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To the reader

This publication is part of the *"Integrated Flood Management Tools Series"* being compiled by the Associated Programme on Flood Management. The *Flood Loss Assessment: Case Studies* Tool is based on available literature and draws on the findings from relevant works wherever possible.

This Tool addresses the needs of practitioners and allows them to easily access relevant guidance materials. The Tool is considered as a resource guide/material for practitioners and not an academic paper. References used are mostly available on the Internet and hyperlinks are provided in the References section.

This Tool is a "living document" and will be updated based on sharing of experiences with its readers. The Associated Programme on Flood Management encourages flood managers and related experts around the globe who are engaged in the Social Impact Assessment or whose activities are related to the perception of risk by social actors to participate in the enrichment of the Tool. For this purpose, comments and other inputs are cordially invited. Authorship and contributions will be appropriately acknowledged. Please kindly submit your inputs to the following email address: apfm@wmo.int under Subject: *"Flood Loss Assessment: Case Studies"*.

Acknowledgements

This Tool makes use of the work of many organizations and experts as listed in the references and the Associated Programme on Flood Management is very grateful to the authors of the work from which this Tool built its case studies.

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CONTENTS

ACRONYMS

APFM	Associated Programme on Flood Management
CAPRA	Comprehensive Approach to Probabilistic
CORFU	Collaborative research on flood resilience in urban areas
DALY	Disability Adjusted Life Years
DPSIR	Drivers-Pressures-State-Impact-Response
DRR	Disaster risk reduction
DTM	Digital Terrain Model
EAD	Expected Annual Damage
EMA	Emergency Management Australia
FPU	Food producing units
GCM	Global Circulation Model
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Risk Reduction
IO	Input-Output
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Co-operation and Development
QMRA	Quantitative Microbial Risk Assessment
RCP	Representative Concentration Pathways
RISPOSTA	Reliable Instruments for POST event damage Assessment
SSP	Shared Socio-economic Pathways
USAID	United States Agency for International Development

1 INTRODUCTION

1 Climate change will increase the frequency and magnitude of extreme weather events. Its effects are more and more tangible as population growth (particularly in developing countries) and assets (socio, economic, institutional, cultural, etc.) multiply in the areas at risk, therefore increasing the severity and magnitude of disasters. In addition, while total economic losses from floods are higher (in values) in developed countries, the impacts on the economic development and the number of fatalities are more significant in developing countries (Suárez, 2011).

2 In response to the future exposure to floods, a wide range of tools and mechanisms have been developed to reduce and manage the risks of flooding and to provide an interdisciplinary approach to analysing flood management strategies and measures. These tools and mechanisms could focus on the development of thorough flood damage assessment methodologies in order to provide a point of comparison for different future scenarios with socio-economic and climate change drivers. The assessment of such scenarios would provide an improvement to current flood management practices.

3 The scale on which the tools and procedures are targeted, is likewise essential to concentrate efforts to avoid and/or mitigate risks. Even if increasing attention is being given to strategic global assessments of disaster risks, several actions could be conceived to be implemented under a local, national or higher context such as the European Directive on the Assessment and Management of Flood Risks–the Floods Directive (EC, 2007). This legislation is one of the main drivers for the legislation on flood which, together with the EU Flood Action Programme, requests countries within the European Union to improve their forecasting and early warning systems and develop precise flood risk mapping.

4 National and regional governments, international organization, and financial/insurance institutions require such assessments to decide on investments, mitigation and adaptation activities, and risk reduction strategies, among others.

5 In developing countries, investments are more focused on recovery from a disaster than on the creation of adaptive capacity. Increased capacity to manage extreme weather events can

reduce the magnitude of economic, social and human damage and eventually, investments (UNISDR, 2011). Regarding vulnerabilities to extreme weather events, disaster management and adaptation must be part of long-term sustainable development planning and the investment policies must focus more on capacity building instead of just investing in recovery operations and infrastructure development.

6 This IFM Tool collects methodologies in the framework of the flood loos assessment, however, it includes mainly case studies concerning OECD countries due to the lack of available flood impact data with acceptable quality to validate flood damage data and the lack of investments to implement this kind of procedures and tools.

2 COLLABORATIVE RESEARCH ON FLOOD RESILIENCE IN URBAN AREAS — CORFU

7 CORFU was constituted by European and Asian partners, thereby enabling joint collaboration to investigate, develop, implement and disseminate the different strategies at short and medium term for urban flood management according to possible scenarios. Its main objective was to provide an interdisciplinary approach to analysed flood management strategies and measures.

8 The project was carried out in seven large urban centres with different socio-economic and climate characteristics which only three of those, Barcelona, Dhaka and Hamburg, have been selected to showcase the different aspects of the implemented methodology. For all considered cities, direct tangible losses were assessed, while indirect and intangible losses were handled depending on the data availability.

2.1 Methodology (Flood Damage Assessment Framework)

9 CORFU project, as a whole, was based on the Drivers-Pressures-State-Impact-Response (DPSIR) framework. A flood damage assessment framework was conducted, within the CORFU project context, in order to consider socio-economic and environmental impacts. The procedure was based on a five steps approach and established homogeneous categories and subcategories of flood damages assessed at different urban scales (i.e. from property to city-wide scales) as follows:

- Direct tangible, to properties[1];
- Indirect tangible, interruptions to the economy;
- Intangible, impacts on human health.

1 Description adopted from the FLOODSite project, www.floodsite.net

10 The assessment process, including parameters, future scenarios and scales to be taken into consideration, was done for a reference, present state, scenario to which three other different scenarios are compared to. The scenarios combined variations in water levels, land use, assets and vulnerabilities according to climate, socio-economic growth and several other variables (**Figure 1**).

11 The CORFU approach, based on urban units[2], allowed to achieve accurate results which could be used to develop and/or suggest coherent and cost-effective flood resilience strategies. For some of the case studies covered in the CORFU project, the required data were available at the parcel scale, single objects, otherwise data were obtained as an aggregation of larger scales such as blocks and districts. It is important to note that CORFU focused on ex-ante damage estimations that were calibrated and verified with historical data and created based on future hypothetical events.

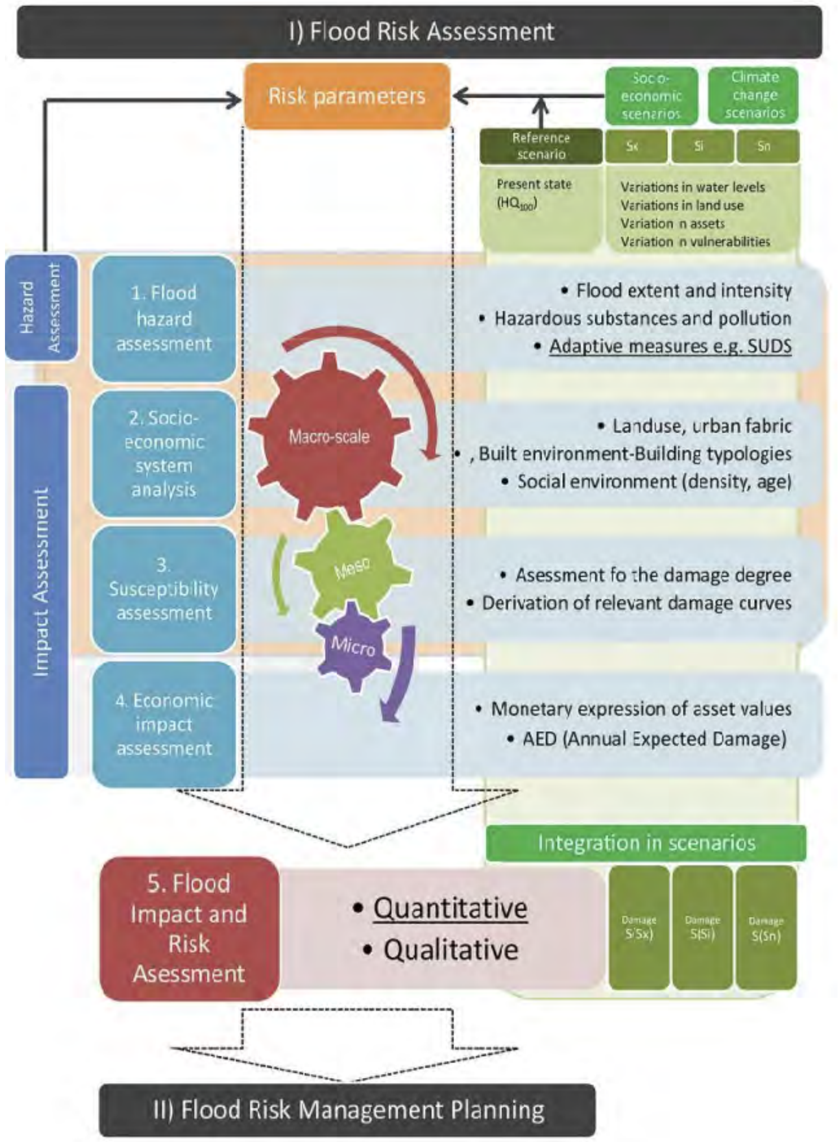

Figure 1 — CORFU's Flood Damage Assessment framework (CORFU, 2014g)

2 The selected urban units were: city, block, district and parcel.

2.1.1 Direct tangible damage

12 For direct tangibles damage, three main categories were considered: residential properties, non-residential properties and technical infrastructure. Agricultural products were not taken into consideration because all case studies represented urbanized areas with minor effects from agriculture **(Table 1)**. Data for this category were widely gathered regarding the following characteristics: flood extent, depth, duration, flow velocity, debris load, contamination concentration and time of occurrence. Information on flood duration was also collected when available, however, its application was linked to indirect damages rather than direct damages.

13 In order to maintain coherence and enable a comparison of the results across the different study areas, CORFU developed a Flood Damage Assessment Tool. The process, embedded in the tool, integrated three main components as inputs, inundation characteristics, land-use data and assets at risk data, to create flood maps for a single rainfall event derived from a particular scenario of climate change and socio-economic conditions. This process could be repeat for a different set of conditions, thus the results could be deployed to support the implementation of resilience strategies.

Table 1 — CORFU damage categories (CORFU, 2014c)

Categories	Subcategories		Subcategories
Residential properties	Flats/apartments	Including age, social class, and building materials	Structural damage
	Terraced housing		Household goods
	Detached housing		Vehicles
Non-residential properties	Commercial and Industrial		Structural damage
	Public administration		Fixed assets
	Educational establishments		Stock
	Healthcare facilities		
Technical infrastructure	Roads and transport		Structural damage
	Water services		
	Power generation and supply		
	Communications infrastructure		
	Flood defence infrastructure		

2.1.2 Indirect tangible damage

14 For indirect tangible damages, an Input-Output **(IO)** model was used to assess the effects on the regional economy resulting from a flood event. The model is used to provide information on the effects of an external shock, such a flood, and about the potential changes to any sector outputs or final demand. This means that the model is able to capture, not only how the flood affects damaged sectors but also, how the sectors related to the affected ones adapt to the changing circumstances (CORFU, 2014a).

15 The expected outputs of the model depend on the information given on direct damages. If available, direct and indirect production losses and employment/income changes in the regional economy can be assessed. If information on direct damage to infrastructure is provided, then the model can reflect reductions of activities in the transport sector and the losses derived from these reductions (CORFU, 2014a).

2.1.3 Intangible impacts

16 The methodology for assessing intangible impacts is based on a four-step framework according to the European Commission (2000): Hazard identification, Hazard characterization, Exposure assessment and Risk characterization.

I | Health impacts

17 Floods are associated with increased risk of illness and diseases due to contaminated waters and/or provide the conditions enabling the development of vectors, such mosquitoes[3] (APFM, 2015). The different health impacts considered under CORFU are shown in **Table 2**. The Quantitative Microbial Risk Assessment (QMRA) was the method used to evaluate health risks associated with waterborne diseases and polluted floodwaters in the CORFU project (Haas, 1999).

18 The parameter to measure risk was the Disability-Adjusted Life Years (DALY) defined by the World Health Organization (WHO)[4] as *"the sum of years of potential life lost due to premature mortality and the years of productive life lot due to disability"*. Duration of illness and life expectancy of the individual who died (when illness leads to death) are the two main components needed to calculate DALYs, as shown in the case study of Dhaka.

Table 2 — Health impacts from flooding (CORFU, 2014e)

Category	Impacts
Direct physical impacts	Death
	Injury
	Hypothermia
Illnesses and disease	Diarreheal: • Cholera • Rotavirus • Cryptosporidium
	Other fecal-oral: • Hepatitis A and E
	Helminth infection: • Schistosomiasis • Bancroftian filariasis (transmitted by mosquitoes)
	Vector-borne: • Malaria • Arboviruses (including Dengue fever and West Nile virus) • Bancroftian filariasis (see above)
	Rodent-borne: • Leptospirosis • Hantavirus pulmonary syndrome
Mental health	Common mental health disorders (depression, anxiety)
	Post-traumatic stress disorder (PTSD)
	Suicide
Other	Chemical pollution Respiratory disease Skin infections Malnutrition General increased mortality

3 For more information on the relationship between floods and health please read the APFM tool Health and Sanitation Aspects of Flood Management, available at: www.floodmanagement.info/publications/tools/Tools_23_Health_and_Sanitation_Aspects_of_Flood_Management.pdf

4 More information at www.who.int/mental_health/management/depression/daly/en/

II | Pedestrian safety

19 An intangible impact considered within the project was pedestrian safety. This impact relates to the velocity of flood waters and the risk of being carried away by the flow, as featured in the case study of Barcelona (CORFU, 2014d). The study defined three different categories for the velocity of flood waters: high, moderate and low. Once the hazard levels were determined, four different variables were chosen to assess pedestrian vulnerability:

Hazard level	Flow conditions
	(for flow depths between 9 and 16 cm)
1 (low)	$v \leq 1.51\ m/s$ below 5 cm depth
2 (moderate)	$1.51 \leq v < 1.88\ m/s$ between 5 and 10 cm depth
3 (high)	$v \geq 1.88\ m/s$ **above 10cm depth**

Vulnerability Index	C people aged <15 or >65 years old [%]	F Foreign population [%]	D People density [hab/km2]
1 (low)	≤ 33%	≤ 33%	≤ 1273
2 (moderate)	33 < X ≤ 50%	33 < X ≤ 50%	1273 < X ≤ 16000
3 (high)	**> 50%**	**> 50%**	**> 16000**

Vulnerability level	Formulation
1 (low)	(D+C+F)/3* < 1.5
2 (moderate)	1.5 < (D+C+F)/3* < 2.5
3 (high)	**(D+C+F)/3* > 2.5**

* In case there is a critical building (B) in the sub-district area, 0.5 must be added to the average value of (D+C+F)/3.

Figure 2 — Hazard levels according to flow parameters in flooded streets (top)
Parameters for the vulnerability variables and formulas for each vulnerabiolity level (bottom)
(CORFU, 2014d)

- C= Density of people with an age below 15 and above 65 years old (critical age)
- F= Density of foreign people
- D= Total people density
- B= Presence of critical buildings (hospitals, schools, police stations, etc.)

20 The final output was a risk matrix, obtained by multiplying the vulnerability by the hazard index, with values from 1 to 9; a risk map was then created following the coding of the risk matrix as depicted in **Figure 3**.

Risk Matrix				
		Hazard		
		1	2	3
Vulnerability	1	1	2	3
	2	2	4	6
	3	3	6	9

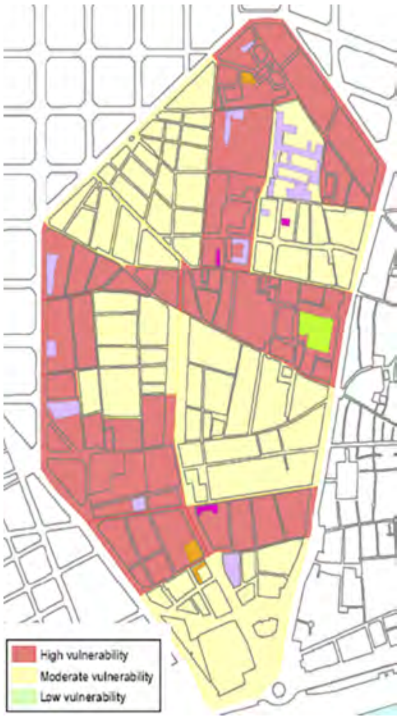

Figure 3 — Left, the risk matrix; Right, example of pedestrian risk map (CORFU, 2014d).

2.2 Application of the methodology

2.2.1 Scenarios

21 The methodology was not only applied to the current state of the analysed districts but also to scenarios taking into account future socio-economical and climate changes (CORFU, 2014f). The project was able to assess and compare future flood damage in the study areas, therefore facilitating both the inception as well as the improvement of flood management strategies considering the resilience and sustainability of the system. The drivers and pressures involved in the future scenarios were the following (CORFU, 2014g):

- Climate change (change in rainfall);
- Economic growth and changes to economic structure;
- Urban growth and changes to impervious surface areas;
- Demographic changes (population growth and age distribution).

I | Barcelona

22 The capital of the Catalonian region is impacted by urban flooding, especially in vulnerable areas of the old city such as the Raval district, one of the most densely populated areas in Europe with 44,000 inhabitants/km^2. The importance of surface-sewage interaction was the main factor for flood modelling in this district where special attention was put to damages related to vehicles and mix-use properties.

23 In order to obtain the Expected Annual Damage (EAD)[5] for computing direct tangible damages, three different events were modelled for return periods of one, ten and hundred years respectively as depicted in **Figure 4**. The EAD could be calculated by plotting flood damage values against annual exceedance probability which has a value of 1,697,299 Euros for the Raval district **(Table 3, Figure 4)**.

Table 3 — Damage and its probability for simulated flood events in the Raval, Barcelona (CORFU, 2014d)

Return period (years)	1	10	100
Probability	1	0.1	0.01
Damage (€)	78,846	1,615,738	19,156,196

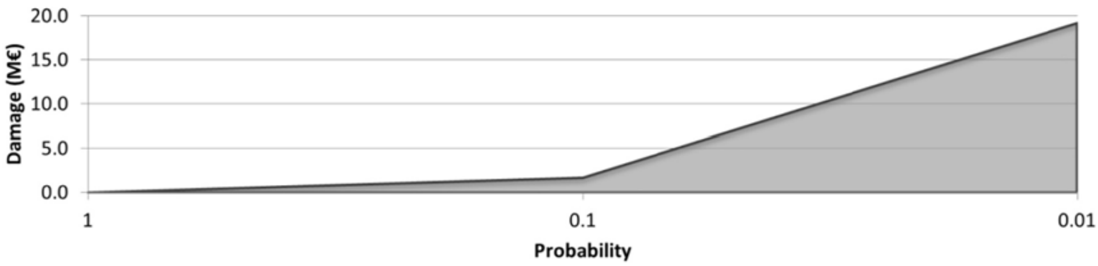

Figure 4 — Damage-Probability curve for a baseline scenario based on three events (CORFU, 2014d)

24 It has to be assumed that water depths below 15cm do not cause direct tangible damage and water depths in the streets are considered to be the ones for the buildings, causing an overestimation of damages **(Figure 5)**.

Figure 5 — Flood model results for three different rain events for Raval, with return periods of 1, 10, and 100 years

25 **Figure 6** illustrates the spatial distribution of land use for ground floors (left) and the potential damage for each asset (right), which goes from 0 to 400 Euros per square meter. Six categories were established for the assets at risk:

– Warehouses and parking garages

– Commercial

5 The EAD used in the project is estimated as the area under the curve of at least three events (corresponding to events with low, medium, and high probability) plotting flood damage against annual exceedance probability.

- Residential
- Hotel and leisure
- Public and cultural buildings
- Sites of interest

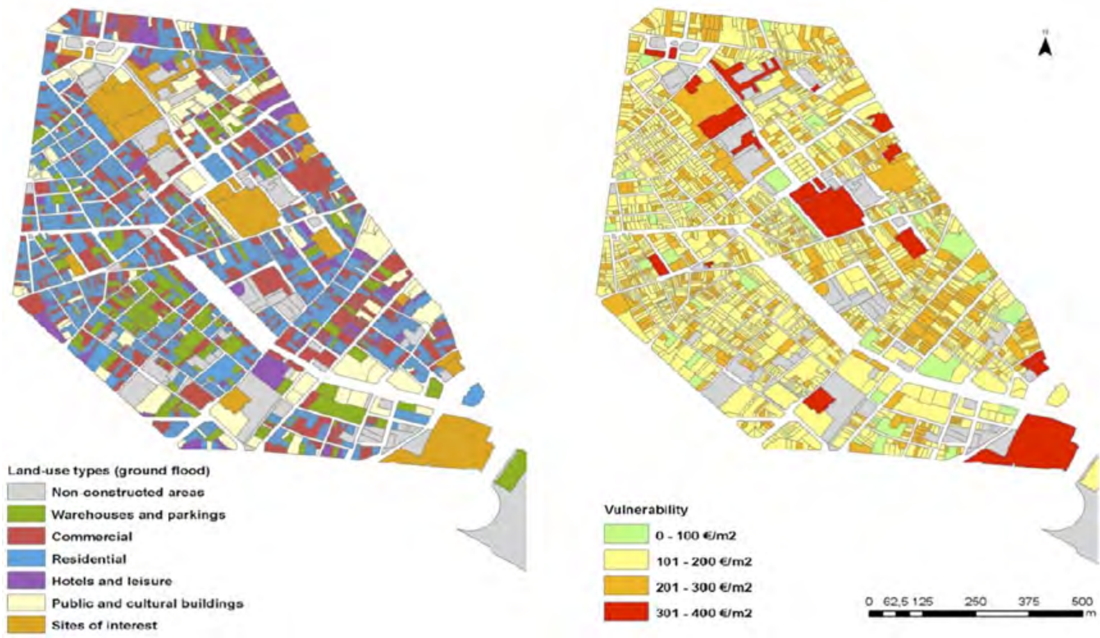

Figure 6 — Designated land use categories for the ground floors of buildings in the study area (left) and a map showing the vulnerability of each building as monetary damage per square meter (right) (CORFU, 2014d)

26 For each of the of assets at risk categories identified above, the stage-damage curves were built from past flood events data and "what-if" scenarios, future conditions for 2050 under the assumption of continuing "business as usual". Two different sets of curves were calculated, for the buildings themselves (structural damages) and their contents. From the curves, it can be appreciated that damages to contents can be as much as five times higher than damages to the buildings which hold them **(Figure 7)**.

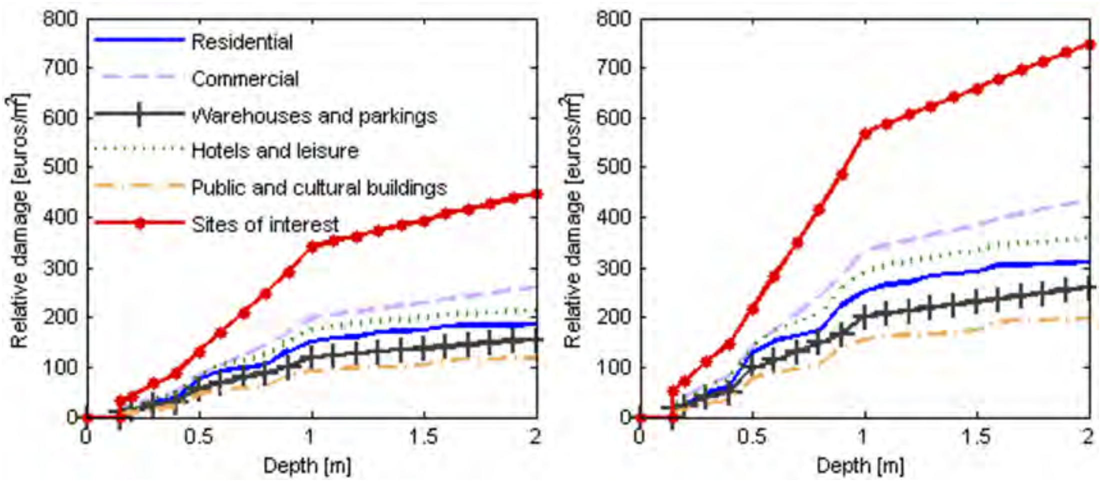

Figure 7 — Example of stage-damage curves per square meter for the Raval in Barcelona for the base line scenario (left) and a future scenario (right) (CORFU, 2014d)

27 The aforementioned data, along with the water depths obtained from the hydraulic model for each event, were used as inputs in the tool. Each value was interpolated from the stage-damage curves created for each land use category and their respective values of relative cost were multiplied by the total area of the affected buildings to obtain total damages. The result was a map with flood damage for each event as seen in **Figure 8**.

Figure 8 — Flood damages for the three modelled rain events, 1, 10 and 100 years return periods (CORFU, 2014d)

II | Dhaka

28 The region of the Bangladeshi capital is impacted by tidal flooding, causing the largest damages when considering tidal, riverine, and flash floods. According to the model used, the indirect effects of flooding to economy were 61% of the direct damages. Moreover, vector-based diseases are widespread when flooding occurs, causing health impacts that needed to be accounted for.

29 Dhaka suffers from flooding due to congestion of storm-water/wastewater drainage systems inside the city which owns both a combined sewer system and a separate sewer system. Despite this structural distinction, the system is blocked or damaged in most part of the network, leading to unhygienic conditions and environmental degradation when flooding occurs.

30 For the hazard identification, a decease profile was used, relating different diseases to a percentage of affected population when exposure occurs **(Table 4)**. The models for illness of the two identified biotypes in Bangladesh, *El Tor Vibrio cholera O1* and *Vibrio cholera O139*, were selected.

Table 4 — Disease profile during flood period (August-September 1998), BRAC

Disease	Percent affected
Diarrhoea	34%
Dysentery	17%
Fever	24%
Eye infection	2%
Helminthiasis	2%
Skin disease	6%
Acute respiratory infection	5%
Others	10%

(BRAC: Building Resources Across Communities, an international development organisation based in Bangladesh; www.brac.net*)*

31 In terms of hazard characterization, the study area covered 39.2 km^2 with 852 sub-catchments and was modelled using the urban hydraulic modelling software MIKE Urban[6]. The model was linked to a Digital Terrain Model (**DTM**) and to the advection-dispersion model for the transportation of contaminated flood waters. The event used was a flood from September 2004 and modelled depths and tracer concentrations which resulted in a map with different concentration values **(Figure 9)**.

32 The exposure assessment was done by means of interviews made in slum and mixed middle class/poor areas. In those zones inhabitants are exposed to different levels to flood water where, for example, small children from slum are exposed during the day and adults are wading or staying in the water from 1 to several hours either because of transport to and from work or by remaining in the flooded area, both living in slum or poor areas.

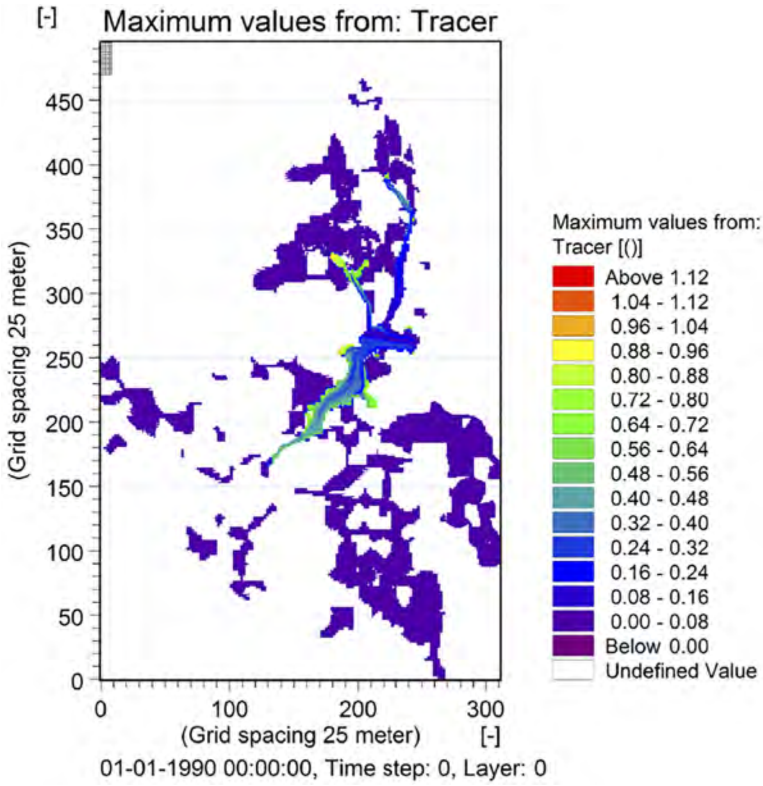

Figure 9 — Result of the concentration values for the September 2004 Flood in Dhaka (CORFU, 2014e)

33 The exposure per day was obtained from various sources of literature for four different groups: Small children in the slum and poor areas, adults in slum and in poor areas, middle class/upper middle class children, and middle class/upper middle class adults **(Table 5)**. Only samples for wet weather were collected, from three locations, and were taken hourly in each location until having seven of them. Dry weather samples were taken from the drainage system every four hours also until having seven. The obtained samples were analysed for *Enterococci*, *E. coli*, *V. cholerae*, and *V. cholerae 01 El Tor*.

6 MIKE Urban is an urban water modelling software developed by DHI; www.mikepoweredbydhi.com

Table 5 — Exposures in Dhaka for the different identified groups (CORFU, 2014e)

Group	Exposure description	Exposure/day
Small children in the slum and poor areas	The children stay partly emerged in the water for several hours. Considered exposed as children in recreational water	37 ml Gamma distribution $r = 0.64$, $\lambda = 58$
Adults in slum and in poor areas	Wading 1 hour/day on the way to work or other business.	Log normal $\mu = 3.5$ ml $\sigma = 3{,}6$ ml
Middle class/upper middle class children	Exposed on the way to school etc., but exposure usually restricted by parents.	Mean: 1.7 ml 95% CI: 0 - 4.6
Middle class/upper middle class adults	Avoids exposure but still exposed via hands	Mean: 0.016 ml 95% CI 0 - 0.068

34 The results of the model were based on the dilution of sewage water in flood waters and showed that the highest risks were found among children of the Paltan slum and the lowest risk among middle class adults.

35 The findings were in accordance with incidence of cholera in Dhaka and display a correlation between socio-economic factors and risk of infection. Regarding the risk model, it could be inferred that direct contact to sewage and flood waters are a significant route of cholera.

III | Hamburg

36 The city of Hamburg, in northern Germany, served to test a methodology for direct and indirect tangible losses. The area assessed was the Island of Wilhelmsburg, where storm surges are the main flooding condition.

37 For the study area, an open source software package called KALYPSO[7] was used to model flood dynamics. Additionally, a software tool called FLORETO, also developed by TUHH[8], was used to analyse direct tangible damage at a property scale.

38 Moreover, indirect tangible losses were assessed with the Input-Output model (IO) taking a regional approach for the area of Hamburg and surroundings accounting for changes in imports and exports. The region already possessed information on economic imports and exports per sector, allowing filling the IO table needed for the modelling of economic losses.

39 The model shows the results for three different scenarios where the losses on value added can be perceived over time. The three scenarios show recoveries within the first year and a half after the event, with the first two having sharp peaks where the added values show gains due to reactivation of the economy **(Figure 10)**.

7 Software package developed jointly by the Hamburg University of Technology (TUHH) and Bjornsen Consulting Engineers.

8 More information about the FLORETO software at floreto.wb.tu-harburg.de/

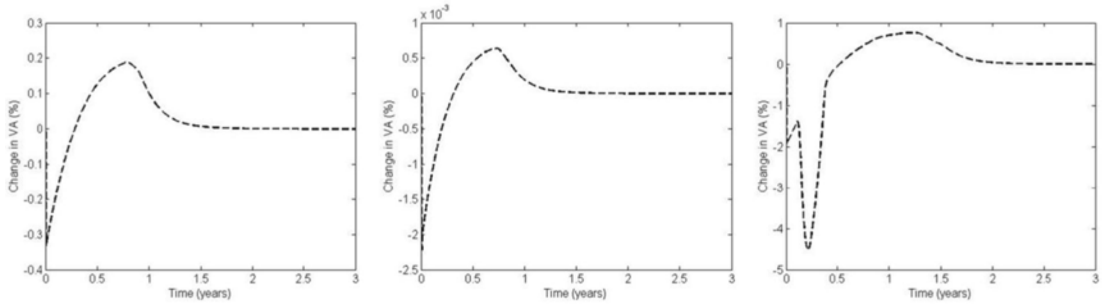

Figure 10 — Changes in value added for three different scenarios with flooding (CORFU, 2014d)

40 Furthermore, the model shows results for direct and indirect tangible damage per sector which the most affected ones being real estate, wholesale and retail trade, and transport, storage and communication.

41 This happened mainly because of the presence of these sectors in the flooded areas of the study, however, the construction sector experienced gains from the high demand of reconstruction services.

42 Direct and indirect tangible losses change depending on the scenario, as summarized in **Table 6** *(next page)*. It is pertinent to highlight that in two of the three scenarios there are indirect economic gains rather than losses and this behaviour is due to the large-scale flooding suffered under the third scenario.

43 Reconstruction needs and destruction of productive capital is larger in a large-scale flood event, which makes the economic recovery difficult, while the small-scale events seen in the first two scenarios, although affecting several sectors directly, promote a reactivation of the general economy.

44 It must also be noted that in none of the scenarios do the indirect gains balance the direct damages caused by flooding.

Table 6 — Direct and indirect tangible losses for three different scenarios in Hamburg (CORFU, 2014d)

	XR2010A		XR2010B		XR2010C	
	direct damages	indirect losses	direct damages	indirect losses	direct damages	indirect losses
Sector	million					
Agriculture, forestry, fishing, mining	28.6	0.6	0.00	0.00	173.0	8.9
Manufacture of food products and beverage, manufacture of tobacco products	2.3	-0.4	0.00	0.00	35.5	11.1
Manufacture of textiles and textile products; leather and leather products	0.0	0.0	0.00	0.00	4.0	0.7
Manufacture of wood and wood products (except furniture)	0.2	0.0	0.00	0.00	0.7	0.3
Manufacture of pulp, paper and paper products; publishing, printing	2.4	-0.4	0.00	0.00	8.7	10.2
Manufacture of coke, refined petroleum products and nuclear fuel	0.0	-0.4	0.00	0.00	0.0	7.2
Manufacture of chemicals, chemical products and man-made fibres	44.4	4.2	0.00	0.00	192.2	32.1
Manufacture of rubber and plastic products	20.0	2.0	0.00	0.00	84.6	15.5
Manufacture of other non-metalic mineral products	0.0	0.0	0.00	0.00	0.0	0.5
Manufacture of basic metals and fabricated metal products	2.5	1.4	0.43	0.07	10.4	0.4
Manufacture of machinery and equipment	3.8	-4.3	0.20	0.03	13.7	-11.0
Manufacture of electrical and optical equipment	0.0	-5.9	0.00	-0.01	0.0	-19.8
Manufacture of transport equipment	0.2	-7.4	0.00	-0.02	0.4	-17.6
Manufacture n.e.c., Recycling	0.0	-0.9	0.00	0.00	1.9	-3.1
Electricity, gas and water supply	2.6	-0.6	0.00	0.00	87.4	8.0
Construction	5.2	-49.8	0.00	-0.17	20.0	-234.1
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	28.3	4.2	0.20	-0.02	224.3	174.6
Hotels and restaurant	2.3	-0.6	0.00	0.00	23.0	11.2
Transport, storage and communication	100.2	5.8	0.11	0.00	989.1	164.2
Financial intermediation	2.1	3.3	0.00	0.01	6.9	25.1
Real estate, renting and business activities	768.6	8.2	0.41	-0.04	3,226.6	261.3
Public administration and defence; compulsory social security	2.2	2.9	0.00	0.01	109.9	23.8
Education	0.2	-2.2	0.00	-0.01	9.6	10.8
Health and social work	0.6	-3.7	0.00	-0.01	13.6	18.4
Other community, social and personal service activities	27.1	-1.6	2.06	0.12	259.5	50.5
SUM	**1,043.7**	**-60.8**	**3.41**	**-0.09**	**5,495.1**	**548.4**

3 AQUEDUCT GLOBAL FLOOD ANALYZER

45 The Aqueduct Global Flood Analyzer is an open access interactive platform which evaluates river flood impacts and affected population, and indeed these estimates can be displayed on maps available, at multiple geographical scales, on the web platform (**Figure 11**, next page). It aims *"to raise awareness about flood risks and climate change impacts providing open access to global flood risk data free of charge"* (WRI, 2015).

46 Unlike the other two case studies included in this document, AQUEDUCT focuses on risk analyses rather than flood assessment and therefore is not a post disaster tool. Despite this fact, anticipated potential flood risk can be identified which is especially useful within the planning, development and management of flood management plans, strategies and/or policies.

47 Decision makers could benefit from this practical and simple tool in the performance and creation of cost-benefit analyses, risk mitigation and climate adaptation projects as well as strategic planning while, at the same time, allowing the identification of climate change and socio-economic factors that bear an effect on the development, in the concerned area (WRI, 2015).

48 The assessment of flood risk at a global scale can be employed by different types of organizations and institutions as an element that enhances the decision-making process for activities, investments, and general strategies for flood risk reduction in specific areas of a certain country, region or basin. The AQUEDUCT website identifies four different kinds of potential users:

– International and national disaster risk reduction (DRR) monitoring organizations, including national governments and United Nations agencies, could use the Analyzer to assess progress on flood risk reduction activities and evaluate baseline risk conditions;

- International development and financing organizations, such as the World Bank and USAID, might use these data for investment prioritization with regards to disaster risk reduction in general and flood risk reduction strategies in particular;
- Insurance companies might use the information for insurance coverage and premiums, as well as identify areas where they could offer their services to the general public in flood prone locations;
- Multinational companies can use this assessment to evaluate their facilities around the world and the risk on their supply chains. They can use data for applying local risk reduction and mitigation strategies.

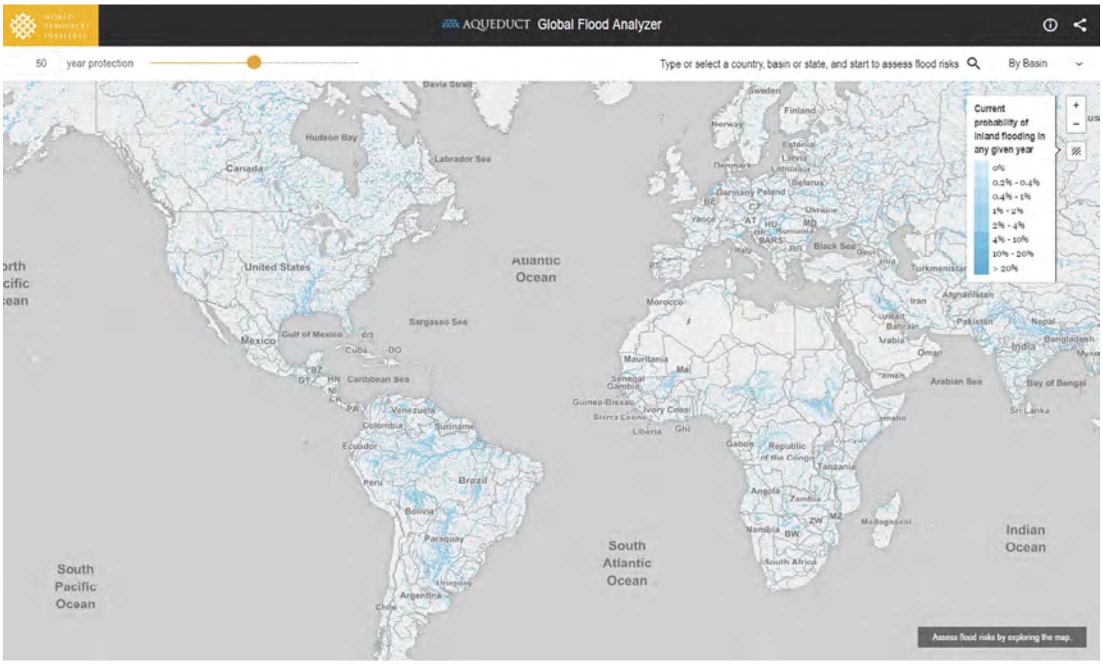

Figure 11 — AQUEDUCT platform represents a map of the world with basins and flood probability in blue (WRI, 2015)

3.1 Methodology

49 The Flood Analyzer AQUEDUCT platform is based on the framework of the Global flood risk model with image scenarios (GLOFRIS) which is composed of a model cascade including five steps, only the fourth and fifth are the ones which concern to the scope of this case study as shown in **Figure 12**.

Figure 12 — Model cascade for the global risk assessment of AQUEDUCT (Ward, 2013)

50 The approach implement facilitates the current and future global river flood risks for any region in the world, in addition, it is divided in two main components:

- Hazard estimation: where the current and future conditions are determined to obtain inundation at global and local scale;
- Exposure estimation: where the current and future conditions are determined to obtain data on vulnerable areas, for population and assets.

51 The AQUEDUCT focus relies on the second part of the approach, as it is the one containing a global assessment of flood impacts, both for current conditions and future scenarios. The assessment of flood impacts is achieved within the framework by making use of inundation depths for different return periods as an input for the impact model, as with four other variables: population, GDP, agricultural value, and land use.

52 The aforementioned data were fed into the impact model along with stage-damage functions which results in a map of 30″x 30″ grid-cells resolution for each return period[9]. A flowchart of the framework as a whole is given in **Figure 13**.

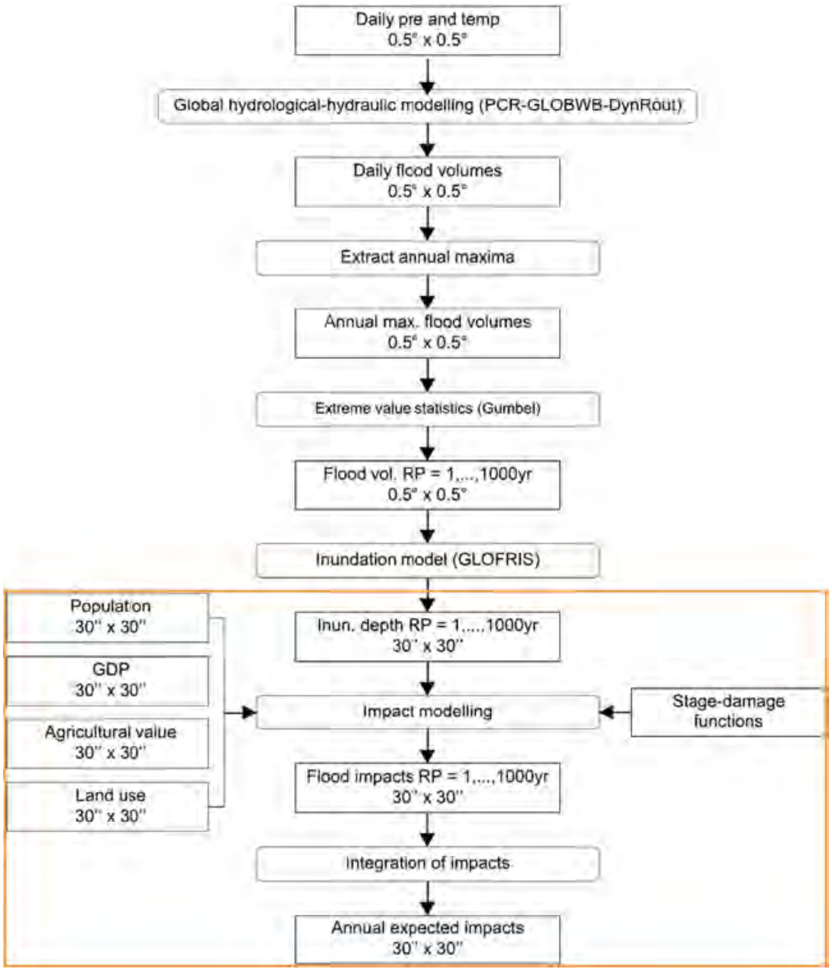

Figure 13 — Diagram of flow of data and models for the assessment of flood risk.
The process relevant to Flood Loss Assessment is shown inside the red rectangle (Ward, 2013)

9 GLOFRIS can make use of up to nine return periods of: 2, 5, 10, 25, 50, 100, 250, 500 and 1000 years.

3.2 Impact modelling

3.2.1 Exposure

53 The methodology considers five different types of impacts for calculating the exposure of flood loss for current state and possible (future) scenarios. These impact indicators, described in the following list, were calculated for all the nine return periods possibilities within the model:

- Population exposed to flooding (number of people)[10];
- GDP exposed to flooding (U.S. Dollars PPP)[11];
- Economic urban asset exposure[12];
- Urban damage from flooding (U.S. Dollars);
- Agricultural value.

54 The calculation of damage presented some methodological limitations: the estimated maximum damage values directly linked to GDP per capita, scarcity and low resolution of available spatial population and land use data, and equal productivity among inhabitants, as a result of using a homogeneous distribution of GDP over all areas within a country (Ward, 2013; Winsemius, 2013).

55 After running the model, impact results were aggregated into countries, states or basins. This aggregation' process into geographic units is used within AQUEDUCT platform to allow users to select a given return period representing the protection threshold, in order to visualize data for their specific area of interest (Ward, 2013; Winsemius, 2013).

3.2.2 Vulnerability

56 Vulnerability is represented in the model by stage-damage curves, illustrating the amount, or percentage in this case, of damage dependant on flood depth. A single stage-damage curve was applied to all countries, as a first approach, where the values and their respective graph for the stage-damage function used in the model are presented below.

Inundation depth (m)	Damage factor (0-1)
0.0	0.000
0.1	0.034
0.5	0.150
1.0	0.228
1.5	0.278
2.0	0.324
2.5	0.408
3.0	0.498
3.5	0.618
4.0	0.746
4.5	0.906
5.0	0.981
10.0	1.000

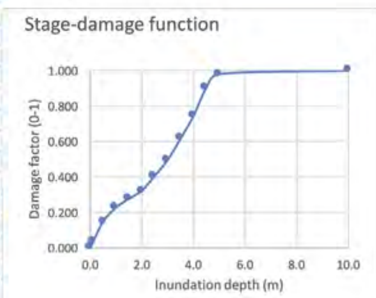

Figure 14 — Stage-damage function applied for calculating economic loss (Ward, 2013)

10 It considers population scenarios from 26 world regions from Integrated Model to Assess the Global Environment (IMAGE) and 2000 population maps from LandScan 2010 with data from 2010

11 IPCC-SRES scenarios were used for acquiring economic growth rates.

12 For assessing this impact, land use maps were taken from the HYDE database and estimations assumed a linear relationship of GDP per capita to quantify value of assets at risk of flooding.

3.2.3 Risk

57 Flood risk was estimated in terms of annual expected impacts. As mentioned, for all impact indicators, exposed population, exposed GDP and urban damage, damage was calculated for floods for all the nine return periods considering that only one extreme event takes place within a year because the events are associated with annual timescales. Besides, the model assumes that a two-year event has zero impact.

58 The model was tested for both hazard and impacts in Bangladesh to demonstrate the viability of GLOFRIS[13]. The river flood hazard maps and damage estimates obtained, for this particular case study, were in the same order of magnitude as those of the global EM-DAT database and World Bank demonstrating that the model approaches used as implementation of GLOFRIS provide satisfactory and plausible results.

3.2.4 Scenarios

59 In order to provide damage estimates for future scenarios (2030), the methodology includes future flood risk projections that depend on two variables, GCM data (Global Circulation Model) for climate change and Shared Socio-economic Pathways **(SSP)** for socioeconomic change (Winsemius, 2013).

60 Data on climate change are based on IPCC scenarios, more specifically the **SRES A1B** scenario (IPCC, 2013). This scenario includes economic growth rates that were combined with baseline GDP per country on a map and used to scale future-scenario maps by using a detailed population map of the current scenario. On the AQUEDUCT website, three scenarios are considered which take into account two variables relating to climate and socio-economic changes Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSP), from the IPCC (5th assessment report) (IPCC, 2013):

- **Scenario A**: RCP variables assume a moderate climate change and SSP variables assume a continued current socio-economic development trends;
- **Scenario B**: RCP variables assume severe climate change and SSP variables assume a continued current socio-economic development trends;
- **Scenario C**: RCP variables assume a severe climate change and SSP variables assume an uncontrolled population growth and fragmented economies.

3.3 Implementation of the AQUEDUCT platform

61 As mentioned previously, results can be aggregated in different geographical units. **Figure 15** shows results in terms of food producing units (FPU)[14] as a percentage of damage for the four impacts taken into consideration: affected population, GDP, affected agricultural value, and urban damage (Ward, 2013).

13 For more information, *"Assessments for Investments Dutch Business Case for Adaptation with focus on the case of Bangladesh"*; goo.gl/As4ofR

14 Food Producing Units are spatial units where economic regions intersect with river basins. The concept was developed by the International Water Management Institute and the International Food Policy Institute.

62 According to the results, the majority of the urban damage is concentrated in North America, Europe and China, while most of the affected population and affected agricultural value are located in Asia, specifically South East Asia and China. Return periods for flooding can also be perceived as protection standards in the AQUEDUCT platform. The amount of urban damage, for example, will be dependent on this level of protection.

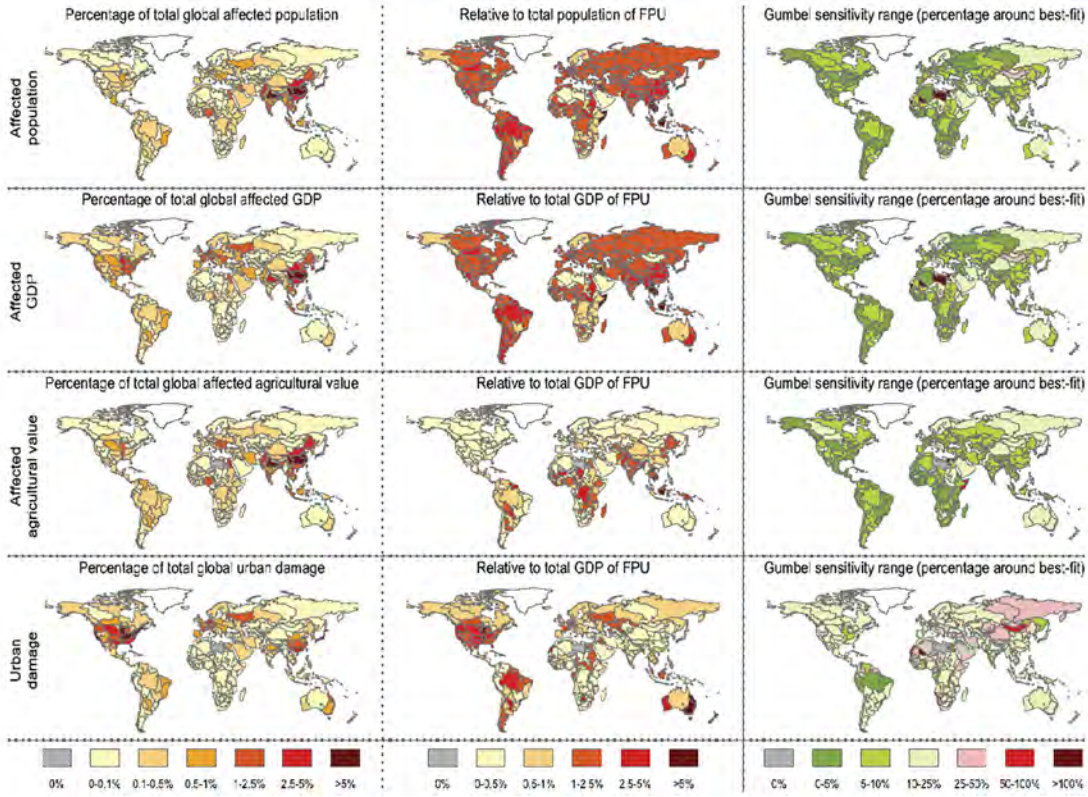

Figure 15 — Initial annual expected impacts per FPU for affected population, GDP, agricultural value and urban damage; darker colors represent larger percentages of impacts relative to total exposed population or assets (Ward, 2013).

63 In order to validate the cascade model, a comparison was made with the Munich Re's NatCatSERVICE database using data from 1990 to 2000 and results from the model for exposed assets and affected population for each of those years **(Figure 16)**.

64 .

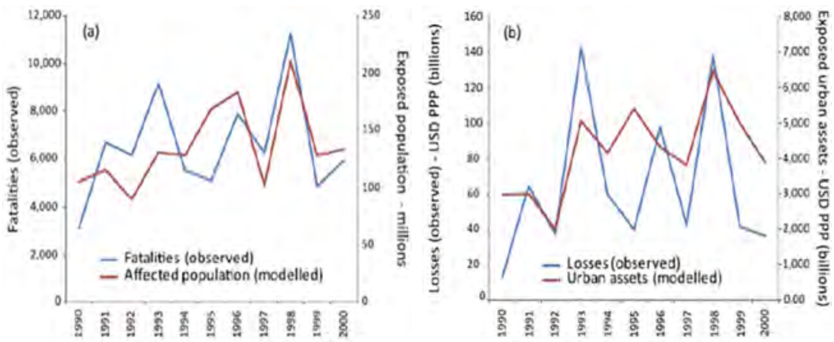

Figure 16 — Comparison between reported fatalities and modelled affected population (left) and reported losses and modelled urban assets (right) (Ward, 2013)

65 The results of the assessment are integrated into the Aqueduct Global Flood Analyzer web-based interactive platform[15] consequently users can select a protection level for a specific return period, from two to 1000 years, and search a country, basin or state to query flood risk. The results are depicted as a map with a blue colour code indicating the probability of inland flooding in any given year

66 As an example, for a basin, **Figure 17** indicates the details for the Mississippi-Missouri River Basin, providing information in form of a graph depending on the chosen level of protection. Users can choose to visualize urban damage, affected GDP or affected population and, for each of these indicators, the graph provides detail on the prevented damage from the level of protection and the residual damage. Moreover, the user can choose among three different scenarios for the three variables as mentioned in **Section 3.2.4**.

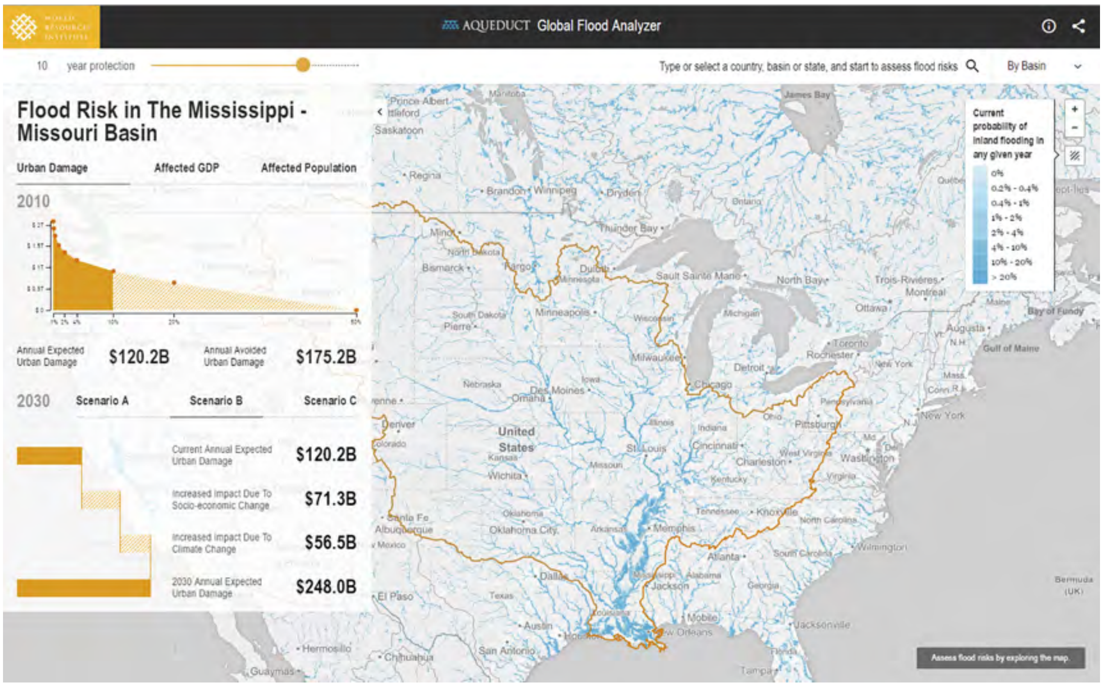

Figure 17 — Flood risk details for the Mississippi-Missouri Basin (WRI, 2016)

3.4 Limitations and Future development

67 The AQUEDUCT interactive platform is based on a model and requires, among others, climatic and geomorphological data to achieve as main result risk maps. In this context, there are still improvements to be made since AQUEDUCT presents some limitations that need to be solved in order to obtain more accurate results:

- Types of flooding: The current model considers only large-scale river flooding given the large amount of inputs and computing required to compile losses at a global scale. Other types of flooding such as coastal, flash and pluvial flooding were not considered;
- Flood management: The programme considers that no flood management measures are in place for any given area. In this sense, where such measures already exist, the flood extent and the affected population is overestimated. To compensate this assumption, the user can

15 Results available at floods.wri.org/

include a management standard (expressed in terms of a return period in years) in their query on the Flood Analyzer website;

- Damage estimate assumptions: In the case of damages in urban areas, a single stage-damage curve was applied throughout the world. This assumes that the relationship between the inundation depth and the actual damage is the same for all urban areas, which in reality is not the case;
- Additional limitations: Among the possible additional limitations are inaccuracies in climate data, elevation data, and model simplifications that may cause further uncertainties in the hazard and risk estimates.

68 The model will be enhanced to address different existing flood protection levels by creating a database of flood protection structural measures globally; likewise, these measures will be programmed in order to spatially disaggregate protection standards around the world and provide more accurate damage estimates (Ward, 2013).

69 Future developments will include a more detailed vulnerability modelling in the form of more local/regional stage-damage functions (similar to those present in the CAPRA[16] vulnerability model) and considering other vulnerability indicators such as mortality as a function of total exposed population, and damage as a function of total exposed assets, among others (Peduzzi, 2009).

16 Comprehensive Approach to Probabilistic Risk Assessment (CAPRA), more information at www.ecapra.org/

4 RISPOSTA

70 In the local context, Italian authorities have been increasingly demanding better methods and procedures for post-event damage assessment. As such, **RISPOSTA**[17] (Reliable Instruments for POST event damage Assessment) was born from the need of revamping the way data collection is made at the local scale after flood events and it was conceived to be implemented under the Italian institutional context.

71 The RISPOSTA main objective is to develop a methodology for compiling flood damage information after an event, and the area of study is the Italian Umbria Region[18]. RISPOSTA addresses the change in needs for users' information depending on the time after the flood and standardises the process to obtain this information. The first three weeks after a flood, the information required are the characteristics of the physical event, the affected areas, the state of essential services, available resources, and people requiring assistance, to name a few. In contrast, from the first to the sixth month, a comprehensive scenario of incurred damages should be provided, including priorities of intervention and resources involved. From the 6th to the 12th month after flooding, the scenario should be completed with data on indirect damages, i.e. loss of income due to service disruptions, environmental damage, health issues, etc. In every timeframe, there is a need to collect data from stakeholders, including local authorities, utility companies, private citizens, insurance companies, etc.

4.1 Methodology

72 RISPOSTA is inspired by other methodologies for data collection including the PDNA - GFDRR methodology (GFDRR, 2013), the guidelines for Disaster Loss Assessment from Emergency Management Australia **(EMA)** (EMA, 2002), and the Associated Programme on Flood Management post-flood losses assessment guidelines from the World Meteorological Organization and the Global Water Partnership (APFM, 2013). RISPOSTA also took in consideration successful practices

17 RISPOSTA is a procedure which was developed within a research project called Poli-RISPOSTA.

18 Umbria is one of the 20 regions of Italy that act as first-level subnational administrative units.

from Italy, more specifically in the field of surveying damage to building after earthquakes. Furthermore, the methodology was established in collaboration with the Civil Protection Authority of the Umbria Region in central Italy, involving several stakeholders in the process.

73 The scope of RISPOSTA is small-scale or scattered events depending on the number of affected assets in the flooded area and the methodology is based on three logical axes, as described in the following paragraphs:

I | Time of action

74 One of the main aspects of RISPOSTA is defining when each activity within the procedure must be performed. The time of action depends on several factors including the nature of the flood event itself, the information needed by users during the emergency and recovery phase, and the administrative procedures for damage compensation, recovery management and loss accounting depending on national and European regulations.

II | Actors

75 This axis refers to the identification of users and providers within data management. In the Italian context, several actors have been identified: municipal and provincial authorities, authorities from specific sectors, the Regional Civil Protection Authority, utility companies, trade associations and private citizens. The Regional Civil Protection Authority acts as a data coordinator during the emergency and recovery phase. Public actors are bound by law to report their data to Civil Protection while the private actors are not under this obligation, except in the case of key data for emergency management, e.g. disruption of essential services and environmental contamination. In the case of private citizens, they collect data only when there are compensation funds available and, in this case, they must report to the Regional Civil Protection Authority to access such funds.

III | Sectors

76 Another important aspect of the procedure is to have a proper categorization of the assets. The selected classification is based on abovementioned methodologies, PDNA and APFM, and adopts the European Flood Directive recommendations. RISPOSTA categorises assets according to the following sectors:

- Residential buildings,
- Industrial and commercial premises,
- Farms
- Infrastructure
- Public items
- Emergency costs
- People
- Environmental and cultural heritage

77 Current practices for data collection in Italy highlighted the most critical aspects which are gathering and integrating already collected data and the acquisition of missing information, the latter being addressed by means of field surveys. These two aspects have to be performed by the data coordinator which, in the case of Italy, is the Regional Civil Protection Authority. So far, formal agreements with other actors have not been reached so there is a need to negotiate the acquisition of relevant data every time that a disaster occurs. In the Umbria Region already exists a collaboration between the Regional Civil Protection Authority and the Politecnico di Milano, the latter acting as the expertise centre in charge of the remotely coordinating of the activities.

78 The damage data are acquired and organized depending of their availability, emphasizing the fact that data is not organized according to collecting methods. In the Umbria Region, the data gathering is done by Civil Protection and both the Expertise Centre and the Regional Civil Protection Authority follows an extensive list of activities related to flood loss assessment to be performed before, during, and after a flood event, short and long-term, as shown in **Table 7**.

Table 7 — Main activities included in RISPOSTA (Molinari et al., 2017)

Legend:

- Data survey (sectors a, b + physical event)
- Data gathering (sectors c, d, e, f, g, h)
- Data coordination

	Regional Civil Protection Authority	Expertise Centre
BEFORE THE EVENT	Acquisition of pre-existing knowledge on the hazard	Set-up and management of the IS
	Acquisition of pre-existing knowledge on the exposure and vulnerability of residential buildings/industrial/commercial premises	Data sharing
	Acquisition of pre-existing knowledge on the exposure and vulnerability of potentially affected items	
DIRECTLY AFTER	Acquisition of data on the hazard scenario (monitoring and forecasting data, satellite and aerial images)	Data sharing
2-3 DAYS AFTER	Survey of the flooded area/water elevation	Organisation and coordination of the survey (flooded areas)
		Data analysis (field survey)
		Data validation (physical event)
		Inputting data (physical event)
		Data sharing

20 DAYS AFTER	Survey of damage to residential buildings/ industrial-commercial premises	Organisation and coordination of the survey (residential buildings/industrial-commercial premises)
		Acquisition of damage data from the Regional Emergency Room (SOUR)
		Data analysis (field survey)
		Data validation (residential buildings/ industrial-commercial premises/SOUR)
		Inputting data (residential buildings/ industrial-commercial premises/SOUR)
		Data sharing
90 DAYS AFTER	Survey of damage to residential buildings (optional)	Organisation and coordination of the survey (residential buildings)
		Acquisition of damage data from the responsible stakeholders (optional)
		Acquisition of monetary damage data
		Acquisition of monetary damage data
		Data validation (residential buildings/other sectors/ monetary damage data)
		Inputting data (residential buildings/other sectors/ monetary damage data)
		Data analysis (field survey, report 1)
		Data sharing
6 MONTHS AFTER	Survey of damage to industrial/ commercial premises	Organisation and coordination of the survey (industrial/commercial premises)
		Acquisition of damage data from the responsible stakeholders
		Acquisition of monetary damage data
		Acquisition of monetary damage data
		Data validation (industrial-commercial premises/other sectors/ monetary damage data)
		Inputting data (industrial-commercial premises/other sectors/ monetary damage data)
		Data analysis (field survey, report 2)
		Data sharing

4.2 Survey-based data collection

79 The core of RISPOSTA is the development of a survey-based procedure to obtain damage data from flooding. It is used when there is a lack of meaningful information on flood impacts or where no specific entity is responsible for data collection. In order to cover different types of

information, the procedure has different timing for acquiring the needed data. Usually from the moment flooding occurs and up to 6 months after if we also consider industrial sector.

80 The approach consists of two parts, being: survey of flooded areas, including extension and hazard magnitude, and survey of damage, to residential buildings and to industrial/commercial premises. The categories are described in the following sections.

4.2.1 Direct survey of flooded areas extension and hazard magnitude

81 The Regional Civil Protection Authority is in charge of carrying out the activities with the help of trained technicians while the Expertise Centre is in charge of organizing and coordinating the survey.

82 Surveys are done when information from satellite or aerial images is not usually reliable for short-timed events, i.e. flash floods, as the images might provide an underestimated extension of flooded areas. However, the flooded area alone does not provide a full depiction of risk, making it important to appraise other variables such as water depth, water velocity, and sediment and contaminant loads **(Figure 18)**. These variables can be obtained through numerical modelling and its calibration and validation are made possible with field surveys.

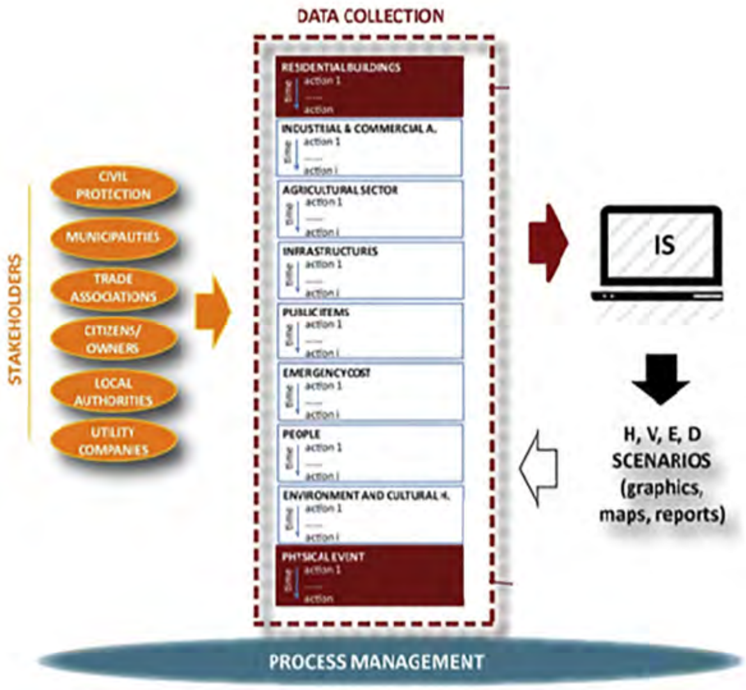

Figure 18 — General scheme of the RISPOSTA procedure: links between data collection, storage and analysis (Ballio, 2015)

83 The activities needed to be undertaken within this procedure are the following:

- Acquisition of pre-existing knowledge on the hazard by aid of existing databases, monitoring networks, and hazard models;
- Acquisition of data on the physical event including monitoring data, satellite and aerial images, notifications by experts on the field, etc.;

– Survey of the flooded consisting of a topography analysis of the area and a register of watermarks to define the perimeter of the flooded area defined in a map. Additionally, reports by citizens in the region can also provide inputs for the delimitation;

– Survey of water elevation. In order to accurately refer water elevation to the available DTM, special attention must be placed on having the depth referred to elevations which are more accurate than building locations in the DTM, i.e. plain areas.

4.2.2 Direct survey of damage

84 Under this action, several activities must be undertaken by both the Regional Civil Protection Authority and the Expertise Centre as follows **(Figure 19)**:

– Acquisition of pre-existing knowledge. Information on exposure and vulnerability of buildings is obtained via cadastral databases and/or risk maps, among other sources. Several data are to be retrieved such as surface area, number of floors, building's age, level of maintenance, type of activity, and number of dwellers;

– Survey of damage to buildings. Within this activity, the first step is to identify the premises to be surveyed on a map, then dispatch teams of surveyors to those areas using survey forms as means to collect data (see **Annex**). Additionally, a second survey may be performed after some month with the objective of acquiring information on long-term damage (Molinari, 2014a);

– Acquisition of monetary damage data. In a first stance, the damage assessment is carried out based on physical units within the building, e.g. number of damaged doors or square meters of damaged floors. Consequently, the damage value is assessed against compensation requests by owners and national authority funds that are made available by regional and/or national authorities.

– A second survey of damage is optional for residential buildings to obtain data on losses such as time spent outside the house and loss of rental income. However, for the industrial and commercial premises this assessment is vital to calculate indirect losses such as loss of income, loss of orders, unemployment and physical damages to assets due to humidity.

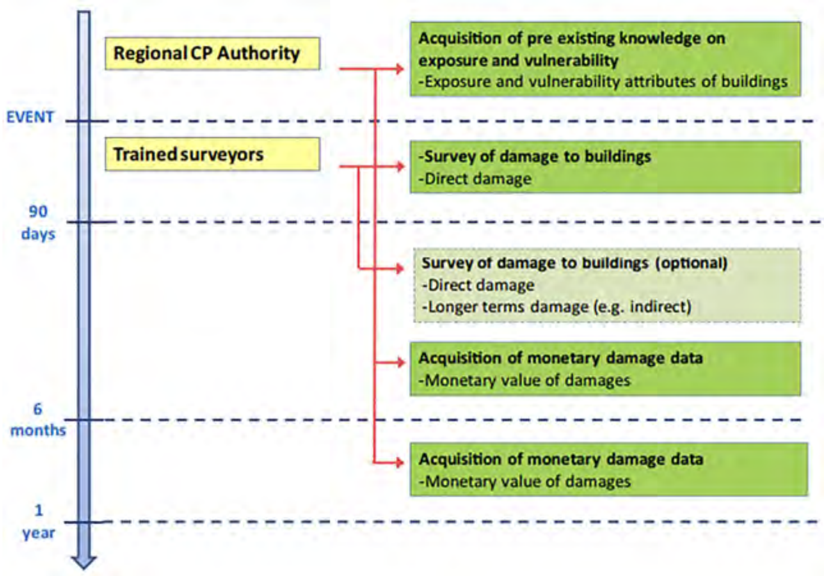

Figure 19 — Scheme of the RISPOSTA procedure for data collection on the damages at the residential sector: actions to be performed, times of actions, collected data and responsible actors (Molinari, 2014a)

85 The activities described above, can be used for the residential buildings as well as industrial/ commercial buildings, however, for industrial and commercial premises the structural damage is not always the main component of the losses suffered. This means that, under survey of damage, hinders and affectations to production must be taken into account and should be recorded (including damage to machinery, equipment, raw materials, finished products, and stock). Indirect losses such as lost working days, lost clients, and consequences for labour are also part of the damage calculations (Molinari, 2014b). Moreover, evaluation criteria are provided for the surveys when dealing with subjective data.

4.3 Other sectors

86 The procedure for other sectors not included under residential or commercial and industrial building, in addition, the procedure does not follow direct survey patterns, However, the organization of available data[19] is the procedure carried out as mentioned in **Section 4.5.1**. Those sectors not included under residential, commercial and building categories are covered within the "other sectors" category. Despite this categorization, the procedure carried out to collect data is the same as described in **Section 4.5.1**:

87 Acquisition of pre-exiting data of the exposed items. Databases with thematic maps, direct mapping, and information from owners can be used to obtain the data that will help build event scenarios;

88 Acquisition of damage data from the Regional Emergency Room (SOUR). SOUR's database compiles information collected from data owners, who are legally bound to share this information;

89 Acquisition of damage data, direct and indirect. The sources of these data are entities and authorities responsible for data collection. The information can be collected a few months and several months after the event;

90 Acquisition of monetary damage data by using physical units to which monetary values are assigned either from the Accounting Division of the Regional Civil Protection Authority or from data owners.

4.4 Data management

91 RISPOSTA is supported by an Information System composed of three main components for the management of all the collected data. A mobile application is used for data gathering. Data are stored in a PostGIS database and data visualization is achieved through a web portal with different clearance levels for different actors. It is worth noting that, currently, data surveys are done with selected survey teams conformed by trained technicians but the possibility of expanding surveys to the general population is being explored.

19 If data are available but fragmented they will not be used.

4.4.1 Mobile app

92 One of the main advantages of the procedure is the ability to compile surveys digitally. Surveys are stored on a handheld device and sent to the database when completed. However, incomplete forms may be filled, browsed and modified but are kept from being sent to the database. The digital surveys have the functionality of adding a location to the form and it can be manually done, or automatically using the tablet's GPS **(Figure 20)**.

93 Each surveyor is provided with a list of buildings to be surveyed and the application guides the person through the survey providing information on the kind of answers it needs, whether the answer has a constrained domain, a dropdown list of possible options, among others (see **Annex**).

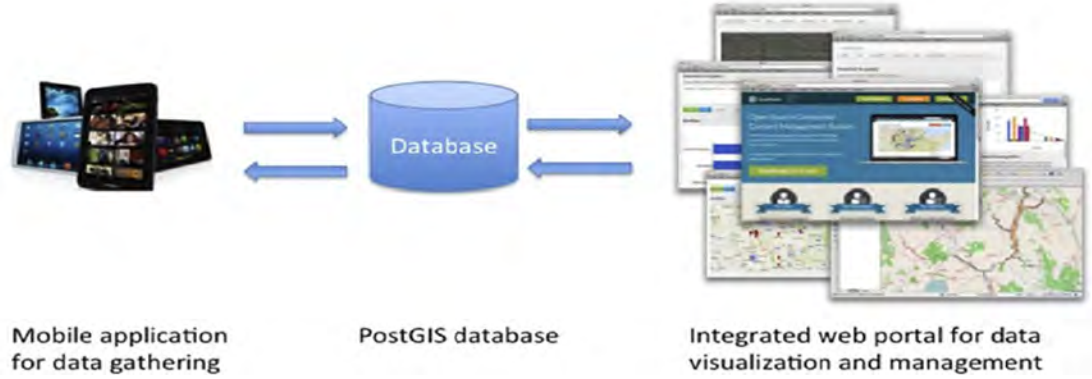

Figure 20 — The three components of RISPOSTA's Information System (Ballio, 2015)

4.4.2 Database

94 The database was specifically designed taking into account the procedure created by RISPOSTA of data gathering through surveys. It was designed under a Database Management System (DBMS) and has GIS functionalities, such as importing and processing of georeferenced information. All data from surveys is stored in the database for further manipulation and queries.

4.4.3 Web portal

95 Data from the database are accessible via a web portal. The site has several security levels that allow different users to access, visualize, and manipulate specific instances of information acquired during the surveying phase. Information is presented with natural language allowing non-expert users to use predefined forms and hints to access data. **Figure 21** (next page) showcases an example of data visualization in the RISPOSTA web portal. The image shows a land-use map for the Municipality of Marsciano, Umbria, Italy complete with a base map and a colour coding for the types of use ranging from residential and commercial to cultural and hospital land uses.

96 The RISPOSTA web portal provides different maps for damage that range from number of affected people to direct and indirect damage. It also has exposure and vulnerability maps available with of the buildings and the flood levels at which each building is vulnerable. Additionally, information on sediments and contaminants is also presented in the form of maps. The different stakeholders can access their data of interest and do some manipulation in accordance with the Administrator, i.e. the Civil Protection.

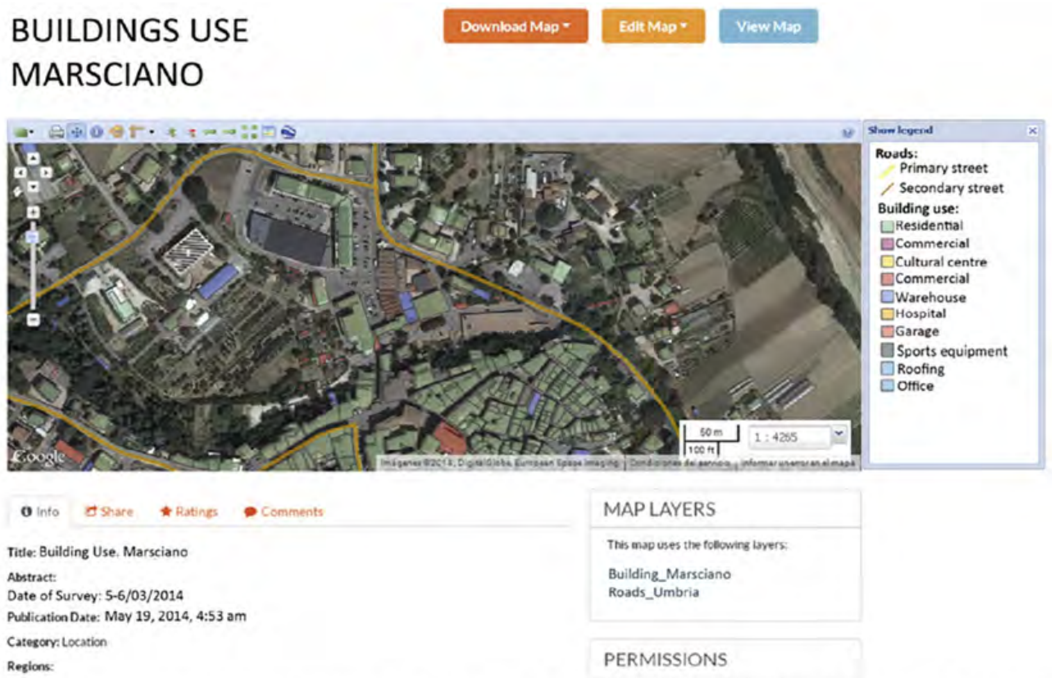

Figure 6 **An example of standardised maps provided by the RISPOSTA procedure: building use map for the Municipality of Marsciano (Umbria Region).**

Figure 21 — Example of standardized map within RISPOSTA portal (Ballio, 2015)

4.5 Implementation

97 The following subsections highlight important findings from implementing RISPOSTA:

4.5.1 Acquisition of pre-existing knowledge

98 After a flood in the Umbria Region in 2012, the procedure for the acquisition of pre-existing knowledge was tested. The main remarks about the implementation are the following:

- The Regional Civil Protection Authority collected orthophotos and land use data while municipalities collected cadastral data;
- Difficulties for data integration derived from a lack of standard formats among the different authorities in the region;
- Based on the aforementioned experience, a standard format was introduced for RISPOSTA.

4.5.2 Survey of the flooded area

99 After a flood in November 2014 in the Umbria Region, the data collection procedure was put to the test. A short summary is presented on the conditions of the event and the procedure:

100 Conditions of the flood:

- No satellite or aerial images available;
- Use of hazard assessment maps included in flood and landslide management plans.

101 Procedure:

- Two teams of experts in topography;
- Equipment: map of identified areas, GPS localizer, measuring tape, compass, camera, and other common measurement tools;
- Each team spent 4 hours surveying an area of about 1.5 km^2 in the town of Foligno in the province of Perugia in Umbria.

102 Results:

- The flooded areas were defined just a few days after the event in comparison to previous floods in the region, where flood maps where obtained several months after its occurrence;
- Surveyors had problems interpreting minor incoherencies in topography;
- Some measurements were referenced to high slopes, proving to be no reliable points on the DTM;
- Concerns about the time spent for survey completion.

4.5.3 Survey to damaged buildings

103 The procedure for the survey of damage to buildings was tested after a series of floods in the Umbria Region in 2012 and 2013. The main remarks about the implementation are the following:

- There was a need to work through a mobile application instead of using paper-based forms;
- Some data in the forms was filled using aerial images, cadastre information, and the locations of damaged buildings;
- There is a consideration of involving private owners as actors in the procedure so that they declare damages in order to access compensation funds (requirement by the national authority).

4.5.4 RISPOSTA's mobile application

104 The mobile application was tested during survey missions in 2014 in the Umbria Region. The main remarks about the implementation are the following:

- The application permits the georeferenced inputs such as delimitation of flooded area, surveyed points, and photographs on a digital map;
- Measurements can be electronically captured and stored;
- It provided an overview of the already surveyed buildings and the ones missing;
- There is a need to provide an overview of which forms are complete and which ones still need important questions to be answered;
- The application will be updated with an interactive map with the locations of assigned buildings and it will be constantly updated upon completion of a surveyed building to provide surveying teams of an overview of the current progress;
- It will also be updated with a chat element so that survey teams can communicate and interact with each other;

– Surveyors want a search option to be included in the app, making it possible to search questions just by typing key words. They also want the inclusion of notifications when there is missing data or questions lacking answers;
– A new version is under way solving the application's weaknesses. It will run under Android SDK.

105 RISPOSTA addresses the needs of standardizing the collection, storing and analysis of flood related data, more precisely as an aid for the emergency and recovery phases of disaster management for flooding. Among RISPOSTA's achievements are to identify and coordinate data owners and to gather and store their data on risk mitigation strategies (both ex-ante and ex-post) in a database that provides multi-usability to its users, enhancing its transmission to stakeholders such as practitioners, risk analysts, and decision makers.

106 There is confidence on the robustness of the procedure after conducting trials made from 2012 to the present day. Both the responsible actors and timings are dependent on the national context of Italy and the regional context of Umbria. Nevertheless, the procedure is transferable to other juridical backgrounds and different physical conditions by adapting specific aspects of the methodology depending on the context. The procedure is not bound to work only for flood damages but can also be applied to other types of disasters such as landslides and earthquakes

107 A next step for RISPOSTA is to achieve a better integration of data owners to the process of data gathering so that they become active actors within the procedure. A way of achieving this is through the implementation of specific protocols for data sharing which should be followed by the entities involved. Another step would be to tailor further the surveys and their tools for each specific sector from a variety of land-uses. Moreover, the general population can also be integrated into the surveying system by means of crowdsourcing for data collection.

5 CONCLUSIONS AND RECOMMENDATIONS

108 In the global context, the need for more reliable data collection, storage, and sharing has become crucial to better define mitigation and adaptation strategies towards flooding, establish compensation mechanisms, and better calibrate risk assessment in general. Additionally, there is international pressure to enhance these processes as articulated in the *Sendai Framework for Disaster Risk Reduction*, the *Agenda 2030 for Sustainable Development*, the *Paris Agreement*, the *EU disaster prevention framework*, the *European Union Solidarity Fund*, and the *Green Paper on Insurance of natural and man-made Disasters* (EC, 2007; UNISDR, 2011).

109 Overall, flood impact assessments represent a critical area of flood management, hence there is a need for accurate and reliable procedures and methods. It is why in the future, transparent, consistent and replicable assessment procedures and models need to be developed in order to be applied in different study areas, at different scales, and accurately portray real conditions. It is no only one right way to assess impacts but it is essential identify the assumptions made, the considered and methodologies then, the results obtained can be used to evaluate cost-benefit evaluation according to different flood mitigation measures and investments (CORFU, 2014a; Jha, 2012).

110 Data gathering is an important stage in a flood loss assessment process, however, this step is not always conducted in the most efficient manner since standards are not implemented. This, at least, is embedded in the RISPOSTA case study where different methods were used according to each organization responsible for collecting data delaying the assessment due to incompatibilities in methods, formats, and units (Molinari et al., 2017).

111 Geolocalize data damage is a key factor to develop a database on local information support by map. The mapping is better understood by stakeholders including local authorities and community groups, and allows a visual representation of the location of damaged building and public spaces of the affected area (Molinari, 2014a). Indeed, not only post event data are involved

in flood loss assessment process since data available before an event can have significant influence on how develop a flood risk management and flood loss assessment in order to mitigate, reduce and estimate potential damages (WRI, 2015).

112 There is a diversity of flood impact assessments techniques and methods that should be used by local or national governments to support policy and decision making aiming to improve urban flood resilience and community livelihoods (Jha, 2012). The lack of data and a framework on flood assessment as well as the bad performance of actions to be carried promote the implementation of deficient flood risk management strategies, and therefore limited flood loss management strategies to cover the requirements of a flooding event, e.g. flood preparedness and/or flood recovery (CORFU, 2014a).

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ANNEX — SURVEY FORMS

A form was created for both types of buildings with general information on building characteristics, flood event characterization, and damaged features. Moreover, the forms allow to obtain specific information on each unit of the building (i.e. storey or flat), on common areas, and on any attached structures to the building. (Molinari et al, 2017)

I | Information collected by means of surveys to residential buildings (Molinari et al, 2017)

Section	Description	Aspects
Form A: General information		
General information	Includes aspects: to identify building locations describing under what condition the survey was carried out	— geographic coordinates — land registry coordinates — address — who carried out the survey — with/without support
Building features	Includes aspects to characterize building exposure/vulnerability	— building typology (i.e. detached house, apartment building/semi-detached house) — period of construction — building structure (e.g. concrete, masonry, wood, steel) — surface — number of floors — building elevation
Description of flood event	Includes aspects that are important for characterizing stress on the building	— duration — water depth outside the building — presence of sediments/ contaminants
Description of the damage	Includes aspects that are important for identifying affected parts of the buildings and forms to be compiled.	— affected parts (i.e. number of housing units, common areas, number of attached buildings, structural damage) — forms to be compiled (i.e. A,B,C,D)
FORM B: Damage to housing unit (N.B. This form must be filled in for every unit in the building)		
General information	Includes aspects: for identifying the property for describing affected floors for describing residents	— owner — damaged floors — number of residents, children, elderly people, disabled people

Section	Description	Aspects
Damage to affected floor X N.B. This section need to be filled in for every affected floor in the unit	Includes: further aspects that are required to fully characterize the exposure/ vulnerability/location of the floor as well as the stress on it all aspects that are required to characterize the direct damage to the floor certain aspects relating to indirect damage certain aspects relating to mitigation actions	— surface — level of maintenance — technological systems — use (e.g. residential, commercial, storage, etc.) — maximum water depth inside the building — damage to: coating/plaster, windows and doors, floor, technological systems, contents — loss of usability — clean-up cost — mitigation actions: type of action, time of action, motivation
FORM C: Damage to common areas		
General information	Includes aspects: for describing affected floors	— damaged floors
Damage to affected floor X N.B. This section need to be filled in for every affected floor in the common areas	Includes the same aspects as form B- section 2	
FORM D: Damage to attached building (N.B. This form must be filled in for every attached building)		
General information	Includes aspects: for identifying the building locations for identifying the property	— geographical coordinates — land registry coordinates — owner
Building features	Includes aspects for characterizing building exposure/ vulnerability.	— period of construction — building structure (e.g. concrete, masonry, wood, steel) — surface — number of floors — building elevation
Description of flood event	Includes aspects that are important for characterizing stress on the building	— duration — water depth outside the building — presence of sediments/ contaminants
Description of the damage	Includes aspects that are important for identifying damaged floors	— Affected floors
Damage to affected floor X N.B. This section need to be filled in for every affected floor in the building	Includes the same aspects as form B	

II | Information collected by means of surveys to industrial/commercial premises (Molinari et al, 2017)

Section	Description	Aspects
Form A: General information		
General information	Includes aspects: — to identify building locations — describing under what condition the survey was carried out — geographic coordinates	— land registry coordinates — address — who carried out the survey — with/without support
Premises features	Includes aspects to characterize premise vulnerability	— type of activity (commercial/ industrial) — commercial/industrial sector — number of employees — seasonal criticalities (yes/no) — special plant (yes/no)
Building features	Includes aspects to characterize building exposure/ vulnerability	— building typology (i.e. single building/single warehouse/multiple warehouse, building portion, warehouse portion) — property/rent — period of construction — building structure (e.g. concrete, masonry, wood, steel, prefab) — external areas — level of maintenance — surface — number of floors — building elevation
Description of flood event	Includes aspects that are important for characterizing stress on the building	— duration — water depth outside the building — presence of sediments/ contaminants
Description of the damage	Includes aspects that are important for identifying affected parts of the buildings, damage to employees and forms to be compiled.	— affected parts (i.e. damage to building structure and plants, damage to machinery, production plants, equipment and furniture, damage to store e archives, recovery and mitigation costs, damage to mobile goods, indirect damage: usability, activity disruption) — damage to employees — forms to be compiled (i.e. A,B,C,D,E)

Section	Description	Aspects
FORM B: Damage to building structure and plants		
Direct damage to building structure	Includes aspects for identifying main damage to the building structure	— damaged floors — structural damage — damage to external coating/plaster
Direct damage to affected floor XN.B. This section need to be filled in for every affected floor in the building	Includes: — further aspects that are required to fully characterize the vulnerability of the floor as well as the stress on it — all aspects that are required to characterize the direct damage to the floor	— surface — use (e.g. storage, production, shop, office, etc.) — maximum water depth inside the building — damage to: coating/plaster, windows and doors, floor, plants
FORM C: Damage to machinery, production plants, equipment, furniture, store, archive and mobile goods		
Damage to store and archive	Includes aspects for describing damage to store and archive	— damage to stock (raw material, intermediate products, finished products) — damage to papery documents (accounting books, client registers, etc.)
Damage to machinery, production plants, equipment and furniture	Includes aspects for describing damage to machinery, production plants, equipment and furniture	— damage to machinery (electrical appliances at work/stand by, mechanical appliances on work/stand by, thermal appliances on work/stand by, etc.) — damage to production plants (goods lift, pumps, hydraulic plants, specific plants) — damage to equipment — dDamage to informatics equipment — dDamage to furniture
Damage to mobile goods	Includes aspect for describing damage to company vehicles	— number of damaged vehicles — types of damaged vehicles (moto, car, van, trucks, fork lift, etc.)
FORM D: Recovery/mitigation costs		
Recovery costs	Includes aspects for defining recovery costs	— clean up costs (private expenditure vs. public costs) — clearing and disposal of muds, debris and flooded material

Section	Description	Aspects
Mitigation costs	Includes aspects for identify mitigation action taken before and after the flood and their effectiveness	— previous experience (yes/no) — mitigation actions before the event (documents back-up, insurance, etc.) — mtigation actions during the alarm phase (suction pumps, flood shields, stock movements, evacuation, power interruption, etc.) — mitigation actions after the event (archive/store relocation to upper floor, plants/machinery rising above the flood level, use of waterproof material)
FORM E: Indirect damage/reimbursements		
Indirect damage	Includes aspects that are important to identifying indirect damage	— lack of usability (days) — activity disruption (days) — missed orders — unemployment (number of people and days) — damage due to humidity
Reimbursements	Includes aspects to quantify reimbursement	— private reimbursement (from insurance) — public reimbursement

For more information, please contact:

Associated Programme on Flood Management
c/o Climate and Water Department
World Meteorological Organization

tel	+41 (0) 22 730 83 58
fax	+41 (0) 22 730 80 43
email	apfm@wmo.int
	www.floodmanagement.info

World Meteorological Organization
Communications and Public Affairs Office
7 bis, Avenue de la Paix – P.O. Box 2300
CH-1211 Geneva 2 – Switzerland

tel	+41 (0) 22 730 83 14/15
fax	+41 (0) 22 730 80 27
email	cpa@wmo.int
	www.wmo.int

GWP Global Secretariat
Linnégatan 87D - PO Box 24177
SE-104 51 Stockholm – Sweden

tél	+46 8 1213 86 00
fax	+46 8 1213 86 04
email	gwp@gwp.org
	www.gwp.org