Flood lamination strategy for Risk Reduction

Chapter 6

Flood Lamination Strategies for Risk Reduction

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Additional information is available at the end of the chapter

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Abstract

The purpose of 2007/60 UE Directive is namely the establishment of a framework for measures to reduce the risks of flood damage in Europe. In Italy, the Po Basin District Authority, with the contribution of the regional Authorities, published the hazard and risk maps, which are now in force and available for public participation. A common methodology to evaluate risks is now necessary, in order to set priorities for flood management and the financing of countermeasures (ReNDiS procedure). An analysis for the quantification of risk of flooding is presented in the chapter by means of the proportional index of risk (IRP). In particular, it is focused on the flood's lamination strategy, at the entrance of Turin, in terms of hazard and the risk reduction. The sensitivity analysis of the main variables that affect the results is presented and discussed. The benefits of the designed countermeasures are evaluated and quantified in terms of percentage risk reduction. The methodology proves to be a suitable means for decision-makers to compare flooding risks in the flood-prone areas, which are mapped by the 2007/60 UE Directive.

Keywords: flood directive, watershed basin management, risk, vulnerability, hazard

1. Introduction

In Italy, the overall risk of flooding is less severe than in many other European Union (EU) countries [1]; however, there are some areas where there are problematical situations which can be considered among the most important in Europe (**Figure 1**) and, in any case, floods represent the natural instability process more prevalent on the national territory. According to the latest report by the Institute for Environmental Protection and Research [2] on the hydrogeological instability, over 22% of the country is exposed to the danger of flooding: 4%

(12,186 km^2) in areas at high hydraulic hazard,[1] 8.1% (24,358 km^2) in medium hydraulic hazard areas and 10.4% (31,494 km^2) in low hydraulic hazard areas. The total population at risk of floods is therefore to be over 16 million people (26.7% of the resident population) of which almost 2 million (3.3%) in areas of high hazard, almost 6 million (10%) in the areas of medium hazard and more than 8 million (13.3%) in low hazard areas.

This representation of the Italian situation is consistent with the conceptual framework of the Flood Directive 2007/60/EC on the assessment and management of flood risks proposed by the European Commission on 18/01/2006 and finally entered into force on 26 November 2007 [3]. *The Flood Directive* (FD) requires Member States to first carry out a preliminary flood-risk assessment by 2011 to identify the river basins and associated riparian areas at risk of flooding. Secondly, for such zones they would then need to draw up flood-risk maps and, thirdly, establish *Flood Risk Management Plans* (FRMP) focused on prevention, protection and preparedness by 2015.

The adoption of the FD means a major paradigm change in national policies to counteract the flooding, shifting the focus from the illusory idea of physical neutralization of the natural phenomena through the construction of defence systems to the most realistic target of reduction of their destructive potential on human societies by reducing the degree of exposure and vulnerability of people and activities. This new strategic vision therefore requires new cognitive instruments to measure the destructive potential of floods and then to assess the overall adequacy of intervention measures.

In Italy, in regard to implementation of the three steps indicated by the 2007/60/EC Directive (preliminary risk assessment, risk mapping and flood-risk management, plan implementation), it is possible to assert that the different river basin authorities have satisfied these requests (according to the act n.49/2010, the adoption of the flood management plan was due by December 2015) according to the guidelines given by the Ministry, which proposed homogeneous approaches to face the tasks [3]. On the other hand, the river basin authorities could already count on an important previous and common activity of delimitation and management of flood-risk areas, as required by the so-called 'post Sarno strategy'[2] but the approach taken by them for the risk assessment is mainly qualitative in nature and for this reason not entirely suited to an objective evaluation of the flood risk as required now.

Therefore, this chapter aims to provide a useful contribution of methodological and instrumental innovation in this regard. In particular, the strategy for flood lamination, consisting of a flood's lamination area on the Dora Riparia River, upstream of Turin's city, is presented in

1 In accordance to the Legislative Decree 23 February 2010, n. 49 ('Implementation of Directive 2007/60 / EC on the assessment and management of flood risks') are defined areas of high hydraulic hazard, the areas affected by frequent floods, namely with a return period between 20 and 50 years; medium hazard areas those with infrequent floods with return periods between 100 and 200 years; low hazard areas, those with low probability of floods, with return times over 500 years.

2 After the tragic landslide of Sarno that in May 1998 caused the deaths of 160 people, was first issued a Decree (180/1998), later converted in Law (267/1998, the Sarno law), which represents the cornerstone of the national strategy against hydrogeological risk in Italy. Strategy was based on four elements: the perimeter of the risk areas, the imposition of safeguard restrictions and use limitations, planning of structural interventions for risk reduction, the provision of warning systems and emergency plans to alert and protect people in areas still without the necessary structural interventions.

terms of hazard and the risk reduction. An analysis for the quantification of the risk of flooding is presented by means of the *Proportional Index of Risk* (IRP).

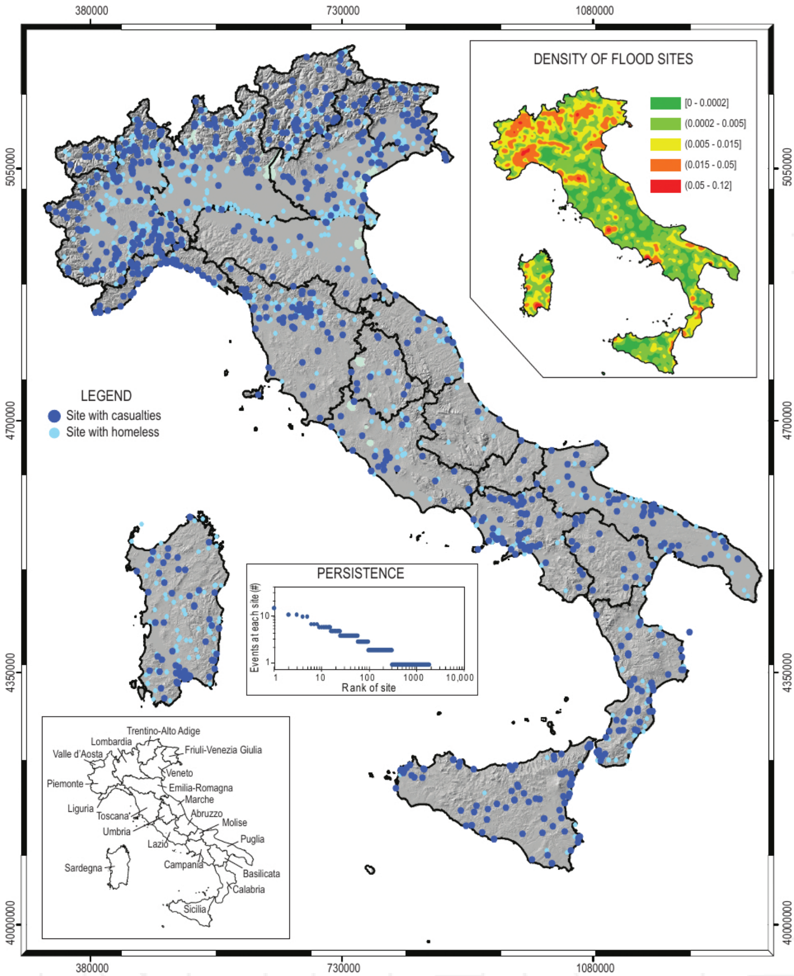

Figure 1. The map showing the location of 1836 sites affected by flood events with direct consequences to the population, in the period 590–2008. The upper-right corner shows the density of flood sites per square kilometre (Source: [4]).

2. The flood-risk management plans of the Po River Basin Authority

In the Po Basin district (about 71,000 km^2), hazard and risk maps have been implemented according to the FD guidelines and are now in force. The institutional committee has recently adopted the FRMP.

Management plans define the objectives of the management of flood risk for areas in which a significant potential risk could exist, in order to reduce the possible negative flood consequences. The plans have to cover all aspects of the management of flood risk, with a particular focus to prevention, protection and preparedness, including flood forecasts and early warning systems, and take into account the characteristics of the river basin or sub-basins.

According to the 49/2010 Decree and the Ministry guidelines [3] specific definitions regarding flood risk have been adopted (**Table 1**).

Term	Definition	Source
Risk	"the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event"	Decree n.49/2010 2007/60 UE Flood Directive
Hazard	"the probability of occurrence, within a specific period of time in a given area, of a potentially damage natural process"	Decree n.49/2010
Exposure	"elements at risk, or receptors, that is, people, properties and goods that can be lost, human health, the environment, cultural heritage and economic activity"	2007/60 UE Flood Directive
Vulnerability	"the degree of a loss to a given element at risk, or set of such elements resulting from the occurrence of a flood with a given intensity"	[3]

Table 1. Definitions of the terms used in this chapter.

Flood and risk maps adopted by PBDA are not merely an information tool, but also a '*valuable basis for priority setting and further technical, financial and political decisions regarding flood risk management*'.

The approach followed for the risk mapping and representation can be qualitative or quantitative [5]. Limitations of a qualitative approach lay in the fact that qualitative assessment is generally based upon perceptions and opinions, as well as on judgements and consent, while quantitative risk assessment is based on numerical values and the use of computations and models to express the various components of risk. Poor resolution and ambiguity in hazard and exposure categorization are the main problems with the matrix approach, while, on the other hand, the lack of available dataset and the difficulty to quantify inputs (e.g. direct and indirect damages) are the main problems with quantitative models [6].

Which approach, qualitative or quantitative, is preferable is a subject of debate. In general, risk assessment can be regarded as a process of determining qualitative and quantitative aspects of risk related to a concrete situation and a recognized threat. The main purpose for flood-risk assessment is to gain a comprehensive understanding of flood risk, before identifying those mitigation measures that are likely to reduce such risk.

The availability of numerical models of risk, and therefore of quantitative estimations of risk, can facilitate the comparison of the benefits and the costs of the implementation of counter-

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measures. In this frame, numerical models are a useful tool for decision-making, helping decision-makers to set the priorities in public financing, and guiding political decisions [7–9].

This true necessity is evident especially when the total amount of financial demand is higher than the available financial resources, regarding the uncertainty in the analysis of the flood risk and the associated management of the decisions' processes [10]. For instance, the recent *ReNDiS* project (*National Database of the projects for soil defence*, by ISPRA) by the Italian Government, which aims at setting priorities for financing the project for natural disaster countermeasures, shows that the demands for financing are over and by far higher than the available annual resources.[3] The collected projects are proposed by public administrations (Regions, Provinces and Municipalities) and refer to non-structural and structural countermeasures against natural hazards, including landslides, debris flows and floods. The geographic location and the state of implementation of the countermeasures is free for consultation for citizens, stakeholders, administrators and decision-makers (**Figure 2**).

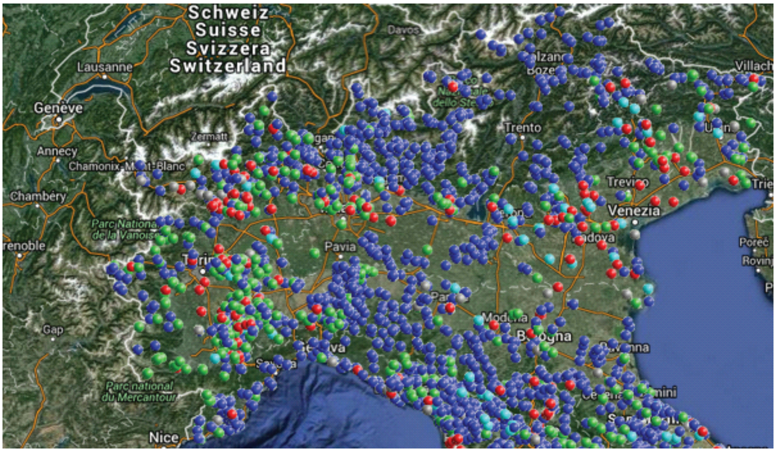


Figure 2. Sketch of the location of the projects for flood and landslide defence: blue indicates the finished work, green indicates the work in progress, red indicates work in the design, light blue indicates work that is no longer supported (Source: RENDIS database).

After the adoption of FRMP, with the recent act of the Prime Minister [11],[4] hazard and risk reduction criteria have become the prominent elements that guide the Ministry for financing

3 RENDIS (Repertory of mitigation measures for National Soil Protection) consists of a repertory developed by ISPRA to share and publish collected data on the web. Through the interface ReNDiS-web, it is possible to view the actions that have been taken within a specific geographical area and query the database, obtaining the corresponding statistical reports on a range of features, or the typological and quantitative data. Currently, the ReNDIS data are limited to the most urgent measures to reduce landslide and flood risks funded by the Ministry of Environment. RENDIS is at address: http://www.rendis.isprambiente.it/rendisweb/

4 D.P.C.M. 28 May 2015 – identification of the criteria and modalities for priority allocation of resources to the mitigation of hydrogeological risk.

the hydrogeological control countermeasures. In particular, according to the decree, some of the elements for the eligibility of financing are related to:

- the goods (if any) at high risk;
- people directly affected by flood;
- frequency of the event;
- reduction of the total number of endangered people; and
- reduction of risk.

As it can be seen, all these points are connected to the contents of the risk and hazard maps. Other elements are related to the environmental amelioration, time scheduling and state of design (preliminary, definitive, executive).

The recent 2015 Prime Minister's decree focuses on the concepts of risk, damage and hazard, with particular regard to their quantification.

The quantification of risk is not a simple task and methodologies depend greatly on the kind of available data. However, in Italy, a uniform methodology is needed, as required by the recent act of the Prime Minister.

In this research, the case of the hazard and risk reduction in Turin is described, with regard to the way on which flood risk due to Dora Riparia river inundation has been evaluated and computed. The effects of the implementation of designed countermeasure are revalidated through risk reduction computation.

3. Hazard and risk at Turin

Turin is a city and an important business and cultural centre in Northern Italy. Four major rivers pass through the city, that is, the Po and three of its tributaries, among which the Dora Riparia.

With the implementation of the hydrogeological asset plan (PAI) in 2001 and the recent flood directive, Dora Riparia flooding areas at Turin have been mapped, inundation areas have been reviewed in time, and are now available online. The flooding areas have been represented in the flood hazard maps, which cover the geographical areas, which could be flooded according to the following scenarios for different return periods (RPs):

- (L) floods with a low probability (RP = 500 years);
- (M) floods with a medium probability (for the Dora Riparia 100 ≤ RP ≤ 200 years);
- (H) floods with a high probability (20 ≤ RP ≤ 50 years).

In FD hazard maps at Turin, flooding areas (**Figure 3**) were obtained by means of a hydraulic approach that is by

1. Implementing one-dimensional (1D) simulation model along the watercourse; for the lack of time and economic resources no 2D models have been used in endangered areas;

2. Considering the state of implementation of the countermeasures (levees, embankments, etc.);

3. Considering the effects of past floods, in particular the recent ones, (the most important recent flood event occurred in 2000 [12]).

Figure 3. Flood inundation areas in Turin (free map available on Regione Piemonte website[5]), for different flood scenarios.

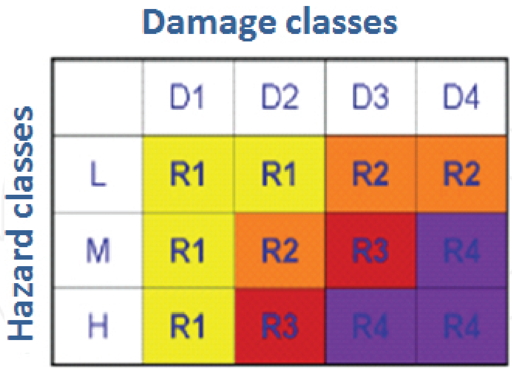
By following the requirements of the FD (Act n.49/2010 of the Italian Government; [13]) risk has been mapped by referring to a qualitative approach, that is a matrix approach described herein (**Figures 4** and **5**):

– hazard has been ranked into three different categories (high, medium and low) according to the indication of the 2007/60 EU directive;

– exposure has been referred to the prevalent land use, based on Corinne land cover and ranked into four different categories; the criteria for gathering the different soil uses qualitatively took into account the value of the exposed goods;

5 http://www.regione.piemonte.it/difesasuolo/cms/42-aggiornamento-delle-mappe-di-pericolosita-di-alluvione.html

– risk has been ranked and mapped according to four categories R1, R2, R3 and R4, which are, respectively, low, medium, high and very high risk; the criteria for the determination of the risk category were debated and made uniform over the territory.



	D1	D2	D3	D4
L	R1	R1	R2	R2
M	R1	R2	R3	R4
H	R1	R3	R4	R4

Figure 4. Matrix method implemented by Regione Piemonte for risk classification. Hazard categories (L = low, M = medium, H = high) and exposure categories (increasing from D1 to D4).

Following this approach, by means of a geographic information system (GIS) implementation, qualitative maps have been published online (**Figure 5**).

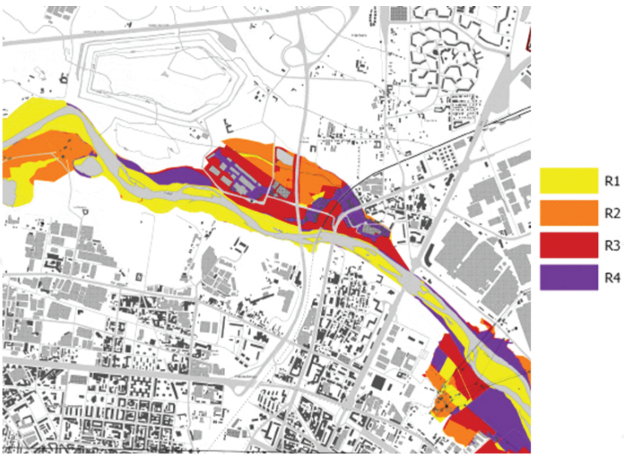


Figure 5. Map of risk in Turin. The map refers to the categorization of risk.[6]

As far as Dora Riparia is concerned, the analysis made in the feasibility study (*Studio di fattibilità della Dora Riparia*, indicated in the following as DRFS) showed the necessity to implement flood

6 Maps can be downloaded at http://osgis2.csi.it/direttiva_alluvioni/cartografia_direttivaalluvioni.html

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diversion areas (FDA) to reduce the impacts of the flooding on the city (**Figure 6**). As it is well known, a flood-diversion-area system consists of floodplain areas equipped with controlled gates. The gate opening creates depression waves that interfere with the flood wave to reduce peak flood discharges. The effects of the FDA control system have been simulated within the DRFS and consist of a reduction of the total endangered areas at Turin. The total cost for the FDA areas is more than 60 M€ and has been qualitatively indicated as a 'high-priority' intervention.

Figure 6. Dora Riparia watercourse (in red). Location (yellow) of the FDA and the city of Turin (right).

The choice of the type of the countermeasure, and, in particular, of the effectiveness of the FDA is not under discussion in this chapter. Such a type of structural countermeasure is the result of public confrontation and discussion, stakeholder's involvement, etc., and is planned to be implemented together with other measures, structural and not-structural, such as public awareness, land use and regulatory plans.

A quantitative approach for evaluating the benefits of the implementation of the FDA countermeasures is described in the following chapter, based on an approach proposed in Regione Piemonte administration. The chief aim is quantifying numerically the risk and flood damages, by means of the available data and for application purposes. This implies the necessity of a robust approach, repeatable in different flood-prone areas of the watershed, in relatively short time.

4. Methodology for flood-risk assessment and quantification

As anticipated, the flood hazard in Turin has been mapped on the basis of the modelling results contained in DRFS. At now, the inundation areas have been mapped by referring to so-called 'design conditions', that is, by considering the effects of the implementation of the designed flood countermeasures. However, flood water levels have been calculated in the DRFS, either referring to the present conditions or referring to the design conditions, by means of a one-dimensional (1D) simulation model.

The chief aim in the activity described herein is to reach an overall quantification of risk and evaluating the benefits of the implementation of countermeasures at Turin, by optimizing the present resources (economic, human, time). In this contest, the implementation of 2D hydraulic simulations or the updating of 1D models (already implemented in the DRFS) would have been too time consuming and resource spending.

The system adopted for flood inundation mapping and for the estimation of water depths in the flooded areas, that is, for hazard mapping, using the available one-dimensional hydraulic model results at cross sections, consists of the following steps [14–16]:

Figure 7. Map of the cross sections at which the flood levels have been computed in the DRFS.

– Water surface elevations are estimated using the hydraulic 1D model already implemented in the DRFS (**Figure 7**); the hydraulic model was executed for the design flow, calculated according to the guidelines of the FD; other hydraulic parameters are obtained by calibration.

– The water surface elevations at the cross sections of the hydraulic model are geo-referenced (mapped) on the digital terrain model, and a water surface (usually a triangular irregular network _TIN_ format) is created; this step of procedure has been developed by means of *QGIS* and *GlobalMapper* software;

– The digital terrain model is subtracted from the water surface (TIN_format) to obtain a water-depth map; the area with positive values in the water-depth map gives the flood inundation map; this step has been implemented by referring to DTM delivered by MATTM (Ministry of environment, soil and sea defence), which has a high spatial resolution (more than one point for square meter);

– the mean water depth at each receptor in the flooding area has been calculated, by referring the centroid of the receptor; all receptors contained in Regione Piemonte database have been considered, regardless of their prevalent use.

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The described methodology was previously applied by Regione Piemonte to the Orco River, to the Dora Riparia River [13] and adopted by the Po Basin District Authority for flood mapping for the Orco River study case [17].

Hazard mapping is the basis for risk evaluation and quantification. The model that is here described (see also [13]) assumes that the quantitative risk for each *i*-th receptor can be calculated by the product of hazard, vulnerability and exposure:

$$R_i = H_i E_i V_i \tag{1}$$

where

H: hazard, *E*: exposure; *V*: vulnerability.

Quantification of the three terms in Eq. (1) is a necessary step to quantify the total risk, as described subsequently. The procedure is the same as that described in [13]:

EXPOSURE CLASSES

HAZARD CLASSES	D1	D2	D3	D4
L	R1	R1	R2	R2
M	R1	R2	R3	R4
H	R1	R3	R4	R4

Figure 8. Dora Riparia watercourse in Turin (blue line) and the zones indicated by OMI (estate market Observatory).

1. As far as the hazard is concerned, according to Maione [18], the term H_i can be calculated by referring to the mean occurrence probability per year of a flood, given by

$$H_i = \frac{1}{RP} \tag{2}$$

   where RP is the return period. Inundation depth for each receptor in the flooding area is not directly considered in Eq. (2), by it is indirectly considered in *E* and *V* terms of Eq. (1), as it is described in the following paragraphs.

2. The exposure E_i for each receptor has been computed by multiplying the area A of the receptor for its economic value 'e' (expressed in €/m^2) and for the total number 'f' of floors; the OMI (estate market observatory, free available online) dataset gives the mean economic value 'e' of the receptors, depending on the prevalent use (commercial, residential) and their location in the urbanized areas (OMI zones), which are considered homogeneous from the economic market point of view (see **Figure 8**).

   For each homogeneous OMI zone and for each prevalent use, the OMI (free available online) dataset indicates maximum/mean/minimum economic values, which are regularly updated in time (see **Table 2**).

   The total number of floors 'f' per building has been deduced by ISTAT data (free available online[7]). A mean value of four floors per building has been adopted in the applied model.

3. Vulnerability can be computed by means of a stage damage curve (SDC) as indicated by [19–20]. There is a wide variety of flood damage models in use internationally, differing substantially in their approaches and economic estimates. Comparison of different methods to evaluate vulnerability showed significant differences between the models that are clearly translated in different contests [20–21].

   In the technical/engineering literature for natural hazards, physical vulnerability is generally defined on a scale ranging from 0 (no loss/damage) to 1 (total loss/damage). In the application to the study case, different SDC curves have been considered (see **Table 3**) and their application to the study case has been discussed. The depth-damage curve proposed by [22] has been adopted, in order to take into account either the content damage or the structural damage. Indirect damages have not been considered.

OMI ZONE	Minimum (€/m^2)	Mean (€/m^2)	Maximum (€/m^2)
C8	1500	1850	2200
C9	1300	1600	1900
C10	1500	1850	2200
C16	2050	2425	2800
D9	1600	1925	2250
D10	1300	1575	1850
D11	1400	1750	2100
D13	1500	1825	2150
D14	1750	2150	2550

Table 2. Economic values (expressed per square meter) of the residential receptors in the flooding areas (Source: OMI market observatory, free available online).

7 Data can be seen at the website http://dati-censimentopopolazione.istat.it/

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SDC model	*Developer*	*Limitation to the study case application*	*Reference*
FLEMO	German Research Centre for Geosciences	Vulnerability can be computed for water depths by far lower than those of the study case	[23]
HAZUS-MH	FEMA	Typology of buildings (wooden-made) is different from Italian cases	[24]
Multi-Coloured Manual	Middlesex University	Typology of buildings	[25]
Rhine Atlas	Action Plan on Floods	The model shows the highest similarities. Vulnerability can be computed for water depths $h > 0$	[22]

Table 3. Discussion of the applicability of different SDC models to the study case.

The ICRP original curve has been changed in order to adapt it to present conditions of the buildings in the flooded areas in Turin. In particular, the adopted vulnerability curve takes into account the presence of basements, and therefore the curve starts from water depths lower than zero (**Figure 9**).

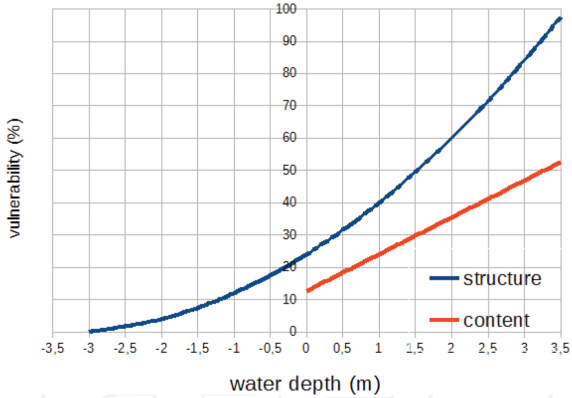

Figure 9. Vulnerability curve adopted in the implemented model.

For a given inundation scenario, that is, for a given return period RP, the vulnerability V_i and the exposure e_i of each receptors are computed.

The comprehensive estimation of the risk, for a given inundation scenario, can be easily obtained by assuming the superposing effects of inundation on each receptor. The *Proportional Index of Risk* [13] is therefore introduced, given by

$$IRP = \frac{\sum A_i f_i V_i e_i}{RP} \quad (3)$$

The term 'proportional' refers to the proportionality of the total economic exposure E_i with the area A_i of the receptor.

5. Results and discussion

The procedure is applied to the study case by referring to present hazard conditions and design hazard conditions.

DTM Source	Accuracy in elevation	Point density	Date of survey
Regione Piemonte	- ±0.30 m	One point per 25 square metres	2009
(MATTM) Ministry of environment, soil defence and sea	±0.05 m	One point per square metres	2011

Table 4. Main characteristics of the DTM tested in the implemented model.

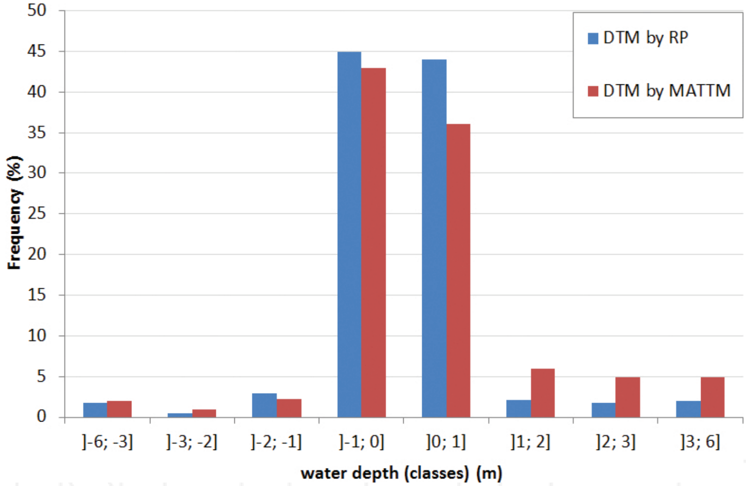

Figure 10. Frequency distribution of the water depths at the centroids of the receptors. Comparison of the results obtained using the two DTMs (Digital Terrain Model) described in **Table 4.**

A sensitivity analysis of the results has been carried out by considering and evaluating:

- the effects of DTM resolution on the results, in particular two DTMs, with a different resolution have been used: the DTM by MATTM and the DTM by Regione Piemonte (the main characteristics of the DTM are shown in **Table 4**); for each DTM, the total number of flooded receptors and the water depths at centroids of the receptors have been calculated, by following the described procedure:

The obtained results show that, notwithstanding the different characteristics and accuracy in altimetry of the two DTMs, the frequency distribution of the inundation depths at the centroids of the receptors is very similar (**Figure 10**). Differences in water depth calculation at the centroids of the receptors are of the same order of magnitude of the uncertainties which affect either the hydraulic model calculation (at cross sections, **Figure 7**) or the methodology applied to extend the computed 1D levels to the flooding areas.

- The effects of the choice on the OMI economic value 'e_i'; in order to test the sensitivity of the model to OMI economic value, the benefits of the implemented countermeasures are calculated by

$$Benefits = \frac{IRP_{pres} - IRP_{des}}{IRP_{pres}} \tag{4}$$

where IRP_{pres} and IRP_{des} refer to the IRP indexes calculated by referring to present situation and design conditions, respectively, expressed in terms of percentage; it can be seen (**Figure 11**) that the benefits do not significantly vary with the choice of the OMI value regarding each OMI zone. In any case, the benefits are about 74%, in terms of IRP reduction. Obviously, in absolute terms, the benefits of the implementation of countermeasures vary in wide range for the minimum or medium or maximum OMI value, as shown in **Figure 11**.

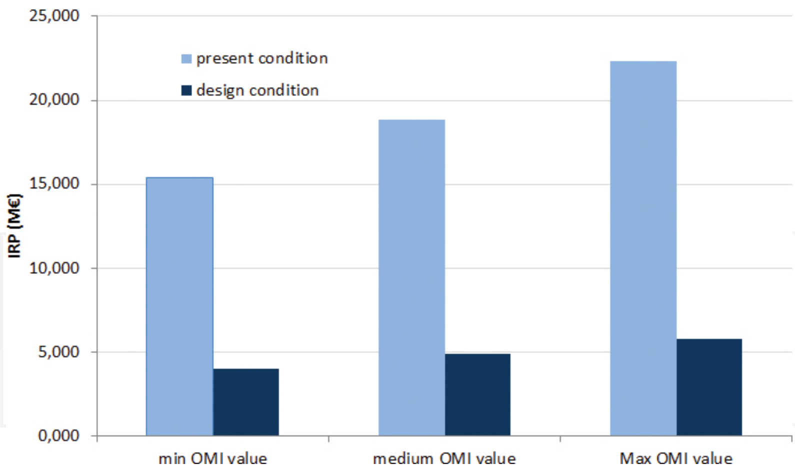

Figure 11. Effects on results of the choice of the OMI economic value.

- The effects of the implementation of countermeasures are not uniform, in terms of risk reduction. In **Figure 12**, the frequencies of receptors, which fall within the *i*-th IRP class intervals, have been calculated by referring to the present and to the design conditions following the same procedure indicated in [13]. The effects and benefits of the implementation of the countermeasures are represented by

– the reduction of the total number of receptors falling in the flooding areas, that is, the total number of receptors for which IRP is higher than zero;

– the reduction of the total number of receptors for each *i*-th IRP class, that is, a reduction of risk for each IRP class.

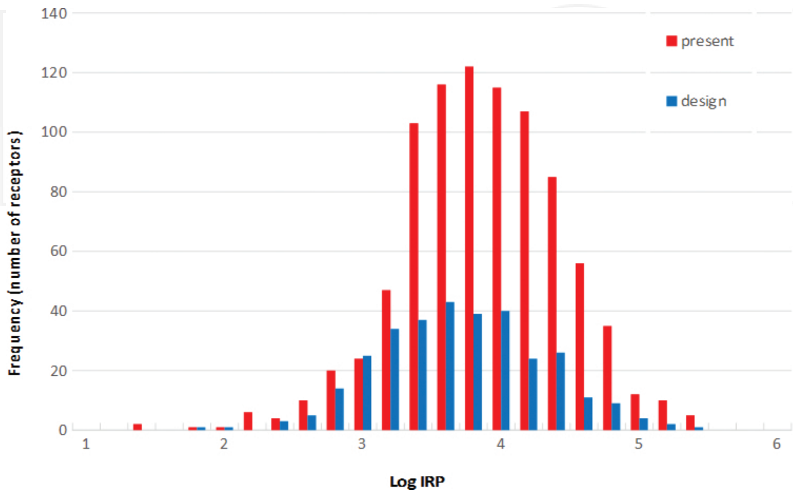

Figure 12. Frequency of receptors falling within the *i*-th class interval.

6. Conclusions

The effects of the implementation of the designed countermeasures at the Dora Riparia River in Turin have been quantified by applying a simple procedure as described in this chapter.

The procedure allows obtaining an overall indication of the benefits of a flood diversion area, located upstream Turin, by means of an index, called Proportional Index of Risk.

The model considers the three main components of risk, which are the vulnerability, the exposure and the hazard. Each component has been quantified by referring to the present conditions and to the design conditions. The procedure allows quantifying the benefits in terms of IRP percentage variation, that is, of risk variation. The results obtained in the Turin study case do not vary significantly when different DTMs are considered for hazard mapping and IRP calculation. In terms of IRP reduction, the effectiveness of the designed countermeasures is about 75%, regardless of the OMI value that has been considered.

On one hand, the application of more complex models to quantify risk and benefits, where indirect effects of flooding risk reduction (such as indirect costs due to recovery procedures and civil protection) or indirect benefits (those on economy and stakeholder involvement) could also be considered, would have allowed a more in-depth understanding of the risk and benefits here described. On the other hand, probably the implementation of more complex models would have revealed to be too time consuming and resource spending. In this contest, the model reveals to be a simpler and easier method by optimizing the available data.

Consequently, the repeatability of the method to the different flood conditions mapped in the framework flood directive can allow a systematic understanding and quantification of the benefits of the design countermeasures.

In this frame, the IRP methodology can represent a simple means to quantify benefits, to rank the design countermeasures and, consequently, to set priorities in financial spending.

Adoption of methodologies, easy to be implemented, can reveal to be a substantial decision to implement administration procedure like the RENDIS procedure described in the text. The increasing demand, for efficient management of designed countermeasures' projects and for efficient allocation of financial spending, should address administration towards methods like the IRP, described in the chapter.

In more general terms, the identification and the use of numerical estimation tools of flood risk and damage have real usefulness well beyond the particular scope of the proposed case study here. In fact, this sort of indicators can be applied in

- policies of flood-risk prevention. The estimate of the damages caused by the potential floods to which a given area is exposed is a key decision-making factor for the choice of any preventive measures. In fact, objective measurements allow undertaking appropriate analysis to compare the cost of any preventive measures with corresponding benefits in terms of the expected damage reduction and, based on these, comparing alternative intervention policies. At a time when the financial resources available to national and regional governments are scarce, the objective justification of the huge costs that often require these policies is an important prerequisite to their implementation;
- policies of emergency management. This kind of estimations can be a support also in preparation, revision and updating of emergency management plans. The knowledge of entity and of spatial distribution of expected damage in fact represents the essential information for the provision of adequate emergency and warning systems of the population;
- damage compensation programmes. The quantification of the potential damage of floods is needed to predict the amounts and the receivers of possible compensatory measures of damages and victims;
- land-use planning. Spatial planning policies that take into account the existing flood-risk conditions and of the potential damages are more necessary than ever;
- insurance schemes. To fix the amounts of insurance against floods, the insurance and reinsurance companies must estimate, with the greatest reliability, the risk levels which the insured goods are exposed. In the event of disasters, if not well assessed, these risks may jeopardize financial coverage provided by the insurance and cause insolvency;

- precautionary choices of businesses and citizens. Even companies or individual citizens may be interested to know the damage that their properties are potentially exposed. Having this information can be useful, in fact, to evaluate the convenience to take out any insurance policies and to undertake individually or ask the competent authorities measures to protect against flooding.

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References

[1] European Environmental Agency (EEA). Water Resources in Europe in the Context of Vulnerability. Luxembourg: EEA; 2012. 96 p. DOI: 10.2800/65298

[2] Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). Hydro-geologic hazards and risk indicators in Italy. Report 2015. 2015 ed. Rome: ISPRA-Settore editoria. 2015. 162 p. DOI: 978-88-448-0751-1.

[3] MATTM-Ministry of environment, soil and sea defence. Indirizzi operativi per l' attuazione della direttiva 2007/60/ce relativa alla valutazione ed alla gestione dei rischi da alluvioni. 2013th ed. MATTM; 35 p. www.minambiente.it

[4] Salvati, P., Bianchi, C., Rossi, M., Guzzetti, F. Societal landslide and flood risk in Italy. Natural Hazards and Earth Systems Sciences. 2010;10:465–483. DOI: 10.5194/nhess-10-465, 2010

[5] Vojinovic, Z., Abbott, M.B. Flood Risk and Social Justice: From Quantitative to Qualitative. International water association ed.; 2012. 600 p. DOI: 9781780400822

[6] Merz, B., Thieken, A.H., Gocht, M. Flood risk mapping at the local scale: concepts and challenges. In: Begum, S. et al., editor. Flood Risk Management in Europe. London: Springer; 2007. p. 231–251.

[7] Hunter, N.M, Bates, P.D., Nelz, S., Pender, G., Villanueva, I., Wright, N.G., Liang, D., Falconer, R.A., Lin, B., Waller, S., Crossley, A.J., Mason D.C. Benchmarking 2D hydraulic models for urban flooding. Water Management. 2008;161:13–30.

[8] Apel, H., Aronica, G.T., Kreibich, H., Thieken, A.H. Flood risk analyses – how detailed do we need to be? Natural Hazards. 2009;49:79–98. DOI: 10.1007/s11069-008-9277-8

[9] Ernst, J., Dewals B.J., Detrembleur, S., Archambeau, P., Erpicum, S., Pirotton, M. Micro-scale flood risk analysis based on detailed 2D hydraulic modelling and high resolution geographic data. Natural Hazards. 2010;55:181–209. DOI: 10.1007/s11069-010-9520-y

[10] Hall, J., Solomatine, D. A framework for uncertainty analysis in flood risk management decisions. International Journal of River Basin Management. 2008;6(2):85–98. DOI: 10.1080/15715124.2008.9635339

[11] President of Council of Minister decree (28th May 2015) (DPCM). 2015. Rome: Istituto Poligrafico Zecca dello Stato. Available at: http://www.minambiente.it/normative/dpcm-28-maggio-2015-individuazione-dei-criteri-e-delle-modalita-stabilire-le-priori-ta-di

[12] Environmental Protection Regional Agency (ARPA). Report of the flood event (13th-16th October, 2000). Turin: ARPA ed.; 2000.

[13] Franzi, L., Bianco, G., Bruno, A., Foglino S. Flood risk assessment and quantification in the Piedmont Region, Italy. In: Tiepolo, M., Ponte, E., Cristofori, E., editors. Planning to cope with tropical and subtropical climate change. Berlin: de Gruyter; 2016. DOI: 979-3-11-048078-8

[14] Interagency Advisory Committee on Waster Data (IACWD). Guidelines for determining flood flow frequency. In: Bulletin 17B of the Hydrology Subcommittee. Reston: Office of Water Data Coordination; 1982. Available at: www.water.usgs.gov/osw/bulletin17b/dl_flow.pdf

[15] Noman, N.S., Nelson, E.J., Zundel, A.K. Review of automated flood plain delineation from digital terrain models. Journal of Water Resources Planning Management. 2001;127:394-402.

[16] Federal Emergency Management Agency (FEMA). Guidelines and specifications for flood hazard mapping partners _Appendix C: guidance for riverrine flooding analysis and mapping. 2003 ed. FEMA. Available at http://www.fema.gov/media-library/assets/documents/13948

[17] Po River Basin District Authority (PBDA). Orco river hazard mapping. 2012. Available at: www.adbpo.it/on-multi/ADBPO/Home/documento13535.html (date of access 19.5.2016)

[18] Maione, U., Moisello, U. Statistics for hydrology. 2nd edition, Pavia: Medea; 2015. DOI: 8866930830

[19] Smith, D.I. Flood damage estimation – a review of urban stage-damage curves and loss functions. Water SA. 1994;20(3):231–238.

[20] Jongman, B., Kreibich, H., Apel, H., Barredo, J.I., Bates, P.D., Feyen, L., Gericke, A., Neal, J., Aerts, J.C.J.H., Ward, P.J. Comparative flood damage model assessment:

towards a European approach. Natural Hazard and Earth System Science. 2012;12:3733–3752. DOI: 10.5194/nhess-12-3733-2012

[21] Ciurean L.R., Dagmar Schro◎ter and Thomas Glade. Conceptual Frameworks of Vulnerability Assessments for Natural Disasters Reduction. In: prof. John Tiefenbacher ed., Approaches to Disaster Management - Examining the Implications of Hazards, Emergencies and Disasters. InTech. 2013. p.3-32. DOI: 10.5772/55538. Available at: http://www.intechopen.com/books/approaches-to-disaster-management-examining-the-implications-of-hazards-emergencies-and-disasters/conceptual-frameworks-of-vulnerability-assessments-for-natural-disasters-reduction

[22] ICPR: International Commission for the Protection of the Rhine. Action plan on flood defence. Koblenz: International Commission for the Protection of the Rhine; 1998.

[23] Kreibich, H., Thieken, A. Assessment of damage caused by high groundwater inundation. Water Resources Research. 2008;44:W09409. DOI: doi:10.1029/2007WR006621

[24] Federal Emergency Management Agency (FEMA), HAZUS-MH MR4 Flood Model Technical Manual. Washington: Department of homeland security, FEMA, Mitigation Division editors. 2009. 569p.

[25] Penning-Rowsell, E., Viavattene, C., Pardoe, J., Chatterton, J., Parker, D., Morris, J., editors. The benefits of flood and coastal risk management: a handbook of assessment techniques. Middlesex: Flood Hazard Research Centre; 2010.