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PROJECT MOLINES: MODELLING FLOODS IN ESTUARIES. FROM THE HAZARD TO THE CRITICAL MANAGEMENT

Final Report

Project funded by Fundação para a Ciência e a Tecnologia (FCT) and developed within the scope of the LNEC's Planned Research Program (P2I) for 2013-2020

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R&D HYDRAULICS AND ENVIRONMENT

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Title

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Final Report

Authors

LNEC – HYDRAULICS AND ENVIRONMENT DEPARTMENT

Paula Freire
Assistant Researcher (Coordination of the Project), Estuaries and Coastal Zone Unit

André B. Fortunato
Senior Researcher with Habilitation, Estuaries and Coastal Zone Unit

Ana Rilo
Junior Research Fellow, Estuaries and Coastal Zone Unit

Kai Li
Research Fellow, Estuaries and Coastal Zone Unit

Ricardo Costa
Doctoral Research Fellow, Estuaries and Coastal Zone Unit

Anabela Oliveira
Senior Researcher, Coordinator of the Information Technology in Water and Environment Unit

Gonçalo Jesus
Doctoral Research Fellow, Information Technology in Water and Environment Unit

João L. Gomes
Junior Research Fellow, Information Technology in Water and Environment Unit

João Rogeiro
Junior Research Fellow, Information Technology in Water and Environment Unit

Pedro J. Pinto
Postdoctoral Research Fellow, Information Technology in Water and Environment Unit

Maria Adriana Cardoso
Assistant Researcher, Urban Water Unit

Maria do Céu Almeida
Senior Researcher, Urban Water Unit

Paula Beceiro
Junior Research Fellow, Urban Water Unit

Rita Salgado Brito
Postdoctoral Research Fellow, Urban Water Unit

LNEC – INFORMATION TECHNOLOGY IN CIVIL ENGINEERING UNIT

João Palha Fernandes
Assistant Researcher

CES – CENTRE FOR SOCIAL STUDIES OF THE UNIVERSITY OF COIMBRA

Alexandre O. Tavares
Senior Researcher

Pedro P. dos Santos
Research Fellow

ANPC – NATIONAL AUTHORITY FOR CIVIL PROTECTION

Patrícia Pires
Senior Civil Protection Officer

Luís Sá
Senior Civil Protection Officer

Giuseppe Cornaglia
Senior Civil Protection Officer

Jorge Dias
Senior Civil Protection Officer

AV DO BRASIL 101 • 1700-066 LISBOA

e-mail: lnec@lnec.pt

www.lnec.pt

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PROJECT MOLINES: MODELLING FLOODS IN ESTUARIES. FROM THE HAZARD TO THE CRITICAL MANAGEMENT
Final Report

Abstract

The final technical report of the project “MOLINES - Modelling floods in estuaries. From the hazard to the critical management” (ref. PTDC/AAG-MAA/2811/2012) is presented. The project was funded by the Portuguese Foundation for Science and Technology (FCT - Fundação para a Ciência e a Tecnologia) and took place between 2013 and 2016. The MOLINES project aims at improving knowledge on estuarine margins inundation processes, considering different climate scenarios, and developing an approach to support risk management in terms of preventive and response measures. The outcomes included the definition of a new decision-making supporting framework and Web platform for emergency and land-use planning, based in three different spatial scales of analysis (regional, municipal and local), that fully benefited from the different skills and experience of the participant institutions and the involvement of the stakeholders.

Keywords: Estuarine flooding / Territorial vulnerability / Extreme events / Early-warning system / Risk management

PROJETO MOLINES: MODELAÇÃO DA INUNDAÇÃO EM ESTUÁRIOS. DA AVALIAÇÃO DA PERIGOSIDADE À GESTÃO CRÍTICA
Relatório Final

Resumo

Apresenta-se o relatório final do projeto “MOLINES - Modelação da inundação em estuários. Da avaliação da perigosidade à gestão crítica” (ref. PTDC/AAG-MAA/2811/2012), financiado pela Fundação para a Ciência e a Tecnologia, e que decorreu entre 2013 e 2016. O projeto MOLINES tem como objetivos melhorar o conhecimento científico do processo de inundação em estuários, considerando diferentes cenários climáticos, e desenvolver uma estratégia coordenada de apoio à gestão do risco de inundação em estuários que contribua para promover ações preventivas e de resposta. Dos resultados obtidos destaca-se a abordagem metodológica inovadora de apoio à gestão do risco de inundação em estuários e a respetiva plataforma Web, baseada em três escalas espaciais de análise (regional, municipal e local), que beneficia da integração das múltiplas valências das instituições participantes e do envolvimento de outras entidades que incorporam as várias dimensões da gestão do risco.

Palavras-chave: Inundação estuarina / Vulnerabilidade territorial / Eventos extremos / Sistema de alerta / Gestão do risco

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1 | Introduction

1.1 Objectives

The present document constitutes the final report of the project *MOLINES: Modelling floods in estuaries. From the hazard to the critical management*, funded by the Portuguese Foundation for Science and Technology (FCT – Fundação para a Ciência e a Tecnologia).

The project was developed within the scope of the LNEC's Planned Research Program (P2I) for 2013-2020 and contributed to the R&D&I strategic lines of the Hydraulics and Environment Department, namely Risk Management and Safety, Environment and Aquatic Systems and Information and Decision Support Technologies.

Below are listed the major identifying elements of the project:

- Project reference: PTDC/AAG-MAA/2811/2012
- Scientific Domain: Natural Sciences and Environment
- Main Area: Environment and Global Changes - Modelling and Environmental Assessment
- Secondary area: Marine Sciences - Estuarine Systems, Coastal and Coastlines
- Principal Investigator: Paula Maria de Santos Freire
- Principal Contractor: National Laboratory for Civil Engineering (LNEC)
- Participating Institutions: Centre for Social Studies (CES) of the University of Coimbra and National Authority for Civil Protection (ANPC)
- Project advisor: Xavier Bertin, Université de La Rochelle, France
- Starting date: 01-07-2013
- Final date: 29-02-2016
- Funding: € 149.954,00

1.2 The project MOLINES

1.2.1 Context and objectives

In the context of climate change, floods in estuarine lowland areas are becoming a general concern and the scientific and management communities are asked to present well-supported prevention and mitigation solutions. Flood risk assessment in coastal and fluvial areas has different approaches, which are not always compatible, and specific methodologies for estuarine environments are still missing. A better and integrated understanding of these events and improved tools to support solutions are needed, and required for the objectives of the European Floods Directive implementation.

The motivation for the MOLINES project is to contribute to improve the state-of-the-art on flood management support through a better understanding on the integration of different hazards in estuaries and to develop flood risk management guidelines that are adequate for transition areas. The main challenge of this project is to integrate different strategies and approaches that are typically used independently in flood risk analyses, and to use two different spatial scales of analysis, on regional and local levels.

The specific objectives of the project are: 1) knowledge improvement on estuarine margins inundation processes including storm surges combined with tide effects, and urban drainage, for different climate scenarios; 2) flood risk assessment of margins with different typologies, including urban and interface areas; 3) development of a coordinated approach to risk management to promote preventive measures of planning, forms of risk mitigation, and alert and warning system optimization, supported by a monitoring network and real time forecasts.

1.2.2 Study area

The Tagus estuary, where the most important infrastructures, equipment and strategic services at national level are located, was chosen as study area (Figure 1.1). Its particular morphological settings and hydrodynamic conditions promote high risk to natural and urban flooding, well-illustrated in recent past events and associated damages. The estuary was chosen as case study because it is a paradigmatic case of territory conflict occupation along its margins, with exposure of critical and sensitive infrastructures, and high potential to flooding from different sources whose consequences are abundantly illustrated in recent past events. The estuary is included in the territorial unit of Lisbon and Tagus Valley, involving 18 municipalities in the metropolitan area of Lisbon, holding an estimated population of about one million inhabitants exposed directly or indirectly to floods.

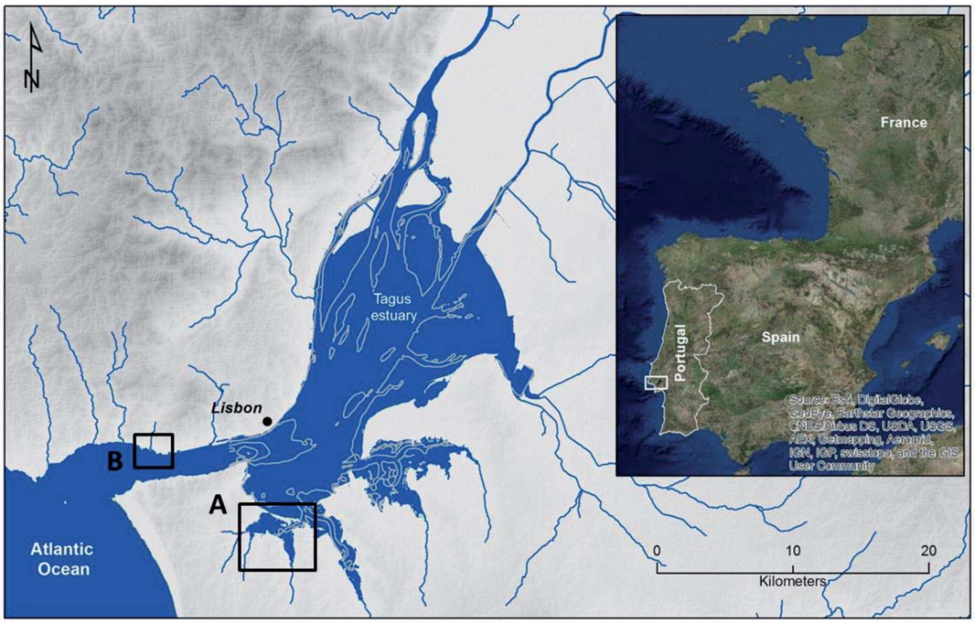


Figure 1.1 – Tagus estuary and the detailed study areas locations: A- Seixal; B - Dafundo

1.2.3 Project structure

To accomplish the project objectives, the research plan was built on 5 interlinked Work Packages, including a total of 12 Tasks (Figure 1.2), with 3 Milestones (Table 1.1).

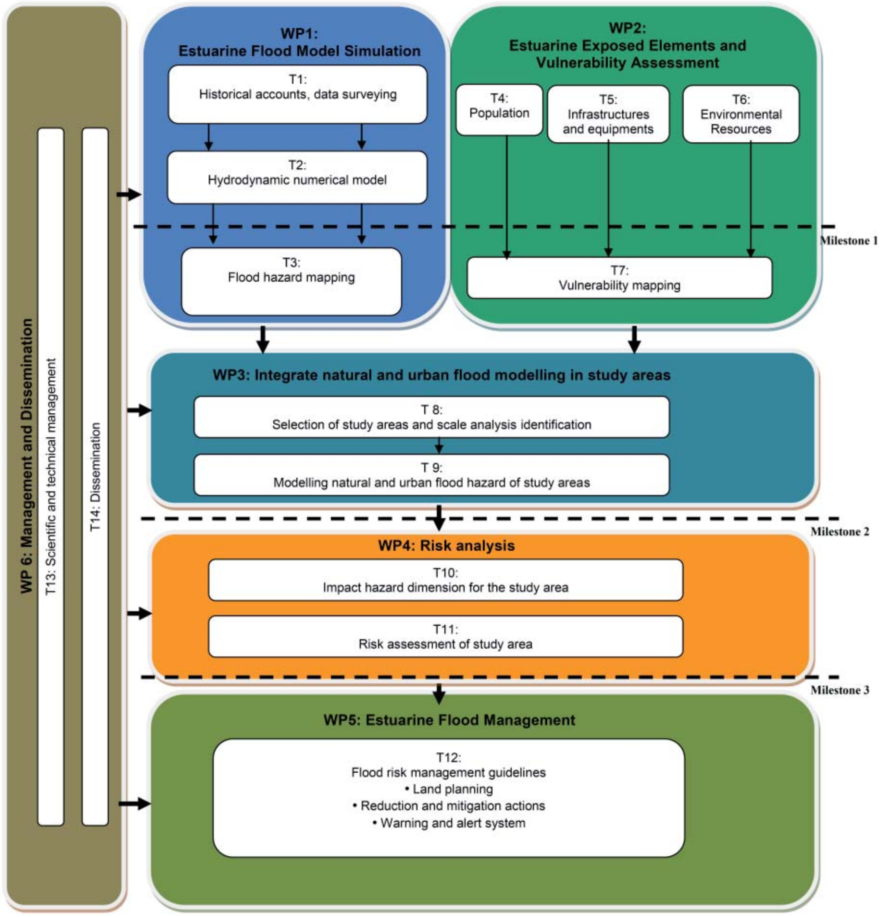


Figure 1.2 – MOLINES project flowchart

Table 1.1 – List of milestones

Milestone		Objetives
M1	Estuarine hydrodynamics and exposed elements evaluation	Characterization of Tagus estuary hydrodynamics and estuarine exposed elements evaluation. Concluded Tasks 1 and 2 of the WP1 and Tasks 4, 5 and 6 of the WP 2.
M2	Integrated approach of flood modeling in estuarine areas	Development of an integrated approach for natural and urban flood modelling in estuaries applied at a local scale. Concluded WP1 (T3), WP2 (T7) and WP3 (T8 and T9)
M3	Risk assessment of the study areas	Natural and urban flood risk mapping and analysis, in a local scale and for different climatological scenarios. Concluded WP4 (Tasks 10 and T11).

1.2.4 Team

The Project team is presented in Table 1.2. The project benefited from the scientific consultant Dr. Xavier Bertin from the CNRS-La Rochelle University (France).

Table 1.2 – Project team

Institution	Researcher
LNEC	Paula Freire *(project Principal investigator and leader of WP1, 4, 5 and 6)* André Fortunato *(leader of WP1 and 3)* Anabela Oliveira *(leader of WP 2)* Maria Adriana Cardoso *(leader of WP 3)* João Palha Fernandes Maria do Céu Almeida Sérgio Teixeira Coelho (resigned from the project in 07/10/2014) Ana Rilo Gonçalo Jesus João Gomes João Rogeiro Kai Li Pedro Santos Pedro Pinto Paula Beceiro Ricardo Costa Rita Salgado Brito Luís Simões Pedro (Technical staff) João Vale (Technical staff)
CES	Alexandre Tavares *(leader of WP 2 and 4)* Pedro P. Santos
ANPC	Luís Sá *(leader of WP 5)* Patrícia Pires Giuseppe Cornaglia Jorge Dias

1.3 Report structure

This report is structured in 10 sections. In section 1 the major identifying elements of the project are presented as well as its context and objectives, general structure and the team. The following sections, from 2 to 7, are organized by the project work packages (WP), in which the objectives and the main results of each task are presented. The list of publications constitutes the section 8 and in section 9 a list of the institutions, projects and people that collaborated with the project is presented. Finally, the main results and a critical appraisal are present in section 10.

2 | WP1 ESTUARINE FLOOD MODEL SIMULATION (TASKS 1-3)

The first Work Package (WP1) addresses the assessment of flood hazard at the estuary scale and is divided in 3 tasks.

2.1 Task1. Historical accounts and data survey

Task 1 is devoted to the literature review, compilation and analysis of available data, including the construction of a historical flood events data base. Part of this information supports the set-up of the hydrodynamic numerical model in Task 2.

Based on literature review and the compilation and analysis of the available data the hydrodynamic and the morphological settings of the Tagus estuary were characterized, providing the set-up data for the estuary hydrodynamic models (e.g. bathymetry and digital terrain model).

Past flood impacts were assessed by the construction and analysis of a geodatabase of historical flood damages for the Tagus estuary area. The data sources included an extensive set of national newspapers, previously collected by DISASTER project (FCT funded: PTDC/CS-GEO/103231/2008) and further complemented in the framework of MOLINES project, totalizing 147 newspapers. Additionally, a national database of flood occurrences provided by ANPC and a collection of 21 photographs provided by Lisbon Port Authority (APL) were also consulted and integrated when appropriate as data sources. The coverage period of the entire database is situated between 1864 and 2013.

The geographic incidence of the database was constrained to the area where estuarine processes are dominant - Oeiras (downstream) and Vila Franca de Xira (upstream) - and between the highest astronomical tide line and 20m above sea level. A set of definitions (occurrence and event) and inclusion criteria were built in order to establish coherency in the input data. The database was structured in four main groups of information: a) basic relevant data on location and data; b) flood impacts (e.g. human causalities, property and infrastructure damages); c) flood characteristics (e.g. extension, depth); d) flood triggering factors (e.g. rainfall, tides, fluvial discharges, urban drainage). An overall of 235 occurrences were registered in the geodatabase comprising 45 flood events. The analysis on flood triggering factors, temporal and seasonal distribution of flood occurrences was performed (Figure 2.1), published in Rilo *et al*., 2015, and a detail analysis on damage assessment is now in preparation to be submitted to the Journal of Flood Risk Management.

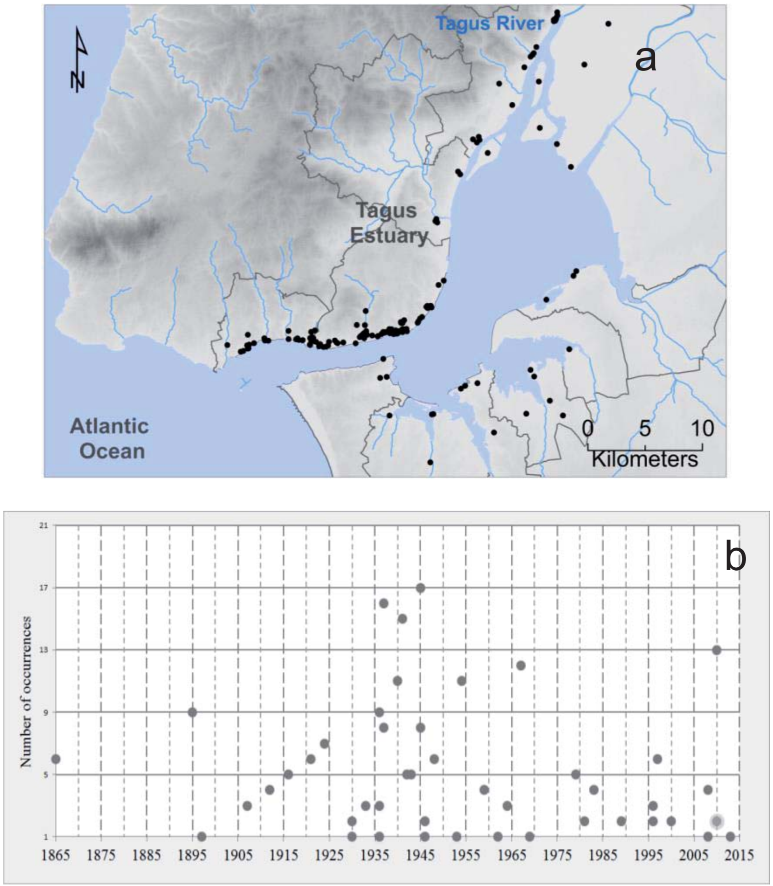
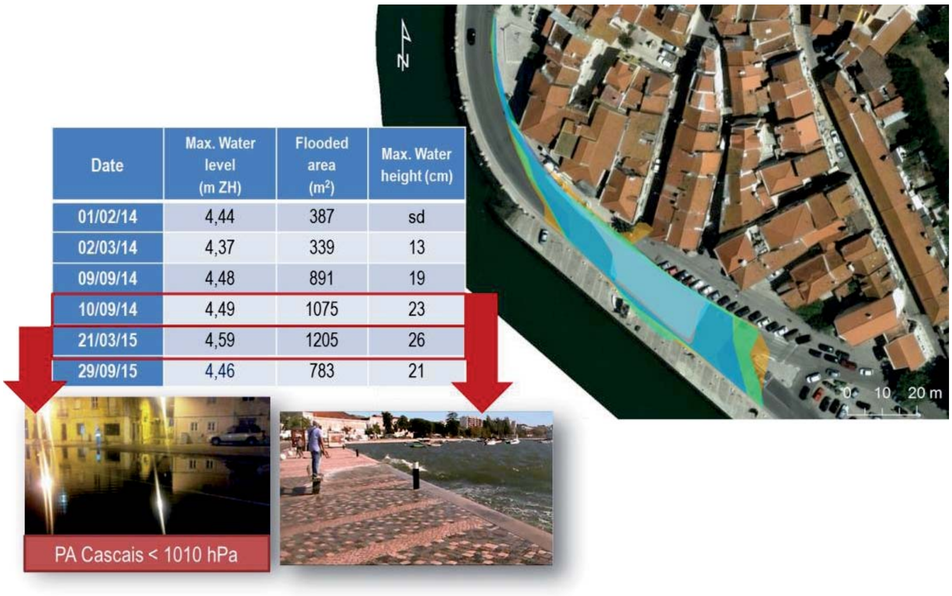


Figure 2.1 – Database estuarine flood occurrences in the Tagus estuary: spatial distribution (a) and temporal distribution (b) (in Rilo *et al.*, 2015)

To complement the historical information, the maximum extension of a historical flood episode, which occurred in February 2010 and affected particularly the Seixal water front, was reconstructed in situ using a RTK-DGPS and with the support of the Seixal Municipal services. The results were further complemented with photographs and other records acquired during the event. Instrumental data of the potential water level forcings (tide, atmospheric pressure, wind and Tagus river discharge) observed during the historical events, with major impact, was analyzed providing crucial information for understanding the flooding process and hazard assessment validation. Results are presented in Freire *et al.*, 2015, Freire *et al.*, 2015a and Freire *et al.*, 2016.

Six monitoring field surveys were also performed in the Seixal during particular oceanographic and meteorological conditions that occurred in 2014 and 2015 (Figure 2.2) in order to characterize the flooding episodes at municipality / local level, their impacts and the possible flooding triggering factors. The data acquired included water level, flood extension and height, and the main territorial and social impacts, and are described in the reports of field surveys (section 8.6.2). The main results are published in Freire *et al.*, 2015 and Freire *et al.*, 2015a.



Date	Max. Water level (m ZH)	Flooded area (m²)	Max. Water height (cm)
01/02/14	4,44	387	sd
02/03/14	4,37	339	13
09/09/14	4,48	891	19
10/09/14	4,49	1075	23
21/03/15	4,59	1205	26
29/09/15	4,46	783	21

Figure 2.2 – Monitoring field surveys performed in Seixal

The collected information was both useful for flood forecasting modelling validation (task 2) and for management purposes namely in the early-warning bulletin construction (task 12) and management guidelines.The engagement of the team in the in-situ data acquisition exceeded the initially proposed but the achieved results were essential for the understanding of the flooding forcing mechanisms in the study area. All the expected results of this task were achieved.

2.2 Task 2 Hydrodynamic numerical modelling

In this task a hydrodynamic numerical model is used to predict the estuarine inundation levels for different climate scenarios and return periods. It was carried out at two distinct levels: regional (NE Atlantic Ocean, with a major focus on the Portuguese shelf) and local (Tagus estuary, with a major focus on the Seixal bay).

At a regional level, a tide and storm surge model was developed and validated for the NE Atlantic Ocean. Hindcast simulations were performed for 1980-2010. Statistical analyses performed on those hindcast simulations led to the development of maps of extreme sea levels along the Iberian coast for different return periods (Figure 2.3, published in Fortunato *et al*., 2014a, b, c, 2016a). Simultaneously, this regional model provided boundary conditions for the local Tagus model (published in Fortunato *et al*., 2015a, 2016b).

At a local scale, a 2D hydrodynamic model was developed and validated for the Tagus estuary, including flood-prone areas in the southern margin of the estuary. In its simplest form, the model was forced only by tides, storm surges and river flows. Using this simpler model, we analyzed the hydrodynamics of the estuary and made a prospective analysis on how this hydrodynamics would change in the future, considering climate change and the morphological evolution (Figure 2.4, published in Guerreiro *et al*., 2015). This model was also used to provide boundary conditions for the urban flood model (Task 9, Cardoso *et al*., 2015).

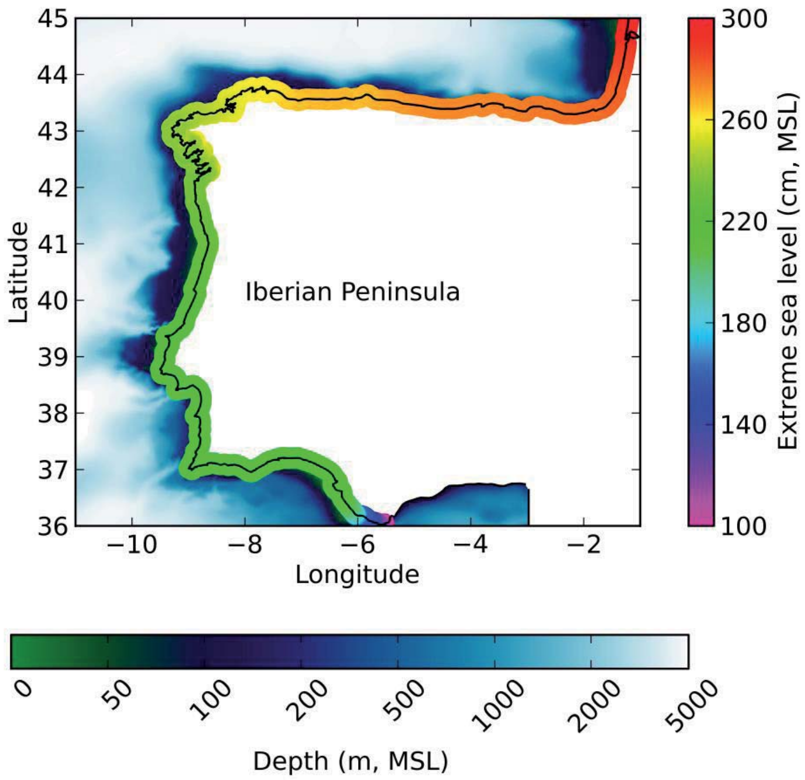


Figure 2.3 – Extreme sea levels along the Iberian Atlantic coast for a return period of 100 years. From Fortunato *et al*. (2016)

Using a more sophisticated implementation of the model, we simulated the coupled circulation and wave propagation, including atmospheric and wave forcings. This model allowed us to explore specific extreme events, such the Xynthia storm (Fortunato *et al.*, 2015b). A preliminary analysis of the relative importance of the various forcings was also performed (Fortunato *et al.*, 2015b) and is now being extended in the scope of another project. This implementation of the model was the one implemented operationally in the forecast system (Task 12, Fortunato *et al.*, 2015a, 2016b).

All the expected results of this task were achieved.

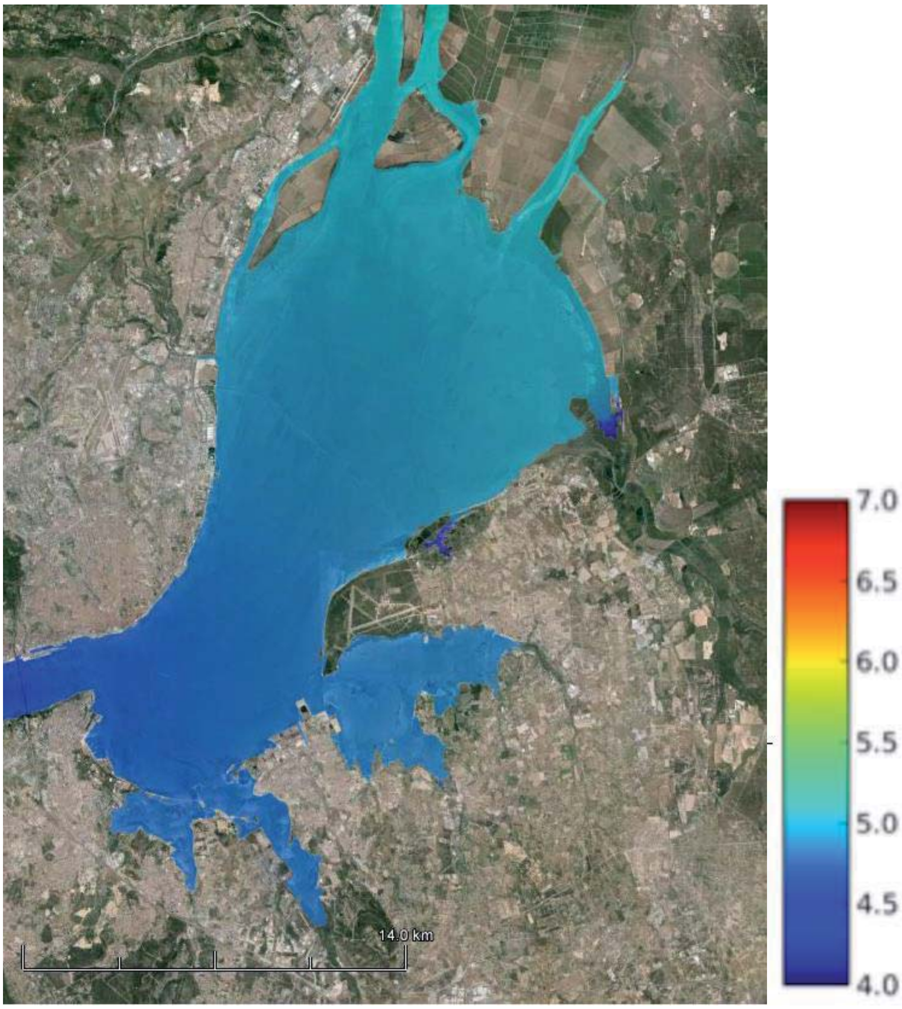


Figure 2.4 – Map of extreme water levels in the Tagus estuary for a 100 year return period (adapted from Guerreiro *et al*., 2015)

2.3 Task 3 Flood hazard mapping

The ability of the model developed in Task 2 to reproduce marginal inundation during extreme events was validated by comparison with the inundation extent that occurred in the Seixal area during the Xynthia (2010) storm (Figure 2.5, Fortunato *et al.*, 2015b, 2016b). Two alternative approaches to determine flooded areas were compared: an approach based on a statistical analysis of the sea levels at the estuary mouth, and the simulation of past extreme events (Fortunato *et al.*, 2015b, Freire *et al.*, 2015). Once validated, the model was then used to determine the extent of inundation in the Tagus estuarine margins in the Seixal Bay (Tavares *et al.*, 2015, Santos *et al.*, 2015a, b) and to compute a hazard index for the Seixal waterfront (tasks 9 and 10).

All the expected results of this task were achieved.

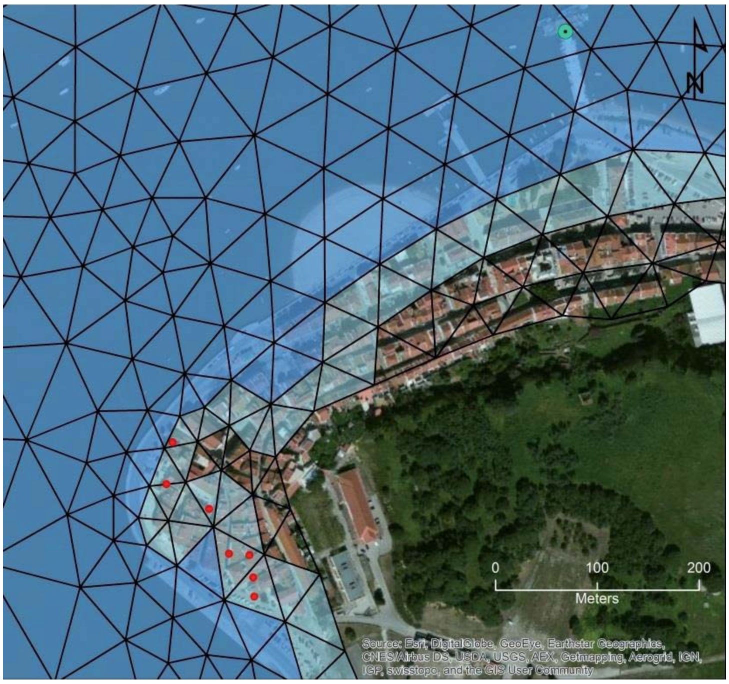


Figure 2.5 – Validation of the Tagus model for an extreme event (Xynthia storm, February 2010). The red circles indicate the surveyed extent of the flooding in the city of Seixal. The wet elements (elements with three wet nodes) are indicated in dark blue, and the partially wet elements (elements with one or two wet nodes) are shown in light blue. From Fortunato *et al*., 2016b

3 | WP2 ESTUARINE EXPOSED ELEMENTS AND VULNERABILITY ASSESSMENT (TASKS 4-7)

WP2 is devoted to assessing the demographic elements, the support capabilities exposed and the environmental status to the different scenarios modelled for the case of an estuarine flood. This WP is divided into 4 tasks of evaluation and a synthesis task.

3.1 Task 4 Population

A cartographic expression of the exposed population was obtained at the statistical sub-block, from data provided by the Population Census of 2011. Census data also allowed an evaluation of both resident and floating population using the Census fields related to the concept of “present population”. Additionally, and given the role of fluvial transportation between the margins of the Tagus estuary, the mobility and transiency of population was evaluated at two levels:

- With passenger data from the fluvial transport operator in the fluvial stations;
- With Census fields related to the means of transportation used by employed and studying population (boat, bus, car, train).

During this task 4, the Population Census data was analyzed and prepared in order to support the assessment of vulnerability that was conducted in Task 7. So, beyond the absolute number of exposed population, other dimensions of vulnerability were mapped such as the Census fields related to age, educational level, employment and population with special needs. This analysis was conducted for 1147 geographical units of analysis that are affected both directly and indirectly by flooding.

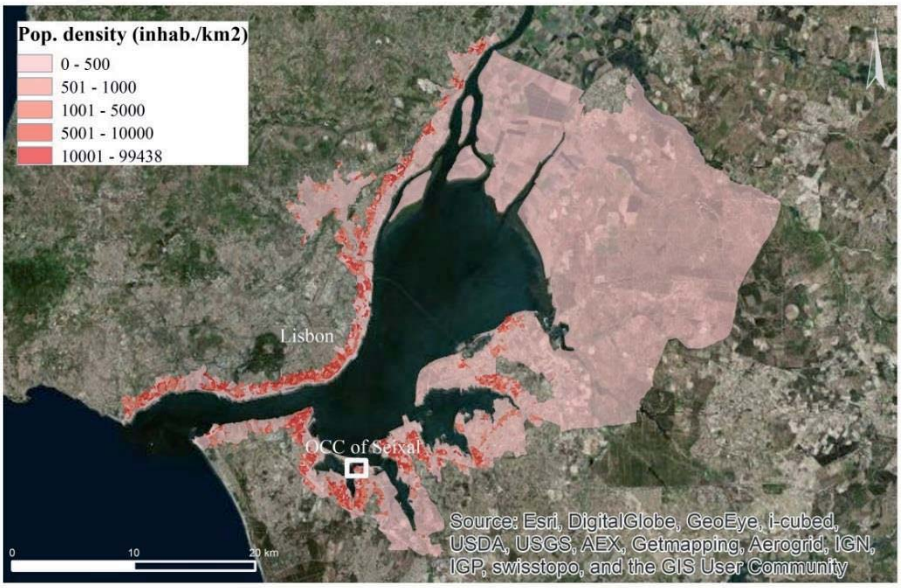


Figure 3.1 – Population density at the statistical block in the selected 1147 geographical units

The methodological approach adopted in task 4 considered the outputs assumed in Milestone 1 that set the scope for the following tasks. After completion of the evaluation of exposed population, a reflexive analysis was done regarding the constraints that would exist in task 7 (vulnerability mapping) in terms of availability of data, typology of data to be collected and geographic scale of analysis to be adopted. Decisions on these aspects were taken considering the usability of results in defining the flood risk management strategies at the estuary level, which comprises 11 municipalities.

3.2 Task 5 Infra-structures and equipment

Data provided by the National Authority of Civil Protection (ANPC), partner of the project, constitute the major source of geographic data used in this task. Data in GIS format was directly integrated in the built GIS platform, allowing an efficient analysis with population and environmental data. ANPC data include road network, railroad network and stations, airports, electric power grid and stations, gas pipelines and gas stations, parking lots, touristic attractions, cultural heritage sites and buildings, industrial buildings, commercial buildings, public gardens, education, health, hotel, sports, leisure, administration and civil protection equipment.

Data from the Portuguese Social Chart (www.cartasocial.pt) revealed extremely crucial in the evaluation of the installed capacity in terms of social equipment (namely regarding the child, youth, elder and special needs population). Data for the 92 parishes that could be directly or indirectly (road network disruption, for example) was collected and include the number of equipment, number of current users (in April 2014) and number of maximum users' capacity.

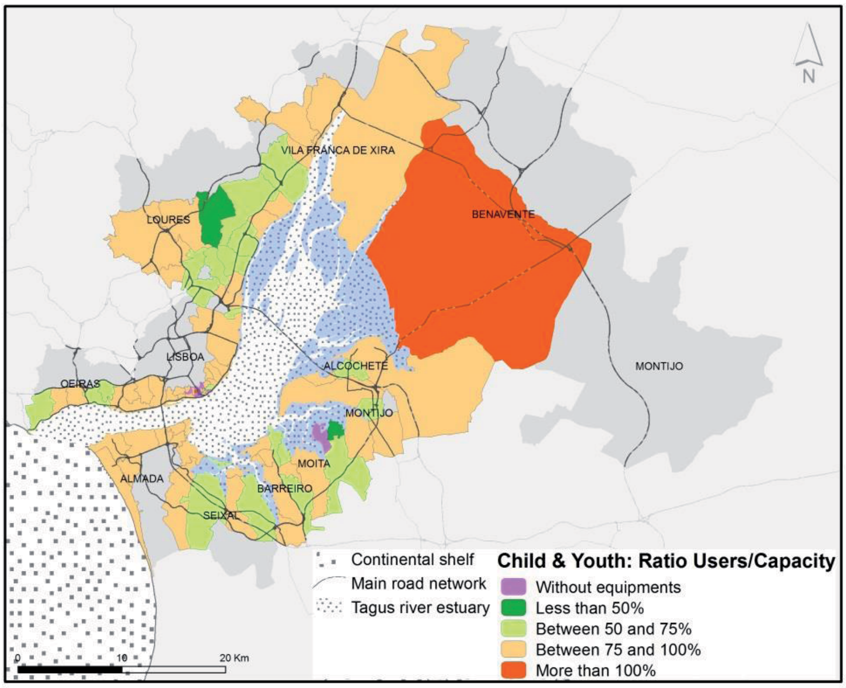


Figure 3.2 – Ratio between users and capacity in the social equipment for child and youth population. Source: Social Chart, 2014

Apart from the simple cartographic representation of the collected elements, indicators based in the relation with the area (densities in km/km^2, for example) and with the population (number of retirement houses' users per resident population) were calculated for each of the 1147 statistical blocks.

The selected infrastructure and equipment considered the objectives assumed in Milestone 1, thus providing an initial set of data that would support the territorial vulnerability assessment (task 7).

3.3 Task 6 Environmental resources

The identification of the typology of environmental resources to be considered in the evaluation in this task 6 follows the elements identified in several European Union directives. In detail, cartographic elements were collected that define ecological areas classified as "Rede Natura 2000" and Ramsar sites; areas classified under the Water Framework Directive (beaches, marshlands, stream network, river mouths and aquifer water sources); pollution sources classified under the Seveso-III and the Integrated Pollution Prevention and Control (IPPC) directives.

Most of this geographical data is publicly available from official institutions such as the Portuguese Environment Agency (APA), although not always with the most adequate level of geographical detail, considering the refinement achieved by the flood hazard model. Land use, ecological and sedimentary data provided by the MORFEED project (a previous research coordinated by LNEC) was also used.

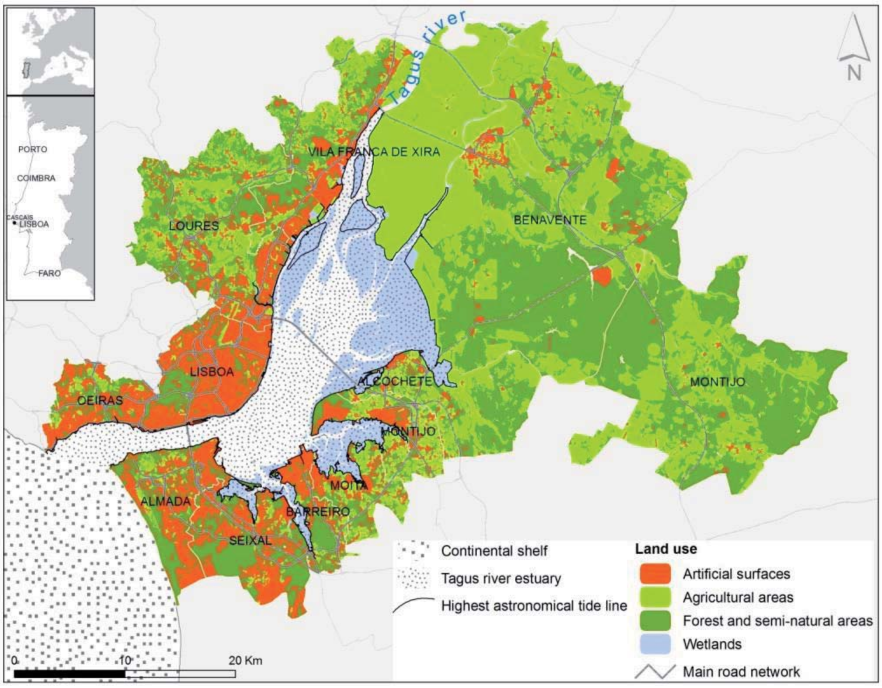


Figure 3.3 – Land use and wetlands in the 11 municipalities contacting the Tagus estuary

Land use data provide a first approach to assess vulnerability (cf. the methodology proposed by APA to assess vulnerability to flooding under the "Floods Directive"), and so, results from task 6 include a representation of urban and rural areas at the statistical block, that supported the territorial vulnerability mapping conducted in task 7.

3.4 Task 7 Vulnerability mapping

Vulnerability mapping is based on the methodology defined in the calculation of the Social Vulnerability Index (SoVI©).The centre of the methodological sequence is the Principal Components Analysis (PCA) performed with a set of data collected for the 1147 statistical blocks that comprise the areas around the Tagus estuary, directly or indirectly affected (Santos *et al.*, 2015a).

The more dimensions of vulnerability are represented the more accurate and holistic will the understanding of vulnerability location, sources and processes be. In this task, an initial set of 126 variables was considered (Table 3.1). Results of PCA, presented in Table 3.2, identify eight principal components.

Table 3.1 – Characteristics of the initial 126 input variables considered in the vulnerability assessment

Source	Aggregation	Dimension of vulnerability represented by the variables	No.
Population Census	Sub-statistical block	Age, gender, education, housing, employment, socio-economic status, mobility and commuting	76
Population Census	Parish	Particular features of vulnerability dimensions (mobility and commuting, persons with special needs, immigration, housing accessibility, homelessness)	27
Social Chart	Parish	Child, youth, adult and community social support (no. of beneficiaries and equipment)	9
Official mapping institute	Polygonal	Land use	7
Civil protection national authority	Point, linear and polygonal data	Educational, health, transportation, civil protection, road network and elderly equipment and infrastructure	6
Fluvial transport company	Point data	Passengers between fluvial stations	1

Table 3.2 – Principal components of vulnerability in the Tagus estuary (source: Tavares *et al*., 2015)

# of FAC – Principal component (% variance explained)	Signal	No. of variables	Explicative variables (loading > 0.5)
1 – Old neighborhoods and population with constraints (21.9)	+	9	Buildings needing repair (0.820) Resident population who use a car as a regular means of transportation (-0.778) Housing units with only one member (0.699) Resident population with at least one difficulty (0.667) Residential construction built before 1919 (0.613) Renter-occupied housing units (0.543) Single-parent families (0.534) Residential construction built between 1971 and 2011 (-0.504) Resident population studying or working in the municipality of residence (0.563)
2 - Residential areas of families with care-giving responsibilities (15.7)	-	6	Resident population between 15 and 24 years old (0.865) Families with 5 or more members (0.753) Resident population attending secondary school (0.737) Mean family size (0.681) Resident population attending secondary school in the municipality of residence (0.659) Resident population over 65 years old (-0.537)
3 - Residential areas of population with high economic status (10.5)	-	6	Housing units with an area greater than 200 m^2 (0.796) Resident population with higher education completed (0.696) Housing units with an area between 50 m^2 and 100 m^2 (-0.676) Housing units with 5 or more rooms (0.650) Resident population with 3rd cycle of primary education completed (-0.570) Housing units without parking spaces (-0.596)
4 - Population mobility (9.2)	-	4	Mean duration of commute (-0.840) Employed or studying resident population who potentially use fluvial transportation (-0.799) Resident population between 3 and 5 years old attending pre-primary education (0.684) Resident population studying or working in the municipality of residence (0.600)
5 – Building size (6.5)	+	3	Buildings with 3 or more housing units (0.810) Buildings with 5 or more floors (0.783) Floors by building (0.772)
6 - Old urban areas with an aged population (4.2)	+	3	Residential construction built between 1991 and 2011 (-0.778) Resident population over 65 years old (0.674) Housing units without parking spaces (0.609)
7 - Educational level of the population (3.9)	-	2	Resident pop. with secondary education completed (0.818) Illiterate resident population (-0.780)
8 – Urban development (3.2)	+	3	Road network density (0.823) Population density (0.766) Building density (0.766)

The individual interpretation of each principal component (FAC) allowed to identify the drivers of vulnerability in each block, thus providing a valuable tool in the task 12 (flood risk management guidelines). In fact, the distinct territorial, demographic and social dynamics are underlined in the cartographic expression of individual (Figure 3.4) and composite result of vulnerability scores. A scaling of vulnerability scores is done, at the parish level, in order to differentiate areas at a higher administrative level, to support the definition of regional planning instruments.

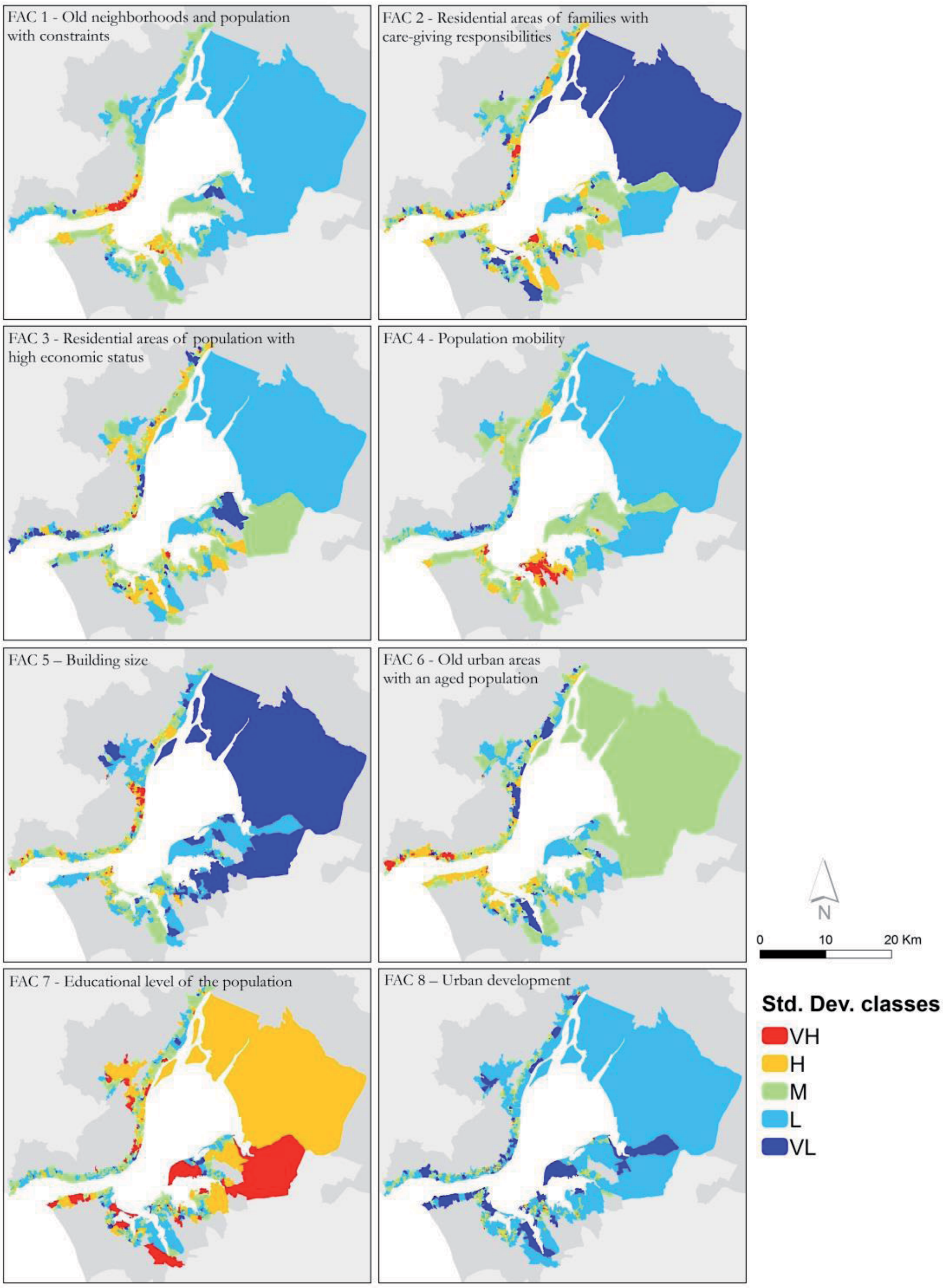


Figure 3.4 – Principal components of vulnerability in the Tagus estuary. Source: Tavares *et al.*, 2015

4 | WP 3 INTEGRATE NATURAL AND URBAN FLOOD MODELLING IN STUDY AREAS (TASKS 8 and 9)

In WP3, that includes 2 tasks, the natural and urban flood modelling at the local scale allowed a more refined assessment of the flood hazard.

4.1 Task 8 Selection of study areas and scale analysis identification

In this task the selection of the local study areas and the identification of the more suitable scale for flood hazard analysis were supported by the hazard, exposure and territorial vulnerability assessments at a regional scale obtained in tasks 1 to 7 (Tavares *et al*. 2015; Freire *et al*. 2015). The waterfront of the Seixal Municipality (Figure 1.1) was particularly affected by past floods and shows specific territorial vulnerability characteristics, both justifying its choice to assess flooding risk and implement the warning-system.
This area, including the old downtown of Seixal, was also initially selected regarding the urban drainage component of the project. In the first phase related to data collection of the urban drainage catchment and the sewer systems, information was provided by the Municipality of Seixal, regarding project implementation of sewer networks of domestic and storm water systems of the Integrated Project for the Seixal Public Space Qualification. It was necessary to carry out field inspections and it was found that the available project mapping and inventory information has not yet been built. The configuration of the current system does not provide results that significantly contribute to the MOLINES project objectives. Consequently, it was considered to include an additional study area that would allow contributing more significantly to the MOLINES project objectives. After a joint analysis with the project partners it was decided to integrate the urban drainage catchment of Dafundo as additional study area (Figure 1.1).

4.2 Task 9 Modelling natural and urban flood hazard of study areas

For different climatic scenarios, numerical modelling of natural and urban floods was performed for the chosen areas and results supported an integrated flood hazard analysis at a local scale.

The different morphological characteristics of the two study areas justified the distinct approaches followed in each one. In the Seixal area, only the inundation associated to the overflowing of estuarine waters was considered because 1) the role of the urban drainage system was considered negligible, and 2) its simulation was prevented by the lack of detailed and updated information on this system. The inundation was therefore simulated with the estuary model, as described in section 2.2. The opposite situation occurs in the Dafundo area. Inundation by overflow of estuarine waters is prevented by an elevated railroad that runs parallel to the estuary margin. Hence, the estuary water level only affects inundation by determining the downstream boundary conditions of the urban drainage system. These boundary conditions were therefore provided by the estuary model to the urban drainage model. Hence, both in the Seixal and the Dafundo areas a detailed integration of the estuary and urban drainage models was not necessary.

Mathematical modelling of the urban drainage system was applied to the study site in Dafundo. The main storm water sewer corresponds to the local stream, the Junça river, which has been canalized for decades. In the lower area of the catchment, downtown of Dafundo, a parallel duplication of the canalized Junça river was constructed, to solve flooding problems. Flooding in the estuarine marginal area was significantly reduced in terms of frequency, severity and flooded area. However, after the construction of the parallel sewer, flooding still occurs and it was studied using the 1D/2D coupled modeling. During field work, significant sediment deposition in sewers was detected, as well as a relevant sand deposits accumulation at the system outfalls to the Tagus estuary (Figure 4.1). The natural tidal dynamics at the Dafundo beach promotes frequent accumulation of sediments at the outfalls. After sand removal operations, sediments were naturally replaced two or three weeks after.

a) Junça river (left) and parallel sewer (right) 2014/09/04

b) Junça river totally obstructed and parallel sewer 2014/10/21

Figure 4.1 – Sand accumulation at the outfalls to the Tagus estuary at different dates

In situ inspections detected a vertical drop between two branches in the storm water system. This condition allowed considering the Dafundo catchment segmented into upper and lower hydraulic areas, being the hydraulic behaviour of the network almost independent in each of them. The vertical drop controls the flow from its upstream to its downstream branches, and reduces the possibility of sewer surcharge in the lower area, which was of particular interest for MOLINES purposes. In terms of urban drainage modelling, the presence of the vertical drop allowed using a simplified model for the upper area, whereas the lower area was modelled using a 1D/2D coupled model. The 1D mathematical model was applied to the storm water network, using Mike Urban (DHI, 2014). The 2D overland flow model was applied to the surface runoff modelling, using Mike Flood (DHI, 2014).

Several scenarios were simulated to analyse the consequences in terms of flooding extension and water depths over the surface. The objective was to forecast flooding in the Dafundo catchment, in three hour time-windows, based on estuarine water level and rainfall for a forecast horizon of two days, in order to support population alerts. For the forecast, the accumulated rainfall forecast for a three hours period and the estuarine water level at the Dafundo beach are available. The aim was to create a set of simulations that reproduce the typical flooding in the area, for different conditions of rainfall and tide. These simulations are the basis of the urban flood forecast.

However, for a time interval of three hours, the same accumulated rainfall may have significantly different consequences, in terms of flooding, depending on the hietogram configuration during this period. Therefore, the characteristics of the event (in terms of previous dry weather period, maximum rainfall intensity and the variation of rainfall intensity before and after the peak) have an important role and must be taken into account. The simulated scenarios were intended to assess, for each pair of values x1, x2 (tide, accumulated precipitation in 3h), the best and worst case scenarios (as far as water depth over the surface is concerned).

The influence of the hietograms' shape was analysed through the calculation of maximum average precipitation intensity associated with the return periods (T) of 10, 20 and 50 years, based in the IDF (intensity-duration-frequency) curves of the national Decree-Law 23/95 for Portugal. The corresponding maximum intensities were, respectively, 56 mm/h, 63 mm/h and 73 mm/h. The shape of the rain event was defined by a design rainfall pattern (Figure 4.2). For the corresponding generated rainfall volume, an additional uniform hietogram was defined, during the pre-established time-interval of 3h. Three monitored rain events, registered in the Dafundo catchment, were also simulated.

The tide scenarios were established taking into account both the tidal amplitude and the storm surge effect, which is due to extreme conditions of atmospheric pressure. Low levels of pressure result in a sea level over-elevation. To consider the storm surge effect, a variation of the water level of 0.5m and -0.3m was considered. A maximum and minimum limit of 4.2m and 0.8m, respectively, were considered for the amplitude value of the tide, based in Fortunato *et al*. (2014). The scenarios for the tide level were defined with reference to the mean sea level (MSL) of 0.14m, leading to a minimum sea level of -2.3m and a maximum sea level of 2.7m, corresponding to the best and worst case scenarios, based in Fortunato *et al*. (2014). The tide values are referred at the topographical zero, considering that this value is 2.08 m above the hydrographical zero in the region. Around ten intermediate levels of the tide were simulated.

As referred, besides accumulated rainfall and tide, flooding can be related to the operational conditions of the sewers, such as sediment deposition or obstruction of the outfalls. A sediment depth of 0.20 m was established as the standard condition and a 90% cross-section obstruction was adopted at the outfalls. These values were considered based in the previous field work and their conjugated effect was designated as the operational condition with obstruction.

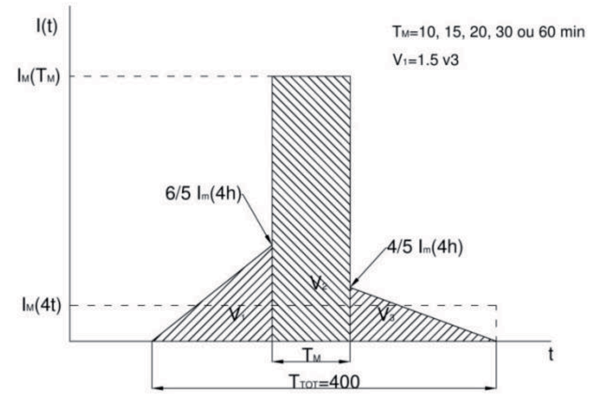
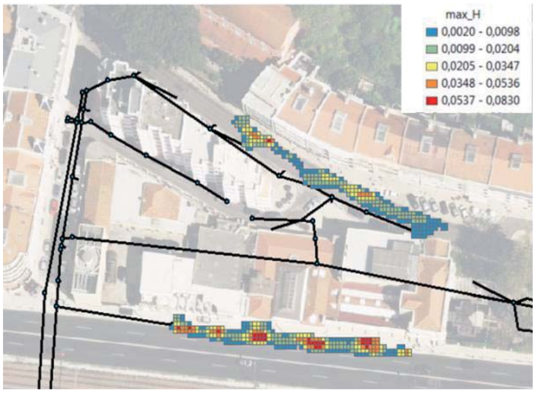


Figure 4.2 – Design rainfall pattern (Matos, 1987)

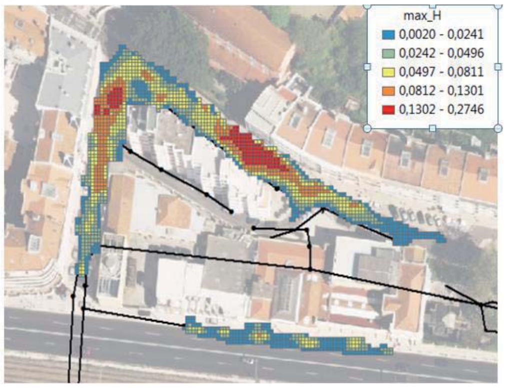
For the operational condition without obstruction, flooding presents a reduced dependence on the tide level at the Tagus estuary. The tide level only acts as a restriction in term of the duration of flooding, but the flooding area and the water depths do not change. For the scenarios of low precipitation and uniform intensity, a significant area in the main street in downtown Dafundo is flooded, but the maximum water depths over the surface are low. The highest water depths are obtained for a return period of 50 years being the flooding area quite large, although the water depths are below 10 cm. For the higher intensity scenarios, such as the ones corresponding to the design rainfall, the eastern locations in the study area also floods. For the maximum rain intensity studied, the main central avenue, a very important transportation route in greater Lisbon, is also flooded, but still with reduced water depths (Figure 4.3a).

For the operational condition with obstruction, the system presents higher dependence on the tide level. The water level in the flooded area, for the higher simulated tide levels and for the rainfall event with higher intensity, triplicates the water depth obtained for the operational condition without obstruction, mainly due to the reduced outfall capacity to the Tagus estuary. The flooded area reaches even further eastern areas, and goes all the way up to almost 30 cm (Figure 4.3b). Stricter additional sediment and obstruction rates were simulated, but generally the same results were obtained.

The results were confirmed with the historical data (Figure 4.3c and d) in terms of extension and depth of the flooded area. An overall good model performance was obtained, allowing identifying the main technical shortcomings of the storm water drainage system.



a) Without obstruction



b) With obstruction

c) Historical flooded area records

d) Flooded area records

Figure 4.3 – Flooded area and water depths over the surface (max_H, in m) in downtown Dafundo, for the design rain event for T=50 years, tide elevation of 2.7 m and historical records

5 | WP 4 RISK ANALYSIS (TASKS 10 and 11)

The WP4 aims at the flood risk analysis of the local study areas based on the WP3 results and includes 2 tasks.

5.1 Task 10 Impact hazard dimension for the study area

Based on the numerical modelling results for different return periods and sea level rise scenarios, obtained in task 9, flood hazard was assessed for the Seixal waterfront. Considering that the flood hazard at a given location depends on the hydrodynamic conditions, its assessment was based on the hazard index defined by DEFRA (2006):

$$\mathrm{I_h} = \mathrm{H}(\mathrm{U} + 0.5) \quad \text{(Eq. 1)}$$

where H (in m) is the total water depth and U (in m/s) is the depth-averaged velocity. Four classes of increasing hazard are defined based on the value of I_h (Table 5.1). The hazard maps are presented in Figure 5.1 (published in Freire *et al.*, 2016).

Table 5.1 – Classes of the hazard index and description based on DEFRA (2006)

Hazard index	$I_h \leq 0.75$	$0.75 < I_h \leq 1.25$	$1.25 < I_h \leq 2.5$	$I_h > 2.5$
Degree of hazard	1 - low	2 - moderate	3 - significant	4 - extreme
Description	caution	dangerous for some	dangerous for most people	dangerous for all

The maximum water levels were extracted from the model and compared with the Digital Elevation Model values in order to obtain water height and inundation extent maps, using ArcGis capabilities (published in Rilo *et al.*, 2014; Freire *et al.*, 2015).

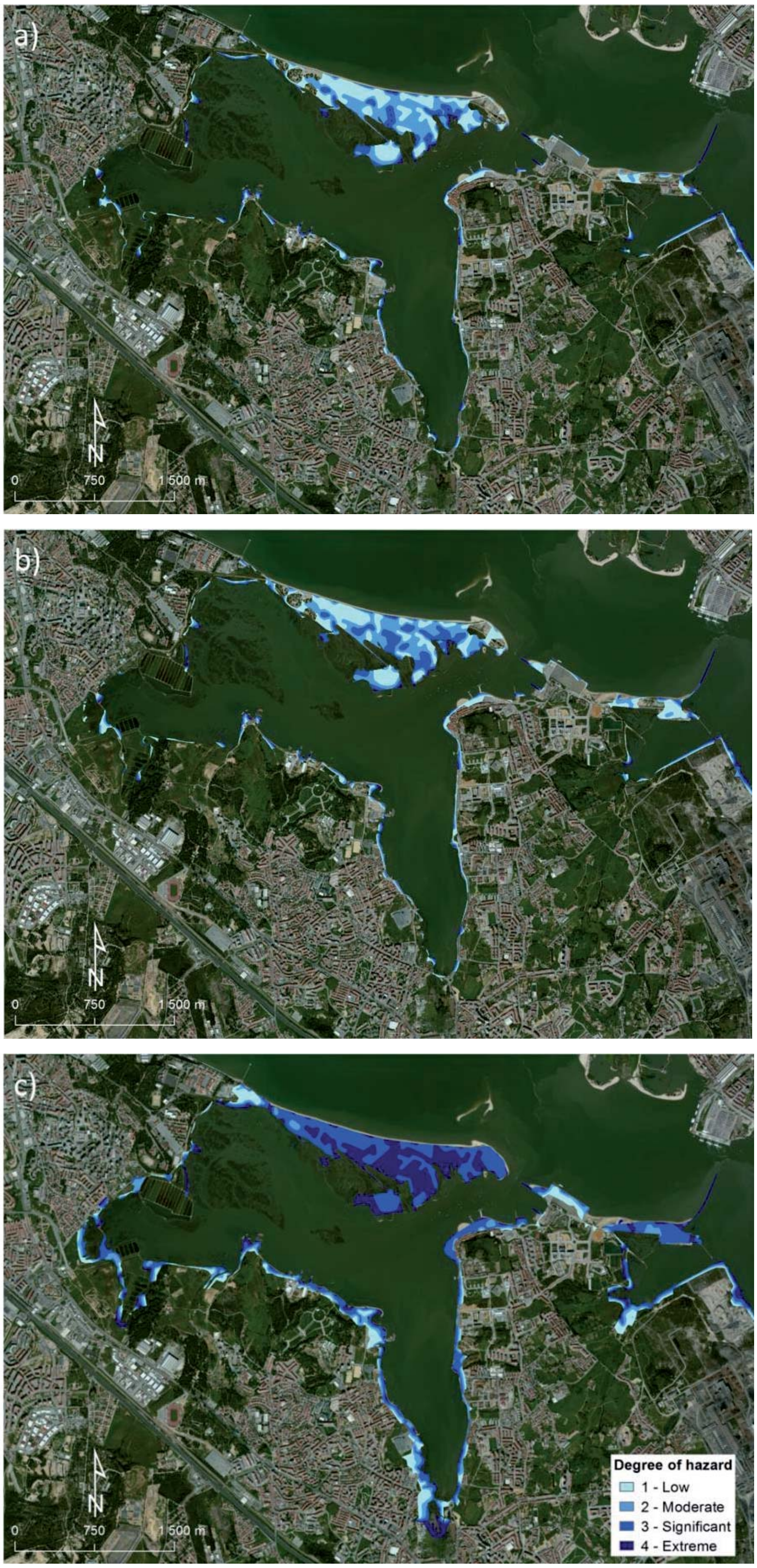


Figure 5.1 – Flood hazard index classification for different scenarios: a) 20-year return period; b) 100-year return period; c) 100-year return period with sea level rise (image: ESRI Aerial Imagery) (source: Freire *et al.*, 2016)

5.2 Task 11 Risk assessment of study area

Damage evaluation in Seixal study area was assessed through a compilation of two local databases of flood records provided and maintained by Seixal fire department and Seixal Municipal Service for Civil Protection (SMPCS). Those two databases were gathered and compiled into a single local database structure in order to integrate different types of information, following similar criteria as described in 2.1. In total 48 occurrences between 2002 and 2013 in Seixal water front area were registered. Results show that societal impacts related with traffic disruption due to flooding forcing is the most common damage (42%) followed by damages in basements, commercial stores and private houses area e (40%) (Freire *et al*, 2016).

The analysis allowed a full evaluation on the most important damages types in the study area and provided background information to emergency and spatial planning guidelines (Task 12).

The refinement of flood hazard at the local level motivated the decision of conducting risk assessment in the Seixal study area at two levels: one for the entire waterfront of the municipality and another for the Seixal old city centre. Accordingly, two distinct methodologies to assess vulnerability were adopted.

5.2.1 Vulnerability and exposed elements assessment for the Seixal municipality

The identification of exposed elements was based on geographic data obtained from the National Authority for Civil Protection (ANPC), the Municipal Service for Civil Protection (SMPCS) and from the results of previous projects (essentially, the MORFEED project) or made publicly available by Central Administration entities. The typology of exposed elements includes: building implantation, road network and business/commercial points of interest; critical infrastructures: civil protection, elderly population, childhood and education, leisure and sport, health, transportation, industrial areas, water supply and treatment; cultural and architectural heritage; land use and land value; environmental assets sensitive zones and coastal ecosystems. The spatial representation of these elements was overlaid with the considered present and future estuarine flooding scenarios.

The vulnerability assessment is resumed in the Vulnerability Index, which considered the following input data (Freire *et al*., 2016) (Table 5.2).

Table 5.2 – Input data and processing for the evaluation of the vulnerability index

Input data		
Variables	*Units*	*Scores*
Road network density (a)	km/km^2	
Proportion of built areas (b)	%	
Vehicles' location (c)	Average of the number of vehicles in 3 different time frames	
Bus stop coverage (d) ATM and bank coverage (e) Fluvial station (f) Environmental infrastructures (g)	Dimensionless	1 – exact location, 0.5 – adjacent location, 0 – other locations [1]
People Vulnerability (P_v)	Dimensionless	Score of the territorial vulnerability assessment (between 0 and 1)
Intermediate parameters		
Mobility parameter (M_p)	M_p=[(c)+(d)]/2	
Concentration areas' parameter (Ca_p)	Ca_p=[(e)+(f)]/2	
Area Vulnerability (A_v)	A_v=[(a)+(b)+(M_p)+(Ca_p)+(g)]/5	
Vulnerability Index (I_v)	I_v=A_v.P_v	

[1] In regard to the triangular network: score 1 if the geographical entity (bus stop, etc.) touches a given triangle; score 0.5 if a given triangle is adjacent to the triangle(s) touched by the geographical entity

Finally, the Vulnerability Index was combined with the Hazard Index to result in the Risk Index (Figure 5.2). The cartographic expression of this index shows that the Seixal old city centre and the fluvial transport station of Transtejo are the most critical areas. The mapping also shows that not only built areas are identified with high risk, as specific sites related to accessibility and socioeconomic activities were also scored with high and very high risk (Freire *et al*., 2016).

Figure 5.2 – Cartographic expression of risk index in the Seixal waterfront for different scenarios: a) 20-year return period; b) 100-year return period; c) 100-year return period with sea level rise (image: ESRI Aerial Imagery) (source: Freire *et al*., 2016)

The identification of diverse territorial typologies that resulted from the risk assessment was nuclear for the selection of critical points, and therefore, contributed to the establishment of a comprehensive framework of emergency and spatial planning guidelines (Task 12), strongly supported by the implemented early warning system.

5.2.2 Vulnerability assessment for the Seixal old city centre

As mentioned, the high levels of risk and vulnerability in the Seixal old city centre led to the exploratory definition of a detailed assessment of vulnerability in that specific location. Field collected data at the building and the statistical sub-block, and statistical data from the Population Census of 2011 at the statistical sub-block supported the mapping of vulnerability in the Seixal old city centre.

Eight parameters were defined, scored and summed in order to – individually as well as condensed in a single indicator – quantify vulnerability to flooding (Santos *et al*., 2016) (Table 5.3):

Table 5.3 – Local parameters for the assessment of vulnerability in the Seixal old city centre

Data collection level	Parameter	Raw units	Source
Sub-statistical block	P1. Profile of the more vulnerable population	%	Census data
Sub-statistical block	P2. Absolute resident population	n.º of inhabitants	Census data
Sub-statistical block	P3. Present population	Scores [0,1]	Field matrix
Sub-statistical block	P4. Surrounding urban context	Scores [0,1]	Field matrix
Building	P5. Vital functions in buildings: social, health, administrative and civil protection infrastructures	Scores [0,1]	Field matrix
Building	P6. Severity of the individual loss	Scores [0,1]	Field matrix
Building	P7. Buildings' physical vulnerability	Scores [0,1]	Field matrix
Building	P8. Human presence inside buildings	Scores [0,1]	Field matrix

Results highlight the vulnerability of specific buildings whose characteristics in each of the parameters, combined with the urban context provided by the parameters assessed at the statistical sub-block, allow a detailed representation of vulnerability factors. A differentiation of blocks in terms of permanent and transient occupancy was also made possible.

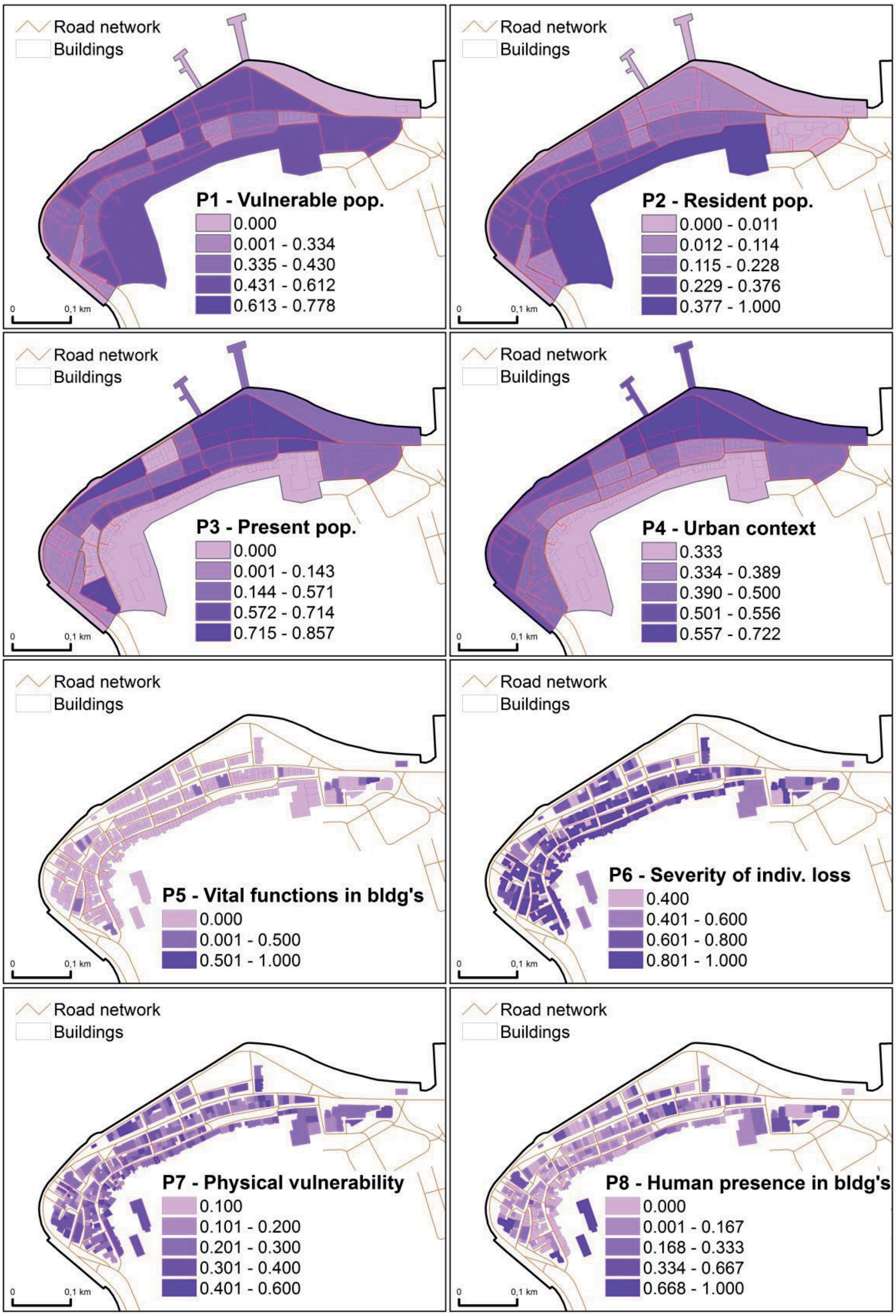


Figure 5.3 – Cartographic expression of the vulnerability parameters in the Seixal old city centre. Source: Santos *et al.*, 2016

The advantages and constraints of the adopted methodologies, as well as the applicability of results in risk management were discussed between the team members, in light of the objectives described in the Milestone 3.

6 | WP5 ESTUARINE FLOOD MANAGEMENT (TASK 12)

The WP5 is organized in one task: Task 12 Flood risk management guidelines. It is dedicated to design consistent and integrated guidelines and advanced information technology tools for flood risk management in the Tagus estuarine margins that can be applied and tangible for other areas. The objective of this task is to develop new tools to improve early-warning and emergency and support preventive measures related to land use and occupation planning.

6.1 Innovative early-warning systems for the Tagus estuary, Dafundo area and the Portuguese coast

In order to provide timely warnings of inundation events in the study areas, dedicated early-warning systems were built based on the modeling structures developed for the Portuguese coast, Tagus estuary (including the Seixal area) and Dafundo area. The first two are presented in section 2.2 and the last one in section 4.2.

These early-warning systems were built using different strategies for the Tagus estuary and coastal areas and for the Dafundo area, developed taking into account the approach used for the hazard calculation. For the estuarine and coastal modeling, a real time forecast system for the Portuguese coast and Tagus estuary was built using LNEC's operational prediction infrastructure WIFF (Water Information Forecast Infrastructure). It was carried out at two distinct levels: regional (NE Atlantic ocean, with a major focus on the Portuguese shelf) and local (Tagus estuary, with a major focus on the Seixal bay). At a regional level, the tide and storm surge forecast system for the NE Atlantic ocean was developed and presented in Fortunato *et al*. 2015 and 2016b. These regional forecasts provided boundary conditions for the local Tagus forecast system (published also in Fortunato *et al*., 2016b). As the Tagus forecast, that includes the Seixal bay, is forced by tides, waves, river flow and storm surges, an additional regional model is necessary to provide the wave boundary conditions. These boundary conditions were provided by WIFF's application to the North Atlantic's and Portuguese coast's wave propagation, developed in a previously FCT-funded project (G-Cast) and summarized in Fortunato *et al*., 2015. 48 hour forecasts are provided for both regions.

As these forecast systems are computationally intensive, computer science strategies were explored to determine the best resources to provide a faster warning, as described in Oliveira *et al*., 2015. Likewise, the integration of real time data, for validation purposes, with forecasts was explored using sensor-fusion techniques. Results are published in Jesus *et al*., 2015.

The early-warning system for the Seixal bay was built along the following steps, developed in strong cooperation with the Seixal municipality:

- Define the critical areas at risk, based on the vulnerability and hazard analysis and historical records
- Define critical points to support the alert bulletin and establish carefully the topographic level for these points
- Define the water level thresholds and corresponding alert levels
- Define the methodology to extract the water levels from the forecast model results

This information was then implemented and an alert bulletin for the Seixal bay was created, providing alert evolution in time for all critical points as well as relevant information for emergency response: maximum water levels and corresponding times of occurrence, maximum wind speed and minimum atmospheric pressure. Whenever alert levels exceed the “no alert” level, this bulletin is sent by email to the national and local civil protection agents. The following figures illustrate this bulletin (Figure 6.1) and corresponding email (Figure 6.2).

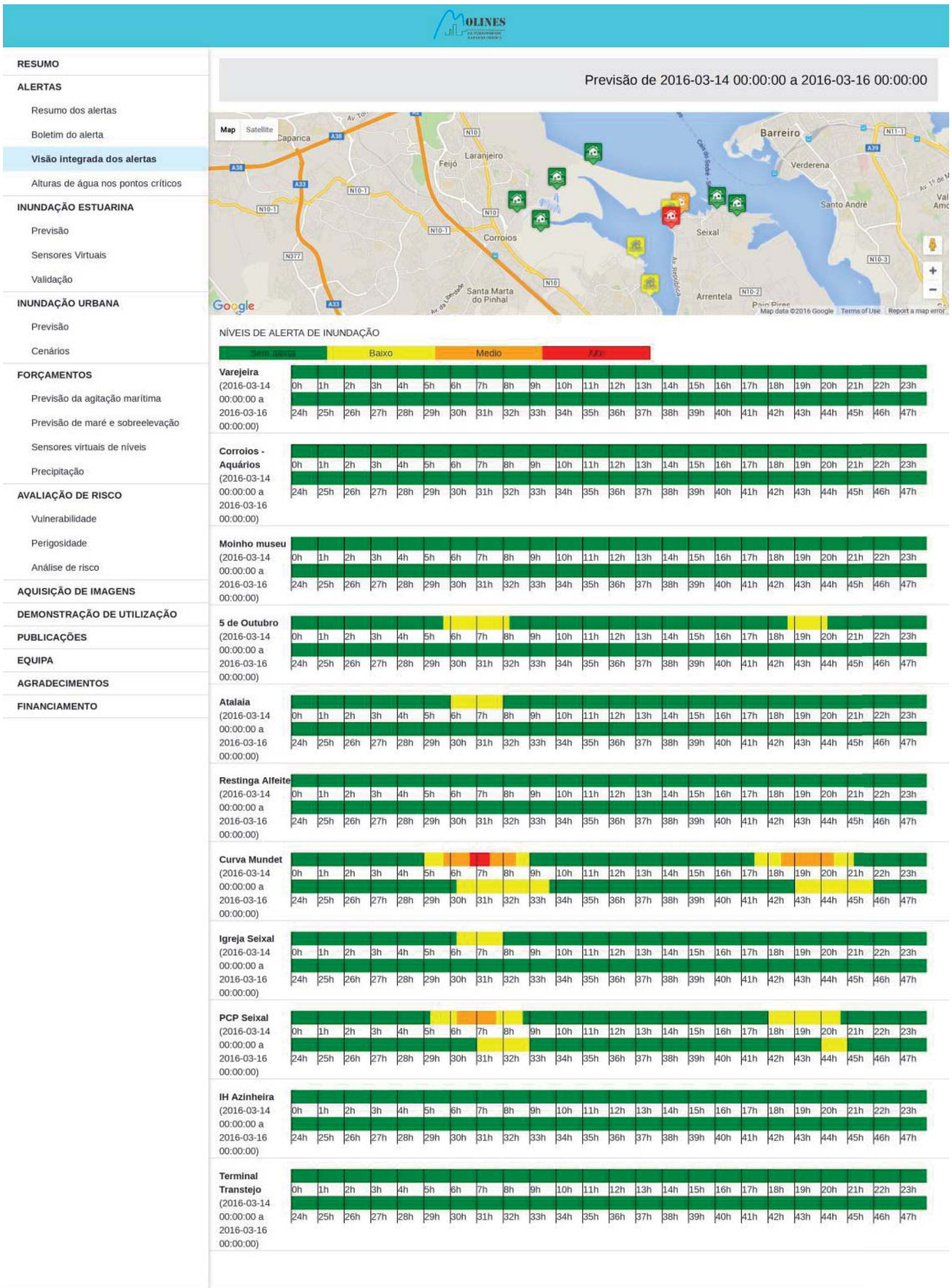


Figure 6.1 – Sample alert bulletin for the Seixal bay (source: Freire *et al.*, 2016)

Subject: ALERTA DE INUNDAÇÃO ESTUARINA
Date: Wed, 9 Mar 2016 12:50:57 +0000 (WET)
From: molines@lnec.pt
To: ...

O nível máximo da água previsto para as próximas 48h é suscetível de provocar inundação e/ou galgamentos da orla estuarina no Concelho do Seixal.
Anexa-se o Boletim de Alerta, também disponível em http://ariel.lnec.pt/molines/#/alerts/bulletin. Nele estão detalhados os horários e nível de alerta previstos para cada um dos pontos críticos.
A presente mensagem foi gerada e enviada automaticamente porque o sistema de previsão em tempo real do estuário do Tejo desenvolvido pelo Projeto Molines/LNEC determinou condições correspondentes a um nível de alerta Moderado ou Elevado para um ou mais pontos críticos na Baía do Seixal, durante as próximas 48h.

Aviso Legal:
O Laboratório Nacional de Engenharia Civil (LNEC) disponibiliza a informação do sistema de previsão em tempo real para fins científicos, não se responsabilizando pelo uso indevido dos dados, nem pelas consequências que daí possam resultar, mesmo que provocadas por eventuais incorreções das previsões. Não obstante o esforço permanente desenvolvido pelo LNEC e seus parceiros para assegurar a qualidade das previsões, estas poderão não estar completas ou atualizadas.
O LNEC não pode garantir que os conteúdos, software, produtos e serviços deste sistema estejam isentos de erros ou falhas técnicas, não sendo garantida a não interrupção ou perturbação do serviço devido a tais problemas. O LNEC declina toda e qualquer responsabilidade por eventuais danos ou problemas que possam surgir na sequência da utilização deste site ou de quaisquer outros serviços ou sites externos a ele ligados. Em caso algum deverá a informação constante deste boletim ser considerada como substituta das atualizações permanentes e da avaliação da situação em tempo real efetuada pelos serviços de proteção civil e forças de segurança. A responsabilidade pela emissão de alertas e avisos à população relacionados com inundação e intempérie é do Sistema Nacional de Proteção Civil.

O Projeto Molines foi financiado pela Fundação para a Ciência e Tecnologia - Projeto Molines (PTDC/AAG-MAA/2811/2012)

Figure 6.2 – Sample alert email

A similar alert bulletin was conceived for the Tagus estuary based on the analysis of historical events and the team's scientific knowledge on inundation in the Tagus estuary. An early-warning system for the coast was also built based on the regional wave and storm surge forecasts. Based on a statistical analysis of occurrences at several points along the coast, a matrix of alerts was built. A conceptual alert bulletin was also envisioned and both were presented to the relevant end-users for approval. An implementation of this bulletin for the May 2016 event is shown in Figure 6.3.

For the Dafundo area, the 48 hour forecasts were built using the several hazards scenarios defined in section 4.2, As the scenarios set of simulations reproduce the typical flooding in the area, for different conditions of rainfall and tide, a sequence of forecast snapshots was built based on the prediction of the maximum estuarine water level and prediction of precipitation provided by the WINDGURU site (published in Cardoso *et al.*, 2016).

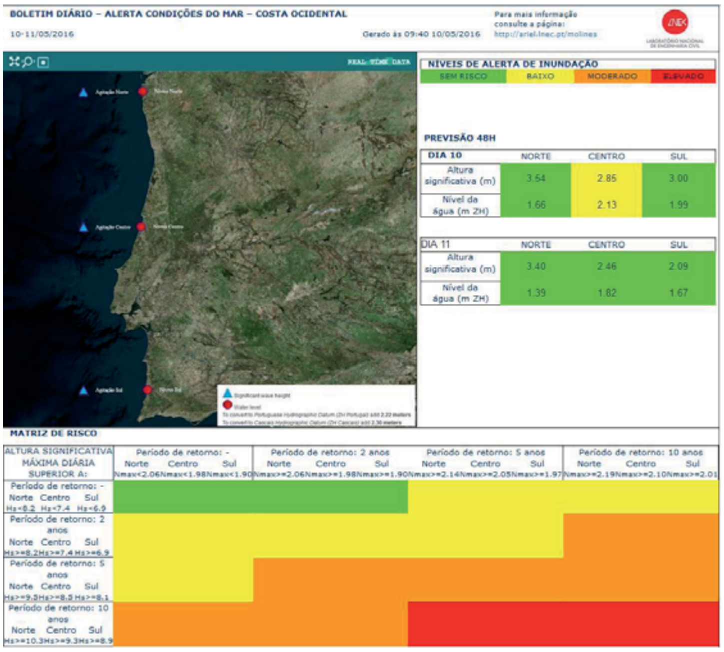
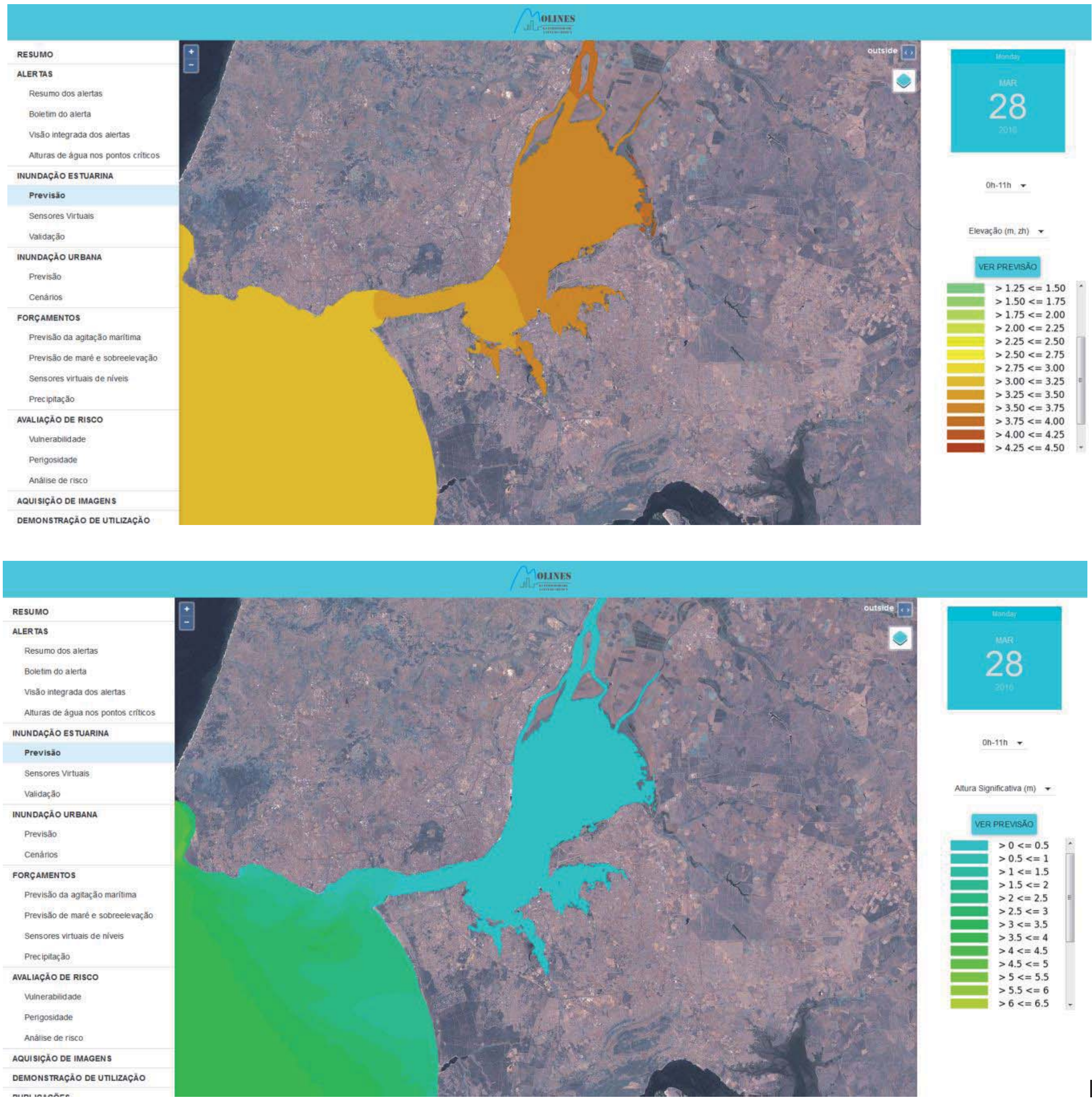


Figure 6.3 – Alert bulletin for the West Portuguese Coast (source: Oliveira, *et al.*, 2016)

The early-warning system was built by identifying three critical points in the affected area. As inundation impact is distinct in each point, the threshold values for emission of alerts were defined accordingly.

Inundation forecasts as well as alert information (including the bulletin) were included in an innovative real-time, responsive WebGIS platform for enhanced support to flood risk emergency in urban and nearby coastal areas, targeting multiple users with distinct access privileges. The platform addresses several user requirements such as 1) fast, simple, online access to relevant georeferenced information from wireless sensors, high-resolution forecasts and comprehensive risk analysis; and, 2) the ability for a two-way interaction with civil protection agents in the field. The platform adapts automatically and transparently to any device with data connection. Given its specific purpose, both data protection and tailored-to-purpose products are accounted for through user specific access roles. The platform constitutes a single point of access to all information developed in the MOLINES project both for emergency and planning purposes.

Gomes *et al.*, 2015 and Gomes *et al.*, 2016 described this platform in detail. The following figures (Figure 6.4 to Figure 6.7) illustrate some of the services provided.



a)

b)

Figure 6.4 – Snapshots of the forecast of a) water weight and b) significant wave weight

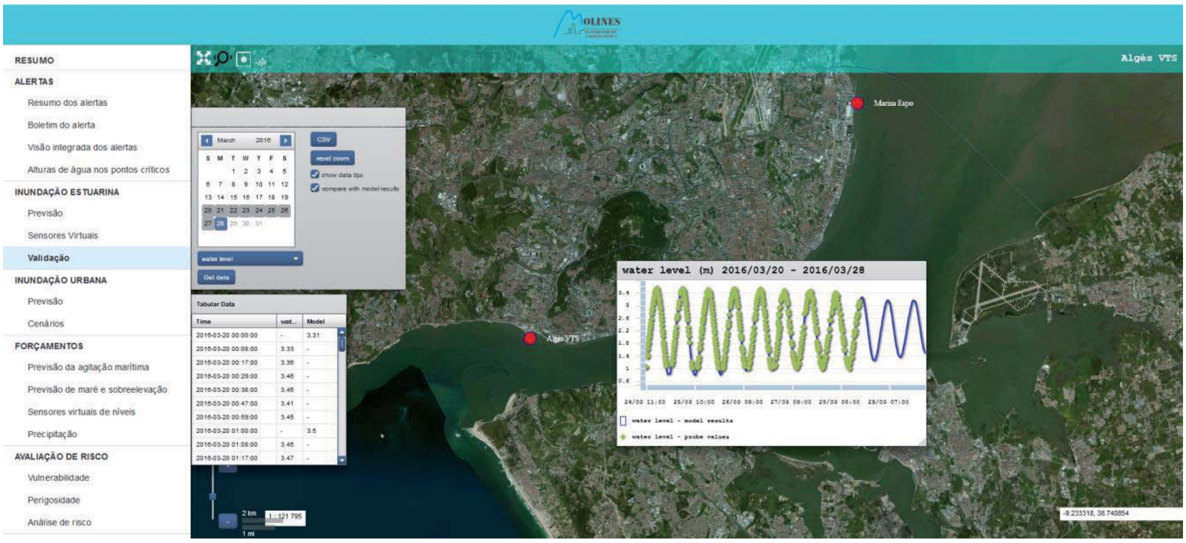


Figure 6.5 – Forecast validation against real time data

Figure 6.6 – Forecast of urban inundation and alert information

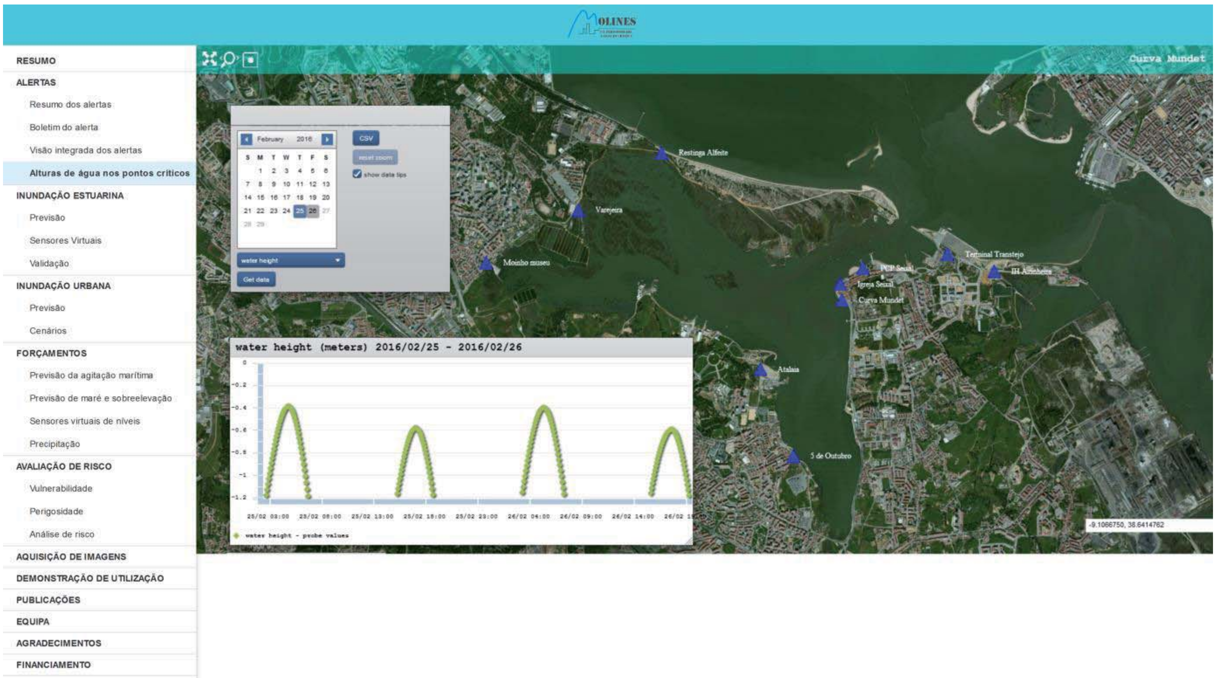


Figure 6.7 – Forecast of inundation levels at a critical point

The platform is also a repository of all hazard, vulnerability and risk information. Figure 6.8 illustrates the risk-dedicated section of the portal.

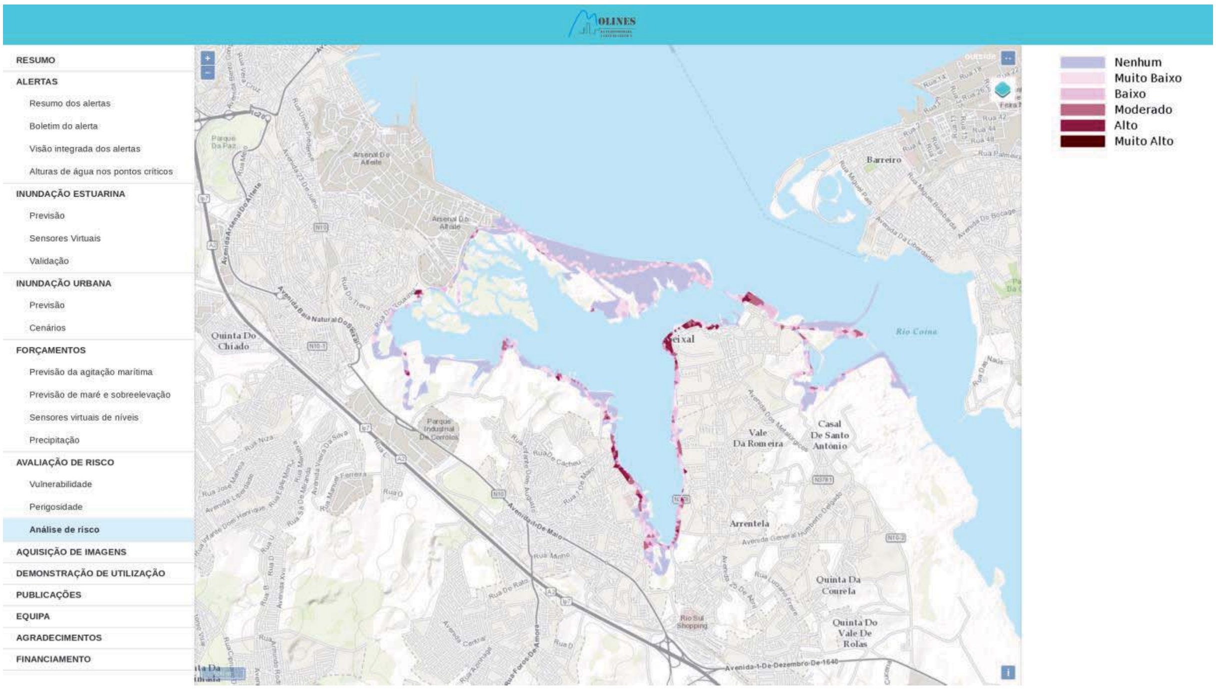


Figure 6.8 – Risk level for a 100-year return period plus SLR scenario

6.2 Population warning system design and testing in controlled conditions

The main objective of this subtask was to design and test an intelligent and reliable population warning system for multi-hazard risks that could also be used in inundation events. First, we decided to disseminate the warnings through the mobile phone network, by sending text messages. Consequently, the success of the population warning system became linked to the use of this communication channel. In a real emergency situation, the population warnings should be disseminated through various channels, such as local radios or sirens, but could also be enhanced by the system proposed herein.

Framework specification

The requirements for the population warning system using mobile technology were defined in dedicated meetings between the MOLINES team and the local and national civil protection authorities. Three criteria were identified:

- The warning system should provide the mobile service provider with the area of the warning, based on the early-warning information;
- The system should be location-based so that the warning could be sent to all the mobile phones in the chosen area, including visitors as well as residents present in the chosen area;
- The message should be clear and simple to contribute to the best response from the population.

After defining the criteria for the warning system, the next steps were to define the text message, the location for the test and also the way to identify the people to be warned. The setting chosen for the warning exercise was the Seixal municipality, as it is one of study areas of the project. .

The purpose of the MOLINES “warning message” test was to demonstrate how modern technologies can be used and enhance current warning systems. In particular, our intention was to send a mobile phone-based warning message to selected phone numbers in Seixal to determine the reliability and coverage of such systems, as well as a preliminary evaluation of the possible population response.

The planning of the exercise was carried by LNEC, in cooperation with the local and national civil protection authorities.

In general, phone-based warning messages can be sent through the use of different technological solutions: population-based technology and location-based technology.

Using a population-based technology, identified residents on the warning area would receive a warning on their mobile phone, but visitors travelling through the warning area would not receive the warning. In this case, mobile phones belonging to residents in warning area, but not being in warning area during the exercise, would also receive the warning. Visitors travelling through the warning area would not receive the warning.

In the case of using a location-based technology, all system provider mobile phones within the warning area would receive the warning as a text message. Hence visitors or tourists roaming on the system provider's network would also receive the warning.

For simplicity and independence relative to the SMS providers, the project team opted for a population-based technology. The warning exercise was done with the cooperation of the local authorities. No information was sent about the exercise, to better simulate the real behavior of the warning recipients.

The warning exercise was performed on February 25th, 2016 using the facilities provided by the Seixal municipality mobile phone services provider bulk message platform. The warning message was sent out at 17:50, to 252 people.

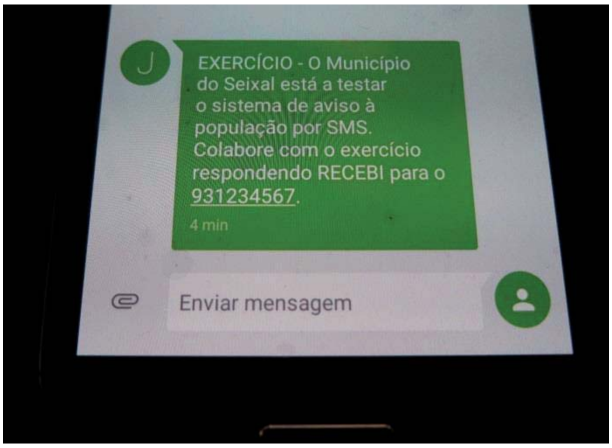


Figure 6.9 – Warning message: Drill – The Seixal municipality is testing a population warning system using SMS. Please cooperate with this drill and send back GOT IT to *931234567*

Evaluation

An analysis of the test was then performed. By combining the logging capabilities of the bulk message platform with an electronic survey we aimed to measure the efficiency of the warning system by answering the following questions:

- Did the warning message reach everyone we targeted?
- How many were alerted?
- How many reacted to the warning?
- Does the population want to be warned through this channel?
- How should this communication channel be supplemented?

The warning message asked for a reply from the part of the recipients to simulate their action in a real crisis situation. The log capabilities of the bulk message platform (Figure 6.10) registered that 225 out of the 252 phones received the message, while 26 didn't receive because the message validity time (1:10) expired (e.g. because the phones were disconnected or without battery).

Figure 6.10 – Bulk message platform

The electronic survey was completed by 125 people (Figure 6.11), several of whom had received the message.

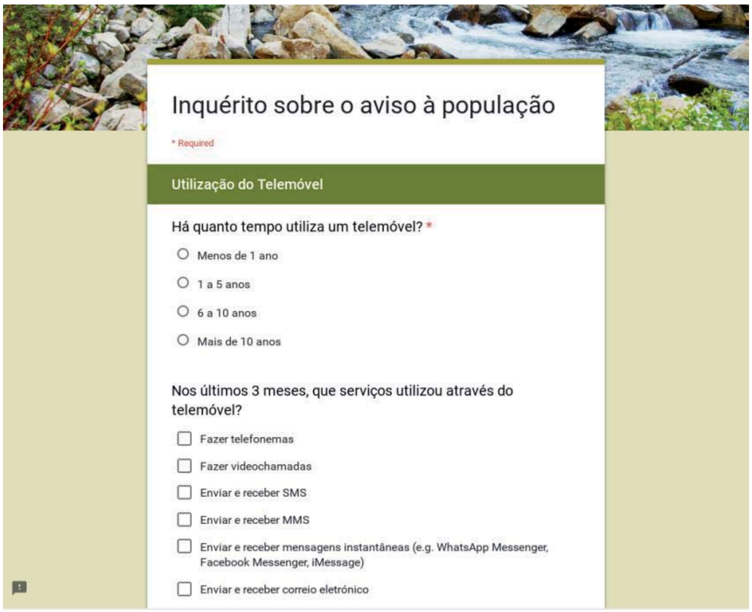


Figure 6.11 – Warning Population Electronic Survey

Some of the respondents are heavy users of SMS (23.2% receive more than 30 SMS per day), while others use this service lightly (25.6% receive less than 5 SMS per day) (Figure 6.12).

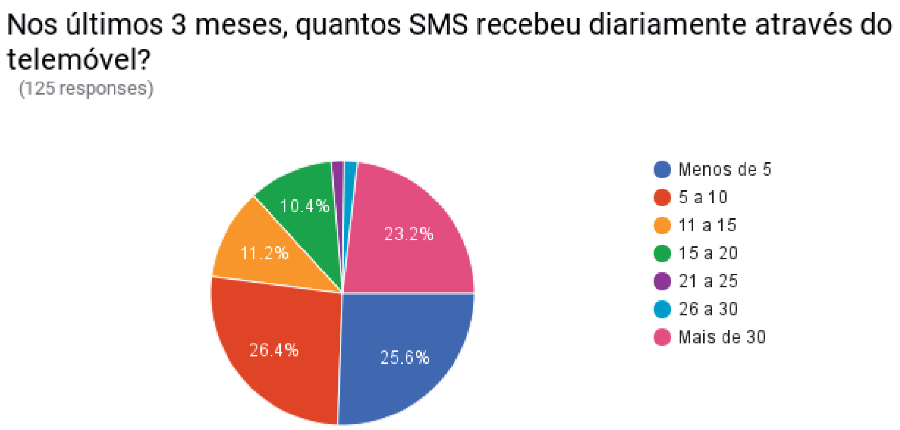


Figure 6.12 – Results of the electronic survey

Nearly all of the respondents (97.5%) supported this way of sending warnings, but a small minority would prefer to receive through other channels. Everybody would prefer to have supplementary warning channels. In a real emergency situation, the use of a local radio would probably be one of the best ways to supplement the information to the general public.

This analysis showed that by implementing emergency population warning systems, civil protection authorities can effectively inform the general public of an incoming hazardous event. These systems have the ability to improve emergency and rescue operations. Implementing reliable and efficient population warning systems should be a high priority for emergency management, in order to save lives and better protect the population.

Given that the technical aspects of location-based technology in mobile phone networks are entirely feasible (e.g. by using cell broadcast or by using the internal databases of the phone network), the roadblocks for adopting the technology can be solved by improvements in the emergency legislation (e.g. requiring the operators to participate as was done in Netherlands and Lithuania) and addressing some aspects of the data protection legislation (e.g. allowing location logging of recipients in crisis situations).

6.3 Emergency guidelines

Emergency guidelines are defined according to the two scales of analysis that characterize the project: regional scale for the entire Tagus estuary, and local scale for the Seixal municipality.

Subjacent to the defined guidelines at the regional level, it was concluded that a proactive and preventive approach is needed which – based on the results of the risk assessment-related tasks (tasks 1 to 7) regarding historical impacts, hazard, exposed elements and vulnerability (see Figure 6.13) –, anticipate the consequences and recurrence of flooding scenarios, permitting to plan risk management strategies in advance.

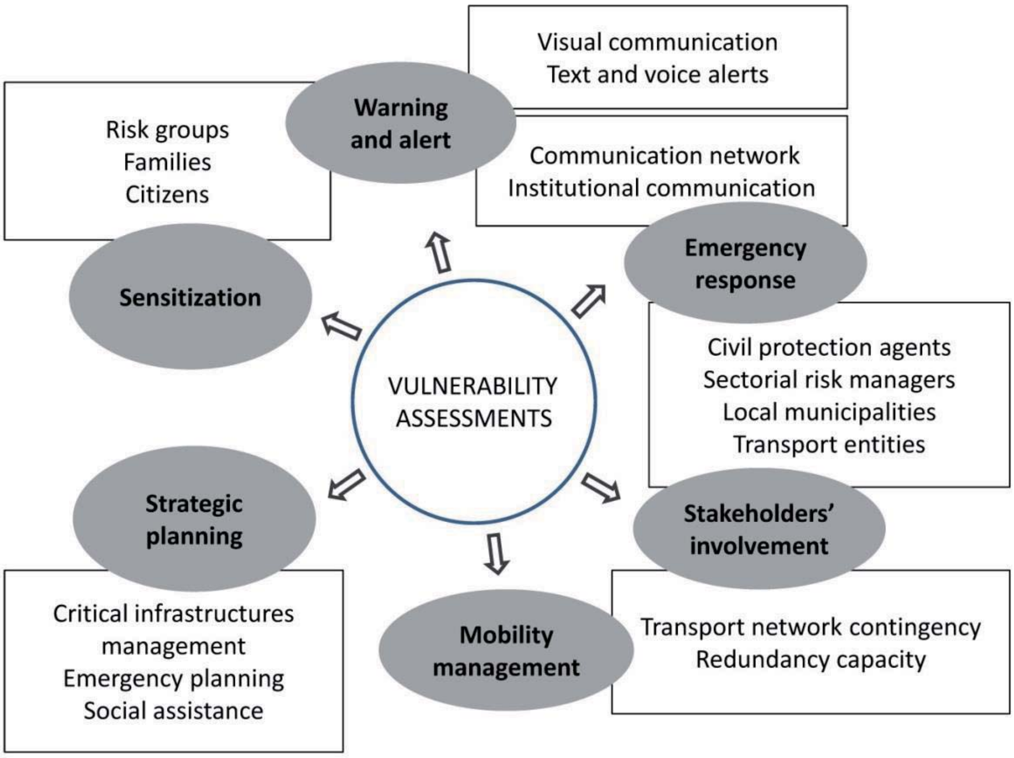


Figure 6.13 – Applications of vulnerability assessments in risk management

At a regional scale, early warning systems were identified as crucial in the management of risk communication and stakeholder involvement. The former would be devoted to inform and make more aware risk groups, families and citizens, and the later would require an institutional approach connecting civil protection agencies, sectorial risk managers, local municipalities and transport entities. In terms of planning, flood risk management was concluded to be much more extended than the emergency response alone, to incorporate risk planning for social assistance and population's mobility.

Table 6.1 – Potential applications of territorial vulnerability Information in early warning and planning of estuarine flood risk management (Source: Santos *et al*., 2015b)

Early Warning	
Communication	*Involvement*
Risk groups Families Citizens	Civil Protection Sectorial Risk Managers Local Municipalities Transport Entities

Planning		
Social Assistance	*Population Mobility*	*Emergency Response*
Critical infrastructure management	Redundancy system capacity	Contingency plan

At the local level, the research developed in the Seixal municipality allowed to sustain a set of emergency guidelines which involve local and national civil protection agents (see Freire *et al*., 2016). The guidelines are contextualized in the four emergency management stages that define the commonly designed disaster cycle: preparedness, response, recovery and prevention/mitigation. This is also the logic behind the official and mandatory emergency planning instruments at the municipal level, to which the defined guidelines are complying with. A list of recommendations was defined in order to facilitate the integration of the present guidelines in the Seixal Municipal Emergency Plan: the early warning system implemented within the MOLINES project continuously monitors and informs local civil protection agents; depending on the level of the alert, assets and population at risk, communication routines are foreseen to upscale the level of involvement (to the district or national level) as well as to involve local and regional entities (related to economic activities, mobility, fluvial transport, education, environment and health equipment, and individually to risk groups and potentially affected citizens); the defined critical points are suggested to be the target of specific civil protection preparedness and response procedures.

In both scales of analysis, the guidelines highlight a concern for mobility contingency, as demonstrated by the historical databases of damages (both regional and local databases) and the identification of exposed elements and vulnerability drivers.

6.4 Spatial planning guidelines

Based on relevant literature and field observations a set of 26 possible adaptation actions for the urban riverfront of Seixal were compiled. These actions were divided into structural-/non-structural measures, and further sub-divided into “hard/grey”, “green” and “soft” adaptation actions. A sub-set of 19 actions was then selected as viable and recommended to be implemented locally in Seixal waterfront (Figure 6.14). These actions range in scope (from small actions at the dwelling scale to large, region-wide policy shifts or improvements to the legal framework), in the time horizon expected for their full implementation (some have already been implemented or could be within a couple of years, others would require a generations’ time or more to be concluded), and in the costs involved. The actions are equally characterized on the level of “regrets” they entail. Some actions, and especially those garnering multiple benefits and flood protection with existing conditions, are considered of low- or no-regrets. Others, would only be of real use if expected scenarios of sea-level rise come to be, and would be either wasteful or would be of negative impact if not. These are high-regrets actions, and should be avoided while there is a significant level of uncertainty over the timeframes of sea-level rise. A description of these actions is presented in Pinto (2016) and complete discussion is in Freire *et al*., 2016.

	Action	Time horizon	Cost	Scale	Regrets	Implemented in Seixal?	Agents
1	Equip vulnerable dwellings with removable, fixed, or automatic flood gates for doors, windows, airholes and garage doors	1-2 yrs	Low	Dwelling	Low	No	Homeowners, storeowners (installation), Municipality and parishes (supervision)
2	Implement formal system of road signs providing warning of flooded roadways and sidewalks	1-2 yrs	Low	Dwelling	Low	No	Municipality (installation), civil protection agents (supervision)
3	Protect existing wetlands, beaches and dune systems	1-2 yrs	Low	City/Region	No	Yes	Municipality (planning instruments), Environment Agency (management)
4	Identify safe routes alternative to flood-vulnerable roadways and transit lines	1-2 yrs	Low/ Medium	Block	No	Partially	Municipality, civil protection agents, public transit companies
5	Forbid the construction of basements in flood-prone areas	3-10 yrs	Low	Dwelling	Low	Yes	Municipality
6	Forbid new construction in vulnerable areas through local planning instruments	3-10 yrs	Low	Neighborhood	Low	Partially	Municipality
7	Remove valuable or perishable items and sensitive infrastructure from basements and flood-prone ground floors	3-10 yrs	Low/ Medium	Dwelling	Low	Partially	Homeowners, storeowners (implementation), Municipality (supervision)
8	Waterpumps must be installed on all basements, underground garages, or ground floors below flood stage	3-10 yrs	Low/ Medium	Dwelling	Low	No	Municipality, homeowners, storeowners
9	Implement early flood warning and monitoring systems (SMS, Media alerts, Sirens…)	3-10 yrs	Medium/ High	City/Region	Low	Partially	Civil Protection Agents
10	Actively manage existing wetlands so as to increase their resilience and promote their expansion	3-10 yrs	Low/ Medium	Neighborhood	No	No	Environment Agency (planning/ managing), Municipality (assistance)
11	Map risks, highlight vulnerable areas, and increase awareness	3-10 yrs	Low/ Medium	Block	No	Yes	Municipality
12	Transfer machinery, generators, elevator shafts to higher floors	3-10 yrs	Medium/ High	Dwelling	Medium	No	Homeowners, storeowners (installation), Municipality (supervision)
13	Improve stormwater drainage systems by replacing pipes, introducing tidal valves, pumping stations or reservoirs	10-25 yrs	Medium/ High	Neighborhood	Low	Partially	Municipality
14	Raise waterfront parapets/guards to increase protection against low flood levels or wave spill-over	10-25 yrs	Low/ Medium	Neighborhood	Medium	No	Municipality
15	Raise waterfront public spaces and/or design them so as to double as barriers against flooding	10-25 yrs	Medium/ High	Block	Medium	No	Municipality
16	Reduce peak surface runoff by introducing green infrastructure and improving infiltration and detention	10-25 yrs	Medium/ High	Neighborhood	Low	No	Municipality (planning, major features), homeowners, parishes
17	Enact changes to flood risk insurance policies so as to increase accountability for "risky" location choices	10-25 yrs	High	City/Region	High	No	Central Government
18	Revise building standards so as to require higher ground floor clearance on new buildings or reconstructions	+25 yrs	Low	Neighborhood	Low	No	Municipality
19	Create new artificial wetlands, namely by reconverting underused reclaimed landfill	+25 yrs	High	City/Region	Low	No	Baía do Tejo Society/ Environment Agency

Figure 6.14 – Selection of adaptation actions to coastal flooding and sea-level rise in the municipality of Seixal

6.5 Flood risk management guidelines for actors (dissemination)

Based on the work developed within the project, a Flood Risk Management Guidelines for Actors was developed (Sá *et al.*, 2016). This publication aims to list the best practices and existing tools for the management of floods, based on the framework for action of Floods Directive - Directive 2007/60/EC - with special attention to urban and peri-urban component, where there are significant risks and vulnerabilities, being also a contribution to a more sustainable development by increasing the resilience of communities thus assisting to an effective implementation of a National Strategy for Disaster Reduction in the framework of United Nations ISDR. From the point of view of protection and relief this document is an asset in seeking to systematize the procedures inherent in the whole process of planning in areas of risk, specifically to the entities responsible for the development of civil protection emergency plans and generally to all the entities directly linked to the Portuguese National System of Civil Protection and others with the duty of cooperation in pursuit of Civil Protection purposes.

7 | WP6 MANAGEMENT AND DISSEMINATION (TASKS 13 and 14)

The project scientific and technical management and dissemination activities are gathered in the WP6, divided in two specific tasks.

7.1 Task 13 Scientific and technical management

This task is dedicated to the scientific and technical management. The functioning and coordination of the team was ensured by the Principal Investigator (PI), assisted by the coordinators of the work packages (Table 1.2), in order to ensure the fulfillment of the project program and the technical coordination. General and sectorial team meetings were fundamental to promote the collaboration in task execution and the good communication within the team and with the project consultant. The technical workshops promoted the communication between the team and the local and national stakeholders.

Four general project team meetings, 2 technical workshops and a final workshop took place (Table 7.1, agendas in Appendix 1). The team general meetings, involving the project consultant, Dr. Xavier Bertin, by skype, allowed a periodical monitoring of the project progress and the planning of the future actions, as well as the discussion of management issues. In the project technical workshops, a detailed discussion of the on-going activities with national and local stakeholders allowed the integration of different views and dimensions in the project activities with a great benefit to the final outcomes. Several sectorial task meetings and specific meetings with the stakeholders (e.g. to discuss the early-warning system or the population warning exercise with the municipality services and local civil protection agents) also took place whenever needed. The final workshop promoted a broad dissemination of the project results to managers and technicians, to national and local stakeholders, as well as general public (described in detailed in task 14).

A cooperation protocol between the Consortium of the project and the Municipality of Seixal was signed for collaboration and information transfer during the project. Partnerships between the Consortium of the project and the Portuguese Environment Agency (Agência Portuguesa do Ambiente - APA) and the Port of Lisbon Authority (Administração do Porto de Lisboa - APL) were also made official.

Two annual scientific progress reports were submitted to FCT.

A dedicated folder in Dropbox facilitated the file exchange between the project participants and the stakeholders.

The expected results of this task were clearly achieved.

Table 7.1 – Project general meetings and workshops

Type	Designation, local, date			
Team general meetings	Kick-off meeting LNEC 24/09/2013	1 st Progress meeting ANPC 24/02/2014	2 nd Progress meeting LNEC 27/06/2014	3nd Progress meeting LNEC 20/04/2015
Tecnhical workshops	1st Project Workshop LNEC 27/06/2014 (1)	2nd Project Workshop LNEC 20/04/2015 (1)		
Final Workshop	Final Workshop ANPC 12/11/2015			

(1) with representation of the following institutions: Agência Portuguesa do Ambiente (APA), Administração do Porto de Lisboa (APL), Câmara Municipal do Seixal, Simarsul e Simas de Oeiras/Amadora.

7.2 Task 14 Dissemination

The dissemination of the project outcomes took place throughout the project using different channels for different targeted audiences.

A dedicated webpage in Portuguese and English was developed and maintained:

PT: http://www.lnec.pt/hidraulica-ambiente/pt/projectos/detalhe/molines-modelacao-da-inundacao-em-estuarios-da-avaliacao-da-perigosidade-a-gestao-critica/

EN: http://www.lnec.pt/hidraulica-ambiente/en/projects/details/molines-modelling-floods-in-estuaries-from-the-hazard-to-the-critical-management/

The dissemination to the scientific community was made essentially through the publication in peer-review journals and presentations in national and international conferences (section 8). The publications of the project include 3 book chapters, 3 papers in peer-review journals and 2 submitted, 7 publications in proceedings of international conferences and 12 of national conferences, one PhD thesis and a Guideline for Actors.

The dissemination of the project to managers and technicians, local and national stake-holders and general public was made through different channels including:

- A flyer of the project in Portuguese and English was prepared in two different formats (Appendix 2): presentation of the project and dissemination of the main final results;
- Project technical workshops;
- Specific meetings with stakeholders for the project presentation;
- Invited presentations in seminars (e.g. at the Portuguese Agency of the Environment - Appendix 3);
- Publications in dedicated newspapers (Jornal Água e Ambiente and Jornal Alto Risco – Appendix 3).

Besides the above channels, the final workshop of the project allowed a wide dissemination of the project objectives and results. The final workshop (Figure 7.1 and Appendix I for the agenda) included 7 communications of the project team and two invited speakers, the project consultant Dr. Xavier Bertin (La Rochelle University) and Dr. John Tacken (NL-Alert). The workshop had about 90 attendees representing several institutions (e.g. Portuguese Agency of the Environment, Port of Lisbon Authority, Hydrographic Institute, municipal civil protection services and municipalities, other research institutions), most of which with national and local responsibilities in flood risk management.

Figure 7.1 – Aspects of the Final Workshop that took place in the Autoridade Nacional de Proteção Civil

The document Flood Risk Management Guidelines for Actors (Sá, 2016), prepared within the project, lists the best practices and existing tools for the management of floods and is addressed to all the entities directly linked to the Portuguese National System of Civil Protection, and others with the duty of cooperation in pursuit of Civil Protection purposes.

The expected results of this task were clearly achieved with a broad dissemination of the project results in different targeted audiences. The expected output indicators were in general reached and in some cases exceeded: 8 papers in international journals and books chapters (4 proposed); 7 communications in international conferences (6 proposed); 12 communications in national conferences (6 proposed); 20 reports (2 proposed); 3 organizations of seminars and conferences (2 proposed). Exception is the publication in national papers that was compensated by a wider dissemination in proceedings of national conferences and other forms targeting different audiences as described above. Advanced training was also achieved through a PhD thesis.

8 | Publications of the project

8.1 Book chapters

Rilo, A., Freire, P., Tavares, A.O., Santos, P.P:, Sá, L., 2015. Historical flood events in the Tagus estuary: Contribution to risk assessment and management tools. In: Safety and Reliability of Complex Engineered Systems – Podofllini *et al*. (Eds) 2015, Taylor & Francis Group, London, ISBN 978-1-138-02879-1: 4281-4286. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/534_rilo_et_al_2015_historical_flood_events_esrel.pdf

Santos, P., Tavares, A.O., Fortunato, A.B., Rilo, A.R., Freire. P., 2015. Assessment of social vulnerability in a estuarine context. In: Kremers and Susini (Eds.), Risk Information Management, Risk Models and Applications. Lecture Notes in Information Sciences, vol.7: 105-116, CODATA Germany, Berlin. ISBN: 978-3-00-048844-3. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/santos_et_al_2015_rimma_berlin_2014lnis.pdf

Santos P.P., Tavares A.O., Freire, P., Fortunato, A., Rilo, A., 2015. Territorial vulnerability to flooding in an estuarine area: Challenges valuing the structural and societal local . In: Safety and Reliability of Complex Engineered Systems – Podofillini *et al*. (Eds) 2015 , Taylor & Francis Group, London, ISBN 978-1-138-02879-1: 4273-4280. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/533_santos_et_al_2015_territorialvulnerability_esrel.pdf

8.2 Papers in international journals

Fortunato, A.B., Oliveira, A., Rogeiro, J., Tavares da Costa, R., Gomes, J.L., Li, K., Jesus, G., Freire, P., Rilo, A., Mendes, A., Rodrigues, M., Azevedo, A. 2016. Operational forecast platform for extreme sea levels at regional and local scales. (submitted to Journal of Operational Oceanography, March 2016)

Fortunato, A.B., K. Li, X. Bertin, M. Rodrigues, B.M. Miguez., 2016. Determination of extreme sea levels along the Iberian Atlantic coast. Ocean Engineering, 111 (2016) 471–482. http://www.sciencedirect.com/science/article/pii/S0029801815006538

Freire, P., Tavares, A., Sá, L., Oliveira, A., Fortunato, A., Santos, P., Rilo, A., Gomes, J. L., Rogeiro, J., Pablo, R., Pinto, P.L., 2016. A local scale approach to estuarine flood risk management. (accepted to Natural Hazards, July 2016)

Guerreiro, M., Fortunato, A.B., Freire, P., Rilo, A.R., Taborda, R., Freitas, M.C., Andrade, C., Silva, T., Rodrigues, M., Bertin, X., Azevedo, A. 2015. Evolution of the tidal dynamics of the Tagus estuary in the 21st century. Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, volume 15 (1): 65-80. http://www.aprh.pt/rgci/rgci515.html

Tavares, A. O., Santos, P. P., Freire, P., Fortunato, A. B., Rilo, A., Sá, L., 2015. Flooding hazard in the Tagus estuarine area: The challenge of scale in vulnerability assessment. Environmental Science & Policy Environmental Science & Policy, 51 (2015): 238-255. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/tavares_et_al_2015.pdf

8.3 Proceedings in international conferences

Fortunato A.B., Li K., Bertin X., Rodrigues, M., Miguez, B.M, 2014. Determination of extreme water levels along the Iberian Atlantic coast, 2014. IMUM2014 – 13th International workshop on multiscale (un-) structured mesh numerical modeling for coastal, shelf, and global ocean dynamics, 25-27 agosto 2014, Lisboa: 2p. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/fortunato_imum2014.pdf

Fortunato A.B., Li K., Bertin X., Rodrigues, M., Miguez, B.M., 2014. Détermination de la période de retour des niveaux extrêmes et des submersions. In Colloque international "Submersions marines: passé, présent, futur". 19-21 junho 2014, Rochefort/La Faute sur Mer/La Rochelle, França, 2pp. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/fortunato_etal2014.pdf

Freire P., Fortunato A.B, Rilo A., Bertin, X., Li, K., 2014. Flood risk assessment in estuaries. The importance of historical data integration in predictive tools development. ECSA54. Coastal systems under change: tuning assessment and management tools, 12-16 May 2014, Sesimbra, Portugal. Programme and Book of Abstracts, Centro de Oceanografia, ECSA: p.70. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/freire_ecsa.pdf

Gomes J.L., Jesus G., Rogeiro J., Oliveira A., Costa R., Fortunato A., 2015. Molines – towards a responsive Web platform for flood forecasting and risk mitigation. Proceedings of the Federated Conference on Computer Science and Information Systems pp. 1171–1176 ACSIS, Vol. 5 DOI: 10.15439/2015F265. http://annals-csis.org/Volume_5/pliks/265.pdf

Jesus G., Oliveira A., Azevedo A., Casimiro A., 2015. Improving sensor-fusion with environmental models. IEEE Sensors 2015, 1839-1842

Rilo, A., Taborda, R., Freire, P., Freitas, M.C., Andrade, C., Silva, T., Caçador, I., 2014. A simple model to forecast estuarine morphologic evolution in response to sea level rise. In: ECSA54 . Coastal systems under change: tuning assessment and management tools. 12-16 May 2014, Sesimbra, Portugal. Book of Abstracts, Centro de Oceanografia, ECSA: 82. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/riloecsa14.pdf

Santos, P. P., Tavares, A. O., Freire, P., Rilo, A., 2016. Scale issues in local vulnerability assessments: implications in risk and urban planning. Atas do ICUR 2016 - International Conference on Urban Risks, Lisboa, 30 de junho a 2 de julho de 2016, Centro Europeu de Riscos Urbanos, 455-462

8.4 Proceedings in national conferences

Cardoso, M. A., Almeida, M. C, Brito, R. S., Beceiro, P. 2015. Modelação integrada da drenagem urbana em zonas estuarinas: avaliação da inundação para cenários climatéricos. 10º Encontro Nacional de Entidades Gestoras de Água e Saneamento, ENEG 2015, Porto, 1-4 de dezembro. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/cardoso_et_al_molines_eneg2015_final.pdf

Fortunato, A.B, Li, K, Bertin, X, Rodrigues, M., 2014. Determination of extreme sea levels along the Portuguese coast. Actas das 3.as Jornadas de Engenharia Hidrográfica, 24, 25 e 26 de junho de 2014, Instituto Hidrográfico, Lisboa: 151-154. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/fortunato3jeh14.pdf

Fortunato, A. B., Li, K., Freire, P., Rilo, P., Bertin, X., 2015. Numerical modeling of extreme events in the Tagus Estuary. in Matias, A. (Ed), *MEC 2015 - Conferência sobre morfodinâmica estuarina e costeira Universidade do Algarve, 14-15 Maio 2015. Livro de Resumos*: 37-38. http://mec2015.lnec.pt/pdf/livro_resumos_MEC2015.pdf

Fortunato, A. B., Costa, R. T., Li, K., Rogeiro, J., Gomes, J., Rilo, A., Freire, P., Oliveira, A., 2015. Sistema operacional de previsão dos níveis extremos na costa Portuguesa. *VIII Congresso sobre Planeamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa*, 14-16 outubro de 2015, Universidade de Aveiro, 15p. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/fortunato_et_al_2015_congresso_planeamento_gestao_zonas_costeiras.pdf

Freire, P., Tavares, A., Fortunato, A.B., Oliveira, A., Cardoso, M.A. and Pires, P., 2014. An Integrated Approach for Flood Risk Assessment in Estuaries. In: Actas das 3.as Jornadas de Engenharia Hidrográfica, 24, 25 e 26 de junho de 2014, Instituto Hidrográfico, Lisboa: 313-316. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/freire3jeh14.pdf

Freire, P., Rilo, A., Santos, P. P., Fortunato, A. B., Tavares, A. O., Cardoso, M.A., 2015. Risco de inundação em estuários. Caracterização das componentes de perigo a diferentes escalas espaciais*,* in Matias, A. (Ed), *MEC 2015 - Conferência sobre morfodinâmica estuarina e costeira Universidade do Algarve, 14-15 Maio 2015. Livro de Resumos*: 19-20. http://mec2015.lnec.pt/pdf/livro_resumos_MEC2015.pdf

Freire, P. M. S., Tavares, A. O., Fortunato, A. B., Sá, L., Oliveira, A., Rilo, A., Santos, P. P., 2015. Modelação da inundação em estuários. Da avaliação da perigosidade à gestão crítica. *VIII Congresso sobre Planeamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa*, 14-16 outubro de 2015, Universidade de Aveiro. APRH (eds), 15 p. http://www.lnec.pt/fotos/editor2/dha/DHA%20PDFs/freire_et_al_2015_congresso_planeamento_gestao_zonas_costeiras.pdf

Freire, P., Fortunato, A. B., Rodrigues, M., Santos, P. P., Rilo, P., Tavares, A. O., 2016. The effect of storm events in the Tagus estuarine margins. Atas das 4as Jornadas de Engenharia Hidrográfica, Lisboa, 21 a 23 de junho de 2016: 261-264, Instituto Hidrográfico. (http://websig.hidrografico.pt/www/content/Documentacao/jornadas_2016/4JEH2016_Actas_v2.pdf)

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9 | Collaborations and acknowledgements

- APL – Administração do Porto de Lisboa, SA
- IPMA - Instituto Português do Mar e da Atmosfera
- APA – Agência Portuguesa do Ambiente
- DGT – Direção Geral do Território
- Câmara Municipal do Seixal (Serviço Municipal de Protecção Civil do Seixal; Divisão de Desenvolvimento Económico e Apoio ao Turismo da Câmara Municipal do Seixal)
- União das Freguesias de Seixal, Arrentela e Aldeia de Paio Pires
- Projeto DISASTER (PTDC/CS-GEO/103231/2008)
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- SIMARSUL
- Associação dos Bombeiros Voluntários do Concelho do Seixal
- Associação Humanitária dos Bombeiros Voluntários do Dafundo
- Associação de Beneficiários da Lezíria Grande de Vila Franca de Xira
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- Prof. Margarida Liberato, Universidade do Minho. Simulation of extreme atmospheric events at regional and local scales.
- Danish Hydraulic Institute (DHI). Provision of the software licence used in this research project to perform the urban drainage modelling.

10 | Main results and critical appraisal

The proposed project scientific objectives were clearly achieved. The project contributed to the knowledge improvement on flood process in estuaries, and in particular the Tagus system, and with an innovative approach to support flood risk management in transitional systems taking into account different levels of the decision-making process. The results of the project also contributed to the capacity-building of the participant institutions through the availability of information and the improvement of tools (e.g. risk assessment approaches, numerical modelling, real-time forecast system).

The main project results are: 1) the knowledge improvement of estuarine margins flooding processes taking into account different hazard sources; 2) the characterization of the causes and effects of floods in the Tagus estuary, in particular at the study sites that include urban areas (Dafundo and Seixal); 3) numerical modelling of natural and urban floods to support an integrated flood hazard analysis at a local scale (Dafundo); 4) the assessment of flood risk in the Seixal waterfront for different climate scenarios through the integration of hazard, exposed elements and territorial vulnerability evaluations; 5) the development and application at a local-scale of an integrated approach to support flood risk management in transitional systems taking into account different levels of the decision-making process, emergency and land-use and occupation planning; 6) at the emergency level, the development of a WebGIS interface providing innovative early-warning systems for the Tagus estuary (including Seixal and Dafundo areas) and the Portuguese coast; 7) the proposal of emergency planning guidelines to assist the municipal civil protection authorities in preparedness and emergency response; 8) the proposal of a set of flood adaptation actions based on land-use and occupation measures to increase resilience in face of flooding and future sea-level; 9) the design of a population warning system and a warning test in controlled conditions using mobile technology; 10) Flood Risk Management Guidelines for Actors, listing the best practices and existing tools for the management of floods.

The team dynamics enhanced a wider dissemination of the project results than the expected at the time of the proposal. The expected output indicators were in general exceeded (Table 10.1): 8 papers in international journals and books chapters (4 proposed); 7 communications in international conferences (6 proposed); 12 communications in national conferences (6 proposed); 20 reports (2 proposed); 3 organizations of seminars and conferences (2 proposed). Exception was the publication in national papers that was compensated by an extensive dissemination in proceedings of national conferences and other forms of communication, targeting different audiences (project webpage and flyer, technical workshops, specific meetings with stakeholders for presentation of the project, invited presentations in seminars, publications in newspapers). Within the project, advanced training was also achieved through a PhD thesis.

The expertise of the participant institutions and the other dimensions added by the close collaboration with the local and national stakeholders made possible the integration of different strategies and approaches that typically are used independently in flood risk analysis. Also, the development and implementation of the early-warning system for the Seixal waterfront benefited from the strong cooperation with the Seixal municipality and the local civil protection services.

Table 10.1 – Expected and accomplished output indicators

Description	proposed	achieved
A - Publications		
Books chapters		3
Papers in international journals	4	5
Papers in national journals	6	
B - Communications		
Communications in international meetings	6	7
Communications in national meetings	6	13
C – Reports (including the Guidelines for Actors)	2	20
D - Organization of seminars and conferences	2	3
E - Advanced training		
PhD theses		1
Master theses		
Others		
F - Models		
G - Software	5	5
H - Pilot plants		
I - Prototypes		
J - Patents		
L - Other		
Webpage	1	2

Lisbon, LNEC, July 2016

APPROVED BY

Head of the Estuaries and Coastal Zones Unit

Luís Portela

COORDINATION

Paula Freire

Assistant Researcher

Head of the Hydraulics and Environment Department

Helena Alegre

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Annexes

ANNEX I
Project Meetings

Kick-off Meeting Agenda

LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL

MOLINES - Modelação da inundação em estuários.
Da avaliação da perigosidade à gestão crítica.

Reunião de Arranque

Sala de Reuniões do Departamento de Hidráulica e Ambiente (LNEC), 24 de setembro de 2013

Agenda

10h00 – 10h30	Abertura da reunião. Apresentação geral do projeto, aspetos de gestão e disseminação, informações gerais.	P. Freire
10h30 – 11h30	Apresentação sumária das WP e tarefas pelos responsáveis e discussão: *WP1- Estuarine Flood Model Simulation (A. Fortunato)* *WP2 - Estuarine Exposed Elements and Vulnerability Assessment (A. Tavares)* *WP3 - Integrate natural and urban flood modelling in study areas (M. A. Cardoso)* *WP4 - Risk analysis (A. Tavares)* *Sistema de Previsão em Tempo Real do Estuário do Tejo (A. Oliveira)* *WP5 - Estuarine Flood Management (L. Sá / J. Dias)*	
11h30 – 11h45	Intervalo para café	
11h45 – 12h00	Sistematização dos dados necessários ao projeto. Discussão	P. Freire
12h00– 12h45	Discussão sobre a comunicação no projeto, plataformas de transferência de informação entre participantes, meios de divulgação para o exterior (logotipo, webpage, folheto, …)	
12h45-13h00	Outros assuntos. Fecho da reunião.	

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First Progress Meeting Agenda

LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL

MOLINES - Modelação da inundação em estuários.
Da avaliação da perigosidade à gestão crítica.

Reunião de Progresso

Autoridade Nacional de Proteção Civil, 24 de fevereiro de 2014

Agenda

14h30 – 14h45	Aspetos de gestão	P. Freire
14h45 – 15h30	Ponto de situação das Tarefas em curso e discussão: *Tarefa 1 - P. Freire / A. Rilo* *Tarefa 2 – A. Fortunato* *Tarefa 4 a 6 - A. Tavares / P. Santos* *WP3 (Drenagem urbana) - M. A. Cardoso*	
15h30 – 16h30	Discussão sobre o caso de estudo e continuação das atividades	
16h30-17h00	Outros assuntos. Fecho da reunião.	

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[1/1]

First Technical Workshop and Second Progress Meeting Agenda

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

MOLINES DA PERIGOSIDADE À GESTÃO CRÍTICA

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

MOLINES - Modelação da inundação em estuários.
Da avaliação da perigosidade à gestão crítica.

1º Workshop Técnico

Laboratório Nacional de Engenharia Civil, 27 de junho de 2014

Agenda

9h30 – 9h40	Abertura	P. Freire
9h40 – 10h35	Apresentação de resultados e discussão: *Caracterização de eventos históricos de inundação no estuário do Tejo e recolha de dados in situ (15 min.) – P. Freire* *Determinação dos níveis extremos a escalas regionais e locais (15 min.) – A. Fortunato* *Análise da suscetibilidade à inundação das margens estuarinas (10 min.) – A. Rilo*	
10h35 – 10h50	Pausa para café	
10h50 – 11h40	Apresentação de resultados e discussão: *Avaliação dos elementos expostos e modelo de vulnerabilidade (15 min.) – A. Tavares / P. Santos* *WebGIS para acesso à previsão da inundação no estuário do Tejo (10 min.) – A. Oliveira* *Metodologia para o desenvolvimento do sistema de alerta (10 min.) – J. Palha Fernandes*	
11h40 – 12h30	Discussão alargada	

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Second Technical Workshop and Third Progress Meeting Agenda

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

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ANPC AUTORIDADE NACIONAL DE PROTECÇÃO CIVIL

MOLINES DA PERIGOSIDADE À GESTÃO CRÍTICA

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

**MOLINES - Modelação da inundação em estuários.
Da avaliação da perigosidade à gestão crítica.**

2º Workshop Técnico

Salão Nobre, Laboratório Nacional de Engenharia Civil

20 de abril 2015

Agenda

9h30 – 9h40	Abertura	P. Freire
9h40 – 11h00	Apresentação de resultados e discussão: *Caracterização das componentes de perigo a diferentes escalas espaciais – P. Freire* *Simulação numérica dos níveis extremos e da inundação no estuário do Tejo – A. Fortunato* *Suscetibilidade à inundação das margens estuarinas a diferentes escalas espaciais – A. Rilo* *Modelação integrada da drenagem urbana no caso de estudo – M.A. Cardoso*	
11h00 – 11h15	Pausa para café	
11h15 – 12h15	Apresentação de resultados e discussão: *Modelo de vulnerabilidade territorial para gestão do risco de inundação à escala local – A. O. Tavares & P.P. dos Santos* *Desenvolvimentos do Portal Web MOLINES: previsão, alerta e análise de risco – A. Oliveira & J. Gomes* *Preparações para um piloto de SMS localizado para aviso à população – J. Palha Fernandes*	
12h15 – 13h00	Discussão alargada	
13h00 – 14h30	Almoço	
14h30 – 16h00	Reunião da equipa do projeto (discussão sobre a execução financeira e científica e técnica do projeto)	

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Final Workshop Program

MOLINES
DA PERIGOSIDADE À GESTÃO CRÍTICA

WORKSHOP
GESTÃO DE CHEIAS EM AMBIENTES ESTUARINOS

Autoridade Nacional de Proteção Civil (Carnaxide)
12 de novembro de 2015

PROGRAMA

9H30 Abertura
10H00 **Risco de inundação em estuários: uma abordagem integrada**
Laboratório Nacional de Engenharia Civil
10h30 **Inundações Costeiras na região Central da Biscaia: Lições apreendidas com a tempestade Xynthia**
Universidade de La Rochelle (França)

11h00 Coffee-Break

11h30 **Vulnerabilidade territorial como suporte à gestão do risco de inundações**
Universidade de Coimbra
12h30 **Simulação numérica dos níveis extremos e da inundação do estuário do Tejo**
Laboratório Nacional de Engenharia Civil
12h00 **MOLINES Web: Plataforma web integrada para a gestão do risco de inundação**
Laboratório Nacional de Engenharia Civil

13h00 Almoço (livre)

14h30 **Comunicação de Risco e de Crise em Cenários de Riscos Hidrológicos**
Autoridade Nacional de Proteção Civil
15h00 **Aviso de marés vivas na Baía do Seixal – Um desafio futuro para a proteção civil**
Serviço Municipal de Proteção Civil do Seixal
15H30 **NL-Alert – Um Sistema de Aviso às populações via difusão celular**
Ministério da Justiça e Segurança da Holanda
16h00 **Utilização da rede móvel para informação pública**
Laboratório Nacional de Engenharia Civil
16H30 Encerramento

Inscrições até 11 de novembro através do correio eletrónico: luis.sa@prociv.pt

ORGANIZAÇÃO

Proteção Civil – Autoridade Nacional
LNEC – Laboratório Nacional de Engenharia Civil
ces – Centro de Estudos Sociais, Laboratório Associado, Universidade de Coimbra
FCT – Fundação para a Ciência e a Tecnologia

ANNEX II
Project flyer

Flyer the the project presentation

OBJECTIVES

- Improving scientific knowledge in estuarine margins flooding processes for different climate scenarios: storm surge combined with tide effects and urban drainage
- Flood risk assessment in different territory typologies: urban and interface
- Creating an integrated strategy for risk management, to promote preventive actions for planning, risk mitigation, and alert and warning system optimization.

MAIN INNOVATIVE ASPECTS

- Integration of hydrodynamic and urban drainage modelling
- Different spatial scale of risk assessment: estuarine and urban scale

PARTNERSHIPS

CONTACTS

Paula Freire (project coordinator)
National Laboratory for Civil Engineering
Estuaries and Coastal Zones Division
Av. do Brasil, 101, 1700-066 Lisboa PORTUGAL
Phone: 21 8443637 / Fax : 21 844 3016
Email: pfreire@lnec.pt

TEAM

NATIONAL LABORATORY FOR CIVIL ENGINEERING
Estuaries and Coastal Zones Division
Paula Freire (project coordinator)
André Fortunato
Ana Rilo
Kai Li

Urban Water Division
Maria Adriana Cardoso
Maria do Céu Almeida
Sérgio Teixeira Coelho

Information Technology in Water and Environment Group
Anabela Oliveira
João Palha Fernandes
Gonçalo Jesus
João Gomes

CENTRE FOR SOCIAL STUDIES
University of Coimbra
Alexandre Tavares
Pedro Santos

NATIONAL AUTHORITY FOR CIVIL PROTECTION
Patrícia Pires
Luís Sá
Jorge Dias
Giuseppe Cornaglia

SCIENTIFIC CONSULTANT
Xavier Bertin (La Rochelle University, France)

Funded by:
Portuguese Foundation for Science and Technology
(PTDC/AAG-MAA/2811/2012)

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MOLINES
FROM THE HAZARD TO THE CRITICAL MANAGEMENT

Modelling floods in estuaries. From the hazard to the critical management

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WEBPAGE
http://www.lnec.pt/organizacao/dha/nec/estudos_id/Molines/index_html-en

ABSTRACT

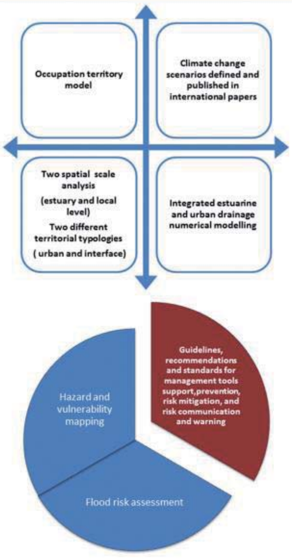
Floods in estuarine marginal zones are associated with particular climatological conditions, as **high tidal levels, storm surges and intense fresh-water discharges.** In **urban areas**, the effects of high water levels in the estuary can be exacerbated due to insufficient drainage conditions associated to episodes of very intense and concentrated in time rainfall and flash floods in small watersheds tributary to the estuary. The **quickness** of these phenomena makes difficult to timely triggering of warning system with **serious consequences for people and goods**.

In a context of **climate change,** rising sea levels and more extreme climate conditions will increase the vulnerability to inundation of estuarine margins. The **main challenge** of this project is to integrate different strategies and approaches that are typically used independently in flood risk analysis.

As an example of territory conflict occupation along its margins and high potential to flooding, the **Tagus estuary** was chosen as case study.

METODOLOGY

The project will follow an **integrated and interdisciplinary methodology**, based on **two distinct spatial scales** (regional and local). The evaluation in a larger scale will use as reference **two territorial typologies,** urban and interface zone.



The **numerical modeling of the estuary hydrodynamics and urban drainage** will provide the extension of flood prone areas, velocity and depth of the water levels in flood stages. An assessment of flood risk will be made, based on which a set of **guidelines** will be produced, as well as **recommendations** and **standards** for **management** supporting tools, **prevention** and **risk mitigation,** and **risk communication and warning** .

EXPECTED RESULTS

- Database of historical flood events in Tagus estuary
- Natural and urban flood prediction through integrated numerical modelling
- Flood hazard and vulnerability cartographic representation and risk assessment
- Flood risk management guidelines
- Support the optimization of the alert and warning system
- Web-Gis platform for information integration
- Creation of a knowledge platform for flood risk management in estuaries

Flyer for dissemination of the project main final results

ABSTRACT

Floods in estuarine marginal zones are associated with particular climatological conditions, such as **high tidal levels, storm surges and intense fresh-water discharges.**

In **urban areas**, the effects of high water levels in the estuary can be exacerbated due to insufficient drainage conditions associated to episodes of very intense and concentrated in time rainfall and flash floods in small watersheds tributary to the estuary.

The **quickness** of these phenomena makes it difficult to timely trigger warning with **serious consequences for people and goods**.

In a context of **climate change,** rising sea levels and more extreme climate conditions will increase the inundation hazard of estuarine margins.

The **main challenge** of this project is to integrate different strategies and approaches that are typically used independently in flood risk analysis.

As an example of territory conflict occupation along its margins and high potential to flooding, the **Tagus estuary** was chosen as case study.

The project followed an **interdisciplinary methodology**, based on **two distinct spatial scales** (regional and local), integrating **numerical modeling of the estuary hydrodynamics and urban drainage, hazard, territorial vulnerability and risk assessments** considering different climate scenarios.

INSTITUTIONS PARTICIPANTS

NATIONAL LABORATORY FOR CIVIL ENGINEERING
Estuaries and Coastal Zones Division

Urban Water Division

Information Technology in Water and Environment Group

CENTRE FOR SOCIAL STUDIES,
UNIVERSITY OF COIMBRA

NATIONAL AUTHORITY FOR CIVIL PROTECTION

PARTNERSHIPS

CONTACTS

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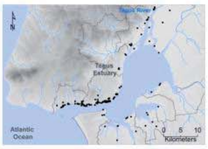
WEBPAGE

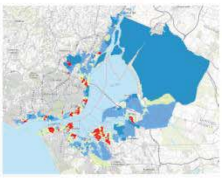
http://www.lnec.pt/en/organization/dha/nec/rd-projects/molines/

MAIN RESULTS

- Database estuarine flood occurrences in the Tagus estuary



- Territorial vulnerability assessment



- Natural and urban flood prediction for different scenarios

MAIN RESULTS

- Risk assessment for different climate scenarios

- WebGIS interface providing an innovative early-warning systems for the Tagus estuary and the Portuguese coast

- Emergency planning guidelines to assist the municipal civil protection authorities in preparedness and emergency response
- Flood adaptation actions based on land-use and occupation measures to increase resilience in face of flooding and future sea-level
- Design of a population warning system and a warning test in controlled conditions using mobile technology
- Flood Risk Management Guidelines for Actors, listing the best practices and existing tools for the management of floods

ACHIEVEMENTS

- **Knowledge improvement on flood process in estuaries,** and in particular the Tagus system, and with an innovative **approach to support flood risk management** in transitional systems taking into account different levels of the decision-making process.
- **Capacity-building of the participant institutions** through the availability of information and the improvement of tools (e.g. risk assessment approaches, numeric modelling, real-time forecast system).

SELECTED PUBLICATIONS

Cardoso, M. A., Almeida, M. C, Brito, R. S., Beceiro, P. 2015. Modelação integrada da drenagem urbana em zonas estuarinas: avaliação da inundação para cenários climatéricos. 10º Encontro Nacional de Entidades Gestoras de Água e Saneamento, ENEG 2015, Porto, 1-4 de dezembro.

Fortunato, A.B., K. Li, X. Bertin, M. Rodrigues, B.M. Miguez., 2016. Determination of extreme sea levels along the Iberian Atlantic coast. *Ocean Engineering*, 111 (2016) 471–482.

Freire, P., Tavares, A. O., Fortunato, A. B., Sá, L., Oliveira, A., Rilo, A., Santos, P. P., 2015. Modelação da inundação em estuários. Da avaliação da perigosidade à gestão crítica. *VIII Congresso sobre Planeamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa*, 14-16 outubro de 2015, Universidade de Aveiro. APRH (eds), 15 pp.

Gomes J.L., Jesus G., Rogeiro J., Oliveira A., Costa R., Fortunato A., 2015. Molines – towards a responsive Web platform for flood forecasting and risk mitigation. *Proceedings of the Federated Conference on Computer Science and Information Systems*: 1171–1176 ACSIS, Vol. 5.

Guerreiro, M., Fortunato, A.B., Freire, P., Rilo, A.R., Taborda, R., Freitas, M.C., Andrade, C., Silva, T., Rodrigues, M., Bertin, X., Azevedo, A. 2015. Evolution of the tidal dynamics of the Tagus estuary in the 21st century. *Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management*, volume 15 (1): 65-80.

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Rilo, A., Freire, P., Tavares, A.O., Santos, P.P., Sá, L., 2015. Historical flood events in the Tagus estuary: Contribution to risk assessment and management tools. *Safety and Reliability of Complex Engineered Systems*, Podofllini et al. (Eds) 2015, Taylor & Francis Group, London, ISBN 978-1-138-02879-1: 4281-4286.

Santos P.P., Tavares A.O., Freire, P., Fortunato, A., Rilo, A., 2015. Territorial vulnerability to flooding in an estuarine area: Challenges valuing the structural and societal local . In: *Safety and Reliability of Complex Engineered Systems*, Podofillini et al. (Eds) 2015 , Taylor & Francis Group, London, ISBN 978-1-138-02879-1: 4273-4280.

Tavares, A. O., Santos, P. P., Freire, P., Fortunato, A. B., Rilo, A., Sá, L., 2015. Flooding hazard in the Tagus estuarine area: The challenge of scale in vulnerability assessment. Environmental Science & Policy Environmental Science & Policy, 51 (2015): 238-255.

ANNEX III
Dissemination of the MOLINES project

Invited conference in Agência Portuguesa do Ambiente, 04/12/2013

Newspaper: Jornal Água e Ambiente, 04/02/2016

// CAPA

Risco de cheias e inundações motiva investimentos superiores a 200 milhões

Os Planos de Gestão de Risco de Inundações, em consulta pública até Março, prevêem medidas para prevenir e preparar o Continente para eventos de inundação fluvial até 2021. Já a autarquia lisboeta planeia investimentos para evitar cheias urbanas na capital.

Cerca de um terço das perdas económicas na Europa que resultam de desastres naturais são causadas por inundações. Após as cheias que assolaram a Europa central entre 1998 e 2004, com elevados prejuízos para a economia europeia, a Comissão decidiu tomar medidas, tendo sido aprovada três anos depois, em 2007, uma directiva para a avaliação e gestão do risco de inundações. Esta directiva – transposta para a legislação nacional em 2010 – veio obrigar todos os países do espaço comunitário a elaborar cartas de risco e a definir planos de gestão para as zonas críticas identificadas até ao final de 2015.

Construção em zonas inundáveis vai ser restringida

Em Portugal, as cartas de risco e de zonas inundáveis estão feitas, tendo sido identificadas 22 zonas críticas no Continente, para as quais foram delineados planos de gestão com medidas para implementar até 2021. Os Planos de Gestão de Risco de Inundações (PGRI) estão em consulta pública até ao próximo mês de Março e envolvem um investimento global superior a 110 milhões de euros.

Mais de 99 por cento do volume de investimento está previsto nas regiões hidrográficas do Vouga, Mondego e Lis e Tejo e Ribeiras do Oeste. As medidas mais pesadas em termos orçamentais são de protecção estrutural, envolvendo a regularização de vários rios e ribeiras, assim como a construção de açudes e bacias de retenção ou a transposição de sedimentos (ver página 6).

É também nestas duas regiões hidrográficas que se concentra a maior parte da população que poderá ser afectada pela ocorrência de inundações, considerando um período de retorno de 20 anos (número médio de anos entre dois eventos sucessivos em que uma determinada quantidade de água precipitada ou de caudal é excedida). As 22 zonas críticas foram, de resto, seleccionadas a partir da descrição de mais de 651 ocorrências de cheias e inundações, tendo sido escolhidas áreas onde estes eventos levaram à retirada ou desalojamento de, no mínimo, 15 pessoas, ou causaram pelo menos uma vítima mortal (ou desaparecida).

Nas áreas inundáveis destas 22 zonas foram identificados os elementos que poderiam ser atingidos, incluindo instalações PCIP, infra-estruturas e edifícios públicos (hospitais, escolas, quartéis de bombeiros, etc.), equipamentos com valor patrimonial (incluindo monumentos nacionais ou imóveis de interesse público), unidades turísticas, terrenos agrícolas e estações de tratamento de água e águas residuais.

Tendo em conta o nível de risco (muito alto, alto, médio, baixo e insignificante) previsto para cada período de retorno – 20, 100 e 1000 anos –, foram definidas medidas de prevenção, preparação e protecção. Na maior parte dos casos, estamos a falar da integração destas centenas de "elementos expostos" no Sistema de Vigilância e Alerta de Recursos Hídricos (SVARH) e nos Planos de Emergência da Protecção Civil, que contemplam medidas de minimização de impacto como barreiras de protecção ou procedimentos de evacuação. Para um número reduzido de instalações (dez) determina-se a relocalização no prazo de dois anos.

Prevê-se também investir na melhoria dos modelos de previsão hidrológica e hidráulica e no reforço do sistema de alerta através de novas estações com teletransmissão.

Os impactos das inundações deverão ainda ser minimizados por diversas medidas associadas ao ordenamento territorial "que promovam a infiltração, retenção ou intersecção da precipitação" – como a instalação de galerias ripícolas ou parques urbanos nas margens de rios e ribeiras –, a maioria das quais já enquadradas noutros instrumentos de planeamento. Está ainda prevista a elaboração, até 2020, de um plano nacional de dragagens.

Nos próximos dois anos será também publicada legislação que proíba e restrinja a edificação nas zonas inundáveis. E para aumentar a "percepção do risco" por parte da população e dos agentes sociais e económicos, estipula-se a divulgação das cartas de zonas inundáveis e de riscos de inundação, bem como das listagens de elementos expostos às cheias.

Vários planos preveem ainda que sejam definidas regras para a exploração de infra-estruturas hidráulicas em caso de ocorrência de cheias. De acordo com Adérito Mendes, especialista em hidráulica e recursos hídricos, os modelos hidrológicos e hidráulicos hoje disponíveis – para previsão da ocorrência de fenómenos extremos e simulação dos escoamentos dos caudais nas redes hidrográficas naturais e modificadas – "permitem fazer a exploração dos equipamentos hidráulicos de modo a optimizar as suas capacidades para atenuar a magnitude das ameaças de cheias e inundações". No entanto, "não é nada fácil fazer esvaziar uma albufeira" com base em resultados computacionais. Por isso, defende, "é necessário ter esses modelos afinados e testados em situação real, o que está longe de ser conseguido, não apenas devido à diversidade da natureza das entidades envolvidas, mas sobretudo porque a iniciativa deveria ser do Estado, cuja autoridade no domínio dos recursos hídricos nunca esteve tão enfraquecida".

Para o investigador da Faculdade de Ciências da Universidade de Lisboa (FCUL) Filipe Duarte Santos, era também "desejável" que as cartas de risco que sustentam os programas de medidas "tivessem em conta que o clima está em mudança". "Os mapas de risco de inundação da APA não estão feitos em cenários de alterações climáticas", observa.

Ora, de acordo com os dados compilados no âmbito do projecto CIRAC – Cartas de Inundação e Risco em Cenários de Alterações Climáticas, elaborado pelo grupo de investigação Impactos, Adaptação e Modelação em Alterações Climáticas da FCUL, as projecções futuras demonstram uma diminuição da precipitação, em particular no sul do país, mas também que eventos extremos se tornem "mais frequentes e intensos". Isto significa que a precipitação máxima verificada no dia mais chuvoso dos anos futuros "tem tendência a aumentar", explica Filipe Duarte Santos, logo também "o risco de inundação". Há, no entanto, ainda "poucos estudos em Portugal sobre como tem evoluído a precipitação" e sobre a gestão do risco de inundação, reconhece o investigador.

A contribuir para melhorar o conhecimento sobre inundações, considerando diferentes cenários climáticos, mas também para estudar acções preventivas e de resposta, está o projecto MOLINES – Modelação da inundação em estuários, coordenado pelo Laboratório Nacional de Engenharia Civil e concluído em Fevereiro de 2016. Esta iniciativa focou as áreas marginais do estuário do Tejo, tendo os estudos mais detalhados incidido sobre as zonas do Seixal e do Dafundo. Para além de ter sido aprofundado o conhecimento sobre os factores que originam inundação no estuário e seus impactos, explica a coordenadora do projecto, Paula Freire, aumentando a capacidade de previsão, foi desenvolvida "uma abordagem metodológica inovadora de apoio à gestão do risco" que se baseia em três escalas espaciais (regional, municipal e local) e envolve diversas entidades. Estes resultados foram vertidos para uma plataforma WebGIS "que fornece uma interface de alerta para o Seixal e Dafundo, baseada num sistema de previsão e de monitorização em tempo real". No Seixal será ainda testado um projecto-piloto de utilização de redes móveis como canal de comunicação para o aviso à população em caso de inundação.

Cheias urbanas (ainda) de fora

Os PGRI agora em discussão pública estão vocacionados "nesta fase" apenas para a prevenção de inundações de origem fluvial, provocadas pelo aumento do fluxo dos rios em virtude de precipitação persistente. De fora fica, assim, a prevenção e gestão de ocorrências de origem pluvial – as chamadas cheias urbanas – que resultam de chuvadas intensas num dado local onde haja solos impermeabilizados, como acontece nos centros urbanos, gerando-se uma rápida acumulação de água. "No meio urbanizado, as linhas de água pré-existentes foram transformadas em redes de drenagem enterradas que terão sido dimensionadas para condições, no horizonte do projecto, muitas vezes já ultrapassadas, quer pela redução de solo em estado natural quer pela impermeabilização do espaço urbano, para já não referir a explosão das áreas urbanas inicialmente previstas", contextualiza Adérito Mendes. "Estas condições originam o aumento dos caudais de ponta e reduzem os tempos de concentração, o que impede que as secções existentes [rede de drenagem] esgotem as águas como desejado", explica.

4 / Fevereiro 2016

Newspaper: Suplemento do Jornal Alto Risco da Associação Nacional de Bombeiros Profissionais (instituição de utilidade pública), N.º54 | 7ª Série | Dezembro 2015

Técnico

Jorge Dias, ANPC

John Tacken, Holanda

João Ralha Fernandes, LNEC

Rui Pabulo, SMPC Seixal

Gestão de Cheias em Portugal foi tema de debate na ANPC

A Gestão de Cheias em Ambientes Estuarinos foi o tema que levou vários especialistas da área a participarem num debate ocorrido na Autoridade Nacional de Proteção Civil, no dia 12 de novembro. O risco de cheias, nomeadamente de localidades situadas junto a curso de águas, serviu de fio condutor para as várias intervenções, feitas por convidados nacionais e internacionais.

O risco de inundações em estuários foi abordado pelo Laboratório Nacional de Engenharia Civil. Já a Universidade de La Rochelle (França) abordou as lições aprendidas na sequência da tempestade Xynthia e das inundações costeiras na região Central de Biscaia.

Um dos pontos altos deste workshop foi a apresentação do "molines Web", uma plataforma web integrada para a gestão do risco de inundação.

O Projeto Molines

O projeto aborda o risco de inundação em áreas adjacentes e ambientes estuarinos considerando os diferentes perigos, de uma forma integrada, tomando como referência o contributo EU/EXMAP, assim como os objetivos da Diretiva Europeia sobre inundações. O estuário do rio Tejo foi o escolhido como tema de estudo.

De acordo com informação disponível no site do Laboratório Nacional de Engenharia Civil (um dos parceiros do projeto, a par do Centro de Estudos Sociais, Fundação para a Ciência e Tecnologia e Autoridade Nacional de Proteção Civil), o objetivo do projeto é melhorar o conhecimento científico sobre os processos de inundação em lugares estuarinos, a avaliação do risco de inundação de zonas com diferentes tipologias, criação de uma estratégia coordenada de gestão do risco.

Comunicação em cenário de risco

A distinção entre a comunicação de crise e a comunicação de risco foi o ponto de partida para a abordagem de Jorge Dias da Autoridade Nacional de Proteção Civil sobre a "Comunicação de Risco e de Crise em Cenários de Riscos Hidrológicos". Durante esta intervenção foi introduzida a importância do conceito Kiss (Keep in Short, Simple and Stupid), ou seja, quanto mais clara a informação, mais eficaz é a comunicação. Já o Serviço Municipal de Proteção Civil do Seixal abordou um novo desfio para a proteção civil e que consiste no aviso de marés vivas na Baía do Seixal, estando o concelho abrangido pelo projeto Molines.

Vindo da Holanda, John Tacken, representante do Ministério da Justiça e Segurança da Holanda apresentou um sistema de aviso às populações via difusão celular. O interveniente falou dos diferentes sistemas de alerta utilizados na Holanda, desde o recurso a sirene à utilização de viaturas com megafones que transmitem a informação até ao mais sofisticado sistema de comunicação celular.

A utilização da rede móvel para informação pública foi um tema também abordado por João Ralha Fernandes, do Laboratório Nacional de Engenharia Civil, que apresentou a importância da utilização das sms no alerta à população.

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