed through e-Government system of Turkey.)
AFAD-RED	Scenario-based seismic hazard assessment is carried out.	Seismic Intensity, PGA, PGV, S_S and S_1	-	Defined by user.	Soil effect is considered.	AFAD	Outputs of AFAD-RED for scenario earthquakes are not publicly accessible. They are shared only with Provincial AFAD directorates through AYDES.

2.4.1.2 Seismic vulnerability/exposure assessment data and the availability of impact indicators

AFAD-RED estimates the structural damage by utilizing fragility curves defined for four damage states: slight, moderate, extensive and complete. AFAD-RED enables to define fragility curves in terms of seismic intensity, PGA, PGV, PGD, spectral displacement etc. Since the available building and population database used by AFAD-RED contains only the number of buildings and population in each neighborhood/village in Turkey, spectral displacement and seismic intensity-based fragility curves, which are average for all buildings, are utilized in current analyses. The vulnerability analyses and exposure data used in current analyses by AFAD-RED are summarized in Table 2.21.

Regarding impact indicators, as explained in Deliverable 2.1, AFAD-RED estimates numbers of slightly, moderately, extensively and completely damaged buildings; numbers of outpatients, slightly injured people, severely injured people and life loss; number of people who need temporary shelter as well as serviceability of critical facilities, transportation systems and lifeline systems. As for National Disaster Risk Assessment Report of Turkey (AFAD, 2019), following impact indicators are used: number of fatalities, number of severely injured/ill, lack of fulfilment of basic needs, number of people who need to be evacuated, total economic impacts, impacts for nature and environment, disruptions to every day's life, loss of cultural heritage and loss of reputation.

Table 2.21: Vulnerability analyses and exposure data used in current analyses by AFAD-RED.

Vulnerability classes	Damage scale	Intensity measure (IM)	Available exposure data type (buildings, dwellings, population)	Data for buildings/dwellings	Exposure data spatial scale
Fragility Curves	Four damage states: slight, moderate, extensive and complete	Seismic Intensity and Spectral Displacement	Buildings and Population (not publicly accessible)	Number of buildings	Entire country at neighbourhood/ village level

2.4.1.3 Data adaptations and modifications for seismic risk assessment

According to National Disaster Risk Assessment Report of Turkey (2019), key elements of risk assessment are explained below (Figure 2.9). Firstly, it is outlined how potential disasters are assessed through scenarios. Next, it is explained how and by whom these scenarios are developed, how they are assessed in terms of their impact and probability elements, and how the developed scenarios are filtered by their size and areas. Finally, detailed information on the developed scenarios is provided.

This information is as follows:

- Brief information should be provided about the characteristics of the scenarios, why they have been selected, the differences between the selected scenarios, and the characteristics of the selected area and location.
- Probability, frequency, size, and impact (affected population and their characteristics, and the economic, environmental and social effects) of the incident.
- A brief summary of similar disasters witnessed in the same area in the past.

- What kind of works have been or are being carried out to reduce the risks and impacts of disasters in selected scenarios, and if no such works have been undertaken, what should be done.

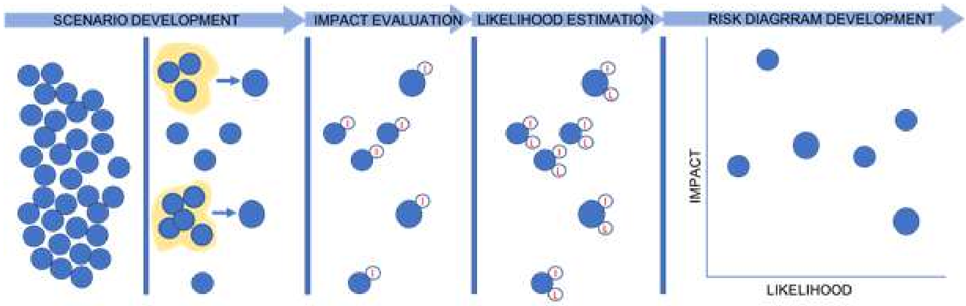


Figure 2.9: Method of the risk assessment.

As explained in Deliverable 2.1, in the risk assessment, three impact criteria, which are represented by eight impact indicators, were used. The effects of the indicators were evaluated with a five-class system. The five classes correspond to an increasing level of seriousness: ‘limited’, ‘significant’, ‘severe’, ‘very severe’ and ‘catastrophic’.

In the National Disaster Risk Assessment Report of Turkey (AFAD, 2019), two worst-case scenarios and two probable scenarios are considered (Table 2.22). Probable scenarios were developed by selecting a couple of the regions containing active faults. The worst-case scenarios were selected from areas referred to as seismic gaps, where the main fault segments have not generated earthquakes for a long time and there is a high probability of earthquakes in the future.

Table 2.22. List of earthquake scenarios used in the National Disaster Risk Assessment Report of Turkey (AFAD, 2019).

Disaster Type	Sub-hazard Type	Worst-case Scenario	Probable Scenario
Earthquake	Continental	Istanbul	Muğla
	Continental	Kahramanmaraş	Afyonkarahisar

Risk can be defined as a combination of impact and likelihood, and can be represented on a graph in which the two are plotted against each other. Such a representation of risk is different from the single-dimensional conventional representation, which takes the form of “Probability x Outcome”. Figure 2.10 shows the risk charting process. For all the evaluated scenarios, the impacts and likelihood were calculated, and the obtained values are shown on the risk assessment graph.

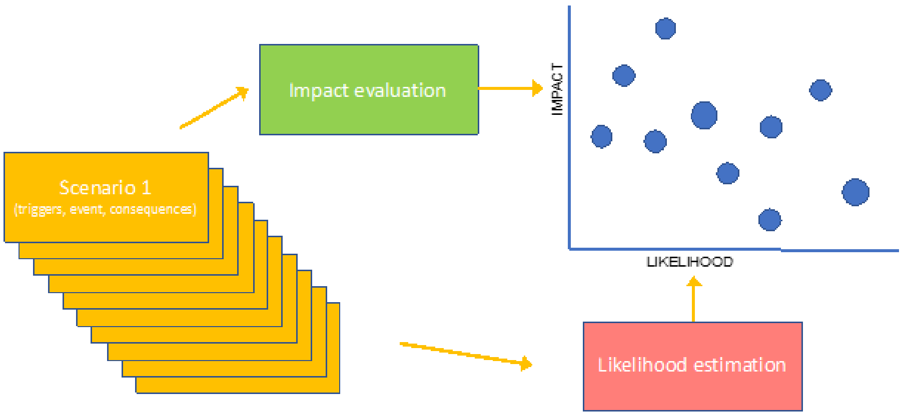


Figure 2.10: Risk Graph Development Process.

2.4.2 Flood risk assessment data

Turkey has started to implement and transpose the EU Floods Directive (2007/60/EC) and works for preparation of flood hazard maps, flood risk maps and flood risk management plans for river basins in Turkey in 2013.

Consequently, the implementation of Floods Directive in Turkey in a wider spatial scale has been started during the twinning project on Floods Directive and The Preparation of Flood Management Plans in 2013. Currently, the flood management plans have been finalized in 23 out of 25 basins and ongoing for 2 basins.

The Flood Risk Management Plans for the basins in Turkey have been prepared by undertaking the preliminary flood risk assessment:

- The preparation of the flood hazard (in a scale 1:5,000 or 1:1,000);
- The preparation of the flood risk maps (in a scale 1:5,000 or 1:1,000);
- The preparation of flood risk management plans (including risk management measures) (in a scale 1:1,000);
- Revision of existing Flood Warning System as Flood Forecasting and Early Warning System and extension of coverage to the basin scale.

The flood risk assessment contains information on the number of inhabitants potentially affected, the type of economic activity of the area potentially affected, the integrated pollution and prevention control (IPPC) installations as referred to in Directive 96/61/EC (European Union 1996), the potentially affected protected areas identified according to the EU Water Framework Directive (WFD), and other information such as sediments and contaminants. The maps will be updated every 6 years.

The data used for risk assessment is obtained from The General Directorate of State Hydraulic Works (DSI), The Ministry of Environment and Urbanization (MoEU), General Directorate of Meteorology, Metropolitan Municipalities and their Water and Sewage Administrations, Directorate of Disaster and Emergency (AFAD) and Other Local administrations.

Determination of required data and collection

Studies shall begin with data needs assessment based on existing data provided by DG Water Management and required data sets for preparation of PFRA in EU practices. A list of data set to be collected from the relevant stakeholders shall be prepared for the approval of the end recipient.

Data collection study covers gathering, organization and evaluation of all required data. These data shall cover at least:

- Negative effects of past floods on human health, environment, cultural heritage and economic activities;
- Topography, the route of streams and rivers, natural water retention areas, floodplains, soil groups, vegetation;
- General hydrological and geological characteristics of the basin;
- Existing manmade infrastructures, natural features to mitigate flooding impact;
- Land use information, population, location of settlement areas, economic activity areas, strategic structures, cultural heritage building and protected areas;
- Legal framework and existing administrative structures for preparation, prevention, and recovery phases.

Physical characteristics of basin and meteorological-hydrologic time series with sufficient length are gathered within the context of Flood Management Plan. The length and reliability of the data set which is used in statistical and modelling studies affect directly the results. For this reason, meteorological and hydrological data in basin, physical characteristics of basin; size, length, gradient, soil structure, land use, storage structures in basin, characteristics of these structures, rule curves of these structures and past operation results are procured sensitively from the related institutions and organizations. Historical flood events, alluvium areas, residential areas, efficiency of existing flood control structures, expected number of people affected from floods, and 1-D hydraulic model results are analyzed together to evaluate flood risk pre-assessment.

Multi-criteria decision-making model - the analytical hierarchy process for PFRA

Taking into consideration the results of data needs assessment, a methodology shall be selected in agreement with the End Recipient for assessment of past floods and possible future floods including the impacts of climate change on the occurrence of floods. The method adopted successfully at two separate projects, namely

Preparation of Flood Risk Management Plans for the Tigris Rivers and Western Blacksea Basins, suggested the following steps for continuation of this activity as described below.

Multi-Criteria Decision-Making (MCDM) method is used to compare and analyze the flood risk in a basin. A theory of tangible criteria measurement was proposed by Saaty (Saaty, T.L., 1980). The weight of the criteria is evaluated through pairwise comparison matrices. The method supports the decision-making process by quantifying alternative priorities for decision-makers. Therefore it is a powerful and flexible technique to support setting priorities (Figure 2.11).

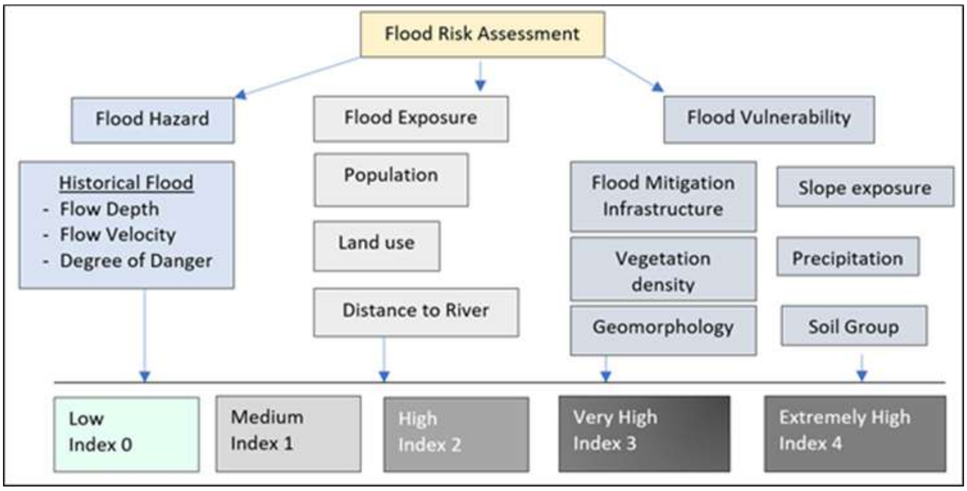


Figure 2.11: The hierarchy framework for flood risk assessment of a basin.

For PFRA, the significance of historic floods is assessed by assigning an index number (impact score) for each parameter based on the effects on human health, social and economic activity, environment and cultural heritage in the specific area. An impact score ranging from very low to a very high impact is allocated to each flood event to highlight the area historically prone to flooding. Similarly, population density, magnitude of economic and social activity, density of infrastructure, cultural heritage area and environmentally significant lands are assessed by assigning risk scores to quantify the vulnerability of the society against flood hazard. Inherent ambiguity in 'vulnerability term' in the risk analysis, the susceptibility of a community to the impact of hazards, is overcame by making impact (risk) score for an assessment area dimensionless. Then the matrix for a set of criteria is used to explore flooding impacts. By utilizing GIS software, the maps of the flood hazard and impact analysis are overlaid to obtain a quantitative risk map, which is also qualitative risk map of the area showing aggregated risk score, based on a matrix derived from the set of criteria.

The analysis will identify the methodology and procedure adopted in the PFRA and criteria set to estimate risk scores and consequently aggregated scores throughout the basins.

Catchment and district specific types and source of flood (i.e., fluvial or pluvial flooding, floods from artificial water bearing infrastructure): The historical floods will be classified and tabulated based on type and adverse consequences of future floods for human health, the environment, cultural heritage and economic activity. Although the focus of the assessment will be on fluvial floods (river floods), probability of flood arising from the failure of artificial water-bearing infrastructure (reservoirs gates and other structures) will be assessed if such flooding is prone to generate water-related damage for the country.

PFRA study shall be based on the information and assessments listed below, as minimum:

- Hydrography, topography, and land use;
- Floods that have occurred in the past and had significant adverse impacts on human health and life, the environment, cultural heritage and economic activity;
- Assessment of potential adverse consequences of floods that may occur in the future;
- Forecast of long term developments of settlements or agricultural purposes;
- Possible impacts of climate change on floods;
- All stream networks on urban areas, which have population over 100;
- Areas containing alluvial soils;
- Agricultural areas over 200 ha;
- Industrial areas.

Eight parameters, namely hydrological and geomorphological features of basin, vegetation density, slope of topography, historical events, dwelling density, existing flood mitigation infrastructure along with social and economic activity will be determined as evaluation criteria for flood risk management. Although these parameters are generally considered to be a mathematically continuous physical entity throughout the basins, gridded matrices of the parameters may give adequate representations of the distribution of these parameters within the basin. Hence the layer for each parameter with an assigned index number is produced to digitize the parameter throughout the basin. Then, these layers are to be combined in a GIS obtaining an Index number digital model which will be aggregated for each watershed to estimate the flood risk spatially. Finally, geomorphological, hydrological, and socio-economic data shall be integrated in a GIS framework using a multi-criteria decision tool called the Analytical Hierarchy Process (AHP) (Saaty, T.L., 1980) to generate a process-based flood risk map for the basin as the end product (Figure 2.12).

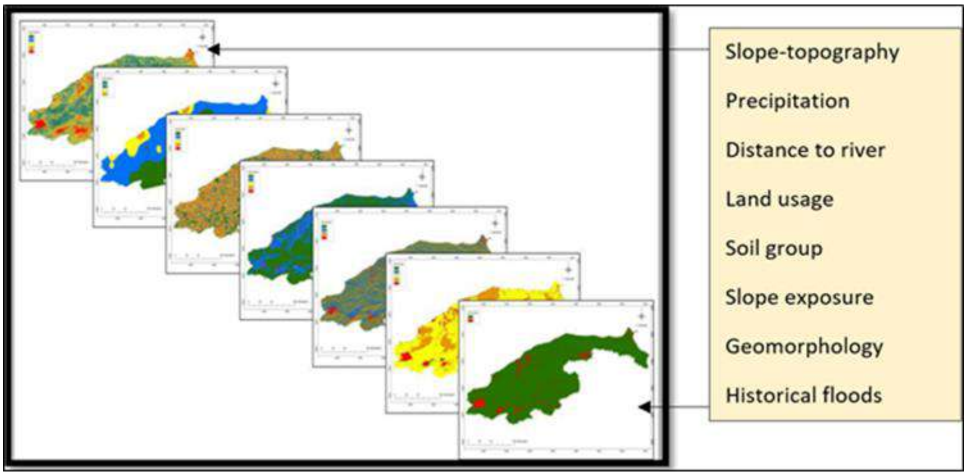


Figure 2.12: End Product with multi-criteria decision-making (MCDM) method: framework for flood risk assessment – Source Flood Risk management Plan for Batı Karadeniz.

The possible flood risk will be assessed through 1-D modelling of the selected river catchments, the river reaches covered by the Law No. 4373 on "Protection Against Flood and Inundation" published in the Official Gazette, No. 5310 on 21/1/1943, and the first, second and third highest ranks on the Strahler stream order, which are used to define the stream size based on a hierarchy of tributaries (Horton-Strahler method). Besides, areas with landslide risk that may cause flooding will also be determined. Flood risk areas shall be shown both on map and in list form that includes settlements, streams, agricultural, and industrial areas. The list shall include all assessed areas with their explanations why they are defined as under risk/not under risk.

2.4.2.1 Flood hazard assessment data

Flood hazard assessment in Turkey is done in line with the Floods Directive and follows the general probabilistic approach where the flood hazard classes are defined based on the hydrologic and hydraulic modelling. Flood hazard is assessed for 5-, 10-,50-, 100-, and 500-years flood return periods. The flood hazard maps should show the flood extent, water depth or water level as applicable, and, where appropriate, the flow velocity or relevant water flows. For flood hazard assessment;

(a) Topography: The topographic data used in flood hazard assessment is CORINE as land use data, surveys of stream channel cross sections as well as digital elevation data.

(b) Hydrology: Hydrographs are obtained with the Classical Method(NTFA, BTFA, Synthetic Methods) and Hydrological Model (Hec-HMS) within the scope of hydrology studies. In the light of data obtained from DSİ and MGM in basins, studies are carried out using streamgage stations and precipitation gage stations in basins.

(c) Hydraulics: Hydrological and hydraulic studies for particular areas using hydro-dynamical modelling software, generally combination of 1D/2D models (e.g. HEC-RAS, Mike Flood, SOBEK).

Table 2.23: Comparison of flood hazard assessment at national level (fluvial flooding).

Intensity parameter	Return periods (Qx)	Scenario considered	Spatial scale	Data type	Projection	Data accessibility	Source of each data layer
discharge (Q), water level [m], water velocity [m/s], product of water velocity and water depth	5 years, 10 years, 50 years, 100 years, 500 years	four classes: very high, high, medium, low	Flood hazard maps in 1: 1.000 scale (preferred) or 1:5000	vector, raster	ITRF96 TM 3	Legal framework (publicly available/restricted), data protection rules	Ministry of Environment and Urban, General Directorate of Meteorology, Directorate of Water Affairs

Definition and representation of flood hazard

As a result of 1-D hydrodynamic modelling studies; 2-D hydrodynamic modelling was done for the cities, the districts or the settlements which have population above 2,000 if Q_{500} flood discharge overflows the river bed. In addition to this, for the settlements with population above 100,000, 2-D hydrodynamic modelling was done considering Q_{1000} flood discharge if Q_{500} flood discharge overflows the river bed. Sensitive superimposed digital elevation model in the river bed and flood inundation area generated by combining digital elevation model for the settlements and cross-sections taken previously in the field is used in 2-D hydraulic modelling studies in basins. The flow of water is tried to be represented realistic as much as possible by adding the buildings in the region to the superimposed digital elevation model.

The flood hazard maps should show the flood extent, water depth or water level as applicable, and, where appropriate, the flow velocity or relevant water flows. For flood hazard assessment, there should be at least one cross-section which will represent the river bed in every 2,000 m and at least one cross-section in every 250 m.

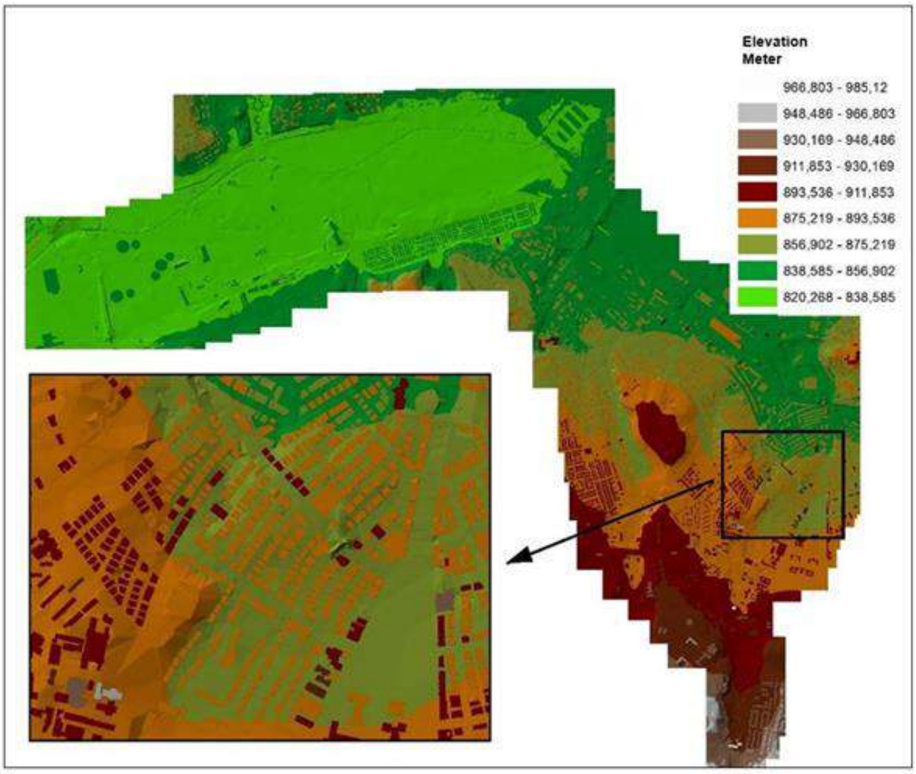


Figure 2.13: Digital elevation model.

Below, there is an example of floodwater depth maps and flood hazard maps for 500-years return period and flood hazard map for Kırşehir City Center District Creeks, which are critical in terms of probable flood events are shown (Figure 2.14).

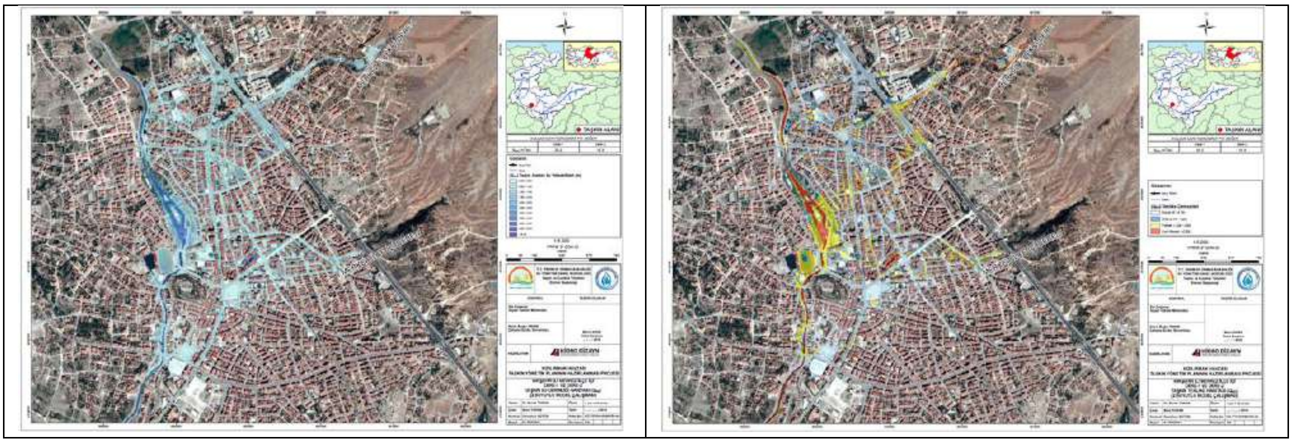


Figure 2.14: Kırşehir City Center District Creek-1 and Creek-2 floodwater depth map (Q500) (left) and flood hazard map (Q500) (right).

2.4.2.2 Flood vulnerability/exposure assessment data

The flood exposure and vulnerability for the flood risk assessment is evaluated with the analysis of the potential negative impacts of flood based on freely available spatial databases which are people, environment, cultural heritage and economic activities (Table 2.24).

Table 2.24: Infrastructure data for evaluation of flood vulnerability and exposure.

Essential infrastructure Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood.
Highly vulnerable Police stations, ambulance stations and fire stations and command centres and telecommunications installations required to be operational during flooding. Emergency dispersal points. Schools, worship buildings, kindergartens, age care and nursing homes. Basement dwellings. Caravans, mobile homes and park homes intended for permanent residential use. Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as "essential infrastructure")

Table 2.24 continued.

More vulnerable
Hospitals.
Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels, worship buildings, kindergartens, age care and nursing homes.
Buildings used for dwelling houses, student halls of residence.
Non–residential uses for health services, nurseries and educational establishments.
Landfill and sites used for waste management facilities for hazardous waste.
Sites used for holiday and camping, subject to a specific warning and evacuation plan.
Less vulnerable
Buildings used for shops, financial, professional and other services.

2.4.2.3 Data adaptations and modifications for flood risk assessment

Flood risk evaluation is the analysis of the most probable negative effects of the flood. The main objective of the evaluation of the flood risk and flood damage is providing safety of the people, supporting flood prevention decisions to protect the environment, preventing flood damage in commercial and other economic activities at public and private sector infrastructure. Transition from the flood hazard to probable risk (hazard and consequences) enables determination of the most risky areas and necessary precautions, which should be taken.

The listed factors are chosen to evaluate flood risk:

- Affected population from the flood;
- Building and content damage due to flood;
- Affected strategic structures and infrastructure facilities;
- Total flood effects.

By using "Floodwater Depth Maps" for three return periods Q_{50}, Q_{100}, and Q_{500} in a flood location, nine maps are generated for flood risk assessment: affected population maps (3 maps), economic flood damage maps (3 maps), flood risk maps (superimposed effect) (3 maps). Example maps of Kırşehir City Center District Creeks for 500-years return period floods is given in Figure 2.15.

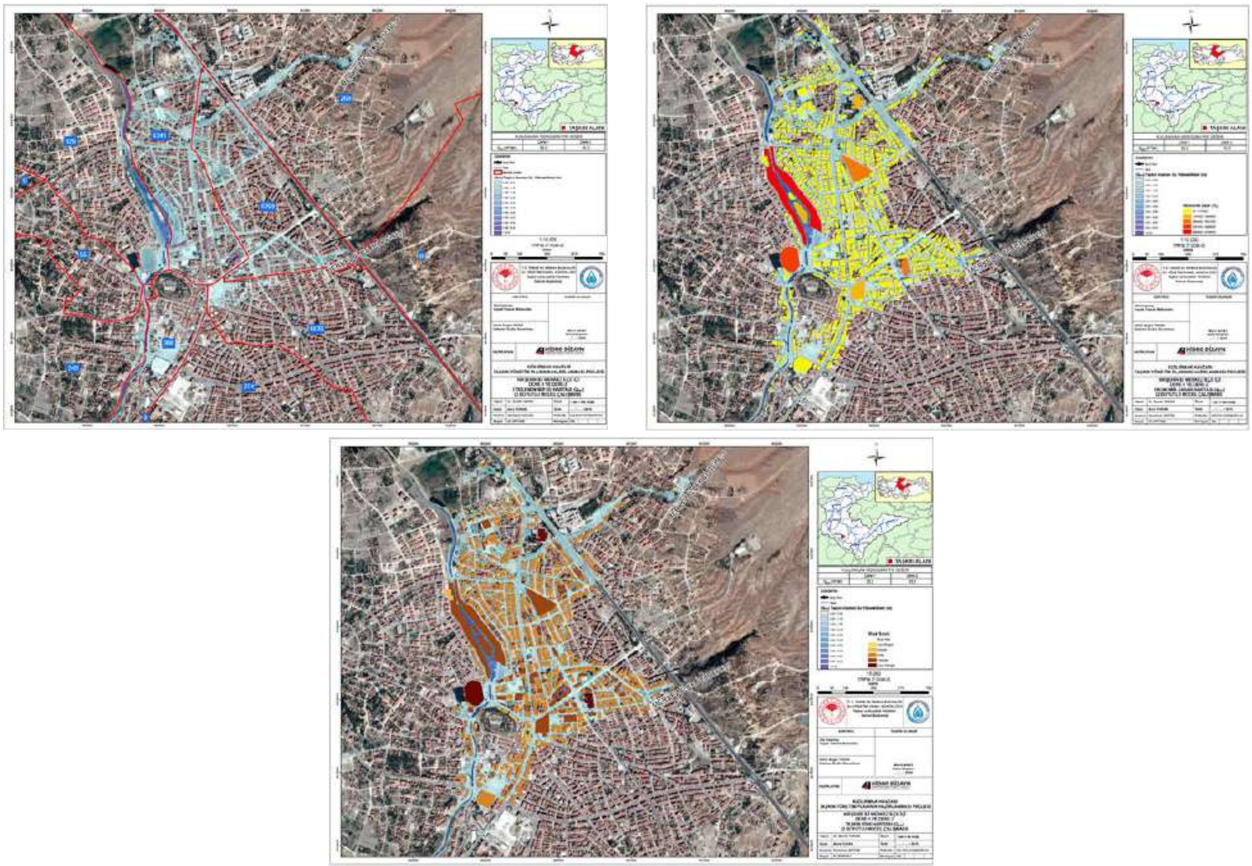


Figure 2.15: Kırşehir City Center District Creek-1 and Creek-2 affected population map (Q_{500}) (left above), economic damage map (Q_{500}) (right above), and flood risk map (Q_{500}) (below).

Response-capacity analysis

The main objective of Flood Risk Management Plan is preventing flood hazard in flood exposed regions and necessity of expensive flood control structures in advance in the long term. Reducing the probable loss of life and property and reducing necessity of emergency response significantly by the public during the flood are aimed in the short and medium term. Protection and prevention works might reduce this necessity before floods but it cannot be removed completely. For this reason, response-capacity analysis should be improved continuously for the probable floods by carrying out the actions summarized in Table 2.25, while flood risk should be reduced and prevented at the same time.

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Project co-funded by the European Union Civil Protection

Strategic facilities, environmental damage and economic activities maps were prepared considering 50, 100 and 500-year return periods flood to take flood precautions in every region. Furthermore, evacuation plans were prepared based on 500-year return period flood. Hence, probable affected strategic facilities, environmental elements and economic activities were determined and an evacuation plan was prepared (Figure 2.16). The generated maps for Kırşehir City Merkez District Creeks are given in the following figures. Mosques, health and education facilities are given in strategic facilities maps. Parks, forests, wastewater treatment plants, etc., are given in magnitude of environmental damage maps. Roads, commercial facilities, industrial buildings, gas stations, etc., are given in economic activities maps.

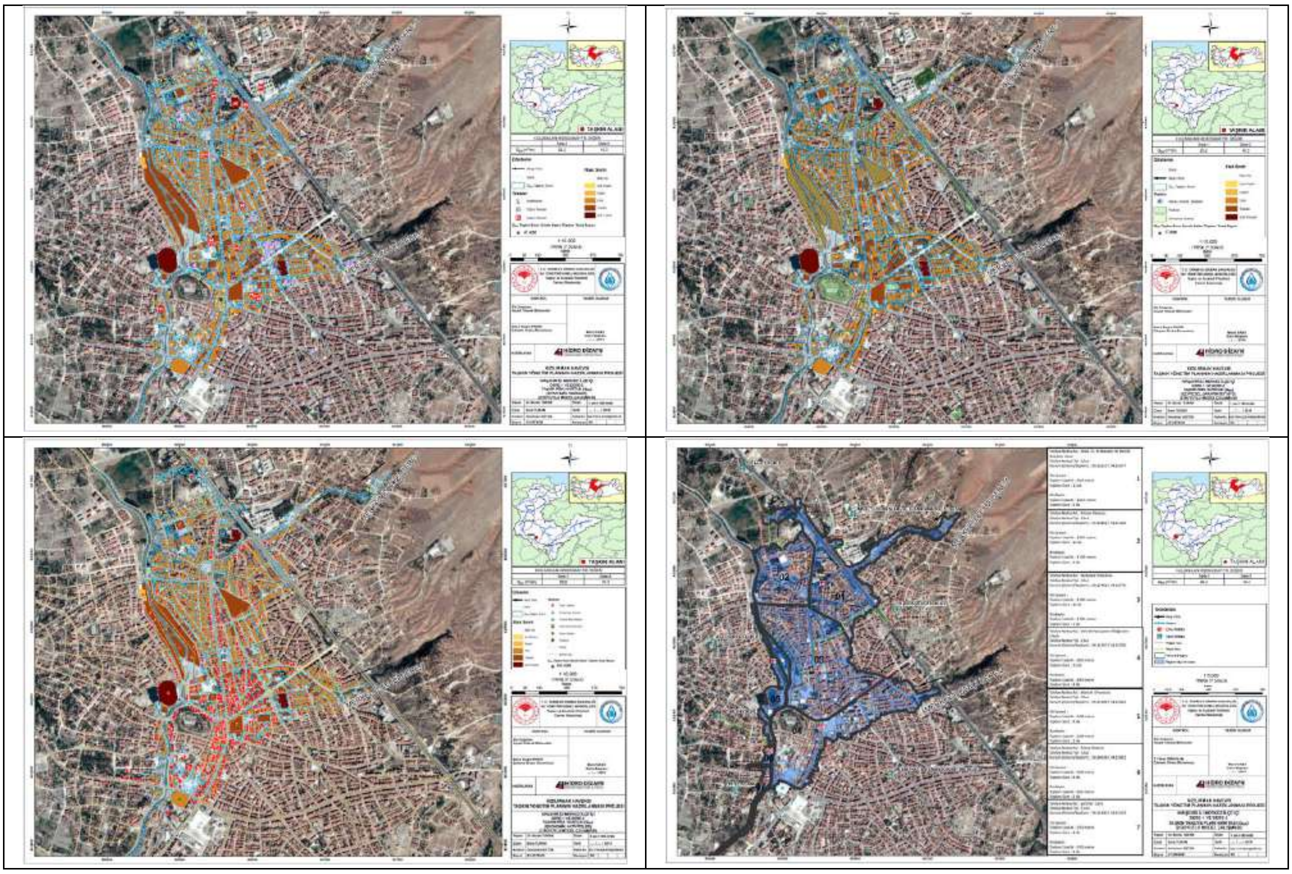

Figure 2.16: Kırşehir City Center District Creek-1 and Creek-2 Q500 strategic facilities map (left above) and environmental damage map (right above), economic activities map (left below), and evacuation plan map (right below).

Table 2.25: Classifications and Criterion Used in Preparation and Evaluation of Flood Response-Capacity Analysis Maps.

CLASSIFICATION	Sub-classification Maps	Mapping and Evaluation Parameters
CAPACITY (coping with response and floods)	1. Flood Control Structures and Early Warning	Existing flood control structures, flood control structures under construction, Hydro-meteorological observation network, Siren, Communication and local media tools, Sandbag preparation areas
	2. Evacuation	Evacuation zones, Open and closed assembly areas for people and animals, Emergency case transportation
	3. Emergency Situation Facilities and Services	Hospitals, Schools, Fire stations, Police stations, Kiln, Dry warehouses, Cold storage warehouses, Some public buildings, Stadium etc. and main roads, The intersection station of different transportation types, Bridges, Tunnels, Energy transfer stations, Water tanks
	4. Wreck and Recycling Areas	Abandoned mines and quarries etc., the locations which are suitable for wreck, waste storage and recycling works

Prioritization of areas at flood risk

Application of hazard description and analysis aims to specify and record the hazards which have potential causing deaths and physical injuries in a detailed and systematic way. In addition to this, hazard identification and analysis underlies specification of applied precautions.

5 x 5 matrix diagram (L-type matrix) is especially used to evaluate cause and effect relationship. This method is ideal due to its simplicity for the analysts who are obliged to make risk analysis alone. However, it is not enough for the works which includes different processes or different flow diagrams. Evaluation and measurement of probability of an event and consequences of that event are made primarily with this method. Risk score can be calculated by multiplying probability and degree of impact. Flood event is mentioned as “threat” here.

Table 2.26: Hazard Frequency/Return Period Classes.

Description	Frequency (Event/Year)
Very high	% 1.0 < F
High	% 0.5 < F ≤ % 1.0 (1 in 100 years)
Medium	% 0.2 < F ≤ % 0.5 (1 in 200 years)
Low	% 0.1 < F ≤ % 0.2 (1 in 500 years)
Very low	F ≤ % 0.1 (1 in 1,000 years)

Table 2.27: Flood Impacts and Risk Indicators under Different Risk Categories

CATEGORY	FLOOD IMPACT				
	VERY LOW (1–2)	**LOW (3–6)**	**MEDIUM (7–9)**	**HIGH (10–19)**	**VERY HIGH (20–25)**
HEALTH (Affected Number of People, Health, Social/Societal etc. Critical Facility Number)	Number of people ≤ 5,000 or Social Facility (number) ≤ 40 or Critical facility (number) ≤ 20 or Affected population density ≤ 40	5.001 ≤ Number of people ≤ 10,000 or 41 ≤ Social facility (number) ≤ 100 or 21 ≤ Critical facility (number) ≤ 50 or 41 ≤ Affected population density≤ 100	10.001 ≤ Number of people ≤ 15.000 or 101 ≤ Social facility (number) ≤ 150 or 51 ≤ Critical facility (number) ≤ 75 or 101 ≤ Affected population density≤ 150	15.001 ≤ Number of people ≤ 30.000 or 151 ≤ Social facility (number) ≤ 300 or 75 ≤ Critical facility (number) ≤ 150 or 151 ≤ Affected population density≤ 300	Number of people ≥ 30.001 or Social Facility (number) ≥ 301 or Critical facility (number) ≥ 151 or Affected population density ≥ 301
ENVIRON-MENT (Affected Protected & Green Areas and Number of Pollution Sources)	Protected area (Ha) ≤ 80 or Green area (Ha) ≤ 40 or Pollution source (number) ≤ 40	81 ≤ Protected area (Ha) ≤ 200 or 41 ≤ Green area (Ha) ≤ 100 or 41 ≤ Pollution source (number) ≤ 100	201 ≤ Protected area (Ha) ≤ 300 or 101 ≤ Green area (Ha) ≤ 150 or 101 ≤ Pollution source (number) ≤ 150	301 ≤ Protected area (Ha) ≤ 600 or 151 ≤ Green area (Ha) ≤ 300 or 151 ≤ Pollution source (number) ≤ 300	Protected area (Ha)≥ 601 or Green area (Ha) ≥ 301 or Pollution source (number) ≥ 301
CULTURAL HERITAGE (Affected Number of Cultural Heritage)	Cultural heritage (number) ≤ 1	2 ≤ Cultural heritage (number) ≤ 3	4 ≤ Cultural heritage (number) ≤ 5	6 ≤ Cultural heritage (number) ≤ 9	Cultural heritage (number) ≥ 10

Table 2.27 continued.

CATEGORY	FLOOD IMPACT				
	VERY LOW (1–2)	**LOW (3–6)**	**MEDIUM (7–9)**	**HIGH (10–19)**	**VERY HIGH (20–25)**
ECONOMY (Affected arable land, Road Length, real estate etc., The Number of Commercial Elements)	Real estate (number) $\leq$ 750 or Arable land(Ha) $\leq$ 90 or Commercial element (number) $\leq$ 90 or Road length (km)$\leq$ 20	751 $\leq$ Real estate(number) $\leq$ 1,750 or 91 $\leq$ Arable land (Ha) $\leq$ 180 or 91 $\leq$ Commercial element (number) $\leq$ 180 or 21 $\leq$ Road length(km) $\leq$ 50	1,751 $\leq$ Real estate (number) $\leq$ 2,500 or 181 $\leq$ Arable land (Ha) $\leq$ 270 or 181 $\leq$ Commercial element (number) $\leq$ 270 or 51 $\leq$ Road length(km) $\leq$ 75	2,501 $\leq$ Real estate (number) $\leq$ 5,000 or 271 $\leq$ Arable land (Ha) $\leq$ 600 or 271 $\leq$ Commercial element (number) $\leq$ 600 or 76 $\leq$ Road length(km) $\leq$ 150	Real estate (number) $\geq$ 5,001 or Arable Land (Ha) $\geq$ 601 Or Commercial element (number) $\geq$ 601 or Road length (km)$\geq$ 151

Risk scoring is related to combination of flood impact and probability of flood hazard (Q50, Q100 and Q500). Decision matrix, one of the risk evaluation methods, might be generated in this step. Unacceptable (unmanageable) event, emergency case or disaster management of high risks must be reduced to acceptable level to manage them.

Flood risk areas shall be shown both on map and in list form that include settlements, streams, agricultural, and industrial areas. The list shall include all assessed areas with their explanations why they are defined as under risk/not under risk.

2.5 Montenegro

2.5.1 Seismic risk assessment data

In Montenegro, a deterministic scenario approach is used for seismic risk assessment. Two scenario earthquakes are considered: 1) Scenario 1 - most likely adverse event (earthquake with a return period of 95 years corresponding to a probability of exceedance of 10% in 10 years) and 2) Scenario 2 – the event with the worst possible consequences (earthquake with a return period of 475 years corresponding to a probability of exceedance of 10% in 50 years). The overall seismic risk is expressed descriptively as small, medium, high or very high. The level of risk is obtained from the consequence level and the likelihood level. The consequence level is obtained as the mean of three values, which indicate the impact on (i) people, (ii) economy and environment, and (iii) society. The seismic hazard maps are developed by Sector for Seismology of Hydrometeorogical and Seismological Institute of Montenegro (ZHMS) (Glavatovic, 2015). These maps are accessible in MEST EN 1998-1/NA (2015) and at ZHMS by demand. Since systematized data on the exposure model for buildings in Montenegro are not available, SERA exposure model for Montenegro is used (Crowley et al., 2020a). SERA model is based on expert judgement and available census data of Montenegro from 2011. Information for vulnerability classification exists in census database 2011 (year of construction, the number of dwellings, dwelling areas and population number). Census database is provided by MONSTAT (Montenegrin national institute of statistics) and it is publicly accessible at municipality levels. The vulnerability model for residential buildings is based on EMS-98 methodology: buildings are divided into six vulnerability classes from A to F.

2.5.1.1 Seismic hazard assessment data

The seismic hazard in Montenegro is obtained by the probabilistic seismic hazard analysis (PSHA). The results of the PSHA model in terms of maps showing the value of peak ground acceleration (PGA) corresponding to two different return periods 95 and 475 years. The seismic hazard maps are obtained for rock. Seismic intensity on the terrain surface is calculated by multiplying the values at the rock by an amplification coefficient. There is no publicly accessible soil amplification map. Soil classes and amplification parameters are defined for every location by separate geological elaborate on demand. Input parameters and results of the hazard assessment are summarized in Tables 2.28 and 2.29. The official seismic hazard maps of Montenegro on rock for return periods of 95 and 475 years are accessible in MEST EN 1998-1/NA (2015) and at ZHMS by demand. Other data are obtained from the Sector for Seismology of Hydrometeorogical and Seismological Institute of Montenegro (ZHMS).

Table 2.28: Data available for seismic hazard assessment.

Seismotectonic model	Regional ground-motion model	Soil effects	Possible types of hazard analysis	Data source	Data accessibility
From the official seismic hazard model in Montenegro made by ZHMS	From the official seismic hazard model in Montenegro made by ZHMS	There is no local soil amplification map. Soil classes and amplification parameters are defined for every location by separate geological elaborate on demand	Return period-based (for any return period), scenario-based (for any magnitude and hypotrentral location)	Hydrometeorogical and seismological Institute of Montenegro - Sector for Seismology (ZHMS)	Accessible in MEST EN 1998-1/NA (2015) and at ZHMS by demand

Table 2.29: Comparison of seismic hazard assessment at national level (results of past analysis).

Type of hazard analysis	Intensity parameter	Return periods	Spatial scale	Soil effects	Data source	Data accessibility
Return period-based	PGA, EMS-98 intensity	95 and 475 years	Entire country	Distribution of seismic intensity on the terrain surface is calculated by multiplying the values at the rock by amplification coefficient.	Hydrometeorogical and seismological Institute of Montenegro - Sector for Seismology (ZHMS)	Accessible in MEST EN 1998-1/NA (2015) and at ZHMS by demand

2.5.1.2 Seismic vulnerability/exposure assessment data and the availability of impact indicators

In Table 2.30, the available results of the existing vulnerability analyses and exposure data for buildings are summarized. In addition, the NRA of Montenegro considers exposure and vulnerability model for traffic infrastructure (here not presented in the table). The impact indicators that can be estimated from the existing vulnerability models are: the number and net floor area of collapsed dwellings and unusable dwellings, the number of homeless people, injured people and fatalities, the length of the damaged roads, direct economic losses, and indirect economic losses. The exposure data about dwellings and population (year of construction, the number of dwellings, dwelling areas and population number) were obtained from census database provided by MONSTAT (Montenegrin national institute of statistics). Data are publicly accessible and aggregated at the municipality level.

Table 2.30: Parameters of the existing vulnerability analyses and exposure data.

Vulnerability classes	Damage scale	Intensity measure (IM)	Available exposure data type (buildings, dwellings, population)	Data for buildings/dwellings	Exposure data spatial scale
Vulnerability model is based on EMS-98 methodology: six vulnerability classes (A to F).	EMS-98	EMS-98 intensity	Buildings (not publicly available), number and distribution of dwellings and population (publicly available)	Dwellings information: location, year of construction, net floor area, Building data are not available.	Dwellings information aggregated from Cenzus data, entire country included and data are available at municipality level.

2.5.1.3 Data adaptations and modifications for seismic risk assessment

The National Risk Assessment for Montenegro (2021) is based on a deterministic scenario approach for seismic risk estimation. Two scenario earthquakes are considered for two return periods. Since systematized data on the exposure model for buildings in Montenegro are not available, SERA exposure model for Montenegro is used (Crowley et al. 2020). The highest uncertainties in NRA are related to the used exposure model since it is based on assumptions necessary for transforming census dwelling data to building data. Buildings are divided into six vulnerability classes from A to F and for each vulnerability class, the occurrence rates of the designated damage states (D1–D5) are specified for each degree of the EMS-98 intensity. The classification of buildings to vulnerability classes is done based on expert judgement and available census data:

year of construction. The risk is expressed in terms of four risk classes: low, moderate, high and very high depending on the calculated impacts on people, economy and environment, and society. Risk is calculated at the national level. Risk information at the municipality level and risk maps are not available. Implementation of the seismic risk assessment data into the Administration of the Montenegro is given in risk treatment (in NRA) with specific activities and measures that need to be taken for seismic risk reduction in future.

2.5.2 Flood risk assessment data

EU Directive 2007/60/EC on flood risk assessment and management has been fully transposed into the Montenegrin legislative system through the Law on Waters and the Decree on the detailed content of the preliminary flood risk assessment and the flood risk management plan. The current legislation in this part anticipates the preparation of a preliminary flood risk assessment, identification of areas of potential significant flood risk, development of risk maps and flood risk maps for areas significantly affected by floods based on three return periods, i.e. floods of low- (T = 500 years), medium- (T = about 100 years) and high probability (T = 10 years) and development of flood risk management plans for areas significantly affected by floods.

Bearing in mind the fact that the implementation of the Floods Directive is at an early stage, that a lack of capacity (organizational, personnel and technical) has been noticed, that it is necessary to secure public participation and information, collect missing data and that the Water Information System has not yet been established, Montenegro requested a transitional period for the full implementation of the Floods Directive, in the part related to the development of Flood Risk Management Plans, until the end of 2024.

2.5.2.1 Flood hazard assessment data

a) Input datasets used for flood hazard assessment:

(a) Topography: There is a database with digital maps of the entire Montenegrin territory (DEM 5 x 5m), which could be used for flood studies. For site-specific flood studies (which are done as needed for individual case flood analyses) maps of adequate scale have been designed. For example, this was the case for the needs of the study “Adaptation to Climate Change in Transboundary Flood Risk Management in the Western Balkans” - a project implemented by GIZ - German Gesellschaft für internationale Zusammenarbeit.

(b) Hydrology: The Institute of Hydrometeorology and Seismology of Montenegro, in accordance with the Law on Hydrometeorological Affairs, is a center for observation, measurement, collection, processing, analysis and dissemination of hydrological data and information. The Institute provides hydrological data to all organizations in charge of flood defense, sends data for international exchange, based on international conventions and on signed cooperation, as well as the media. At the WEB presentation of the Institute (http://www.meteo.co.me/), hydrological data from all stations from the observation system are available to users. Automatic stations record water levels every 15 minutes, and they can be assessed through the website of the Institute.

(c) Hydraulics: Hydraulic studies are done for particular areas (small parts) using hydrodynamical modeling software, generally a combination of 1D/2D models (e.g. Hec-Ras, Mike Flood). For example, "The study of regulation of Skadar lake and Bojana river water regime" was done in 2015. using Mike Flood model. However, the results of this study were not applied for preparation of the flood risk assessment.

Table 2.31: Comparison of flood hazard assessment at national level (fluvial flooding).There is no database regarding land use classification. For some projects CORINE LAND COVER databases were used (https://land.copernicus.eu/pan-european/corine-land-cover).

Intensity parameter	Return periods (Qx)	Scenario considered	Spatial scale	Data type	Projection	Data accessibility	Source of each data layer
discharge (Q), water level [m], water velocity [m/s]	10 years, 100 years, 500 years	Three hazard classes: high (10 years), medium (100 years), low (500 years)	Flood hazard maps in 1:5000 scale or larger scale	Digital and analog	EPSG:3857	Water administration is in charge of Flood risk assessment. Risk maps will be publicly available.	Water administration, Institute of hydrometeorology and seismology, Ministry of agriculture, Forestry and Water management, Ministry of the Interior

Representation and definition of flood hazard

The Water Directorate is responsible for the development of hazard maps and their implementation. The method of preparing maps is defined by the "Rule book on the detailed content of the preliminary flood risk assessment and the flood risk management plan". Flood hazard maps will be prepared in a scale of 1: 5,000 or higher, in electronic and analog form.

Flood hazard maps will be developed for:

- low probability floods,
- floods of medium probability, and
- floods of high probability, as needed.

For floods caused by seawater in coastal areas, where there is an adequate level of flood protection, as well as for areas where floods occur due to rising groundwater levels, flood hazard maps will be made only for low probability floods.

Flood hazard maps will be developed on the basis of geographical and geological characteristics of the area, hydrological data and characteristics of watercourses, taking into account:

- natural and anthropogenic factors of watercourses and their catchments,
- historical and archival data on floods in the past,
- studies, research and analysis of flood phenomena,
- meteorological and hydrological data,
- data on land use, and
- other data and estimates as needed.

2.5.2.2 Flood vulnerability/exposure assessment data

The Water Information System in Montenegro has not yet been established, but the available data are in most cases public (located in the competent ministries or local governments). Data on the number of endangered residents were obtained based on the data collected from the field. The protection and rescue system in Montenegro has access to data on human and material resources in certain areas.

The lack of systematized data on flood events, causes and damages make it difficult to review them historically. The analysis of the occurrence of floods on the territory of Montenegro, showed that the available data on flood events before 2010 are either incomplete or do not exist at all. For that reason, the comment on the historical floods until 2010, had to be reduced only to the analysis of the hydrological situation of the time period when the flood occurred. The result is represented by the return periods of the water level during the flood event. Data from the year 2005 can be found on the website http://www.desinventar.net, regarding the floods in Montenegro. However, on this site, some events are described based on information from the media.

Impact indicators are defined on the basis of available data. Impact indicators/elements for describing the exposure:

- casualties,
- severely injured/ hospitalized/ threatened,
- endangered people basic needs,
- number of people to be evacuated,
- total economic impact,
- environmental impact,
- disrupted everyday life,
- loss of cultural heritage.

Descriptors of the exposure elements related to impact indicators are as follows:

- casualties: number of fatal outcomes

- severely injured/hospitalized/threatened: water pollution; poor sanitary and hygienic conditions may lead to epidemic outbreak; overflowing cesspits may lead to germ infestation,
- endangered people basic needs: employees could not go to work, children to schools and kindergartens, inability to receive health care etc.,
- number of people to be evacuated: number of interventions carried out by civil protction service
- total economic impact: damage to individual properties, devastation of agricultural land, damage to family houses etc.,
- environmental impact: increase of water levels in rivers and groundwater which leads to their pollution due to wastewater spills, removal and damage of agricultural land,
- disrupted everyday life: interruptions in water supply, interruptions and difficult functioning of traffic infrastructure etc.,
- loss of cultural heritage.

2.5.2.3 Data adaptations and modifications for flood risk assessment

In The National Disaster Risk Assessment for Montenegro (under development in 2021) the level of risk was analyzed for each scenario individually, as described below.

The combination of the obtained return period for the observed scenario and the consequences for a certain risk indicator (consequences for human life and health, consequences for the economy, consequences for social stability-critical infrastructure and consequences for social stability-institutions of public importance) for an individual risk indicator. Superposition of these matrices yielded a summary risk matrix for a particular scenario. The risk matrix identifies 4 levels of risk:

- very high,
- high,
- moderate, and
- low.

According to "Rule book on the detailed content of the preliminary flood risk assessment and the flood risk management plan" risk maps should be prepared for:

- low probability floods;
- floods of medium probability; and
- floods of high probability, as needed.

Flood risk maps are made on the basis of data and estimates of the harmful effects of floods on human health, the environment, cultural heritage, and economic activities.

Flood risk maps will be made in a scale of 1: 5,000 in electronic and analog form. Flood risk maps should also be developed for areas that are not significantly affected by floods.

3 REVIEW OF EXISTING STUDIES ON RISK ASSESSMENT IN CROSS-BORDER AREAS

The literature review on existing studies focusing on risk assessment in cross-border areas provides a significantly higher number of examples concerning flood risk assessment with respect to the ones dealing with seismic risk. This is not surprising, since the flood risk is associated with a phenomenon that has intrinsically a higher potential for interaction across the borders. Indeed, since floods are basin-wide phenomena, they do not respect borders, whether national, regional, local or institutional (FLAPP, 2007). A classic example of cross-country interaction for flood risk, when water resources are shared by two or more countries, is the influence that measures upstream in country A (e.g. mitigation actions by the construction of an overflow channel) can have downstream in country B. Conversely, earthquake mitigation policies or retrofit actions performed on the building stock in a country do not have a direct influence on the seismic response of buildings in a neighbouring country. Nevertheless, also for the case of seismic risk, it is important to share the same approach for risk assessment, especially to enhance the prevention and preparedness through a shared understanding and knowledge of the potential earthquake effects in transboundary areas or with the scope to develop a cross border approach of seismic risk management.

This section reports on existing studies and projects dealing with flood or seismic risk assessment in cross-border areas, evidencing the (border) areas involved, briefly describing the methodology and evidencing their limitations and/or relevance with respect to the needs of the BORIS project. The section does not pretend to be exhaustive, but reports some examples with the scope to highlight the type of existing studies and prospected solutions that could be found for the flood and seismic risk.

Concerning Floods, an exhaustive report dealing with relevant issues on flood mapping and analysis is represented by Excimap (2007) “Handbook on good practices for flood mapping in Europe”. In addition to a thorough analysis on the use of flood maps, including flood hazard maps, risk maps, dissemination activities etc., the report highlights the benefits of using transboundary risk maps, in particular:

- Production of one single flood map can be more cost-efficient than producing separate maps;
- Common flood maps can facilitate effective cooperation in emergency and calamity management across borders;
- Transboundary flood maps can provide a common basis for an integrated cross-border approach of flood risk management, spatial planning and nature conservation and development;
- The process of developing a common transboundary flood map may strengthen trans-national cooperation and exchange between responsible authorities and may help to increase mutual confidence.

Moreover, Excimap (2007) provides technical and operational recommendations for successful transboundary flood mapping. Some of such recommendations are resumed in Table A1 in Appendix A.

In the “Joint approach to cross-border flood management” prepared by FLAPP (Flood Awareness and Prevention Policy in border areas) project (2007), a series of practical solutions improving effective cooperation in border regions are reported, and general good-practice indications can be inferred (see Table A1).

Other interesting cases and studies dealing with flood assessment in transboundary areas are reported in Table A1, specifically for the Italy-Slovenia border (e.g. KULTUrisk) and Albania, Kosovo, Macedonia, Montenegro.

As previously observed, there are fewer examples dealing with transboundary seismic risk assessment, while it is easier to find examples of projects dealing with seismic risk management, more focused on improving the capacity for institutional cooperation, response coordination or training of first responders (see, for example, project CROSSIT SAFER in Table A1) or more broadly oriented to enhance risk awareness and knowledge in involved communities (see, for example, RISVAL (ALCOTRA) in Table A1). Although it is not specifically focused on seismic risk, it is worth mentioning also project HARMO-DATA (see Table A1), which deals with territorial data harmonization cross-border; being specifically developed at the Italy-Slovenia border, it could be useful for the BORIS project if its results are made available.

Considering projects and studies oriented to improve seismic risk assessment in cross-border areas, the SiSPyr project was mainly aimed at realizing a common seismic data acquisition system at the Spain-France cross-border along Pyrenee. This allowed to increase the exchange of seismological data between Spain, France and Andorra and to create a transboundary seismic informative system to have a homogeneous and shared view of seismicity in the Pyrenee area. As a follow-up of SiSPyr, the POCRISC project had the main aim to promote common culture for seismic risk understanding in the Pyrenee; this objective was achieved through the development of i) tool for quasi-realtime damage assessment at municipality scale, ii) smartphone application to evaluate vulnerability and post-seismic damage for crisis management; iii) guideline on good practice for seismic vulnerability reduction, destined to engineers and practitioners. The buildings vulnerability towards damage assessment was evaluated by using EMS98 based approach (e.g. RISK-UE). However, this type of macroseismic model may be inadequate, considering the availability of more refined vulnerability models specifically developed for each country and for the scope of realistic impact assessment for civil protection purposes. In Monfort et al. (2012), buildings seismic damage scenario in a France-Spain cross-border area are built; as for POCRISC, RISK-UE model can be considered not adequate if more refined models reflecting local buildings vulnerability could be employed. Nevertheless, this study discusses interesting aspects concerning differences in building typologies and vulnerability cross-border.

4 IDENTIFICATION OF OPPORTUNITIES, LIMITATIONS AND GAPS FOR DATA INTEGRATION AND HARMONISATION

4.1 Seismic risk assessment data

In most countries considered in this deliverable, seismic hazard assessment was performed using official seismic hazard models. In Slovenia, however, the official hazard model was combined with the more recent SHARE seismotectonic model (Giardini et al., 2014, Woessner et al. 2015). Seismic hazard assessment data is generally publicly-accessible with some exceptions, where data is available on-demand, e.g., Austria, Slovenia and Montenegro. Seismic hazard models cover the entire territory of the partner countries. However, the mesh of the grid for which the hazard values are calculated differs. For example, a 5 x 5 km mesh isis used in Italy and Slovenia, while a spacing of 0.1° x 0.1° in latitude and longitude is considered in Turkey. Since the SHARE model covers the whole European territory, including Turkey, and allows to calculate seismic hazard for any coordinate, it would be a sensible choice for a cross-border analysis.

The return period-based hazard assessment is possible in all countries, while the scenario-based seismic hazard assessment is not considered only in Austria. Although some countries (e.g. Montenegro and Turkey) consider more than one intensity measure (i.e. ground motion parameter), PGA is the only one used in all the partner countries and is therefore a suitable candidate for cross-border analysis. Several, if not all, return periods are considered in many countries; however, only a 475-year return period is common to all partners. This problem could also be solved by using the SHARE model, since the latter allows to calculate the seismic hazard for any return period, which is especially important in the case of time-based risk assessment. As the seismic hazard is calculated by using uniform ground-motion-prediction equations adopted by each state according to their dominating geology, a unified cross-border hazard map is considered a very special task.

Soil effects are considered in Italy via an amplification map containing Vs30 values, which allows soil effects to be estimated in each municipality or census point. Similarly, a Vs30 database is available in Turkey. However, local Vs30 maps are not available in all partner countries. For example, in Slovenia, soil classes at locations of buildings were estimated based on the known geological characteristics, but the Vs30 values were not determined. Similarly, only soil classes were identified for some locations in Montenegro, while local soil classes have not been estimated in Austria. Defining more specific Vs30 maps should therefore be the focus of future research in order to provide more accurate results. In this project, however, soil effects should be considered at least approximately. The Vs30 values could be estimated based on the geological characteristics, or by using a global Vs30 map (e.g. Worden and Heath, 2019).

The definition of the fragility of buildings across the partner countries also differs. In Slovenia, for example, the fragility curves are defined at the level of building typologies. On the other hand, in Italy and Montenegro, the building typologies are grouped into vulnerability classes, and the fragility curves are defined for each vulnerability class. In Turkey, fragility curves that are average for all buildings are considered because the available data includes only the number of buildings. However, in Austria, no fragility curves of buildings are currently available at a nationwide basis. Another difference can be found in the number of building typologies, which is due the differences in the building stock and also due to the differences in the building data available in the risk assessment. Furthermore, the intensity measure used in the definition of the fragility curves also varies. Peak ground acceleration is used as the intensity measure in Italy, Slovenia and Austria. Turkey considers more than one intensity measure, i.e. seismic intensity and spectral displacement, in current analyses at the national level. Montenegro, however, uses the EMS-98 intensity. In the cross-border risk assessment, it would make sense to make an attempt to unify the building typologies, but only to a reasonable extent; in some cases, the building typologies in bordering countries cannot be unified because of different design codes and/or construction practices used on different sides of the border. For this same reason, it would be sensible to harmonize the fragility curves but not unify them. This means that the fragility curves of buildings from countries considered in a cross-border seismic risk assessment would be defined at the same level (building typology level or vulnerability class level) and for the same intensity measure, while allowing the differences in the fragility curves of buildings with same basic characteristics (material of load-bearing structure, year of construction, number of stories).

A different but comparable damage scale is employed in the partner countries. The five-grade EMS-98 damage scale (slight, moderate, heavy, very heavy, destruction) is used in Italy, Austria and Montenegro, whereas only four damage states (slight, moderate, extensive and complete) are considered in Slovenia (HAZUS scale) and Turkey. Some coordination would therefore be needed in order to provide comparable results, possibly by using a uniform damage scale in all countries. This would require comparing the definitions of the damage states according to the EMS-98 and HAZUS methodologies, selecting the uniform damage scale and modifying the fragility curves so that they are consistent with the selected uniform damage scale. The modification of the fragility curves could be a demanding task. Therefore, special attention should be paid to this task in the risk analyses performed within WP4 activities.

In all countries, some level of exposure data about buildings, dwellings and population is available. In Italy, Slovenia and Austria, detailed information is provided for buildings, e.g., location, number of storeys, year/period of construction, predominant construction material etc. Similar information is available for dwellings in Montenegro. In Turkey, however, only the number of buildings and population in each neighbourhood/village is available. Data is available at the municipality level for most partner countries, with the exception of Slovenia, where building-specific information is provided. A cross-border analysis would therefore be possible only at a municipality level. Population data is obtained from census data, which is generally publicly unavailable or has restricted access, with the exception of Montenegro. It would be reasonable to determine population data at the municipal level, as it is consistent with the level of other available data from the exposure model, and at the same time, it is less controversial from the point of view of personal data protection.

In Austria, no nationwide method for damage-to-impact conversion is available. For other countries, the possible common impact indicators are the number of collapsed or unusable buildings/dwelling and the number of fatalities. Direct economic losses are considered in Italy, Slovenia and Turkey, but not in Montenegro. However, by using a unified damage scale, the same rules for damage-to-impact conversion could be used in all partner countries, allowing for easily comparable impact indicators.

In Italy, Slovenia and Montenegro, seismic risk is obtained with the convolution of hazard, fragility and exposure for each typology and then aggregated. In Turkey, seismic risk is obtained as a combination of impact and likelihood and not with a single-dimensional conventional representation. In all four cases, risk could be expressed in terms of risk classes. However, a different number and definition of classes are considered in each country. In Austria, on the other hand, there is currently no comprehensive seismic risk analysis existing due to the lack of useful data on the building stock. With the harmonization of seismic hazard models and vulnerability models, seismic risk assessment could also be unified for all partner countries, even where quantitative risk measures have not yet been considered.

4.2 Flood risk assessment data

Flood risk assessment in EU member states Slovenia, Italy and Austria is generally following the requirements related to the application of the EU Floods Directive. The EU Floods Directive (2007/60/EC) requires that each Member State assess its territory for significant risk from flooding, to map the flood extent, identify the potential adverse consequences of future floods for human health, the environment, cultural heritage and economic activity in these areas, and to take adequate and coordinated measures to reduce this flood risk. Turkey has started to implement and transpose the EU Flood Directive into national legislation and activities for elaboration of flood hazard maps, flood risk maps, and flood risk management plans in 2013. Capacity Building to implement the Flood Directives into national legislation has started with the twinning project ‘Implementation of the flood Directive in a pilot basin Batı Karadeniz basin in 2012. The project was completed at the end of 2014. Currently, the flood management plans have been finalized in 23 out of 25 basins and ongoing for the 2 remaining basins. EU Floods Directive has been fully transposed into the Montenegrin legislative system through the Law on Waters and the Decree on the detailed content of the preliminary flood risk assessment and the flood risk management plan. The current legislation in this part anticipates the preparation of a preliminary flood risk assessment, identification of areas of potential significant flood risk, development of risk maps and flood risk maps for areas significantly affected by floods. In Montenegro, the implementation of the Floods Directive is at relatively early stage, project partners report lack of organizational and technical capacity that it is necessary to assure public participation and proper information. Additionally, the Water Information System has not yet been established, consequently they face problems with the data availability which should be solved at the beginning of flood risk assessment process implementation. Consequently, Montenegro requested a transitional period for the full implementation of the Floods Directive, in the part related to the development of Flood Risk Management Plans, until the end of 2024.

As for the flood hazard assessment, in all project partner countries, a general probabilistic approach has been followed for spatial delineation and identification of the flood hazard presence through hydraulic modeling approaches. The input hydrological and topographical data for flood hazard assessment are rather similar. Hydrological data in most of the countries are provided by the Environmental agencies or state hydrometeorological services. As for the topographical data, Lidar scanning data are usually used for building the Digital Elevation Models used in hydraulic modelling. In Slovenia, for defining the flood hazard classes, floods with return periods of 10-, 100- and 500- years are considered. As for Italy and Austria, flood events with return periods of 30-, 100- and 300-years are accounted in hydraulic calculations for delineating the flood polygons, whereas in Turkey flood events with 5-, 10-,50-, 100-, and 500-year flood return periods are considered in flood hazard analysis. In Montenegro, flood events with return period of 10- 100- and 500- years are generally considered in flood hazard assessment. In view of the possibilities for flood hazard data integration and harmonization between different countries, it seems reasonable to initially consider the flood events with 100-year return period which are in all project partner countries used as one of the reference flood events. Namely, the 100-year return period is considered in the flood hazard analysis of all project partner countries.

Information about the methodology for defining the flood hazard classes in each country clearly show some important differences. In case of Slovenia, 4 hazard classes are defined (low, medium, high, other) where combination of flood depth and water velocity in case of 100-year flood event is considered. As an additional factor, spatial extension of flood polygons in case of 10- and 500- year return period is accounted. In case of Italy and Austria, 3 hazard classes are identified by considering different flood return periods mentioned above together with the characteristics of water flow (water depth and water flow velocity). In Turkey, 4 hazard classes have been defined (very high, high, medium and low) whereas in Montenegro 3 hazard classes are delineated corresponding to the return period of the flood. In all countries, the maps representing the spatial extension of flood hazard are generally publicly freely available through different web platforms.

As for the flood risk, similar flood exposure and vulnerability elements are used in all partner countries, which could be directly linked to the EU Floods Directive general requirements to assess the flood risk in view of the impact on the human health, the environment, cultural heritage and economic activities. However, based on the gathered information we can see, that the methodological approaches for defining the flood risk classes varies considerably between different partner countries. Additionally, there are also considerable differences in the definition of the flood risk spatial scale resolution (e.g. in Slovenian a 75 x 75 m rater matrix is used whereas in Austria 125 x 125m matrix). In case of Italy and Turkey, flood risk is presented by vector data layers, whereas in Montenegro risk matrices are superimposed for 4 different scenarios in order to obtain the flood risk level.

It is worth noting that in most of the partner countries, the access to most of the datasets used for evaluating the flood exposure & vulnerability and assessment of flood risk have different levels of access restrictions related to General EU data protection regulations and different national legislation regulations. Additionally, the data layers used for identifying the exposure and vulnerability elements in different countries are under the jurisdiction of different ministries and governmental services. In order to enable data integration and harmonization and also make the flood risk assessment more applicable in view of Union Civil Protection Mechanism implementation in different project partner states and also operational purposes for Civil protection, it would seem wise to consider a municipal level as a basic spatial scale for further cross-border flood risk assessment.

4.3 Multi-hazard and multi-risk assessment

Several major natural disasters in different parts of the World have raised many concerns and also increased awareness of the frequent and potentially far-reaching interconnections between different natural hazards. Such interactions occur at the hazard level, where an initial hazard may trigger other events (e.g., an earthquake triggering landslides, followed debris flows triggered by heavy rainfall. Similar consequence of events, however, on a longer timescale, could be identified in the case of the Log pod Mangartom debris flow event in Slovenia (Mikoš, 2010). Several events may occur concurrently (or nearly so), e.g., severe weather around the same time as an earthquake. Natural hazard interactions are also transferred to exposure/vulnerability and rise levels, where the initial (triggering) event may make the affected community more susceptible to the negative consequences of another event (e.g., an earthquake weakens buildings and other infrastructure, which could be damaged further by thunderstorms or floods) and causing the so-called “domino effect”. The increase in multi-risk exposure should be considered both, in spatial and temporal scales (van Wester and Greiving, 2017). Changes in spatial and temporal exposure may considerably alter the total (multi-hazard risk) of a given area. Consequently, there could be a considerable likelihood that the total risk estimated when considering multiple hazard and risks and their interactions is greater than the sum of their individual parts (Liu et al., 2016). Further, important differences in the spatial extension of multiple hazards and consequently also risks can be noted while comparing different types of hazards, e.g. such as seismic and flood risk covered in Boris project. Following the requirements of the Flood directive, most of the efforts related to flood hazard assessment has been dedicated to the assessment of the spatial extension of flood polygons which are in view of spatial extension much more difficult to assess as the flood hazard could generally be much more spatially variable compared to spatial extension of seismic hazard. Information on the spatial extension of hazard and risk is also crucial for operational planning of the civil protection activities.

The problem of multi-hazard and multi-risk assessment has been so far considered in EU FP7 project MATRIX (Multi-HAzard and MulTi-RIsK Assessment MethodS for Europe). MATRIX project tackled multiple natural hazards and risks in a common theoretical framework. It integrated new methods for multi-type assessment, accounting for risk comparability, cascading hazards, and time-dependent vulnerability. Three test sites were considered during the project: Naples, Cologne, and the French West Indies. A software platform, the MATRIX-Common IT system, was developed to allow the evaluation of characteristic multi-hazard and risk scenarios in comparison to single-type analyses.

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APPENDIX A

Table A1: Description of past studies incorporating cross-border risk assessment.

Name of the authors of the study/name of the project	Area analysed	Risks considered (seismic/ flood/both)	Description of the objective/methodology	Identified limitations/obstacles (that may also be problematic in the BORIS project)	Solutions relevant for the BORIS project
KULTURisk (http://www.kulturisk.eu/project-definition)	Italy and Slovenia	flood	The socio-economic analysis for the evaluation of the economic and social benefit of disaster prevention and the development of the mentioned risk-based methodology based on empirical data derived by past case studies, such as the probabilistic flood warnings issued within the 2007 MAP D-PHASE experiment.	Problems with the harmonisation of data used for flood risk assessment in Slovenia and Italy.	Identified some good practices of information exchange between the Civil Protection operation offices at the local level. Organisation of transboundary workshop with local stakeholders from neighbouring municipalities in Slovenia and Italy.
Adaptation to climate change in transboundary flood risk management Western Balkans Client: Federal Ministry for Economic Cooperation and Development of Germany (BMZ) Project realized by: GIZ - German Society for International Cooperation (Deutsche Gesellschaft für international co-operation)	Transboundary river basin of rivers Drim and Bojana. Countries included: Albania, Kosovo, Macedonia, Montenegro.	flood	Available data on water levels and discharges (from the measuring stations) was used along with topography in a HEC-RAS 2D hydraulic model. Superposition of floodplains and areas with significant number of exposed households/ residents and endangered infrastructure indicates zones of potential high risk.	Within the Drim and Bojana river basins, there are individual flood risk management plans (e.g. for the Shkodra region, regional and local plans, GIZ, 2015). Several flood hazard maps have also been developed for selected areas in the river basin, especially after the intensive flooding from 2010 (e.g. Mott McDonald, 2012) However, due to the lack of a comprehensive runoff model and input data, there are doubts about the accuracy of these flood hazard maps. Cross-border coordination of problematic flood issues, such as risk assessment, solidarity actions upstream and downstream on the river, burden sharing and conflict reduction between flood risk and management of hydropower reservoirs, still cannot be done well within the existing mode of cooperation. Pluvial floods have not been modeled for the Drim and Bojana river basins and therefore it is still not possible to perform a systematic risk assessment based on existing information.	Identification of Areas with Potential Significant Flood Risk (APSFR). Geographical view (map) of the APSFR in the Drima and Bojana river basins is shown on the figure below. 

Table A1 continued.

Name of the authors of the study/name of the project	Area analysed	Risks considered (seismic/ flood/both)	Description of the objective/methodology	Identified limitations/obstacles (that may also be problematic in the BORIS project)	Solutions relevant for the BORIS project
SiSPyr (Sistema de Informaciòn Sismica del Pireneo) http://www.sispyr.eu/	Spain-France cross-border along Pyrenee (e.g. pilot Luchon – Saint Béat (France) – Val d'Aran (Spain))	seismic	The realization of a common seismic data acquisition system and an improvement of scientific tools supporting the risk management in the Pyrenee.	Project mainly deals with seismological data; the application for seismic risk does not foresee comparison of national approaches, but applies a sovra-national one (RISK-UE).	Exchange of seismological data between Spain, France and Andorra to create a transboundary seismic informative system to have a homogeneous and shared view of seismicity in the Pyrenee area.
Monfort D. et al., 2012 "Seismic risk scenarios in a cross-border zone of the Pyrenees", 12WCEE, Lisbon	Luchon – Saint Béat (France) – Val d'Aran (Spain)	seismic	Buildings vulnerability assessment by using RISK-UE approach. 2 scenarios: 1st deterministic (based on past event); 2nd based on the probabilistic seismic hazard for Tr= 475 y, accounting also for soil amplification map obtained from the site effects study carried out within the project.	RISK-UE model may be inadequate considering availability of more refined vulnerability models specifically developed for each country.	The highlighting of differences of building types on the two sides of the border, depending on codes and different construction solutions. This leads to different vulnerability.
POCRISC https://pocrisc.eu/es	Transboundary area of the Catalogna region in spain, Occitane in France and Andorra. The project concentrates in areas of high seismic hazard already treated in Sispyr and extended to Catalogne.	seismic	The goal is to promote the common culture for seismic risk understanding in the Pyrenee. To achieve this 3 actions are taken: 1) development of tool for quasi-realtime damage assessment at municipality scale, mainly detiuned to risk management actors; 2) smartphone application to evaluate vulnerability and post-seiusmic damage for crisis management; 3) guideline on good practice for seismic vulnerability reduction, destined to engineers and practitioners.	Buildings vulnerability assessed by using EMS98 based approach (e.g. RISK-UE). This type of macroseismic model may be inadequate, considering availability of more refined vulnerability models specifically developed for each country and for the scope of realistic impact assessment for civil protection purpose.	Implementation of tool for damage assessment and visualization.

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Table A1 continued.

Name of the authors of the study/name of the project	Area analysed	Risks considered (seismic/ flood/both)	Description of the objective/methodology	Identified limitations/obstacles (that may also be problematic in the BORIS project)	Solutions relevant for the BORIS project
RISVAL (ALCOTRA) Project https://www.interreg-alcotra.eu/fr/decouvrir-alcotra/les-projets-finances/risval-risque-sismique-et-vulnerabilite-alpine	French-Italian border	seismic	Project aimed to raise awareness about seismic risks not only among the local and regional authorities and their technical teams, but also among the general public (professionals and schools) through targeted workshops and communication. Implementation: two cross-border workshops bringing together scientists, local authorities and French and Italian rescue services, in order to share experiences and ideas; campaigns to raise public awareness about seismic risks.	Not identified.	The use of a workshop to raise awareness of stakeholders.
EXCIMAP - European exchange circle on flood mapping(2007)	General (handbook of good practices for Europe)	flood	Technical and operational recommendations for successful trans-boundary flood mapping projects.	Not identified.	Useful indications: 1) attention to terminology cross-border (e.g. damage or sensitive areas); 2) scenario definitions have to be agreed among the partners before starting the hydraulic and other type of modeling; 3) store data in common GIS; 4) Relevant input data and parameter for hydraulic modelling like water level-discharge relationship and hydrological data (statistics and / or rainfall-run-off models) have to be harmonized; 5) Adjustment for soft data (vulnerability parameters).

Table A1 continued.

Name of the authors of the study/name of the project	Area analysed	Risks considered (seismic/ flood/both)	Description of the objective/methodology	Identified limitations/obstacles (that may also be problematic in the BORIS project)	Solutions relevant for the BORIS project
FLAPP: Flood Awareness and Prevention Policy in border areas https://www.riob.org/en/file/259663/download?token=oz3e4J-w	Different examples available.	flood	Practical solutions to improve cooperation in border regions.	Not identified.	Agreement on data transfer and compatibility of models will form a common basis for assessing the situation in the river basin. Potential measures can be discussed on their merits, without conflicts about the calculation of their expected effects. As example, for the Border Meuse, Flanders and the Netherlands developed their own plans, and then decided on a joint assessment of these plans by starting a 'cumulative research' program into the effects and mutual impact. The research started with commonly accepted calculation methods and models.
CONSTRAIN - Sharing and application of innovative strategies for seismic protection of masonry buildings https://www.ita-slo.eu/en/constrain	Italy and Slovenia	seismic	The seismic protection of buildings, for the protection of people, structures and contents, is a common problem in the area. A synergy of skills is proposed between productive (4 companies involved) and research (2 research bodies involved) sectors to promote innovation in structural consolidation interventions (aimed at optimized use of resources) and spread acquired knowledge and experience to increase the know-how and competitiveness of construction workers. The project focuses on existing brick buildings, mostly exposed to seismic risk. A joint study on the intervention strategies in use is foreseen to allow the definition of innovative strategies, based on the targeted use of modern fiber-reinforced composite materials.	Mitigation strategies are not specifically analysed in the BORIS project.	The analysis of masonry building typologies in both countries.

Table A1 continued.

Name of the authors of the study/name of the project	Area analysed	Risks considered (seismic/ flood/both)	Description of the objective/methodology	Identified limitations/obstacles (that may also be problematic in the BORIS project)	Solutions relevant for the BORIS project
CAMIS - Coordinated activities for management of Isonzo - Soča (project 2012-2015)	Isonzo- Soca river (Italy and Slovenia). Pilot areas: 1) high valley - Zgornja Soča; 2) low valley - Spodnja Soča; 3) regional park Krajinski park Zgornja Idrijca	flood	The objective is to establish a more adequate cross-border management of the river in the sense of a sustainable use of strategic resources and the conservation of watercourses. Two parts: 1. analysis of river and hydraulic morphology as well as the analysis of water quality; 2. pilot actions that will contribute to a sustainable use of the river and certain areas within the river basin, especially for recreational and tourist purposes. With good practice models and land use action plans, a comparison of the different uses of the river on both sides of the border will be allowed.	Mainly dealing with sustainable use of strategic resources and the conservation of watercourses (not specifically floods).	Existing partnership that can be involved for pilot study in BORIS project: The Lead Partner is the Posoški razvojni center (Soča Valley Development Agency), ten other Partners from both sides of the border collaborate on the project. On the Slovenian side are the municipality of Bovec, the municipality of Kobarid, the municipality of Tolmin, the municipality of Idrija, Zavod za zdravstveno varstvo (Health Protection Authority) of Nova Gorica and Inštitut za vode RS, on the Italian side the Province of Gorizia, the municipality of Turriaco, the Autonomous Region of Friuli Venezia Giulia and the Venice Basin Authority.
CROSSIT SAFER - Cross-border cooperation between Slovenia and Italy for a safer region (2019-2022) http://new.ita-slo.eu/en/crossit-safer	Italy and Slovenia	Other (natural emergencies- forest fires, seismic vulnerability).	CROSSIT SAFER will build on the knowledge and experience of PPs from other EU projects, which will be updated with new and improved forest fire early warning systems, using seismic vulnerability models of buildings and damage assessment, as well as a cartographic software and an application that will allow geographical information systems to be shared in the cross-border area.	Not identified.	Strengthening of the institutional cooperation capacity of public authorities and key actors in the field of civil protection for effective emergency management in the cross-border area.
VISFRIM - Vipava/Vipacco and Other Transboundary River Basins Flood Risk Management (2019-2022) http://new.ita-slo.eu/en/visfrim	Italy and Slovenia	Flood.	The project includes several activities aimed at supporting flood risk management in selected cross-border case studies. Specifically, shared hazard maps and hydraulic risk maps will be drawn up through the use of accurate, jointly developed modelling tools. This will allow common management objectives to be established and potential measures to achieve them to be implemented.	Not identified.	The project involves the international basins of the Isonzo and Vipacco rivers and in the interregional basin of the Lemene River.

Table A1 continued.

Name of the authors of the study/name of the project	Area analysed	Risks considered (seismic/ flood/both)	Description of the objective/methodology	Identified limitations/obstacles (that may also be problematic in the BORIS project)	Solutions relevant for the BORIS project
HARMO-DATA - Harmonisation of data for cross-border land management (2017-2019) http://new.ita-slo.eu/en/harmo-data	Italy and Slovenia	General (not focusing specifically on floor or seismic risks)	To improve the capacity for institutional cooperation, with the mobilisation of the public authorities and key territorial planning operators, in order to create joint solutions aimed at harmonising the systems and more effectively managing the cross-border area, above all through a cross-border platform for the harmonisation of the territorial data.	Not identified.	Transboundary platform with harmonized data